City Centres: Understanding the Travel Behaviour of Residents and the Implications for Sustainable Travel

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Submitted in Partial Fulfilment of the Requirements of the Degree of Doctor of Philosophy, June 2013

Table of Contents

List of Figures

List of Tables

Acknowledgements

This thesis is dedicated with love and gratitude to several people to whom the completion of it will mean a lot:

*To the memory of my **Grandfather**, whom I owe more than I will ever be able to repay.*
*To the memory of my **father**, wish he was here.*
*To my **mother** & my **sisters** and to my **wife** & my **children**, they have never forgotten me in their prayers - they deserve all of the credit.*

Major grant funding for this study and for my staying in the UK was provided by the Iraqi Ministry of Higher Education and Scientific Research, Baghdad, Iraq. The grant was managed by the Iraqi Cultural Attaché, London. The conducted household travel survey was to a large extent funded by the University of Salford. Without this financial support, this work would not have been existing.

I would like to express my sincere gratitude and appreciation to my supervisor, senior lecturer Mr. Ralph R. Henson for his guidance, patience and encouragement throughout the development of this work. And I wish to express my appreciation to my examiners Prof. John Nelson and Dr. Saad Yousif for their helpful and valuable comments.

I would also like to thank all others who have supported me throughout the research stages, particularly: my relatives and friends who were supporting me from distance. Special thanks to my brother-in-law Dr. Hayder Mudhaffar for his uninterrupted support. Many thanks to all the administrative staff at the Computing, Science and Engineering School, to the teaching staff in the English Academic Course in the University of Salford for their support and efforts; and to all my colleagues in the CSE School, Room N244.

Thanks must also go to the respondents of the Manchester city centre survey who participated in the questionnaires and interviews. Finally, I would like to thank the Scottish Household Survey team for facilitating the process of obtaining a special SHS dataset.

List of Abbreviations

ANOVA	Analysis of variance
CBD	Central business district
CC	City centre
CPZ	Controlled parking zone
DETR	Department for Environment, Transport and the Regions
DfCLG	Department for Communities and Local Government
DfT	Department for Transport
DL	Driving licence
ET	Edge of town
ETC	Edge of town centre
FFR	Flats for rent
FPO	Flats privately owned
GLM	General linear model
GsLM	Generalised linear model
GHG	Green house gas
HH	Household
HFR	Houses for rent
HIH	Highest income householder
Ho	The null hypothesis
HPO	Houses privately owned
IIA	Independence of irrelevant alternatives
LOS	Level of significance
MPH	Mixed private housings
MNPH	Mixed non-private housings
MPNPH	Mixed private/non-private housings
NHTS	National highway travel survey
NTS	National travel survey
ODPM	Office of the deputy prime minister
OLS	Ordinary-least-squares
ONS	The office of national statistics
Ped.	Pedestrian
PPG	Planning policy guidance
PPS	Planning policy statement
PT	Public transport
R-square	Coefficient of determination
RA	Random adult
Ref. Cat.	Reference category
SA	Suburban area
SE	Standard error

SHS	Scottish household survey
Sig.	Significant
SVQ	Scottish vocational qualification
TB	Travel behaviour
TC	Town centre
TRB	Transport research board
TRICS	Trip rate information computer system
VIF	Variance inflation factor
VHT	Vehicle hours travelled
VMT/VKT	Vehicle miles travelled/ Vehicle kilos travelled

Abstract

The study aims to understand the city centre living characteristics from a sustainable travel behaviour perspective. Three datasets have been utilised; the UK Trip Rate and Information Computer System (TRICS), the Scottish Household Survey and an original household travel survey which has been conducted in Manchester city centre. An array of univariate and multivariate statistical techniques have been utilised to conduct the required travel analysis and modelling.

Using Trics 2012a, exploratory analysis has shown a significant variation in the urban form characteristics between residential neighbourhoods located in central locations and those located in other areas. Households in the central locations generally travel less than others; in particular, town centre households walk more and drive less than others in out-of centre areas. In contrast, the inferential analysis showed evidence of a mediation effect whereby neighbourhood features such as the ratio of flats, parking density and transit provisions explain some of the differences in trip frequency. The mediation analysis also revealed that built environment features only partially account for these differences.

The Scottish Household Survey and the Manchester city centre survey datasets have been utilised in order to investigate the potential impacts of several socio-spatial and attitudinal attributes on the city centre residents' personal mobility. Whereas the review process disclosed the notable increase in the residents of the UK city centre and a revival of its housing sector over the past decade, the descriptive analysis revealed some distinct characteristics of those residents such as they are typically young adults, modern and well-qualified and living in single person households or as couples. Walking is their common mode for commuting, shopping and leisure. In Manchester city centre, 42% of the residents' journeys were found to be within the city centre catchment area. In contrast, the travel behaviour models indicated the potential impacts of socio-spatial attributes such as car ownership, income and parking on mobility measures such as car ownership, mode choice and vehicular mileage. Finally, some attitudinal factors were found to be influential even after controlling for the socio-spatial effects.

CHAPTER 1: INTRODUCTION

1.1 Overview

The daily rhythm of our modern life has presented transport as a necessity for people and economic prosperity alike. The spatial distribution of people's activities has made travel an essential part of their daily routine; on the other hand, it is hard for planners to set a sustainable renewal agenda for an urban area without planning for an efficient and effective transport system. Regrettably, there is empirical-based evidence that transport is a major contributor to most of the nowadays local, regional and global problems related to sustainability and the environment. While congestion, air pollution and noise are typical examples of local problems, sprawl and deforestation are regional level examples and global warming and energy depletion are paradigms of global concerns. Among all other transport forms, road transport and especially the private car has the major share in causing these concerns; empirical evidence is found in the UK transport trends (DfT, 2010a, p.121, 123, 125 & 133) and in the UK Transport energy and environment statistics (DfT, 2011b, p.5).

Unsurprisingly, in the context of urban central locations, congestion, noise and air pollution are typical examples of car-related concerns associated with a vibrant city centre; urban sprawl and urban decay concerns are typically associated with dormant city centres. The paradox of the importance of transport and its negative consequences has recently motivated national planning policy to address several scenarios to minimise road transport externalities. Technological and behavioural interventions are the most common scenarios in the current planning policy agenda.

1.2 General problem area

The motivation behind this research has come from two aspects. Firstly, contemporary UK planning policy, including the recent National Planning Policy Framework, aims to endorse vital and viable city centres by promoting mixed use, high density developments with an adequate proportion of housing (DfCLG, 2012, p.8). This, along with a current desire of some people to relocate into central areas (Urban Task Force, 2005, p.2), has been recently motivating local planning authorities to develop more residential apartments on brown field or vacant sites in their strategic plan for city centre regeneration. This change in land use and the resulting travel patterns, however, should be rigorously researched for two goals. The overall one is in order to comply with the national planning targets in delivering environmentally sustainable developments; these targets were clearly defined in the old Planning Policy Statement PPS1 (Delivering Sustainable Development) (ODPM, 2005a) and have been confirmed in the most recent UK National Planning Policy Framework (DFCLG, 2012). The particular goal of investigating this change is that it can help in understanding its impact on sustainable travel outcomes including but not limited to mode choice, car ownership and public transit use.

Secondly, urban centres typically include the Central Business District (CBD) of their cities with particular spatial characteristics of their urban fabric. Thus, researching the potential effects of built environment on the travel behaviour of people living in the city centre in comparison with those living in suburban or rural areas is informative for transport and land use planners alike. That is, such research can help in setting out transport and spatial management programmes that might reduce car dependency and increase the propensity of adopting low-emissions modes such as public and active transport.

The benefits of such research may be further emphasised by taking into account that so far the debate over the extent of urban form impacts on travel behaviour is far from reaching a consensus (Antipova, Wang, & Wilmot, 2011; Bohte, Maat, & van Wee, 2009; Dieleman, Dijst, & Burghouwt, 2002; Rajamani, Bhat, Handy, Knaap, & Song, 2003; van Acker & Witlox, 2005; van Acker, Witlox, & Van Wee, 2007).

1.3 Scope of treatment

Technological and behavioural interventions are the typical means in the current UK planning policy agenda for tackling road transport problems. For instance, the Technology and Policy Assessment Function of the UK Energy Research Centre report (Gross et al., 2009) has extensively investigated these two options as available mechanisms for tackling surface transport emissions. Advanced technology interventions, such as electrical hybrid and fuel efficient vehicles, aim to directly target issues like energy consumption and emissions via "ecologising" the automobile industry. Conversely, travel behaviour-based interventions, such as minimising motorised travel and adopting eco-friendly travel modes, indirectly tackle these externalities by affecting traveller decisions. While the former interventions are beyond the scope of this study, this work solely speaks to the understanding of people's travel behaviour to inform the implementation of effective behavioural interventions. These behavioural interventions could be even more effective than technological treatments (Graham-Rowe, Skippon, Gardner, & Abraham, 2011).

1.4 Knowledge gap in travel behaviour research

1.4.1 In the general geographic context

A great amount of literature-based evidence is available regarding the influences of socioeconomics/demographics attributes and spatial features on people's travel related options and decisions. Nevertheless, researchers have not yet agreed on the relative strength of the relationships between these attributes and features (as predictors) and personal mobility measures (as response variables). Moreover, findings are also mixed regarding which specific personal and spatial characteristics are the most influential on people's travel behaviour. For instance, taking density as one of the important urban spatial features, while some researchers confirmed its influence on several travel outcomes (Newman and Kenworthy, 1989; Greenwald and Boarnet, 2001; Chatman, 2009), others concluded that its impact is modest and not significant (Boarnet and Sarmiento, 1998). A possible explanation may be found in that different research techniques and data sample sizes have been applied, and that different types of explanatory variables were included in the research, with different spatial and temporal dimensions (more details about the inconsistency in results and possible reasons will be reviewed in Chapter 2).

On the other hand, only recently, the attitudinal dimension has emerged in travel behaviour research. The overall proposition is that people's perceptions of several travel and housing aspects may intervene to affect the traditional impact of personal and urban form characteristics on personal mobility. Furthermore, the so far available findings are also lacking in harmony. For instance, whereas some researchers including Chatman (2009) and Naess (2005) revealed that the impacts of the spatial characteristics outweigh the impacts of the attitudinal factors, others such as Bagley & Mokhtarian(2002) have found the opposite (further discussion will be presented in Chapter 2).

1.4.2 In the city centre context

The relevant literature presents evidence about the distinction of the mobility measures of city centre residents from those who live in out of centre locations (Nathan and Erwin, 2005; Naess 2011; Perkins et al., 2009; Zegras, 2010; Litman, 2011). Nonetheless, thorough understanding of the relative contribution of personal, spatial and attitudinal characteristics in explaining this distinction is far from being agreed for two reasons. The first and foremost one is the limited amount of evidence. That is, whereas there are countless research articles that address travel behaviour in the general geographic context, there is a lack in such articles in urban centres. In particular, the lack of travel behaviour studies concerning residents in UK city centres is tangible. The second reason is similar to what has been mentioned in the previous section regarding inconsistency in results and accounting for attitudinal factors.

1.5 Aim, objectives and research questions

Given the existence of this literature-based gap in travel behaviour research, the overarching purpose of this PhD thesis is to shed light on the living characteristics of UK urban centres from a travel behaviour perspective and, in particular, to gain pragmatic insights into the potential explanatory variables and factors that might explain the travel choices of the city centres' residents. In so doing, three major objectives have been set to be achieved during the research strategy conducted for this work. The following paragraphs discuss these objectives and their relevant research questions. The objectives have been ordered according to their presence in the study which is in turn rationally ordered according to the chapter in which they have been addressed .

Objective -A-: To conduct a comprehensive thematic review of the published empirical literature, and to explore recent developments in travel demand theory in order to identify the current state of knowledge and to learn from previous research. Five research questions are set to be answered during this research exploration process:

A1- What are the variables and factors that typically have potential impacts on the sustainable travel behaviour of people in general and on city centres' residents in particular?

The findings will help in the creation of parsimonious travel models by assuring well-specified models in which relevant variables are included and irrelevant ones are excluded. This research question has been discussed in the second and third chapters.

A2- To what extent are the findings of previous travel behaviour research certain and consistent? In addition, what are the most likely reasons behind uncertainty and inconsistency? This would help in the design of an adequate conceptual framework and modelling strategy. This research question has been discussed in the second chapter.

A3- What are the factors that have affected urban sprawl in general and the vibrancy of the city centre in particular in the early part of the last century and in the recent past? Outputs would inform the urban renaissance policy makers in investing in factors where literature-based evidence about the effectiveness of their influence exists. This research question has been answered in the second and third chapters.

A4- What are the recent policy aspirations and countermeasures that have been proposed and implemented in the UK in order to attain a sustainable urban renaissance agenda? This would help in developing models that are policy-sensitive by incorporating variables that are controllable by the policy makers. This research question has been addressed in the second and third chapters.

A5- Taking into account the above, what, if any, are the most appropriate UK travel survey data sources? In addition, what is the methodology of analysis capable of achieving the research objectives utilising these data sources? This research question has been addressed in the fourth chapter.

Objective -B-: Initially, to investigate the impact of location of a housing development on its households' travel characteristics; that is sites in city/town centres in comparison with sites located out-of-centres. Next, to examine the specific personal and spatial features that might explain (as mediators) why there is a variation in the travel behaviour of households located in different site locations. Two related research questions are planned to be addressed during achieving this objective. This objective has been tackled in the fifth chapter using the UK TRICS trip generation database.

B1- What are the residential neighbourhood features and travel patterns that vary notably across site locations? What are the neighbourhood and travel characteristics that typically shape each site location; in particular, in central and outer areas?

B2- If there is a significant relationship between household's travel behaviour and the location of their place of residence, then what are the neighbourhood characteristics that might mediate this relationship and hence explain how it has happened? Are these features statistically significant? What is their relative effect size and direction of influence?

Objective -C-: To understand city centre residents' personal mobility by developing a variety of travel behaviour models that are within the general context of travel behaviour theory. This implies specifying the best set of predictors that significantly associate with a specific mobility measure. Three related research questions are planned to be addressed during the achievement of this objective. This objective and its research questions have been dealt with in the sixth and seventh chapters using the Scottish Household Survey dataset in addition to data extracted from an original survey which has been conducted in Manchester city centre specifically to inform the research objectives of this study.

C1- Who lives in UK city centres such as Manchester city centre? In this case, the objective is to investigate the socioeconomic and demographic attributes of city centre households and individual residents and, in addition, to shed light on the residents' lifestyles and perceptions towards several travel and housing aspects.

C2- What are the key travel characteristics of the city centre residents?

C3- How much variation in a specific mobility measure can be accounted for by the urban form characteristics of a city centre and the socioeconomic and attitudinal attributes of its residents? Additionally, where viable and sensible, what is the relative contribution of spatial, socioeconomics/demographics and attitudinal characteristics per se? The latter research question would help in examining the impacts of people's attitude and preferences on their personal travel options and decisions after controlling for socio-spatial features.

1.6 Expected research contribution and policy implications

At the UK policy perspective level, this research is a timely response to the topical national planning policy for revitalising city centres and its concerns regarding the sustainability agenda. Locally, city councils focus on the need to direct their city centres' residents towards more eco-transport options, as is explicitly stated, for example, in the two Manchester City Council publications; A Strategic Plan for Manchester City Centre 2009-2012 and Transport Strategy for Manchester City Centre (Manchester City Council, 2009, 2010a). In order to take this forward, the first step that should be carefully tackled is; what is the travel behaviour of the city centre residents and what are the potential factors that might trigger a change in their behaviour? On the other hand, globally, the study is an attempt to narrow the research gap in our knowledge stated above in Section 1.4. Generally, this study will produce outcomes that help to inform land use and transport planning policy and enlighten the sustainable renaissance agenda.

1.7 Methodology

The original research conducted in this study is non-experimental. It utilises a correlational research design and a quantitative analytical method. Generally, the methodology of the research conducted can be outlined according to the following subsections. A comprehensive discussion will be presented in Chapter 4.

1.7.1 Data

Three different sources of data have been used to gain empirically-based insights into people living in UK urban centres, their travel behaviour and the underlying variables that might affect that behaviour. These data sources are UK TRICS (2012a), the Scottish Household Survey (SHS) and an original household travel survey in Manchester city centre. TRICS is a site-level survey, whereas the SHS and Manchester city centre surveys are household-level.

1.7.2 Conceptual framework

Overall, the behavioural framework of the travel behaviour models developed in this study complies with the traditional utility-based consumer demand and choice behaviour theory (Ben Akiva and Lerman, 1985). In general, it hypothesises that consumers attempt to make a logical decision in choosing a particular choice. In the transport context, choices relate to travel purpose, frequency, car ownership, transit use and mode choice. According to this theory, the rationality involves that consumers (travellers) make a balance between their preferences and expenditures by maximizing their utility and benefits but subject to their budget constraints (income). In addition, attitude and perception factors are also included in the developed models where available and sensible.

1.7.3 Analytical techniques

An array of univariate and multivariate statistical techniques have been utilised to conduct the descriptive and inferential travel analyses. Statistical techniques and analytical strategies have been chosen to comply with several criteria including the type of the preset research questions, sample size and type and number of outcome and predictor variables. In order to end up with models with reliable parameter estimates and with the ability for testing hypotheses according to rigorous statistical standards, the assumptions and requirements of the quantitative techniques have been carefully addressed. The inferential techniques employed are generally members of the family of Generalised Linear Models, including log-linear and discrete choice models. Finally, factor analysis has also been employed to deal with the Likert-scaled attitudinal variables.

1.8 Scope and limitation of the study

The scope of the research conducted for this study is specifically relevant to urban centres in the UK; however, developed models and findings could be adapted for other geographical scales with caution. Regarding transport systems, only surface passenger transport is included; specifically, motor car, transit and active transport (walking/cycling).

The findings may not be applicable for city centre areas within Greater London. Greater London has its own spatial and transport strategies for integration between planning and transport (DfCLG, 2011a); the congestion charge scheme is a noticeable example. This is in addition to the distinct socioeconomic and demographic attributes of London's residents. The central areas of London have a different population profile with many families and elderly residents (Nathan, Urwin, Champion, & Morris, 2005). Londoners also evidently have higher incomes than others in the rest of the UK; while the median full-time gross weekly earnings in the whole UK is £500, the corresponding figure in the London region is £651 (ONS, 2011a, p.22). Other more specific limitations will be highlighted where appropriate in each analytical chapter.

1.9 Structure of the thesis

The thesis is organised into eight chapters as follows:

Chapter One is the introductory chapter where a brief background of the thesis subject is presented; the importance and expected contribution of the research is highlighted; datasets and research methodology are outlined.

Chapter Two deals with three main topics. Firstly, the importance of understanding people's travel behaviour is underlined followed by a literature review based on research articles which address the relationship between the built environment and travel behaviour. Finally, the aspirations of the relevant UK national and local planning policy are covered.

Chapter Three starts, after defining the city centre concept, by briefly highlighting the rise and fall cycles in the vibrancy of urban centres over the last decade. Next, it presents an evidence-based description of the socioeconomic and demographic attributes of the residents of city centre developments. Thereafter, an outline of the typical personal travel patterns and choices of city centre residents is presented based on empirical findings. The chapter ends with the recent perspectives of urban planning policy in the UK and globally towards urban centres.

Chapter Four demonstrates the overall research strategy that has been chosen to integrate the various components of the research process conducted in the thesis. In so doing, the theoretical framework underlying travel analysis and modelling is discussed first. The chapter then turns to describe the sources of travel data utilised in the study. After discussing several research design issues, the chapter briefly illustrates several univariate and multivariate inferential techniques employed. Finally, several statistical-related issues such as the assumptions and requirements of the employed techniques are reviewed.

Chapters Five, Six and Seven are the three analytical chapters of the thesis. They provide the travel analysis and modelling results using the three datasets: TRICS, SHS and the Manchester city centre survey respectively. These chapters are all organised in a similar way. The chapter objectives and related research questions are first highlighted. After that, a description of the data is presented. This is followed by an outline of the conceptual model adopted and the modelling strategy conducted. Finally, the analysis results are listed and the findings are discussed.

Chapter Eight displays the main conclusions that are drawn from the research. The expected implications on the planning policy agenda are discussed. Recommendations arising from this research and recommendations to guide the direction of future research are presented.

CHAPTER 2: TRAVEL BEHAVIOUR, URBAN REGENERATION, AND PLANNING POLICY ASPIRATIONS

2.1 Introduction

There is empirical-based evidence that the car has been the thematic mode in urban travel, particularly in industrialised nations. On the other hand, several national statistics report that car mobility is a major contributor to nowadays transport-related problems including congestion, air pollution and urban sprawl. As a response, recent national planning policy addresses several scenarios to minimise road transport externalities. Technological and behavioural interventions are the most common scenarios in current planning policy agendas. While former interventions are beyond the scope of this study, this chapter speaks to travel behaviour and planning policy. Travel behaviour-based interventions, such as minimising motorised travel and adopting eco-friendly travel modes, indirectly tackle these externalities by affecting traveller decisions.

In so doing, the main structure of this chapter is as follows. Section 2.2 discusses the importance of understanding travel behaviour from three axes; increasing travel demand, sustainability and policy perspective. A general background regarding three different but correlated concepts that are relevant to the research problem is presented in Section 2.3. These are urban regeneration, compact city and car dependency. Thereafter, in Section 2.4, issues such the concept, indicators and determinants of people's travel behaviour are dealt with. The subsection 2.4.4 is devoted to highlight the proposed main reasons behind the discrepancy in the results of travel behaviour research. On the purpose of collecting all the 'jigsaw' pieces of the picture, Section 2.5 is devoted to look over the UK planning policy aspirations and recommendations regarding urban regeneration, sustainable growth and transport. Finally, a brief chapter summary is presented in Section 2.6.

2.2 The importance of understanding travel behaviour

According to Donegan et al. (2007), people's travel behaviour was designated by Pickup and Town (1983) as 'an outcome of the balance between the activity choices and constraints that face each individual'. Stead & Marshall (2001) pointed out that travel behaviour typically speaks to individual's travel characteristics in terms of mode choice (e.g. private car, public transport, or walking) and/or journey purpose (e.g. commuting, shopping or leisure). Unlike travel patterns studies, travel behaviour research usually seek to find justifications and explanation of people's travel-related options; i.e., how and why rather than how much (Handy et al., 1998). People's travel behaviour is typically designated by a number of travel outcomes such as trip frequency, mode share, journey length and time of day (Meurs & Van Wee, 2003). Travel outcomes such as transport energy consumption and CO2 emissions have been recently also used as composite metrics (Headicar, Banister, & Pharoah, 2009). Figure 2-1 shows a typical schematic illustration for the main travel behaviour measures listed in the literature reviewed for the research of this study.

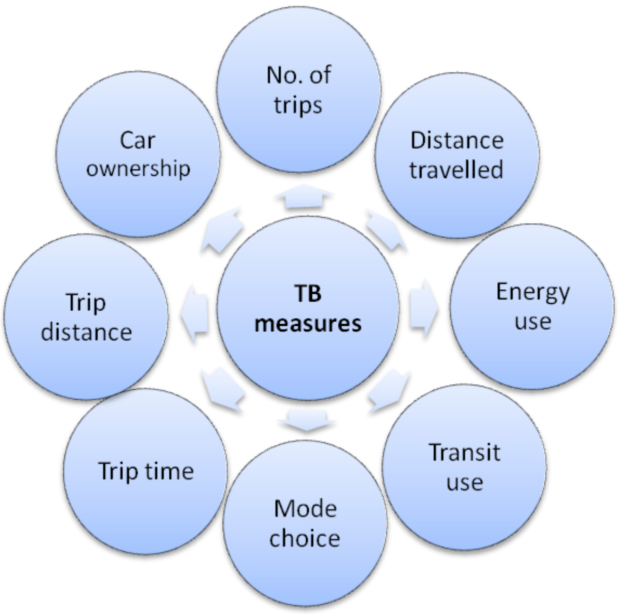

Figure 2-1: The typical key travel behaviour measures listed in literature reviewed for the research of this study.

The spatial distribution in daily activities and increasing rate of car ownership are central to increases in travelled distances and car dependency. Consequently, it has become important to consider the resulting travel-related externalities. Researchers point out adequate understanding of people's travel behaviour could significantly contribute in helping to mitigate these issues (Lleras et al., 2002; Meurs & Van Wee, 2003).

Having reported that, in the following paragraphs the importance of understanding travel behaviour is highlighted in the context of travel demand forecasting, sustainability, and planning policy perspectives per se.

2.2.1 Evolution of travel demand forecasting context

In traditional urban transportation planning, the travel demand forecasting process comprises an essential ring where future traffic on the transportation facilities is predicted. It is generally agreed that demand modelling was firstly developed in the USA through the urban transportation studies conducted in 1952 and 1956 in Detroit and Chicago respectively. The merit of these studies arises from being the pioneering planning efforts that attempt to understand road transport users' behaviour based on household travel surveys. It is worthwhile mentioning that the boom in the economy after World War II was the trigger behind the need of such studies. That era witnessed the post war prosperity and hence an increase in the car ownership and use levels. This was accompanied with the starting of building new major highways.

Based on the literature highlighting the evolution of transport modelling (see for example, Bates, 2000; McNally, 2000a; Weiner, 2008), it sounds clear that the prevailing theme of the transportation planning in the 1950s and 1960s was engineering-oriented. That is, the major concern of the decision makers at that time was how to accommodate the increased traffic volumes by widening existing highways or constructing new ones. Mitigating congestion, especially in urban centres, by increasing the capacity to cope with the future demand was the fundamental target. In the transportation planning policy context this was reflected by following the ***Predict and Provide*** approach.

The prevailing modelling approach of travel demand forecasting adopted at that time was the trip-based approach. This approach was reflecting the current knowledge of understanding and describing people's travel behaviour. The Trip-based approach was structured in what became known later as the four-step model (FSM). This model is traditionally structured in four major steps namely: Trip generation, Trip distribution, Mode choice and Route choice. Briefly, in trip generation, the number of the generated trips is predicted then the proportions of their distribution to predefined attractive zones are modelled. In the third step, mode choice, the trips are further divided according to the proposed travel mode used while in the route choice step the trips are assigned to each possible route. While the first two could highlight the demand side of transport (generated travel by destination), the other two could highlight its supply side (transport services and infrastructure).

It is obvious at this period that no deep understanding of an individual's travel behaviour is needed which might belong for three main reasons. Firstly, most of the planning modelling was conducted at an aggregate level in order to forecast travel demand and then appraise the expected network performance. Secondly, the relatively low number of cars in contrast to the new highways infrastructure being built made the negative impacts of car use minimal. Thirdly, the sustainability agenda had not seriously emerged. Having said that, the major duty of the travel forecasting models developed at that period was only to locate spatially the needed highways and calculate their required capacity (number of lanes) to accommodate the projected traffic. In other words, the models were notably weak in their susceptibility towards capturing the influence of built environment characteristics on travel behaviour (Barnes & Davis, 1999; Bartholomew & Ewing, 2008).

These models, however, faced fundamental challenges in the 1970s in terms of their ability to cope with the new concerns of that decade. Issues like the economic and environmental implications of traffic congestion had arisen and hence thorough insights on personal travel patterns were needed (McNally, 2000b)**.** The essential aim in travel demand forecasting models is not to merely develop complex models; instead it is how to properly recognize the actual travel behaviour that these models are initially constructed to replicate (Barnes & Davis, 1999).

2.2.2 Sustainability context

According to the literature, the most quoted definition for sustainable development is that presented in the United Nations General Assembly in 1987 in the so-called Brundtland Report. Sustainable development was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). Applying the sustainability concept in transport, sustainable transport (green transport) could refer to any transport mode with low impact on the environment (such as non-motorised transport and low emission vehicles), avoiding fatal accidents, and reducing congestion (Black, 2010)**.** Typically the three dimensions of sustainability as defined in the UK Urban White Paper (Our Towns and Cities: the Future), are; environmental, economic, and social (DETR, 2000). In this article, the major focus is on the first dimension, environmental sustainability, where major transport externalities lie within such themes as energy consumption, emissions, and air pollution (Buehler, 2011).

As noted previously, urban sprawl and high car ownership and use rates beyond WWII have indicated several transport-related environmental concerns. The first formal response of policy regarding environmental sustainability was in the USA. The National Environmental Policy Act of 1969 and the Clean Air Act (CAA) of 1970 were major pioneering steps towards promoting sustainable developments. Later, the Clean Air Act put in place numerical standards for vehicle emissions (Black, 2010, p19).

The transport sector is a major energy consumer worldwide. For instance in the USA and according to the U.S. Energy Information Administration (EIA, 2012, p5), almost a third of the energy supply is consumed by the transport sector; 83% of this energy is based on fossil fuels. In the UK and according to the transport energy and environment statistics issued by the Department for Transport (DfT, 2011b), in 2010 transport accounted for 39% of all final energy consumption in the UK with road transport accounting for 27% of final energy consumption; moreover, the direct use of petroleum accounted for 97% of transport energy consumption.

On the other hand, transport is an essential source of carbon dioxide (CO2) emissions which are in turn the major contributor of greenhouse gases (GHG[1]). GHGs trap the energy radiated by the earth within the atmosphere. Transportation accounts for about 25% of the world's greenhouse gas emissions resulted from human activity (Graham-Rowe, et al., 2011). Statistics indicate that CO2 accounts for 95% of the GHG emitted from motorised transportation sources; GHG accumulation is the commonly reported cause for climate change phenomena (Chao & Qing, 2011). In the United States, for instance, according to the 2012 draft version of the U.S. Environmental Protection Agency report 'Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2010', transportation accounts for 33.7% of the total US GHG emissions (EPA, 2012). In the UK, road transport made up 68% of total GHG emissions from transport in 2009 with about 60% of road transport emissions from cars and

[1] The 'basket' of six GHGs consists of carbon dioxide, nitrous oxide, methane, sulphur hexafluoride, perfluorocarbons and hydrofluorocarbons (DfT, 2011a).

taxis alone (DfT, 2011b). Having stated that and bearing in mind that car travel covers more than 75% of the total vehicle distance travelled, influencing people's travel behaviour could notably decrease CO2 emissions. These behavioural interventions could be even more effective than technological treatments (Graham-Rowe et al., 2011).

Additionally, motor vehicles are the largest source of carbon monoxide (CO) emissions. Such on-road sources are responsible for 47% of the emissions, while off-road sources account for another 21% of these emissions (Black, 2010, p37). High concentrations of CO emissions are typically found in congested urban areas like intersections. Motor vehicles may account for as much as 95% of the carbon monoxide found there. The rise in the car ownership rate as well as total vehicle miles driven are major reasons of local air pollutions resulting from high concentration of CO.

As a result, to achieve the sustainability of transport, eco-friendly travel choices should be prompted and then adopted. Typical examples of green travel behaviour are: reducing driving distance, promoting active transport (walking and cycling) and promoting public transport. Hence investigating people's travel behaviour in a neighbourhood and the factors affecting that behaviour is inevitable in order to alter unsustainable travel options to sustainable ones. To what extent land use and transport planning strategies could reduce household transport and hence energy use and CO2 emissions, is the question that has been recently examined (Chao & Qing, 2011). To sum up, careful studies assigned to better understand the potential reasons behind travel-related decisions and /or what might affect these decisions could assist in planning for a more sustainable system (Black, 2010).

2.2.3 Planning policy perspective context

According to the previous two sections, the importance of understanding people's travel decisions in order to promote sustainable ones and working to change ones with negative environmentally consequences is clearly evident. Hence, policy makers and urban planners have to use all the available policy measures such as land use and transport planning strategies in order to motivate people to more sustainable lifestyles (Hickman, Seaborn, Headicar, & Banister, 2009). Definitely, the number of cars owned and travel mode chosen are important components in people lifestyles. The need of policy makers and urban planners to adequately understand travel behaviour is greatly justified recently after the dramatic change to the Transport Supply/Demand Management (TSM / TDM) approach.

Classically, between the 50s and early 90s of the last century, the dominant policy approach was *Predict and Provide*; i.e. forecasting the traffic demand and then building the transport infrastructure (most likely roads) required to accommodate that demand. In the UK national planning policy context, for example, this is reflected in moving from the Traffic Impact Analysis (TIA) approach stated in the 1994 version of the planning policy guidance 13 (PPG13, 1994) to the Transport Assessment (TA) approach emerged in the 2001 and 2011 versions of PPG 13 (DETR, 2001; DfCLG, 2011a).

Only recently, the mobility management philosophy in dealing with transport-related externalities has emerged and consolidated. Transportation Demand Management (TDM) includes an array of policy measures and strategies that aim to reduce motor vehicle travel and encourage use of other non-car travel means. According to Ryley (2006), this spectrum of measures has been categorised by Banister (Banister, 2000) as organisation and operational, infrastructure, financial, land use, and technological changes. Inevitably, the most challenging issue for all these sorts of TDM measures is to understand the extent to which these measures could change people's travel behaviour. That is, the success of a certain TDM measure in practice is a function of the degree of change in behaviour attained (Meyer, 1999). From this, it is obvious how important it is to the policy makers to understand travel behaviour to assure the success of their measures in implementation. This is generally highlighted by Headicar et al. (2009) as a recommendation for better practise in land use and transport planning.

2.3 The development and influence of urban regeneration initiatives

Urban regeneration could be generally seen as the planning policy reaction to the phenomena of urban sprawl and the resultant urban decay. According to (Jones and Evans, 2008), today in the UK, urban regeneration is normally referred to as "The large-scale process of adapting the existing built environment, with varying degrees of direction from the state". It is worthwhile highlighting that in the British urban policy there have been several concepts which have been used in this context. It was the "reconstruction" in the post war building boom years, thereafter, in the 1960s and 1970s "renewal" and "redevelopment". During the 1980s, it was "regeneration" and then "renaissance" in the 1990s (Lees, 2003). Nowadays, the term "urban regeneration" appears to have returned as the most frequently quoted in the policy documents (for e.g., DfCLG, 2009b; DfCLG, 2011b).

Terms such as ‘rebirth’, ‘revival’, and ‘recovery’ are used interchangeably in this study to refer to urban regeneration and renaissance.

In contrast, urban sprawl could be objectively defined as low-density, scattered and car dependent urban development located outside of compact urban centres (Bruegmann, 2006; Handy, 2005). After the post-war boom, sprawl has been to some extent an urban theme in the USA, though it was evident in the U.S. and Europe alike during the inter-war boom period (Bruegmann, 2006, p33; Jones and Evans, 2008, p.142). Two vital reasons could be noticed for that; first, the rigorous planning strategies and controls adopted in rebuilding European cities after the WWII; second, the U.S. economic prosperity, increasing car ownership rates, and significant increases in population and households led people to move outward for more living space (Alexander, 1974, p.7; Muller, 2004, p.62).

This outward dispersion and its consequence was the substantial reason behind the urban decay in central cities (inner cities), especially in America. In the late 40s and early 50s of the twentieth century, the distributional pattern of activities and people in most urban areas in the industrialised world have largely diverged. While both people and activities dispersed out of the urban core, households have left the inner city at quicker rate and farther than the activities. In consequence, there was clear spatial dispersion between the functions in the urban locations and the people in the suburbs (Williams, 1989, p.373).

Speaking to the experience of urban regeneration in the UK, Jones and Evans (2008, p.95) stated that the fundamental consequences of development (growth) on land is the need for more residential development which eventually led to the move of people towards suburbs (areas beyond towns) and hence causing the sprawl. Figure 2-2 shows the sprawl imprint during the inter-war and post-war booms for London. The lines depict the rate in the reduction of population with the distance from London city centre. The essential point that can be clearly seen is that the lines become flatter when moving from the early ninetieth to the mid of the twentieth century. The figure presents two reasons for this reduction in the slope of the lines; first, the tangible reduction in the city centre population. Second, moving from 1801 to 1951, there was a continuous rising in the people who were residing far and far from the centre. Obviously, this is the sprawl effect.

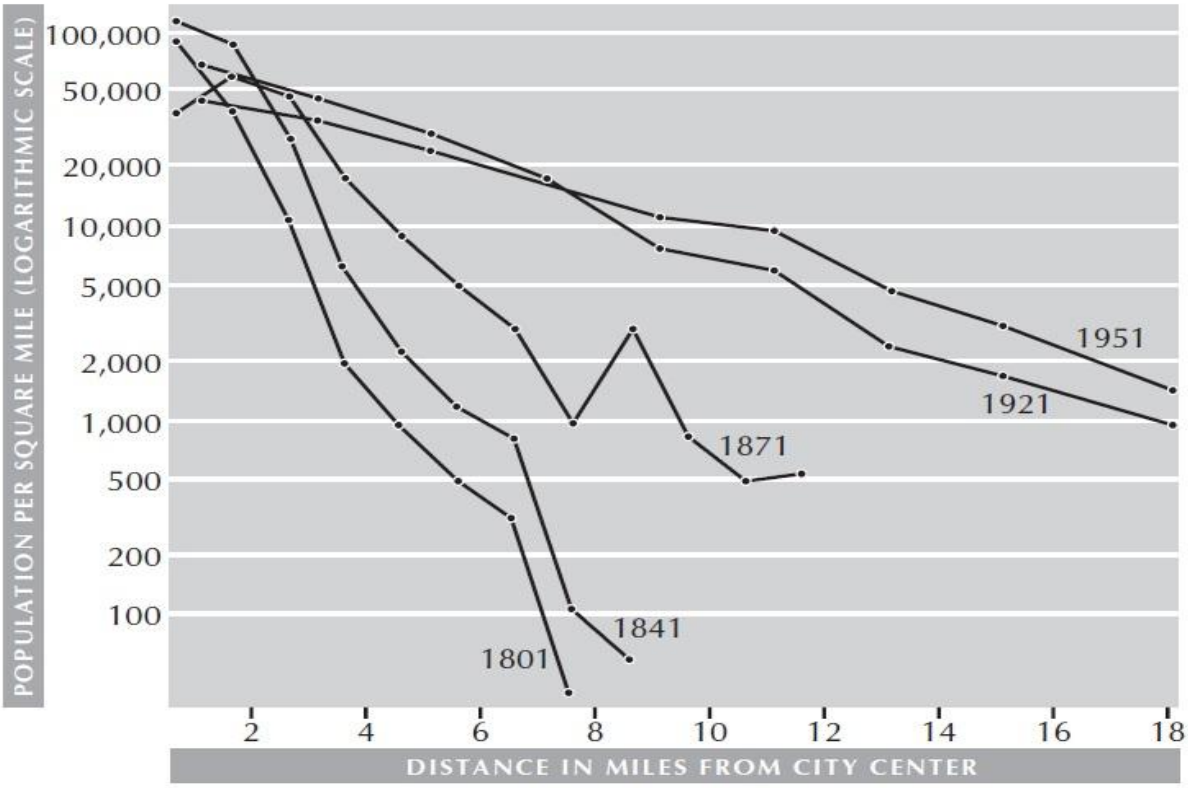

Figure 2-2: Sprawl imprint during the inter-war and post-war booms for London (Source: Bruegmann (2006, p.19).

The city centre has almost lost its discriminate theme as the central business district (CBD). The retail sector in city centres was losing vitality due to the absence of reinvestment and the presence of real competition from new shopping developments in out-of-centre city locations, usually in suburbs. By the end of the 1960s, many American inner cities such as Detroit and Saint Louis had reached a stage of economic crisis due to evaporation of jobs, residents and hence owners. However, it is worthwhile noting here that this urban crisis, especially in its economic dimension, was the essential motivation for governments to consider several urban regeneration (renewal) programmes that hopefully might lead to a dramatic rebirth in the city to be more competitive with suburbs (Bruegmann, 2006, p.47). In the UK planning context, the vital challenge exercising urban regeneration was how to make cities attractive places in which to live and work (Jones & Evans, 2008, p.161).

The economic growth patterns in the industrialised world, since the 70s, have affected the urban fabric of their cities. Central cities have been almost empty of the major industrial and commercial activities which moved out to the suburbs; similarly, population was declining in favour of suburbs. For example, Bruegmann (2006, p.54) stated that the central area of Paris has witnessed a dramatic decline in population density from over 200,000 in around 1850 to about only 75,000 (people/square mile) by the year 2000. It is worthwhile mentioning that signs of urban recovery started to appear (probably in late 80s and early 90s). Many high-status employments such as medicine, business, and law started to be available in the downtown and its nearby neighbourhoods. This renaissance was, however, accompanied with signs of gentrification[2]. Several factors could attribute to this gentrification in inner cities in North America and Europe. First, due to the loss of offices and manufacturing from city centres (CBDs) the vast majority of working-class families that used to reside in developments surrounding the CBD have seen job opportunities disappear and have eventually moved to more affordable houses in suburbs. Second, vacant buildings and areas that used to be sites for factories, docks, and warehouses have been replaced with large developments of more up-market housing typically unaffordable by most people. Thirdly, some suburban residents with new jobs located in central areas have preferred to locate/relocate there rather than commuting for long distances (Bruegmann, 2006, p.55). However, most of the major commercial and cultural centres, such as London, New York, and Paris, are still suffering from relatively low population densities. One of the other reasons is that most residents have a long-term residence address elsewhere. The recent relocation phenomenon in newly revitalised urban cores has caused a rise in land value and hence properties.

Over the past ten years, the effects of gentrification and urban regeneration have become obvious in numerous city centres in the industrialised nations. It sounds obvious that policy programmes regarding urban renaissance and neighbourhood revitalisation have played the main role in tackling the old urban decay crisis. However, a new urban issue which has become a vital concept in all discussions of contemporary urban regeneration instead is "Sustainability" (Jones and Evans, 2008, p.7). The UK planning policy vision for regeneration within a sustainability framework is presented in the Urban White Paper - Our Towns and Cities: the Future, which aimed to:

"…bring together economic, social and environmental measures in a coherent approach to enable people and places to achieve their economic potential; bring social justice and equality of opportunity; and create places where people want to live and work. These issues are interdependent and cannot be looked at in isolation. ... That is why moving towards

[2] Gentrification is a term typically used when new arrival rich people displace poor ones.

more mixed and sustainable communities is important to many of our plans for improving the quality of urban life." (DETR, 2000). It is worthwhile noting here that the concept of sustainability to some extent has many commonalities with the North American idea of "Smart Growth" (Handy, 2005). Handy (2005) reported that according to the American Planning Association (2002), "Compact, transit accessible, pedestrian oriented, mixed use development patterns and land reuse epitomize the application of the principles of smart growth".

In consequence and to comply with this study scope, while urban renewal aims to boost the economic growth in decayed central cities, especially, city centres, by making them attractive places to live and work, the sustainability agenda implies that travel options of the residents should be eco-friendly.

2.4 Travel behaviour determinants – literature review

Based on what has been mentioned in Section 2.2.1 (Evolution of travel demand forecasting model context), this section reviews travel behaviour research related to the first and third steps of the orthodox four-step forecasting model: Trip generation and Mode choice.

However, firstly it is helpful to briefly highlight the underlying theory of the vast majority of the travel behaviour/pattern research: utility-based theory. The utility-based theory of urban travel demand modelling is one of the applications of the general consumer choice theory in microeconomics which has been widely utilised recently in investigating the link between the built environment and travel. There is no clear evidence concerning when utility theory started to be developed, though the 1970's obviously witnessed its spread (Chao & Qing, 2011). In economics, the postulation is that consumers willing to purchase goods or services do a trade off between their preferences and their expenditures by choosing options that maximise their utility (achieving their desires within the available budget). In transport modelling words, travellers optimise between their desires towards mobility decisions and generalised travel cost (travel time and monetary cost) according to the income constraint in order to maximise their utility (Domencich & McFadden, 1975). While the researcher is aware of the line of research which examines the impacts of transport investment (infrastructure and services) on land use patterns, this review is aimed at the second line of research that, in contrast, attempts to shed light on the effects of the built environments and user characteristics on travel behaviour.

The review is mainly devoted to research held in the industrialised countries rather than other countries due to the lack of relevant empirical evidence in such countries. Also to avoid any potential conflicting findings resulting from distinguishing factors such as economic status, difference in culture and planning policy aspirations and applied measures.

Furthermore, it was initially intended to devote the major part of this review to the empirical evidence in Europe and particularly in the UK. There are two reasons behind that; the first is the quite similar urban form patterns while the second is to stay within the scope of the study. However, the acknowledged interesting body of sound and relevant research in the USA (Headicar et al., 2009; van Acker et al., 2007), where the travel behaviour line is well theorised and practised, in comparison with the developing one in Europe (van Acker et al., 2007) and the moderate research output in the UK (Headicar et al., 2009) makes it hard to avoid including reference to American sources. The limited applicability due to dissimilarity in the scale of several built environment features is expected (Aditjandra, Mulley, & Nelson, 2009). For further details regarding spatial transferability issues, comprehensive information can be found in the PhD thesis authored by Karasmaa (2003).

Although the researcher is aware of the existence of hypothetical studies that use simulation models, this review solely considers empirical studies. Simulation studies have a limited role in adding to the understanding of the urban form-urban travel relationship; instead they attempt to examine people's travel behaviour (TB) under several hypothetical changes in influential variables depending on relationships assumed in advance (Crane, 2000; Handy, 1996a) and are often not well defined, understandable or transparent (Stead & Marshall, 2001). In contrast, empirical studies are typically derived from vital field data, based on real life observations and encompass fewer underlying assumptions (Stead & Marshall, 2001). However, there is simulation-based evidence indicating the importance of studying the potential impacts of urban structure on travel patterns (van Wee & Maat, 2003).

According to the reviewed literature, three bundles (dimensions) of characteristics are found to have the greatest potential impact on people's travel behaviour/pattern; namely, spatial, socioeconomic/demographic and attitudinal characteristics (Headicar et al., 2009; Meurs & Van Wee, 2003; van Acker & Witlox, 2005; van Acker et al., 2007). In consequence, this literature is structured accordingly. Figure 2-3 shows a typical schematic illustration for the dimensions that might affect people's travel behaviour.

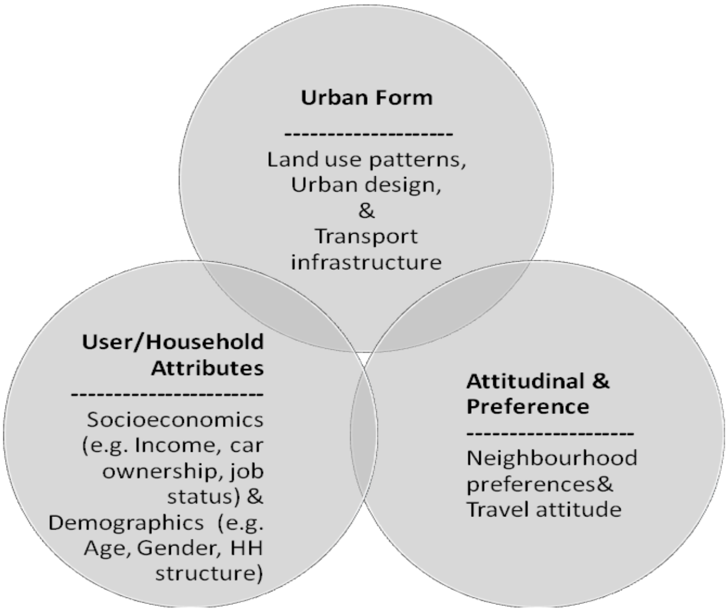

Figure 2-3 Travel behaviour frequently referred determinants and their potential interconnections.

2.4.1 Spatial characteristics

It is worthwhile firstly mentioning that in literature many terms are used to reflect the spatial features of an area. Terms like urban form, built/physical environment, community design and urban structure are the most frequently mentioned for describing more or less similar spatial characteristics. Thus, for the reader's convenience and to avoid misleading, all these terms are used here interchangeably unless otherwise stated.

There is almost an agreement that demand for travel is derived. That is, people often do not originally travel for travel itself (at least for utility trips); instead, they merely want to reach several activity centre locations dispersed spatially in order to pursue their activities located in these destinations. It is worthwhile noting here that this statement appears obvious in the context of the activity-based approach of travel demand modelling in which personal activities and travel patterns are modelled. Hence, the urban structure characteristics of neighbourhoods where people live or activity centres where people travel to are most likely to be important for travellers when making their decisions that maximise their utility.

Broadly, built environment features are often broken into three main aspects; land use patterns, transport system and urban design (Saelens & Handy, 2008; TRB, 2005). Land use patterns are usually defined by variables such as density, diversity and distance to the CBD/major activity centre. Transport system aspects comprise the physical elements of the system (such as roads, bridges and cycle paths) in addition to the service provided. Urban design variables often reflect the geometric setting of the community in terms of the appearance and arrangements of its physical elements (Handy, Boarnet, Ewing, & Killingsworth, 2002).

Nevertheless, researchers for specific reasons almost always choose one or two variables, individually or in combination, to define one or more of the three main dimensions of built environment in order to investigate their potential impact on one or two of the travel outcomes. Issues such as data quantity and availability, study scope and objectives, flexibility of the analytical method employed, and so on are typical objective reasons behind the number of built environment variables selected for inspection. According to the literature reviewed, variables like density, diversity, design, accessibility, neighbourhood theme and residential location are the most frequently examined. On the other hand, the most used travel behaviour measures are trip frequency, trip distance, mode choice or collectively as vehicle distance travelled (See for example, McNally & Kulkarani, 1997; Greenwald & Boarnet, 2001; Snellen et al., 2002; Cervero, 2003; Hickman & Banister, 2004; Boer et al., 2007; Banister, 2007; Wells & Yang, 2008; Buehler, 2011; Chao & Qing, 2011; Melia et al., 2011; Litman, 2011). Vehicle distance travelled (most commonly vehicle miles travelled, VMT) is widely viewed as the single best barometer that reflects the nature of urban travel patterns.

The generally hoped policy implication of urban form - travel behaviour modelling literature is that land use and design planning policy could shape travel patterns via urban form characteristics. For example, the 2011 version of the UK Planning Policy Guidance 13 (PPG13) has confirmed the vital role of land use planning in delivering the government transport strategy – "influencing the location, scale, density, design and mix of land uses, planning can help to reduce the need to travel, reduce the length of journeys and make it safer and easier for people to access jobs, shopping, leisure facilities and services by public transport, walking, and cycling." (DfCLG, 2011a, Paragraph 3; DETR, 2001, Paragraph 3).

The literature considering travel demand modelling and theory indicates that the proposition of the potentiality of land use variables in affecting travel has only been interestingly investigated during the last three decades (Handy, 2005). In the behavioural theory context of travel demand modelling, Domencich and McFadden (1975) mentioned the feasibility of including land use variables in travel demand models with traditional demand variables such as modal and user characteristics. Later, in the practical context of travel demand modelling, the interesting international work by Newman and Kenworthy in 1989 (and later in 1999) has apparently stimulated researchers and planners, both proponents and opponents, to examine this line of research. In their 1989 work, Newman and Kenworthy, studying 32 international cities, concluded that urban density could affect energy consumption; cities with high population density have lower annual gasoline use statistics (Newman & Kenworthy, 1989). In response to these interesting findings and to the emergence of the New Urbanism concept, researchers have gone further by investigating the effects of several built environment variables/factors on travel behaviour (Handy, 2005).

According to the literature, density, diversity, urban design and accessibility have been studied extensively (Chao & Qing, 2011); however, there is no clear agreement about their significance as determinants for explaining the variation in people's travel decisions. Generally, issues like model specification, methodological framework, and the geographical context are the most probable reasons for this (van Acker, et al., 2007). Further relevant issues will be discussed in the end part of the chapter.

2.4.1.1 Density

Density has a long history in the literature, however, earlier studies have mostly considered the effects of population density on the trip generation stage in the urban travel modelling process (for example see, Sharp et al., 1958; Bendtsen, 1967). As previously mentioned, the interesting works by McNally and Kenworthy (1989,1999) have motivated researchers in the last decades to investigate the impacts of land use variables, in general, and density in particular on several travel measures. Bearing in mind that density is defined as the variable of interest per unit of area, researchers usually examine population and housing density in residential neighbourhoods and employment density in activity centres.

Concerning the impact of density on trip frequency, empirical evidence is mixed. Boarnet and Sarmiento (1998) and Snellen et al. (2002) found that both population and employment density within census tract or zip code have no significant effect on the non-work individual car trips. On the contrary, Frank et al. (2000) found that high household density and employment density (in workplace) have significant lower HH trip frequency. Boarnet and Greenwald (2001) found that individual nonwork automobile trip frequency is much lower in high retail employment density areas. Finally, Henson and Essex (2003) have demonstrated that development density is central in determining the journey frequency of individuals. The mixed results above conclude that density is not a good indicator for people trip making behaviour as indicated by trip frequency.

Regarding vehicle miles travelled (VMT), in general, literature shows that if there is any impact of density on the VMT, it is negative; i.e., higher density leads to reduced car dependency. Researchers found that high population density at the residential location (Cervero and Kockleman, 1997; Pickrell and Schimek, 1999) or at the employment location (Chatman, 2008) can significantly lower VMT for nonwork trips. The same effect was found on the total VMT (Frank et al., 2000). Van de Coevering and Schwanen (2006) stated that high residential density cities have found to be influential in reducing distance driven. Regarding vehicle hours travelled (VHT), researchers found that high population and employment density at both residence and workplace can significantly lower the VHT (Frank et al., 2000).

On the other hand, regarding mode share, generally increasing density is thought to increase transit and non motorised trips. Many researchers have found that the propensity of pursuing daily activities on foot or the total number of daily walk trips are found to be increased with increasing population density (Greenwald & Boarnet, 2001; Reilly & Landis, 2003). Increasing employment density (especially retail) has also been found to empirically increase the individual walking frequency (Boarnet, Joh, Siembab, Fulton, & Nguyen, 2011) and the walk mode share (Frank, Bradley, Kavage, Chapman, & Lawton, 2008). Taking travel purpose into account, employment density has a significant positive impact on both work (Zhang, 2004) and nonwork trips (Greenwald and Boarnet, 2001).

Researchers have also found that the propensity for active transport (walking and cycling) for work trips and non-work trips could increase with increasing of the population density (Zhang, 2004). It is worthwhile mentioning that even for studies with non or marginally significant results, the vast majority of them are with positive parameter models; i.e., supporting the above evidence that higher density promotes walking and cycling (See for example, Boer et al., 2007; Chatman, 2009). On the other hand, the effect of density on transit trips and use is quite similar to its effect on walking. Population density (Cervero, 2006; Kuby, Barranda, & Upchurch, 2004; Reilly & Landis, 2003; Cervero, 2002; Zhang, 2004) and employment density (Frank et al, 2008; Zhang, 2004; Kuby et al, 2004) are all found to significantly raise the public transport share for work and nonwork trips (Zhang, 2004; Frank et al., 2008) and also rise the weekday station boarding (Kuby et al., 2004).

2.4.1.2 Diversity

Land use diversity or mix is often defined as the degree to which related land uses (such as housing, retail, office) are located together (Litman, 2011), or the extent to which several land uses are mixed in the same urban tract (Tanimowo, 2006). Different researchers employ different proxies to measure diversity in land uses. Occasionally, diversity is measured either as a jobs/housing balance (Bento, Cropper, Mobarak, & Vinha, 2005) or by an entropy index to scale the evenness of distribution of several land-use types within the region (Cervero & Kockelman, 1997). It is worthwhile mentioning that conventional urban structure planning aims to spatially separate different land uses (Tanimowo, 2006). However, recently in response to the new urbanism and compact city concepts, developments with diverse uses are strongly thought to maintain sustainability and reduce car dependency. The hypothesis is that living in areas with diverse land uses (many nearby non-residential land uses) could reduce car dependency and motivate transit and active transport. There is relatively strong and significant empirical evidence that diversity reduces the individual VMT (Chapman & Frank, 2004).

On the other hand, the literature confirms that increasing the mixture of land uses has considerable impact on the likelihood of using public transport and/or slow modes (walking/biking). Areas with diverse uses are found to significantly increase slow modes shares (Bento et al., 2003), increase walk mode choice for work trips (Frank et al., 2008) and non-work trips (Frank et al., 2008; Rajamani et al., 2003; Rielly and Landis, 2003), and lastly increase non-work walking frequency (Cao et al., 2006a, 2009b; Handy and Clifton, 2001; Handy, Cao, & Mokhtarian, 2006).

Living in housing areas where local shops and stores are nearby could considerably increase shopping walking trips (Cao et al., 2006a; Handy and Clifton, 2001; Handy et al., 2006). The proximity of commercial centres to the residence location has a strong impact on increasing the walk mode share for nonwork trips (Reilly and Landis, 2003). Regarding public transport (transit), similarly, empirical evidence is found in the literature about the positive impact of the land use mixture in promoting the frequency and mode share of public transport. However, there are few reported results.

Using different measures and proxies for land use dissimilarity, several researchers have found significant positive findings, that is, increasing diversity could significantly increase the probability of transit use (Cervero, 2002). Nevertheless, other researchers have found non-significant but positive linkage between diversity and transit (Frank et al., 2008). Finally, as distances between residential location and the nearest commercial use increase the likelihood for choosing transit as a mode for non-work trips decreases (Reilly and Landis, 2003).

2.4.1.3 Urban design

The urban design is typically characterised by several measures, mostly using indicators for the local street network characteristics; ranging from intense urban grid-like to sparse suburban with high cul-de-sac street networks. Collectively, the aim of these measures is to make a distinction between pedestrian-oriented and auto-centred developments (Ewing & Cervero, 2010). Examples of such measures which are frequently employed in research are intersection density (Boarnet et al., 2004; Chapman and Frank, 2004), proportion of 3-way or 4-way intersections (Boarnet, Nesamani, & Smith, 2004; Cervero & Kockelman, 1997), bicycle lane density (Bhat & Eluru, 2009; Bhat, Sen, & Eluru, 2009), and lastly sidewalk dimensions and coverage (Rodríguez & Joo, 2004).

In line with the new urbanism principle, the common hypothesis is that areas or neighbourhoods of grid-like street networks with sidewalk and path continuity, short blocks and traffic calming devices could highly promote non-motorised transport. Nevertheless, grid street networks of high connectivity and direct routing capable of distributing traffic and providing alternative routes for one destination would, on the other hand, appeal to motorised modes. Empirical studies state that household VMT (or VKT) could be significantly reduced with an increase in bicycle lane density (Bhat and Eluru, 2009; Bhat et al., 2009), or with an increase in intersection density (Boarnet et al., 2004; Chapman and Frank, 2004).

In contrast, residential areas with a high proportion of intersections are empirically found to provide a pedestrian-friendly built environment. These areas significantly increase the active transport trip frequency (Chatman, 2009; Greenwald & McNally, 2008) and increase the probability of the walk mode choice for work and other trips alike (Frank et al., 2008). Results also confirm that improvements in footpaths such as increasing its coverage or dimensions (length and/or width) could significantly increase the likelihood of non-car modes for nonwork trips (Cervero and Kockleman, 1997) and for commuting trips in particular (Rodriguez and Joo, 2004). Furthermore, regarding urban design issues concerning the geometric layout of buildings in an area, findings show that reducing block size could lead to a significant rise in the hourly pedestrian volume (Hess, Moudon, Snyder, & Stanilov, 1999).

In comparison with walking trips noted above, few studies found a significant effect of urban design on transit use, though studies with non-significant but logical results exist. The increase in the number of intersections in an area could significantly increase transit mode choice for work trips (Frank et al., 2008). At destinations, increasing the proportion of 4-way intersections could also notably raise the opportunity of transit choice. Finally, a neighbourhood with plenty of footpaths is also found to increase transit mode share. Concerning transport emissions, urban fabric that reduces travel distances would significantly decrease greenhouse gas emissions resulting from urban travel (Banister, 2007).

2.4.1.4 Accessibility

Accessibility (approachability) is one of the common urban form factors that has been widely used in the urban planning discipline. Different researchers define accessibility, theoretically and functionally, in different ways reflecting how complicated it is to express this concept in a single clear definition (Geurs, 2004). Generally, however, accessibility could be defined as ”the ease with which any land-use activity can be reached from a location using a particular transport system” (Dalvi & Martin, 1976). Handy and Clifton (2001) pointed out that the key reason for vitality of accessibility in urban planning is its ability in indicating the possibilities for available activities, such as working or shopping, in an area. They added that both the spread pattern of activities over space and the characteristics of the transport system connecting them could determine the accessibility.

Having said that, this section, however, concentrates mostly on investigating the effects of regional and public transport accessibilities on several travel outcomes. In this context, regional accessibility is largely measured as a function of the proximity and connectivity of a specific site location (such as housing development) to a regional urban centre (central city or CBD area) or to a specific major activity location (such as employment or shopping) (Litman, 2011; Badoe and Miller, 2000). Empirical research confirms there is strong evidence that sites with high accessibility lead to significant reduction in VMT and hence car dependency. Development sites located near the CBDs or city centres show significant reduction in their vehicle miles (or kilometres) travelled for non-work trips (Boarnet et al., 2004).

In addition, proximity to the CBD is found to considerably reduce the individual car weekday trip distance (Naess, 2005). As commuting to work forms an essential and important part of daily travel patterns for employed people, several researchers have investigated the influence of employment accessibility. Those researchers concluded that increasing job accessibility by car (Cervero and Kockleman, 1997) or the number of jobs surrounding the residences (Cervero & Duncan, 2006) is found to be considerably associated with a decrease in the HH VMT. Similarly, increasing accessibility to shopping leads to reduce HH VMT (Bhat et al., 2009). Moreover, Cervero and Duncan (2006) demonstrated that boosting the accessibility between employment and retail development sites significantly lessens the shopping VMT per person.

Evidence about the impact of destination accessibility on pedestrian behaviour is also found in the literature. Proximity to the CBD/town centre is one of the proxies to quantify employment accessibility. Sites located near the downtown (city centre) or CBD could significantly increase the weekday trip length by walking/cycling per person (Naess, 2005). Promoting employment accessibility by walking could have a powerful impact on increasing the likelihood of opting to walk/cycle. In contrast, households living in areas with high job accessibility by car conduct fewer walking/cycling trips. That is to say, a car-oriented development is different from a transit-oriented one.

In the same context, it has been important for planners to know to what extent accessible sites and in particular ones well connected by public transport could promote travel by it. Increasing job accessibility by automobile notably decreases the probability of choosing transit (Lund, Cervero, & Willson, 2004). In terms of quantifying accessibility spatially, Cervero (2006) found that weekday boarding per transit station could notably increase when the site is located within reasonable distance from the CBD. Likewise, Kuby et al. (2004) found weekday boarding at stations also could be enhanced but this time by reducing the average time to other stations.

2.4.1.5 Public transport accessibility

Basically, the hypothesis is that how ease (in terms of spatial proximity) in accessing a transit station could raise the tendency to utilise the station for travel. Thus, the common relevant research question is to what extent could living near a public transport station reduce vehicle distance driven and/or motivate residents to use public transport.

Bento et al., (2005) reported that living near a public transport stop significantly reduces vehicle kilometres travelled for a household. Furthermore, investigating the impacts of residential location on travel, Naess (2005) found that daily trip distance driven per person decreases with the decrease in the distance to a train station. Regarding non-car transport modes (walking/cycling and transit), there is a modest amount of literature studying the linkage of non-car travel behaviour and public transport accessibility. However, in general the findings show that dwelling units with less distance to the nearest stop often have high proportions of walking and cycling (Bento et al, 2005), though the effect is not significant. Rajamani et al. (2003) examined the influence of several built environment characteristics on nonwork trip mode choice. The developed multinomial logit model parameters and the elasticity figures show that the increase in the percentage of dwelling units within walking distance from bus stops could significantly increase the probability of choosing public transport mode for all non-work trips.

2.4.1.6 Neighbourhood prototype

The effects of the urban form characteristics of a neighbourhood (place) on travel patterns have been investigated by many studies. This line of travel behaviour research has widely emerged in the literature especially after proposing spatial policies such as New Urbanism in the USA and Compact City Policy in Europe (Bohte, et al., 2009). The common general goal is to investigate the extent to which land use planning strategies can affect transport options on the purpose of achieving sustainability. As mentioned previously, individual urban form characteristics such as density, diversity, design and accessibility have been quite extensively researched.

In this relatively “new” line of travel behaviour, neighbourhoods are categorised into several types according to their individual characteristics collectively. The general assumption is that developments with high residential density, mixed land uses and non car-based urban design could encourage people towards more walking/cycling and use of public transport and hence address key transport-related externalities such as emission and energy consumption. According to (Stead & Marshall, 2001), neighbourhood type is generally considered as a composite measure which may incorporate road transport network type. However, two issues may be highlighted here; first, categorising two or three neighbourhoods in one categorical variable would typically mean that some of the individual differences may be masked (Cervero, 2003). Second, an individual's decisions relating to their activity space and time often lie beyond their residential neighbourhood (Badoe & Miller, 2000).

Neighbourhood categorisations such as Neo-traditional (New Urbanist) vs. Standard (conventional) suburban, Transit-oriented vs. Auto-centred, or Pedestrian-oriented vs. Car-oriented developments are the most quoted and researched. Typically, each category has several thematic characteristics that differentiate it from others. For example, in contrast to the standard suburban, neo-traditional neighbourhoods are characterized by high densities, mixture of land uses, and non-auto-orientated design. Such characteristics usually decrease HH VMT by reducing auto use and/or trip distance and maximise the tendency towards using public transit and non-motorised transport modes (van Acker, et al., 2007).

Regarding socioeconomics, McNally and Kulkarni (1997) reported that the characteristics of the respondents of households residing in neo-traditional developments (NTD) are different from those residing in suburbs. Generally, in contrast to the suburban household's traits, households located in NTDs usually have lower income, less household members, more full time students, and more in full time work. In addition, they added that households in NTD have fewer tendencies to own a second car; however, this might be because residents in NTD often prefer to live in apartments rather than houses. In the next paragraphs, findings of several relevant studies are highlighted. A number of neighbourhoods that match the compact city policy are compared with standard suburban neighbourhood for several travel outcomes.

As expected in theory, developments with an urban form supporting the compact city land strategy show significant reductions in the vehicle miles travelled (VMT) in comparison with the standard design of suburban development. Similarly, Cervero (2007) in investigating the ridership in transit-oriented developments (TOD) concluded that residents of TOD have notably lower commuting VMT per se than those who live in conventional suburbs.

Furthermore, urban neighbourhood living could remarkably reduce HH VMT (Bhat and Eluru, 2009) and auto VMT per person (Cao et al., 2009a) in comparison with suburbs. Empirical findings demonstrate strong evidence that traditional neighbourhoods motivate people to walk more. Examining individuals nonworking trip patterns in traditional neighbourhoods, dwellers in such neighbourhoods walk more to stores (Handy and Clifton 2001) and conduct more non-work trips (Cao et al., 2009a) than those in standard neighbourhoods. Also research emphasises that new urbanist neighbourhoods could considerably increase walking trips per household (Khattak & Rodriguez, 2005). Additionally, neighbourhoods containing a considerable proportion of retail land uses could boost the chance that people would commute on foot (Plaut, 2005) and increase walking frequency (Lund, 2003).

Another issue that has been reviewed by researchers is whether the increase in non-car (walking/cycling and transit) trips in NTD occurs as substituting for some driving trips or there is a total increase in travel. Handy (1996b) stated that neighbourhood design could play an important role in motivating walking to destinations; however, there is no considerable reduction in the total amount of travel.

2.4.2 Socioeconomic/socio-demographics

As seen in Section 2.4.1, broadly speaking, there is a considerable amount of empirical evidence about the potential influence of urban form (defined by a wide array of spatial proxy features) on travel behaviour. Nonetheless, several empirical research findings concluded that a number of land use or urban design variables have no significant effects on several travel outcomes. Moreover, sometimes studies investigating similar variables reached contradictory results. For example, some researchers found no significant impact of population and job density on the HH VMT (Boarnet et al., 2004), of the destination accessibility on walking mode share (Cervero and Duncan, 2003) or of some urban design proxies like intersection density on transit trips (Cervero and Kockleman, 1997).

This dissonance (disagreement) in findings has raised a prolonged debate about the feasibility of land and transport planning policy in shaping travel behaviour via adapting the built environment. This debate about disagreement in findings is well referenced in the literature (See for example, van Aker et al., 2005&2007; Dieleman et al., 2002; Rajamani et al., 2003; Bohte et al., 2009; Antipova et al., 2011). Different researchers present different justifications and explanations for this disagreement in findings (a brief summary of these reasons can be seen in Section 2.4.4). However, one of the widely accepted reasons is that the linkage between urban form and travel outcomes could be confounded by other exogenous variables or factors. Most frequently such variables are the socioeconomic and attitudinal characteristics. While the potential influence of the attitude and preference variables will be highlighted in Section 2.4.3, socioeconomic and demographic key characteristics are reviewed here.

Researchers have tackled socioeconomics mainly in two ways. First, by controlling for individual or household characteristics when developing urban form-travel behaviour models. Most frequently, the variables controlled for are income and car ownership. Other socioeconomic factors such as age, gender, race, marital status, job status, education and presence of children are also to a lesser extent controlled for. The second way which has been adopted by researchers in dealing with personal attributes is to directly research their impacts on several travel measures like VMT, trip frequency, mode choice and others.

Recently, the vast majority of research investigating the impact of the residential spatial environment on transport follows the first approach in dealing with socioeconomics. Since most of the studies reviewed in the previous Section are of this type, no more effort will be assigned for such studies here. In contrast, in the rest of this section a number of the studies that have directly examined the socioeconomic characteristics are reviewed.

Rather than being theoretically hypothesized, there is sound empirical-based evidence that socioeconomic/demographic traits whether at household or individual level play a key role in people’s travel decisions. For example, McNally and Kulkarni (1997) employing income as the only proxy for other socioeconomics, reported that income has a stronger relationship with people’s travel options than neighbourhood theme. Characteristics such as household composition and life-cycle stages, income, car ownership, job and education are found to be representative explanatory variables in travel behaviour/pattern statistical models. In the theory context, as said previously, personal attributes are employed as proxies for people’s tastes in the consumer choice theory. That is, whether the demand for travel is derived as a need, like a shopping journey for instance, or people merely travel for its own sake, say for jogging, individual traits still obviously dominate the transport mode chosen for the shopping journeys and trip frequency for the jogging journeys.

2.4.2.1 Socioeconomics

1) Income

Income has always been seen as a key factor in influencing traveller's options. Income may affect daily travel decisions directly and indirectly. Simply, low income travellers would walk, bike or use transit rather than taking a taxi mainly because their mode choice set is bounded by the travel fare. In contrast, income could indirectly manipulate travel behaviour by affecting variables that in turn directly affect travel decisions; for instance households able to own a detached house with a double-car garage would probably increase their propensity of owning the second car due to easier parking or/and as a sort of life-style and prestige. Income as an independent variable is generally defined either as a continuous or categorical variable. Issues like availability of data, nature of the research question and the statistical technique planned to be used are the main causes behind that. Nationally, the US NHTS of 2001 shows a clear association between the increase in HH income and the urban personal daily trips and miles travelled (Pucher & Renne, 2003).

Many empirical studies highlight the significant effect of income on travel behaviour. Some of these studies measured it at the individual level or neighbourhood level while others at the region or countrywide level. In contrast, evidence is also found on the negligible or insignificance of income on urban travel, particularly those studies which include car ownership as one of the indicators. Statistically speaking, the surprising findings of the latter set of studies could be associated with the violation of the inferential statistical technique used, often regression analysis. One of the main assumptions of regression analysis is that indicators should not be highly correlated in order to avoid multicollinearty issue. Hence, the expected correlation between income and car ownership could be the reason. Pucher and Renne (2003), using the 2001 US NHTS confirmed this association.

Several research articles investigated the effect of income on trip frequency. McNally and Kulkarni (1997) investigated potential relationships between the neighbourhood design type and the travel behaviour. ANOVA results showed that total household trip rates in neighbourhoods with high income residents are significantly higher than those in neighbourhoods with medium or low income. Paez et al. (2007) pointed out that living in zones with high median income increases the tendency of trip making, though it is marginal. Based on descriptive analysis using the 2001 U.S. NHTS data base, Pucher and Renne (2003) stated that higher income households make more daily trips. Polk (2004), using data collected by the Swedish Research Board for Communication Studies, developed a regression model for the potential variables that might affect daily car use in Sweden. Model parameters show that there are no clear differences between low, medium and high income groups regarding their daily car use.

In addition, the effect of income on VMT is examined in the literature. The impacts of income, car ownership and academic qualification on distance travelled were explored by Dieleman et al. (2002). While all the three variables are statistically significant in the regression model, income has clearer impacts. When income increases, the commuting distances travelled for work by all modes are raised. Further, for all journey purposes included, the increase in income is significantly associated with the increase in driving. As a comparison study for the factors affecting travel behaviour in the US and GB, Giuliano and Dargay (2006) examined the influence of income on the total daily miles travelled. For income, the parameters of both the US and GB regression models show an increase in daily travel with an increase in people's income. Chao and Qing (2011) using the structural equation modelling technique, examined the effects of household socioeconomic traits on vehicle miles travelled. The SEM model parameters show that income is found to have a small impact on the VMT.

The effect of income on mode choice is examined in the literature. McNally and Kulkarni (1997) stated that neighbourhoods with high income dwellers use car significantly more than those neighbourhoods with low income dwellers. Ryley (2006) using the SPSS Answer Tree technique and SHS data, found that income is one of the important variables that increase the likelihood of driving to work. Dieleman et al. (2002) examined the linkages between the individual/household traits and travel behaviour in Dutch communities. They found that household income has quite a modest effect on the transport mode choice (car driver, public transport and active transport). Buehler (2011) conducted a comparative study on the influential variables that affect transport mode choice of Germans and Americans. The Multinomial logit regression parameters show that, generally, an increase in income would reduce the PT ridership, walking and cycling, though the reduction is slight. Chao and Qing (2011) using a structural equation modelling technique, examined the effects of household socioeconomic traits on mode choice. The model parameters show that income has a slight positive impact on the transit ridership and walking.

2) Car ownership

The impact of car ownership and availability[3] on people's mobility are considered in almost all the research attempting to investigate the factors that affect urban travel patterns. In the literature, the presence of a household car is modelled in three main ways. Firstly, and mostly, by including it as a predictor that helps in explaining several travel behaviour measures - as an exogenous variable (e.g., Paez et al., 2007; Dieleman et al., 2002; van de Coevering & Schwanen, 2006; Chao and Qing, 2011). Secondly by considering HH car ownership itself as one of the travel behaviour measures - as an endogenous variable - and building econometric models that link it with several spatial and personal explanatory variables that best reflect the decisions of owning/giving up an auto. Such studies include, Dargay (2001), Clark (2007), Nolan (2010), Zegras (2010) and Giuliano and Dargay (2006). Thirdly, by modelling car ownership as an intermediate variable that mediates or confounds the urban form/travel behaviour relationship. Generally, a moderate amount of empirical work uses this modelling approach, examples of such studies are Scheiner & Holz-Rau (2007), van Acker & Witlox (2010), Simma & Axhausen (2003), Aditjandra, Cao, & Mulley (2012).

Several research articles investigated the effect of car ownership on trip frequency. Paez et al (2007) employed mixed ordered probit models to study the role of the elderly as a factor in trip making behaviour. The results state that the household auto and licence ownership increases the frequency for travel. In addition, the effect of car ownership on VMT is examined in the literature. The impacts of car ownership on kilometres travelled were explored by Dieleman et al. (2002). The car ownership variable is statistically significant in the regression model. The availability of a household car increases the average distance driven for the three journey purposes included; work, shopping and leisure, though the effect on commuting is larger. On the other hand, the presence of a car has trivial impact on public transport kilometres travelled but significantly reduces distances travelled by walking or biking. Giuliano and Dargay (2006) examined the influence of car ownership on the household daily miles travelled in the USA and GB. Regression results show that the presence of a car in the American and British households escalate their propensity towards travel. This effect is, however, more concrete in the US model. This might be a reflection of

[3] Car availability could be quantified by the car availability index which is the ratio of the number of cars in the household to the number of valid driving licences in the household; the ratio is set at zero if a person has no driving licence (Limtanakool, Dijst, & Schwanen, 2006, p330).

the thematic nature of American society regarding the highly auto dependency. Chao and Qing (2011) using a structural equation modelling technique, examined the effects of household socioeconomic features on VMT. Unlike income, the number of vehicles is found to have a strong significant positive impact on the VMT.

Car ownership plays a major role in choosing travel mode. Dieleman et al. (2002) found that, unlike household income, car ownership has quite a high significant effect on the transport mode choice (car driver, public transport and active transport). The presence of car notably lowers the possibilities of using other modes like public transport, cycling or walking. Adopting the greater Dublin area as the study area and using the 2002 Irish Census of population, Vega and Reynolds-Feighan (2008) developed a binary logit approach to model working trips mode choice in employment sub-centres (a site with relatively high employment density). Analysis of the results indicates that the presence of a household car significantly reduces the probability of using transit in favour of the private car. Ryley (2006) found that car ownership is the most important variable that increases the likelihood of driving to work. Buehler (2011) conducted a comparative study on the influential variables that affect transport mode choice of Germans and Americans. The Multinomial logit regression parameters show that the presence of household car significantly increases the chance of using it. Chao and Qing (2011) using the structural equation modelling technique, examined the direct effects of the number of household cars on mode choice. Surprisingly, the structural equation model parameters show that number of cars has no significant impact on the mode selected.

Finally, regarding transport energy use, Chao and Qing (2011) concluded that among number of children, income, race, age and number of cars, only the latter is found to have a significant positive impact on energy consumption.

3) Employment and occupational status

Job status has noticeable impacts on the travel-related decisions on both individual and HH levels. Usually employment status reflects aspects such as employed (part/full time), unemployed, retired and student. Occupation, on the other hand, reflects features like professional, senior/middle management, clerical/administrative, skilled manual. Job status features are either examined as standalone indicators or as proxies for other SE traits such as income and lifestyle.

Several research articles investigated the effect of employment on trip frequency. Paez et al (2007) stated that the employment status (full time or not) has no significant impact on the HH trip generation. However, it has a significant positive impact for females. The effect of employment on trip distance is examined by Vega and Reynolds-Feighan (2008) utilising a logit approach to model working trips mode choice in several Employment sub-centres in Dublin region. Traveller's occupation plays a significant role in determining the travel mode. Professionals, managers, and skilled/unskilled people prefer to use car rather than public transport in their journeys to work. In addition, the effect of employment on the vehicle miles travelled is examined in the literature. Chao and Qing (2011) examined the effects of HH socioeconomic attributes on VMT. The developed model parameters show that the number of household members with a job has no significant impact on the VMT.

The effect of employment on mode choice is examined in the literature as well. Buehler (2011) conducting a comparative study and using multinomial logit regression, showed that while both German and American retirees walk more than drive, only Germans were found to use transit remarkably more than auto. Chao and Qing (2011) examined the effects of HH workers on modal share. The findings indicate that the number of workers in a household has no significant impact on the mode used.

4) Education status

Although it does not have a long history in travel behaviour research, many researchers have investigated the potential association of academic qualifications with several mobility indicators. One of the main modelling issues with categorising the academic qualification for individuals is probably the difficulty of discrimination among categories in order to end up with ones that are as mutually-exclusive as possible.

The effect of education status on the vehicle miles travelled is explored by Dieleman et al. (2002). The three developed models have a modest ability to explain the variation in distance travelled; i.e. a low coefficient of determination. The impact of education status is quite weak and not clear with the exception that people with an education level higher than high school commute less by cycling/walking relatively to others. Regarding the travel mode choice issue, Dieleman et al. (2002) found that education status has quite a significant effect on the transport mode choice (car driver, public transport and active transport). With the exception of people of low education status, work and leisure trips are often done by car whereas public transport is the preferred mode for shopping.

2.4.2.2 Sociodemographics

1) Age

The individual's age is found to be one of the attributes that affect people's travel options. Age as an independent variable in transport planning models is usually either simply defined by the number of years or categorised to reflect the life cycle stages of an individual; for instance, pre-school/school age child, teenager, adult and elderly. The effect of age is either studied as a single traveller trait in an individual level analysis or in combination with other household characteristics, mostly family life-cycle stages, in HH level analysis. Generally, the statistics of the US NHTS for 2001 indicate that middle-aged travellers do more daily trips and for longer distances than their younger and senior counterparts (Pucher & Renne, 2003).

Several research articles investigated the effect of age on trip frequency. In their comparative study on the features quantifying the personal travel patterns in the US and GB, Giuliano and Dargay (2006) found that respondent age as an explanatory variable has a tangible effect. For both the US and GB statistical models, elderly people (> 65 years) travel significantly less than those middle aged (35-64). Conversely, while the youngest American adults (18-34) significantly travel more than those in the middle age, no such significance appears in the GB model. Paez et al. (2007) using data from Toronto's Transport Tomorrow Survey and mixed ordered probit models studied the role of elderly in trip making behaviour. Model parameters confirm that all age groups have a significant impact on the number of the total trips conducted. Furthermore, results show that both the juniors (< 20 years) and seniors (more than 50 years) are less keen to make trips than those in the (34–50) group. Chao and Qing (2011) support Paez et al.'s findings in that the analysis results confirm that the travel behaviour of people under 20 years old is quite similar to those in pre-retirement and elderly (+65) groups and both of them have a low tendency for making trips. Chao and Qing (2011) also confirmed that household members average age has a minor impact on the VMT.

The effect of age on mode choice is examined in the literature as well. Vega and Reynolds-Feighan (2008) claimed that alternative characteristics (travel cost and time) and decision makers sociodemographics are significant. Senior employees were found to be more pro-auto than those under 35 years old. On the other hand, Greenwald (2006) using the 1994 Portland Travel Behaviour Survey, found that traveller age is not a major player regarding mode choice decisions. Chao and Qing (2011) pointed out that household members' average age has no substantial impact on the selection of transport mode.

2) Gender

Historically, gender has a clear position in terms of the travel behaviour patterns of males and females. Roughly, the travel-related gender knowledge gap in research can mainly be summarised in that while the traditional role for men is breadwinning, the usual role of women is homemaking. Consequently, these roles clearly discriminate the mobility characteristics of each of them. For instance, Hanson and Hanson (1980), based on field survey in Sweden in 1971, pointed out that while women do more shopping trips, men within the same life-cycle stage are found to conduct more work trips. However, the statistics of the US 2001 NHTS obviously show that this difference is becoming smaller (Pucher & Renne, 2003). Having said that, recent research has often investigated whether this gender-based travel behaviour is still dominant even after the current notable participation of women in the labour force and the apparent narrowing of the gap (Kitamura, 2009).

Several research articles have investigated the effect of gender on trip making frequency. Handy (2006) found that there was no remarkable dissimilarity between the shopping and strolling (just for a walk) monthly trips for males and females. In addition, the effect of gender on the vehicle miles travelled (VMT) is examined in the literature. Chao and Qing (2011) examined the effects of several household sociodemographics traits on VMT. Unlike age and race, gender was found to have a significant positive impact on the VMT. Males appear to travel longer distances than females. Handy (2006) found that, men drive further than women and that this is significant for all trips as well as non-work trips.

Concerning the effect of gender on mode choice, using the 2002 Irish Census of population, Vega and Reynolds-Feighan (2008) showed that concerning gender, model parameters confirm that females commute less than males by car. Ryley (2006) using the Scottish household survey (SHS) database, found that men are more likely to use the bike for their work journeys. Buehler (2011) conducting an international comparative study and using a multinomial logit technique, reported that whereas there is no clear gender difference in cycling in Germany, women are significantly less probable to cycle than men in the USA.

Speaking to transport energy expenditures, among number of children, workers, income, race, and gender, the latter is found to have a significant positive impact on the energy consumption. Males seem to travel longer distances than females and hence consume more energy (Chao & Qing, 2011).

3) Household composition and life-cycle stages

The household composition and life-cycle stages are the most household-level statistics that generally reflect the extent to which household type and typology can shape their members mobility patterns. However, employment and income characteristics are occasionally combined with one of these statistics to present the HH categorisation that best reflects travel-related decisions.

Regarding trip frequency, Handy (2006) found that, the presence of children reduces the monthly frequency of the woman's trip for shopping or just strolling. Ryley (2006) examined the potential link between Edinburgh's residents life stage and their walking/cycling behaviour using the Scottish Household survey. Using a cluster analysis technique the study sample was grouped into ten population segments according to their life stage dissimilarities. The descriptive analysis for the travel behaviour measures for those ten segments show that students, high income with children and those seeking a job are the highest three segments ranked by cycling rate. In contrast, retirees have the lowest walking/biking trip frequency. Part-time employees with children are found to be the highest population group in the walking trip frequency. Paez et al (2007) found that all other types of household compositions take significantly less trips than single adult households or single parents with children.

With respect to VMT, the effects of household type (typology) on the kilometres travelled were studied by Dieleman et al. (2002). Generally, household type traits as indicators in the regression models add little to the goodness of fit of the model. However, the results show that households with no children often drive slightly longer recreation journeys than those with children. Moreover, couples without children often walk/bike longer distances for shopping. Handy (2006) found that, in general, women with children have a higher total weekly VMT than those without children, this behaviour also exists to a lesser degree for non-work VMT. Dargay (2007) using the UK Family Expenditure Survey, pointed out that households present a continuous increase in the weekly car kilometres driven until the age the head of household reaches about 50 years. Concerning mode shares, the effects of Dutch household typology on the travel mode chosen was explored by Dieleman et al. (2002). Generally, the regression parameters show that the absence of children is significantly linked with the propensity of driving to work, shopping and recreation. On the other hand, families without children are less likely to walk/bike for shopping or leisure trips than those with children. Ryley (2006) examined the potential link between Edinburgh's residents' life stages and their walking/cycling behaviour using the SHS. Using a cluster analysis technique the study stated that high earners with children often prefer to drive to work and occasionally walk to their workplaces.

Buehler (2011) conducted a comparative study on the influential variables that affect transport mode choice of Germans and Americans. American individuals living alone/as couples significantly drive less, though this is more obvious for those who are unemployed. In Germany, similar groups conduct car trips more and are specifically less interested in transit. The presence of children in American HHs significantly increases the propensity of walking and using transit; in contrast, no such effect is found in Germany. Finally, teenagers, as one would expect, are more likely to walk than others. Chao and Qing (2011) examined the impact of the number of children (<16) in a family on the travel mode choice. The structural equation model's parameters show that the presence of children in households significantly boosts the propensity towards carrying out transit and walking trips.

2.4.3 Attitudes and preferences

Attitudes towards travel and neighbourhood preferences are two behavioural factors that have emerged in the travel behaviour line of research only in the recent past. Two factors have notably contributed to this significant interest in investigating the effect of attitudinal variables; first, the change in planning policy from predict-provide (supply measures) to travel demand management (TDM) and the second is the high worldwide concerns about transport-related problems like air pollution and global warming (Schwanen & Mokhtarian, 2005b). The common relevant research question is that whether these factors, individually or collectively, could play a major role in explaining travel decisions rather than urban form characteristics. However, the availability of data is a key barrier in increasing the development of such line of research (Schwanen & Mokhtarian, 2005b; van Acker, et al., 2007). According to the literature available to this study the work conducted by Handy (1996 a,b) could be considered as pioneering research in highlighting the potential effect of travel-related attitudes and residential preferences on travel decisions. Handy (1996b) studied the effect of residential environments on walking behaviour. The study showed that Individual motivations and limitations are found to be vital indicators for strollers (walkers). Boarnet and Sarmiento (1998) are also among the first to highlight the issue of residential neighbourhood preferences. That is, people might make their residential choice to some extent based on their preferred travel option.

As stated previously, the choice of residence location by an individual depending on his/her travel preferences and the extent to which the selected neighbourhood design encourages such preferences is usually referred as residential self-selection or residential sorting. This line of research, however, is more researched in studies conducted in North-America and the Netherlands (van Acker & Witlox, 2005). The general research question in such studies is that although there is evidence that people living in neo-traditional developments (NTD) drive less and walk more than those in suburbs, the important question is to what extent this behaviour could be explained by urban form spatial characteristics alone rather than being as a result of the residential self-selection effect (Cao, Mokhtarian, & Handy, 2009b).

In addition, with the effect of self-selection taken into account, some researchers have questioned the extent to which could land use policy affects travel (Bohte et al., 2009; Chatman, 2009; van Wee, Holwerda, & van Baren, 2002). Generally, it is well reported that urban form affect people's travel decisions, though sometimes this effect is modest. Thus, researchers argue for the role of structural environment in that even with a small effect it still at least provides the residential environment for those who self select their residence (Bohte et al., 2009). Furthermore, Naess (2009) claimed that the self selection of people to live in their preferred developments clearly reflects the importance of built environment. Based on the travel survey in the Copenhagen Metropolitan Area, he also empirically found evidence that residential location relative to the CBD (Copenhagen downtown) has a strong and significant impact on people's travel patterns even after controlling for preferences towards neighbourhood and travel. The relative influences of urban spatial form and residential self-selection on the patterns of travel behaviour have recently been investigated by several researchers. Findings differ about which of them – urban form or attitudes and preferences- has the stronger effect (if any) on people's travel decisions. In the next paragraphs a brief review is presented of a number of travel behaviour studies that take into account, one way or another, the potential influence of residential self-selection. Before moving on to this review two issues are worthwhile mentioning, the first is that all of the included studies have controlled for socioeconomic/demographic traits. Thus, and to reduce possible confusion for the reader, the light is shed only on the relative importance on spatial and attitudinal factors. The second note is that all the listed studies demonstrated that the built environment affects travel outcomes; nevertheless the aim of the review is to underline the size effect of residential sorting in contrast to the built environment.

Empirical evidence is found regarding the joint impact of urban form and self-selection on travel. That is, both the residential environment features and the preferences towards neighbourhood and travel are central in residents' choices regarding transport. This general finding is found by different researchers and for several travel outcomes such as walking frequency (Handy and Clifton, 2001; Handy et al., 2006; Cao et al., 2006a; Frank, Saelens, Powell, & Chapman, 2007), biking travel behaviour (Handy et al., 2006; Cao, Mokhtarian, & Handy, 2007b), vehicle miles travelled (Handy et al., 2005; Scheiner and Holz-Rau, 2007), travel mode choice (Boer et al., 2007; Cervero, 2007; Pinjari, Pendyala, Bhat, & Waddell, 2007) car ownership (Chen, Gong, & Paaswell, 2008; Cao, Mokhtarian, & Handy, 2007a and Cao, et al., 2007b) and vehicle type choice (Cao, Mokhtarian, & Handy, 2006b).

Evidence is also empirically found by other researchers that built environment elements have a stronger influence on travel behaviour than attitudes and preferences. In these studies, unlike residential sorting, urban spatial form characteristics have a significant influence on the frequency of using public transport and non-motorised modes (Chatman, 2009), on the non-commute trip frequency (Schwanen & Mokhtarian, 2005a), on the commute mode choice (Shwanen and Mokhtarian, 2005a), on the distance travelled by car, bus, train and walking/biking (Shwanen and Mokhtarian, 2005b) or generally by vehicle (Zhou and Kockleman, 2008) and finally on the walking level in terms of none, some, and a lot (Salon, 2006). In Copenhagen, Naess (2005) concluded that residential location is central in shaping people's travel patterns, in particular, concerning the amount of travel and mode choice related decisions even after controlling for attitudinal variables. In contrast, fewer researchers have found evidence that the impacts of residential sorting on travel outcomes outweigh the ones caused by the physical environment. The travel measures used in such studies are travel frequency and distance travelled by vehicle, transit and walking/cycling.

Finally, some researchers have claimed that neighbourhood preferences have no or non-significant effects on some travel outcomes such as car and walking frequency, non work trip distance, and trip duration (Khattak and Rodriguez, 2005) as well as the number of cars owned (Bhat & Guo, 2007).

2.4.4 Absence of harmony in findings

In the previous sections (2.4.1, 2.4.2, and 2.4.3), the potential influence of the three dimensions of characteristics (spatial, personal, and attitudinal) on travel behaviour has been reviewed. The review demonstrates that there is almost no consensus in findings whether based on dimension or the variables which describe these dimensions. That is, there is currently no agreement regarding which aspect of characteristics -spatial, personal or attitudinal- has the strongest and more significant impact on shaping travel. Likewise, this is also true for the variables and factors comprising each single dimension; for instance, population density, land use mix, academic qualification status and housing preferences. What is more, this inconsistency in findings and consequent complexity regarding the relative factors shaping urban travel has been frequently and explicitly reported in the literature (e.g., Antipova et al., 2011; Bothe, 2009; Badoe, 2000).

It is obviously not straightforward, and probably quite mind-numbing for readers, to discuss the possible causes behind the findings obtained in each single study or/and the reasons behind its deviation from other relevant studies. Instead, the general and frequently cited potential reasons for this collection of dissimilar findings will be presented. Generally, issues such as analysis level, data issues, model specification, methodology and results interpretation are the most highlighted by researchers (Badoe, 2000; Schwanen & Mokhtarian, 2005b).

2.4.4.1 Analysis level (Aggregate and Disaggregate)

Aggregate travel analysis is usually based on data at the zone, census tract, neighbourhood or city level, while disaggregate analysis is that which is based on data collected at the household or individual level (Handy, et al., 1998; Ortuzar & Willumsen, 2011). While aggregate modelling is classically preferable for travel demand forecasting models, recently household and individual data are central for modelling travel behaviour which is usually conducted at the disaggregate level of analysis. However, in contrast to socioeconomics, most of the built environment elements are inevitably measured at site, neighbourhood or region level.

The vital issue in aggregation is that it is strongly expected to mask differences in travel behaviours between households or individuals and thus might lead to confusing results and decisions (Antipova et al., 2011; Boarnet and Sarmiento, 1998; Ortuzar and Willumsen, 2011). This issue clearly appears in research addressing the impact of neighbourhood design on travel where mean values (averages) are utilised in inferential statistical analysis (often using the t-test or analysis of variance) to examine the existence of a significant difference in travel outcomes; or when using socioeconomic variables, say income or household size, which is initially measured at the census tract level to develop disaggregate – household- travel models.

Another aspect of problems associated with the level of analysis is the discrepancy between the level at which the endogenous variable (outcome) is measured and the expected corresponding spatial extent of the measured exogenous data (predictor). For instance, (Boussauw & Witlox, 2011) confirmed that daily distances travelled could be effectively attributed to land use indicators like residential density, land use mixture and availability of local facilities only if these indicators were measured within the area directly surrounding the residence location; a threshold of 1 km radius was reported.

2.4.4.2 Data-related issues

Overall, data sources employed in travel behaviour empirical studies are either from previous surveys (often national, regional or local household surveys) or sometimes researchers have conducted their own travel survey. Regardless of the source of data, issues like data accuracy, validity and reliability are essential.

One of the clear examples of data accuracy is the way of calculating trip distance in travel behaviour/demand modelling. This travel outcome is frequently calculated and needed either per se or for computing the distance travelled for any mode (often vehicle) and hence estimating the transport energy use and/or green house gas emissions. Differences in results regarding journey distance and consequent related variables usually arise from there being two methods of computing it. The approximate but most common one is simply to calculate the direct fly distance between the centroid of the traffic analysis zone TAZ_1 where the trip originated to the centroid of TAZ_2 where the trip is destined. On the other hand, the accurate method is to calculate the trip length of the actual route between origin and destination via the actual local street network. Obviously, the degree of discrepancy between the actual and direct distance depends on two issues; first, how far is the trip origin or destination from the centroid of the respective analysis zone, second, how direct is the urban design of the local street network.

In contrast, issues like data reliability and validity are fundamental in surveys whether these surveys are conducted by the researchers themselves or pre-conducted surveys. Surveys are a way of collecting data, hence the robustness of the data collected largely depends on the techniques and approaches used in collecting them – statistically speaking, survey design and sampling issues. Regarding sample design, studies with similar research question(s) may differ in the adopted sample size. In general, the larger the sample size the more representative it is of the population. Likewise, similar studies could conduct or use surveys of different designs (cross-section or longitudinal) or different techniques for approaching respondents (e.g. interview, posting self-administrated questionnaires, on-line questionnaires, or by telephone). Issues like availability of funding and time on one hand and response rate on the other hand are often strong challenges for the degree of accuracy required. For example, in order to maximise the response rate by reducing the burden on respondents, surveyors usually call for ignoring short walking trips. While this approach is widely used even in government sponsored surveys, it is obvious that this will lead to underestimate non-motorised modes of transport. Hence, studies investigating walking behaviour for instance may end up with different results.

Another survey data issue that may make findings uncertain is the survey credibility: the reliability and validity of the survey itself. While a reliable survey leads to consistent information, the validity in surveys is essential in assuring accurate information (Fink, 2008). Researchers using household surveys with an array of degrees of credibility would definitely produce findings with variety in integrity. An invalid survey is one which fails, partly or completely, to measure what is supposed to be measured. This may be because of using a misleading or incomplete set of questions that are supposed to measure a specific trait.

Cao et al. (2009b) critically reviewed one of their own earlier works (Cao, Handy, & Mokhtarian, 2006a) to examine the self-selection effect of walking trips for strolling or to a local store. The criticism was focused on two issues. First, there was only one measure used to capture the self-selection trait. Second, no attitudinal measure was used to quantify resident's preferences towards strolling. These two issues are thought to have the potential to bias the results.

2.4.4.3 Model specification

The ultimate target in travel modelling is far beyond only building complex models; instead it is how to be adequately aware of the real life behaviour that these mathematical models are built to imitate (Barnes & Davis, 1999). The regression analysis, in its general form, is the most common statistical technique employed in modelling travel outcomes with its explanatory variables such as socioeconomics, land use, and attitudinal characteristics. Several methodological issues should be rigorously tackled to end up with a robust and parsimonious travel model. Model specification is one of the issues that travel modellers should pay the highest attention to; however, several studies have been incompletely specified (Cervero, 2002).

According to Cohen et al. (2003) and Orme and Combs-Orme (2009), there are two critical issues in order to achieve a well-specified model. First, the mathematical functional form linking independent variable (IVs) and dependent variable (DV) should be well specified to best simulate the relationship between the DV and each IV in the population. Second, a well-specified model should include all the IVs that, according to the relevant theory, have a potential impact on the DV. Misspecification resulting from violating one or both of above issues could lead to biased regression parameters and standard errors. Having said that, ceteris paribus, empirical travel behaviour studies paying different amounts of care concerning specifying their model could unsurprisingly end up with different findings for the same topic investigated (Boarnet & Sarmiento, 1998). For example, while the effect of density on certain travel outcomes could be clear, other unspecified variables such as accessibility and congestion may confound the results and hence lead to biased and unreliable findings (Antipova et al.,2011).

In the travel demand/behaviour modelling context, researchers have been using different sets of personal and spatial variables according to the research objectives and questions.

Socioeconomic and demographic data, urban spatial form, and travel-related attitudinal characteristics have been utilised, individually or in different combinations, in order to quantify or explain people's travel demand and behaviour respectively.

In earlier travel demand analysis, in particular trip generation models, the inclusion of socioeconomic and spatial characteristics as explanatory variables to quantify the number of generated trips was common. However, for forecasting models attempting to predict the number of trips generated by a new proposed residential development, usually only spatial structure characteristics are included because of the difficulty in estimating the socioeconomic characteristics of residents. The informational report on trip generation developed by the American Institute of Transportation Engineers (see for example, ITE (2003)) represents a widely-used manual to predict vehicle trips based solely on land use parameters.

In the 1970's, researchers obviously started to develop travel behaviour models in order to explain rather than quantify the potential reasons behind people's patterns of travel. The personal traits of travellers are confidently included in these models for their clear affects on travel decisions, hence omitting them from any model could be a strong cause of biased findings. On the other hand, the inclusion of built environment features was not as straightforward as socioeconomics. From the literature reviewed for this study, the adding of spatial features has been justified from two different points of views – theory and practice.

In the context of the theory of travel behaviour, it is hypothesised that the consumer attempts to make an equilibrium between their preferences and expenditures (travel cost/price) by maximizing utility subject to consumer budget constraints (income). Hence, the standard behavioural model, in coincidence with the theory of consumer demand, often includes variables that reflect travel prices and traveller income (Boarnet & Greenwald, 2000). In specifying travel models, studies differ in that while some of them include pricing variables (implicitly or explicitly), others ignore these variables. In the former studies, as mentioned previously, three ways are proposed to capture the effects of travel costs. First, by assuming that urban form variables fully capture travel costs. Second, both urban form variables and price variables such as trip length and travel speed are included in the travel model. The third is similar to the second but price variables are included in two steps: in the beginning, urban form variables are regressed to the travel distance and speed and thereafter these price variables are included in the demand model. Adding irrelevant IVs or omitting relevant IVs are typical sorts of misspecifications (Orme & Combs-Orme, 2009, p22). Studies with different strategies to encompass price variables develop travel models with different specifications, analysis of results and thus findings.

In practice, the inclusion of spatial features in travel demand models has been largely motivated by the work done by Newman and Kenworthy (1989). In general, many travel models have been developed with different arrays of land use, transport system, and urban design variables and factors. Again, as shown previously, this variety in model variables leads to a variety of findings.

Finally, the third reason of potential misspecification leading to assorted findings is the issue of including attitude and preference characteristics of the traveller/household. As stated previously, different findings are found between studies of models with and without attitudinal variables. Moreover, even with studies which contain attitudinal variables, the number of these variables and their type regarding attitudes towards travel and/or neighbourhood might cause the final findings to differ.

2.4.4.4 Interpretations of results

Two major issues are highlighted concerning explaining the analysis of the results. The first is the array of concepts used in travel behaviour studies while the second is how to clearly make a distinction between effects arising from different causes. Firstly, concerning the concepts and definitions used, single characteristics might be given different definitions by different researchers, or in contrast different spatial or social attributes might be granted the same name (Stead & Marshall, 2001). Thus, for example works using similar designations for different features would most probably, at least apparently, reach different conclusions. Similarly, concepts might damage the interpretation of findings; for instance, what is considered as a compact neighbourhood in the USA might be labelled as dispersed in the Dutch planning policy criteria (van Wee, 2002).

2.4.4.5 Geographic scale

Given that personal, spatial, and attitudinal features influence travel outcomes, it is unsurprising that applying similar land use and/or transport planning policies in cities/countries with significant differences in these features might lead to inconsistent outcomes. For instance, van Acker (2007) pointed out that there is clear distinction between North-America and Europe regarding urbanisation prototypes. Spatial issues like sprawl are more tangible in the USA than European cities. Mode shares also vary geographically regardless of whether this is because of a lack in transport infrastructure supply or travel-related attitudes. In the Danish and Dutch communities, for instance, cycling is one of the common modes especially for short distances; however, this is not the case in several other countries (van Wee, 2002). In the American communities, it has been reported that regardless of people's preferences it is impractical to use modes other than the private car (Pucher & Renne, 2003). Investigating daily travel distances between US and GB, Giuliano and Dargay (2006) make it clear that the difference in findings could be attached to divergence in travel behaviour determinants in the country level like fuel cost and cultural variables.

Having noted these points, it is then not unusual that studies examining the relative effects of the same factors or of applying similar land use strategies would end up with contradictory conclusions.

2.5 The UK planning policy aspirations

There are many and various documents concerning national, regional and local planning policy guidance, statements and best practices dealing with several different topics such as climate change, waste management, and flood risk. In this section, however, and in line with the scope of this research, urban planning policy objectives/visions will be highlighted regarding four aspects namely, urban regeneration, sustainability, transport, and housing. The initial focus will be on urban areas in general, with planning policy perspectives concerning city centres being outlined in the next chapter. Planning policy Guidance documents and Statements form an important resource for this section, although the Government has now published the National Planning Policy Framework (NPPF) which briefly and collectively addresses these topics (DfCLG, 2012).

2.5.1 Urban regeneration context

A key milestone for urban regeneration in the UK can be dated back to the mid 1980's when Estates Action schemes were specifically designed to enhance badly maintained council housing (Jones & Evans, 2008, p10). At that time, however, urban regeneration programmes were mainly devoted to physical environment renewal with less emphasis on social and environmental issues.

In 1997, the perception is that the replacement of the Department of Environment (DoE) with a more integrated Department - the Department for Environment, Transport and the Regions (DETR) – indicates a turning point in terms of thinking about urban regeneration as a comprehensive mechanism for reviving areas and their communities within sustainable framework. This could obviously be seen from the DETR's Urban White Paper entitled 'Our Towns and Cities: The Future - Delivering an Urban Renaissance' (DETR, 2000). This white paper was partly based on the report 'Towards an Urban Renaissance' produced by Urban Task Force (DETR, 1999).

According to the Urban White Paper, the urban policy aspiration was to assure high quality and equity in city living via urban renaissance; however, several main challenges are reported. First, social changes represented by ageing and living alone means more extra people have to be accommodated. Second, there is the need to encourage (and attract) people to live in (or relocate to) major towns and cities. Third, some urban areas have failed in providing development that is socially, economically, and environmentally sustained. Concerning the third point, the policy vision towards active urban living is one that is socially sustainable in terms of availing equal opportunities and services to people for civilised living (health, transport, housing, employment, ...etc), economically sustainable, in terms of making urban areas competitive in employment and investment in the global marketplace and environmentally sustainable, in terms of efficient urban design and planning that leads to less noise, pollution and traffic congestion (DETR, 2000, Section 2).

While this has been the broad UK policy vision towards sustainable regeneration, there has been a loss of integrity following the replacement of the three arms of the DETR (environment, transport and regions) by the Office of the Deputy Prime Minister (ODPM) in 2001 and then later by the Department for Communities and Local Government (CLG) in 2006. Jones and Evans (2008, p.24) highlighted this explicitly, noting that the reorganisations in governmental bodies and consequent redistribution in responsibilities related to urban regeneration policies have been to some extent the reason behind the weakening of the previous concept of holistic, sustainable regeneration.

Prior to the National Planning Policy Framework, Planning Policy Statement[4] 4 (PPS4) entitled Planning for Sustainable Economic Growth (DfCLG, 2009a) was the main national official document that sets out planning policies for economic development in England. According to this policy statement, the previous government's overarching objective remained as sustainable economic growth; a growth that can be sustained and is within environmental limits, but also enhances environmental and social welfare and avoids greater extremes in future economic cycles (DfCLG, 2009a). In so doing, PPS4 named several objectives for assuring sustainable economic development. Among them, building prosperous urban communities; promoting regeneration; reducing travel-related emissions by reducing car-based travel; and enhancing the vitality and viability of urban centres.

Nowadays, while the government maintains its aspirations and objectives regarding regeneration, there is a significant desire towards supporting community-led regeneration. This new "localised" approach in promoting regeneration is defined by one of the current CLG publications entitled Regeneration to Enable Growth as - *putting residents, local businesses, civil society organisations and civic leaders in the driving seat and providing them with local rewards and incentives to drive growth and improve the social and physical quality of their area* (DfCLG, 2011b).

According to this publication (DfCLG, 2011b), the aim of this approach is to ensure the local economic prosperity in spite of the recent budget scarcity, and moreover, to guarantee resurgence in the private sector and employment, and finally to make certain that everyone is participating in this locally-driven recovery. The government's role will be strategic and supportive.

2.5.2 Sustainable development context

In the general policy context, sustainable development is supposed to tackle effectively the economic, social and environmental issues, in that, the failure in any single dimension could lead to unsustainable development. Apparently, the objectives of sustainable development are closely related to the general goals of urban regeneration in tackling urban decay by boosting its economic growth, community and environment. In governmental publications, this can be clearly seen, for instance, in the Urban White Paper Our Towns and Cities: the

[4] Planning policy statements (PPS) set out the Government's national policies on different aspects of spatial planning in England.

Future (DETR, 2000, p.8). The UK formally committed to the requirement of sustainability two decades ago in the 1992 UN Rio Earth Summit (Jones and Evans, 2008, p84). Ever since, according to the published policy documents, sustainable development has started to be central in all urban planning policy. Furthermore, this interest has spread down from the national to the local level of policy.

In 1994, the Department of the Environment (DoE) published the first formal UK strategy regarding sustainable development. All the three main dimensions of sustainable development were explicitly underlined. In the social sustainability context, the strategy states that development has to satisfy the considerations of social inclusion and cohesion. In the environmental dimension, the strategy speaks to natural environment concerns in terms of enhancement and resource depletion. Promoting sustainable economic growth is the perspective of the strategy regarding economic sustainability. The Department for the Environment, Transport and Regions (DETR) created in the 1997 has included the old DoE. The DETR produced another publication concerning strategy namely, A Better Quality of Life: Strategy for Sustainable Development for the UK (DETR, 1999). Thereafter, a third strategy-related publication was introduced in 2005 by the Office of the Deputy Prime Minister (ODPM[5]) - Securing the Future: Delivering UK Sustainable Development Strategy (ODPM, 2006). It is worthwhile mentioning that the objectives of the last two strategies are generally similar to those in the first one published by the DoE in 1994. Relating to brownfields (previously developed land within existing urban areas), it was set that 60% of the new development for urban renaissance programmes had to be built on existing derelict lands. This target may speak to the social and environmental dimensions of sustainable development.

In the national planning policy context, sustainability and sustainable development are central in the whole planning system and at the national, regional and local levels. For example, in England, Planning Policy Statement (PPS)1: Delivering Sustainable Development set out the overarching planning policies on the delivery of sustainable development through the planning system; this sustainability-related national policy statement was supposed to affect regional spatial strategies and local planning documents (ODPM, 2005a). The replacing of the 1997 Planning Policy Guidance 1: General Policies and Principles with

[5] ODPM replaced the DETR in 2001 and ran until 2006.

the 2005 PPS1 which explicitly focused on sustainable development, obviously reflects the centrality of sustainability in the recent UK national planning aspirations. In the context of the strategic aspiration regarding environmental sustainability, the UK government in 2008 and via the Climate Change Act has committed to shrink the GHG emissions by at least 80% on 1990 levels by 2050 (DfT, 2009). The first three carbon budgets were announced in April 2009, covering the periods 2008-12, 2013-17 and 2018-22. They call for emissions reductions of at least 22%, 28% and 34% respectively. However, it is unquestionable to claim that boosting the economy in an urban area without violating the environment and community is a complicated mission for urban planners.

2.5.3 Transport context

Two of the turning points in the UK transport planning policy during the last two decades are the emerging "Travel Demand Management" philosophy and "Sustainable Transport Choices" programmes. However, in general, travel demand management mechanisms are usually the most efficient and sufficient tools for delivering and promoting sustainable travel choices. As highlighted previously, traditionally and internationally, the transport planning philosophy adopted in accommodating the continuous forecast increase in motor traffic was simply building more roadways, i.e., the "Predict and Provide" concept. In the UK, this was the thematic transport policy from the post war boom era till almost the end of the twentieth century (Ryley, 2005).

The UK Government set out its policy for the future of transport in the 1998 white paper *A New Deal for Transport: Better for Everyone*; one of the objectives was a greater use of traffic management (DfT, 1998, p.11). According to Planning Policy Guidance 13 (PPG13) produced by the Department for Communities and Local Development (DfCLG, 2011a, Paragraph 65), adequately designed traffic management measures could help in achieving planning policy aspirations in several aspects; among them[6]:

1. Minimising transport-related local externalities such as air pollution, accidents, and noise.
2. Endorsing safe environments for walking, biking and public transport.
3. Making urban areas more attractive and minimising severance.

[6] Similar aspirations were originally listed in the 2001 version of the PPG13 (DETR, 2001, Paragraph 64).

4. Mitigating traffic congestion in central areas and adopting effective parking schemes.

On the other hand, regarding sustainability and sustainable travel choices, it is obvious that the objectives of the 2011 PPG13 above are speaking, in one way or another, to the sustainability agenda. Policy visions regarding a sustainable transport system that pave the way towards creating sustainable development have been explicitly highlighted in the 1998 transport white paper:

"We want a transport system that meets the needs of people and business at an affordable cost and produces better places in which to live and work. We want to cut congestion, improve our towns and cities and encourage vitality and diversity locally; helping to reduce the need to travel and avoid the urban sprawl that has lengthened journeys and consumed precious countryside." (DfT, 1998, p.10).

The white paper continues to define an integrated transport policy that makes "our transport choices support a better environment; ... reduce the need to travel; ... (and) help to make a fairer, more inclusive society."(DfT, 1998, p.10). The 2011 PPG13 goes further by proposing some land use planning policies concerning location, scale, density, diversity and urban design that would partially help in decreasing auto-based travel, by minimising spatial separation between essential land uses, and might motivate people to adopt sustainable transport choices (DfCLG, 2011a, Paragraph 3).

2.6 Summary

This chapter discussed four key different but related aspects. At first, the importance of understanding people's travel behaviour was discussed. The discussion proved that it is a necessity for the researchers and planners alike to obtain a precise understanding for people's travel – related decisions. This necessity is grounded on the fact that this understanding would help in tackling three key issues; the soaring travel demand, addressing the sustainability agenda, and recognising the policy perspective. Secondly, the chapter also identified urban regeneration and showed literature-based evidence about the presence, scope and effects of urban sprawl. Thirdly, the travel behaviour literature review, has discussed in quite a comprehensive style the people's travel behaviour in terms of definition, indicators and potential predictors. The discussion provided literature-based evidence about the inconsistency in the recent findings of travel behaviour research about the variables and factors that influence personal mobility. Evidence is also revealed about the inconsistency regarding the amount, direction and significance of that influence. Several potential reasons for that disharmony in findings have been presented. Finally, with respect to policy aspirations, in order to make the output of this study as informative as possible to the planning policy stakeholders, it was seen a necessity to highlight the current UK planning policy and recommendations with respect to urban renaissance, sustainable development and road transport. In brief, the ultimate goal is to set up renaissance schemes in which a sustainable transport agenda is assured.

CHAPTER 3: CITY CENTRES, URBAN RENAISSANCE AND RESIDENTS' TRAVEL BEHAVIOUR

3.1 General

A city centre that fails to attract people at the end of a working day, weekends, and holidays is neither vibrant nor viable. Vital downtown needs people that work, shop, live and benefit from its major activities to the fullest capacity. This chapter sheds light on the city centre's living life cycle and relevant policy agenda from a travel behaviour perspective. Section 3.2, explores the common definition of the concept 'city centre'. After that, Section 3.3 reviews the impacts of the transport developments on the outward dispersion movement of the city centre's residents. Additionally, several aspects of the urban regeneration in the UK city centres are reviewed. Next, the chapter in Section 3.4 addresses the recent issue about the moving back and relocating to the UK urban centres. Three potential reasons of this relocation are discussed. The city living nowadays, with a main focus on the UK cities experience, is then dealt with in Section 3.5. This includes investigating the personal, attitudinal and travel characteristics of the city centre residents. Section 3.6 looks over the recent UK planning policy aspirations and recommendations regarding city centres. Finally, Section 3.7 represents the chapter summary section.

3.2 City centres

It is not straightforward to find a common objective definition for the concept of City Centre (widely used in Europe) or its counterpart, Downtown (widely used in North America). This is also true concerning the relationship between these two concepts and the concept of Central Business District (CBD). Furthermore, it is not easy to find a standard definition for the city centre for residential purposes; some researchers have even reported there is no such definition (Nathan, et al., 2005). However, for reader convenience and the degree to which this study requires a definition of city centre, hereafter, both the terms, city centre and downtown, will be used interchangeably in referring to an urban city centre. Apart from the historical "tidal" waves of change in urban form and function, which will be highlighted in the next section, an urban city centre can be generally described as the city's urban area, often with cultural heritage and historic districts, where commerce, entertainment, shopping and political power are concentrated. The Urban and Economic Development Group (URBED) has presented a description for the centre based on its typical functional base (Table 3-1)(Urban and Economic Development Group (URBED, 1994).

Table 3-1: The functional base of town centres (Source: Adapted from URBED,1994).

Market places	retailing forms the heart of most centres, including comparison, convenience and specialist goods.
Business centres	providing workspace and employment in financial and business services, administration and distribution, as well as 'incubators' for new enterprise.
Educational, health and fitness resources	most centres have schools, colleges and training centres, and there are universities in larger centres as well as doctors, dentists, clinics and hospitals, gyms, sports clubs, swimming pools and health clubs.
Meeting places	whether in the open air or in pubs, cafes, restaurants, clubs of all kinds or more formally in societies, conferences, community or religious groups.
Arts, culture and entertainment zones	with libraries, museums, galleries, theatres, cinemas, concert halls, amusement venues and stadia, possibly supported by a series of festivals or other events..
Places to visit	often having historic or specialist buildings, unique views or well-known sites or events.
Transport hubs	providing interchange and connections to local, regional, national and in some cases international services.
Residential areas	with town-centre accommodation often most suited for students and single professional people, the elderly and those in transitory employment.

In the UK spatial planning context, the national planning policy statement 6 (PPS6) entitled "Planning for Town Centres" recognises four types of centres; city centre, town centre, district centre and local centre. The first two, which this study is interested in, are described as follows:

"City centres are the highest level of centre identified in development plans. In terms of hierarchies, they will often be a regional centre and will serve a wide catchment. The centre may be very large, embracing a wide range of activities and may be distinguished by areas which may perform different main functions. ... . Town centres will usually be the second level of centres after city centres and, in many cases, they will be the principal centre or centres in a local authority's area. ... . Local planning authorities should consider the function of

different parts of the centre and how these contribute to its overall vitality and viability (ODPM, 2005b, p.30)".

While urban centres are usually the first settled part of their cities, their residential population and density have changed within the last century. Nonetheless, most city centres nowadays have, or are developing a considerable and lively housing sector.

In contrast, the Central Business District (CBD), as the name explains, is mostly the district located within the downtown area which contains the economical and financial activities. The CBD could be recognised by its function and form. While it works as the money and trade area in the city, it is often characterised by high vertical buildings. Furthermore, CBDs are full of life during weekdays, but are almost empty during night time, weekends, and holidays.

3.3 City centres: urban sprawl and regeneration – rise and fall

3.3.1 Urban sprawl cycles – historical background

The momentous role of the city centre as the economic heart of the city has fluctuated over the past decades. Collectively, this oscillating role has been largely affected by the movement of people to and from the central area of the city in addition to the city centre per se. Over decades up to now, this in/out movement cycle may be generally summarised in that people move into city centres, often to work, and when thereafter they get wealthy enough to afford a decent house in the suburbs, they simply would move out, with less affluent new comers then arriving. Thus, c*eteris paribus,* to judge whether city centre living is dormant or vibrant in a specific era, we simply have to determine which direction of movement was prevailing at that period. The desire for movement, the affordability, and car mobility status are among the factors which influence people movement. Bruegmann (2006, p.23) argued that factors affecting a change in the density in a district are unsurprisingly economic-related.

The evolution in transport technology has a central role in defining the city, particularly in North America, Europe and Australia. The dramatic changes in the mode of road transport from the walking/horse car era to the recent era of highways have been seen as milestones in shaping urban living in both the spatial dispersion and demographics context (Newman, 1992). Typically, planners name four distinct periods that reflect technological developments in road transport; Walking/Horsecar Era (1800-1890), Electric Streetcar Era (1890-1920), Recreational Automobile Era (1920-1945), and the Highway Era (1945 – 2000) (Muller, 2004). Figure 3-1 depicts a schematic representation of the urban dispersal associated with each period in North American and European cities. Moreover, it is not surprising to consider the current century as the Telecommunication Era (see, for example, Rodrigue, 2013). Overall, whereas in Europe a large role has been given to the public transport, the car dependency is more pronounced in North America.

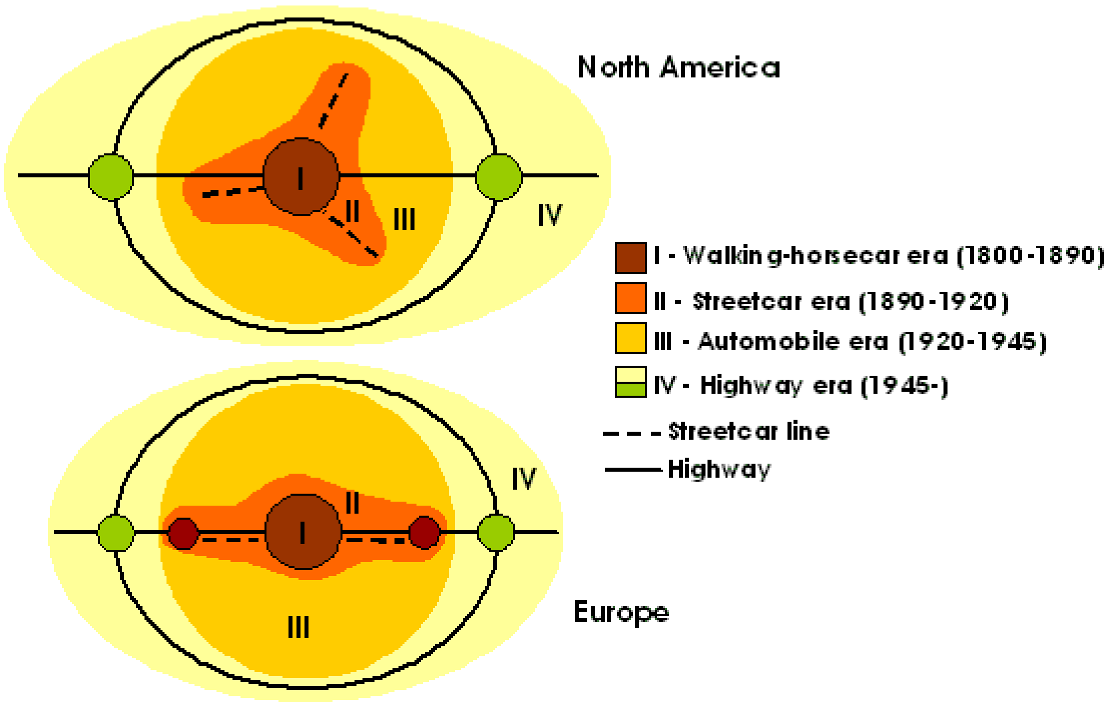

Figure 3-1: The evolution of urban road transport and the associated urban dispersion. (Source: adapted from Muller (2004) by The Geography of Transport Systems (2013).

The first transport period, walking-horsecar era, is distinguished by the absence of public transport. Thus, spatial accessibility was mainly quantified by walking and to less extent by horsecar (horse-drawn tram). Based on Figure 3-1 (Mullar, 2004), no evident difference in the evolution of urban form between the European and North American cities can be noticed in this period. Nevertheless, in the late nineteenth century, the industrial revolution had substantially affected the urban life in the western world cities. Developments in rail transport technology played an essential role as efficient and effective means for people and business alike for moving from central cities to the urban peripheral. Generally, in both Europe and North America there was a recognised trend of decentralisation. In major cities like London, New York, and Paris, wealthy city centres' residents were moving from congested urban city centres towards less dense areas in the periphery (Bruegmann, 2006, p.28). On the other hand, deprived immigrants have stayed for a longer time due to affordability issues; however, some of them eventually moved out of the centre either because they became affluent enough to afford houses in more desired locations or because of the new comers (gentrifiers) who increased the land values and rents.

The presence of the railways in the 1850s and its popularity later had obviously paved the way to the second transport period, streetcar era (1890-1920). The presence of transit corridors and electric streetcars were the distinct aspects of this transport period. These two transport means can be considered as the main reasons for the appearance of residential suburbs that were accessed by electric trams (trolleys). The Europe spatial dispersion at time was mainly directed towards previously established surrounding towns. In contrast, in North America, Figure 3-1 shows that the radial spatial expansion was the theme. According to the literature, the early twentieth century has witnessed continuity in the trend of the outward spreading of inner city dwellers. This was more pronounced, however, in the inter war boom period of 1920s.

This period highlighted the third transport era, the automobile era (1920-1945). it witnessed the remarkable emergence of motorised transport, specifically buses and the private car (Mullar, 2004). Regarding downtowns, these were widely recognised and could be defined at time as “a highly compact, extremely concentrated, largely depopulated business district”; nonetheless, in the 1920s the downtown represented the central business district before becoming only another business district in the city later (Fogelson, 2001, p.2).

There were no large differences in the western cities regarding the phenomena of people’s relocating out of the central areas. Nevertheless, it was more active in most of the North American cities than their counterparts in Europe. In the UK, this process of suburbanisation was noticed in most British cities (Fraser, 2003, p.21). In London, for example, in addition to the moving of manufacturing activities, thousands of families left the congested centres to more dispersed areas with housing density as low as (6-10) units per acre (Bruegmann, 2006, p.33). Furthermore, during the 1920s, the CBDs in most North American cities have witnessed a significant growth, in particular, in retail and office sectors. In consequence, downtowns experienced a mass sprawling of their residents seeking a better living or those who have lost their jobs, especially in manufacturing quarter. As with London, most American cities had downtowns that were lively and active only during day time and weekdays (Bruegmann, 2006). Later, in the late 20s and early 30s, the retail sector started to shrink in the traditional downtowns as well. Two reasons may explain this: the first is the decentralisation of this sector, while the second is the hard competition from out-of-centre shopping districts. For instance, in the Chicago area, by 1935 about 75% of all retail sales were outside the historical city core.

According to Figure 3-1, the fourth transport period, that also significantly helped the dispersion, is the highways era (1945 – 2000) (Mullar, 2004). The two thematic aspects in this period could be the popularity of private cars and the extensive miles of paved highways. After the end of the WWII, the western world experienced the so called boom years. As mentioned previously, at that time America suffered from urban sprawl more than the European counterparts did. The immediate need for rebuilding and strict planning controls in Europe on one hand and the growth in population and economy in the U.S. on the other hand were the most likely reasons.

Regarding downtowns, what started before WWII continued remarkably in the 50s and 60s. Industrial cities continued to lose jobs due to manufacturing companies moving to the suburbs. The retail sector continued to shrink in the old CBDs with significant competitive regional shopping centres appearing in the urban peripheries. At that period, as jobs and dwellers significantly decreased, many owners departed leaving large numbers of vacant and derelict buildings in city centres. In the UK, many industrial cities experienced this urban decline and loss in population in their central areas, Manchester and Glasgow are clear examples (Seo, 2002).

No significant change in the housing sector can be noticed in 1970s and 1980s. For example, the central business districts of many American cities' downtowns were mostly constituted of multi-storey office buildings and large department stores with hardly any eating places to serve the workers in these offices and stores. Nevertheless, these downtowns were almost empty of dwellers (Sohmer & Lang, 2003, P.63). On the other hand, there was a boom in shopping centres in the edge (outer areas) in the late 1980s (Jones and Evans, 2008, p17). Alexander (1974, p.7) added to the city centre redevelopment discussion by stating that activities in the centre have decentralised in response to the dispersion of their potential customers. As mentioned in Section 2.3, he added that this phenomenon was more obvious in the U.S than Europe; this difference can be clearly seen in Figure 3.1 (fourth transport era). The low demand for housing in most city centres led to a drop in housing pricing. This was an opportunity for some new arrivals to reside; most of them are single professionals and childless couples.

In the 1980s and early 90s, in Europe, city centres of most of the British major cities, for example, were experiencing hard years of depopulation and unemployment. However, the 90s, in contrast, also witnessed serious official steps towards countering the prevailing urban decline in city centres; cities like Birmingham, Manchester, Glasgow and Liverpool started to experience a rebirth in their centres – tangible signs of city living started to reappear (Birmingham City Council, 2005; Lasalle, 2002; Seo, 2002). In addition to the traditional reasons of deserted downtowns stated previously, there was one extra new reason in the late eighties that weakened the CBD traditional role as the hub of economic activity and destination for road transport routes. It was the start of the appearance of suburban retail and manufacturing centres in multi-centred urban regions. City centres used to working independently were now facing hard competition from other districts in the same metropolitan urban area. The advance in transport technology as well as in the affordability to own a car made these destinations a feasible choice in the individual choice set (Bruegmann, 2006, p.52; Williams, 1989).

3.3.2 Urban regeneration and revival of housing sector

The city centre crisis is characterised by the moving out of the vast majority of its residents, manufacturing, offices and retails to other out-of-centre urban areas, suburbs, and exurbs. This decentralisation process has recently become a national planning concern in most of the industrialised world countries. In the UK, for instance, several improvements in housing sector and repopulation plans have been adopted as part of the national package of programmes and strategies for urban renaissance (Bromley, Tallon, & Thomas, 2005; Tallon & Bromley, 2004).

Two common essential factors were considered helpful by planners and other stakeholders interested in city centre renaissance; while the first is urban design related, the second is related to people's residential needs and preferences. Speaking to the first factor, the sharp decline in industrial activities in downtowns could be identified on the ground by the presence of many vacant lots which used to be houses for factories, warehouses, and other manufacturing activities. Furthermore, the dispersion of retails and offices results in a great number of brownfield sites including derelict or contaminated underutilised building. With respect to the second reason, the historic core of most major cities has survived to stay quite noticeable by virtue of several original residents who could have moved but opted to stay and thus helped to preserve the centre; new arrivals (gentrifiers) have also participated in keeping up the centre.

Some of the early city centre's revival programmes started in the late seventies of the twentieth century. However, most of these programmes have mainly focused on urban redevelopment unlike nowadays which has seen the adoption of an integrated urban regeneration agenda with its three aspects; economic, social, and environmental. City officials have replaced old street furniture such as benches and lights by others with historical styles. Two points were targeted by those officials; the first considered the aesthetic dimension of urban fabric in the city centre. The second attempted to restore the historical value of the traditional city core (Bruegmann, 2006, pp.52-54). These steps towards downtown's revitalisation accompanied with a gradual loss in interest of affluent people for living at the city edges have encouraged some people to relocate (back) into the centre. According to Sohmer and Lang (2003), the 1990s was "Downtown is back" era for most American cities. However, this trend was far from steep. The same picture could be seen in Europe. For example, in the UK the early 1990s is seen as the era where significant focus was given on promoting a nightlife economy in the city centre as well as for daytime commercial and business economy (Bromley, et al., 2005; Tallon & Bromley, 2004).

What could be mentioned in this context is that, most probably, the disappearance of factories and warehousing led to a decrease in congestion and goods vehicles within the centre. In consequence, streets are less congested, safer with less road pollution and hence city centre developments are started to be perceived as a preferred residential choice for some people at least**.** According to Birch (2006, p29), recently, one of the most common strategies to reinvent downtowns is by residential areas. The call for downtown renaissance by making it vibrant through supporting its urban appeal even during night time and weekends has become a familiar aspiration for those interested in restoring life into the downtown and its CBD. Urban centre renaissance has been widely seen as the policy intervention for containing sprawl and hence its focal externality, car dependency (Jones and Evans, 2008, p.17). In the UK, Liverpool One, for instance, is a clear example of the successful revival strategy to tackle decline in city centres (DfCLG, 2009b)

This strong desire in revitalising the city centre housing sector can be clearly noticed through the local planning authorities' aspirations for most British major cities such as Manchester, Birmingham, Nottingham, Liverpool, Glasgow and Leeds. All of the Core Cities across the UK have experienced, to differing degrees, the construction of new apartment buildings within the heart of the City (Liverpool City Council, 2008). For example, according to the Belfast policy and research unit vision towards city centre regeneration, additional housing and population growth is essential to help develop an inclusive 24 hour city centre society (Belfast City Council, 2006). In the Leeds city centre regeneration agenda, housing has played a major role, and there has been a significant intensification in residential buildings. Between 1996 and 2011, 9500 dwelling units have been built (Leeds City Council, 2011). In Nottingham, the same policy vision can be clearly seen. Since 2001 there has been a pronounced growth in the residential market in the city centre, while previously this was mainly provided by the local authority. Recent years have witnessed a central role for private sector in providing housing, newly built or by converting existing buildings (Nottingham City Council, 2007a).

Based on Birmingham's economic prospects, an adequate expansion in dwelling units should be considered in the city centre if an integrated regeneration plan is intended. The officials stated that city living could add much to the local economy in addition to reducing the amount of commuting (Birmingham City Council, 2005). Manchester is usually cited as one of the pioneer British cities in developing a clear and determined regeneration strategy for its mature city centre. Provision of homes of different types and tenure has been marked as an important part of the rebirth plan. Manchester City Council stated that, between 2003 and 2006, 81 per cent of all planning permissions granted were for flats (Liverpool City Council, 2008). Likewise, Bristol officials have realised the importance of city centre renaissance in enhancing urban life and economic well-being. In so doing, one of the objectives has been to increase the city centre resident population by creating more new dwelling units. Where in 1998 most of the housing was confined to a few blocks of flats owned by the council with scattered private residential developments. Since then there has been a boom in house buildings. More than 2,600 new homes were built between 1996 and 2004 (Bristol City Council, 2005).

Finally, the concerns about sustainability of the whole regeneration strategy are highlighted. A city centre is typically a congested area due to the high rate of occupied floorspace and energetic traffic movement (Bristol City Council, 2005) and thus concentrating many unplanned urban activities could raise significant sustainability-related caveats via the re-urbanisation course of action (Seo, 2002).

3.4 Moving to the city centre

City centres in British cities have been the focus for several housing schemes as part of the national integrated urban regeneration strategy. Thus, many cities are experiencing significant growth in the number of city centre inhabitants. This remarkable rebirth in city living started in 1990s after long years of urban decay and population decline since the 1960s. For example, according to the 1991 and 2001 Census figures, the city centre resident populations in Manchester, Liverpool, and Dundee have risen remarkably. There was growth of about 300% in Manchester, 40% in Liverpool and 100% in Dundee (Nathan et al., 2005). The recent 2011 Census confirmed this trend.

There are several reasons could be attributed to explain the movement of people back to city living. While some of them are related to the changes in Britain's socioeconomic/demographic traits and residential preferences, others are related to the city centre residential environment and recent policy interventions.

3.4.1.1 Personal characteristics and lifestyle change

With regard to the demographic statistics, the continuous increase in the number of single-person households is noteworthy. Single-person households mainly include young adults, elderly and divorced people. The increase in this population group means many dwelling units, mostly flats and apartments, are in demand. Around 80% of the extra households forecast to be created by 2021 are expected to be single people (DETR, 2000). City centre living is seen as one of the most likely choices to accommodate these people; recent local surveys support this hypothesis. The housing market in a town is highly concentrated in offering one and two bedroom apartments (Nathan et al., 2005). Furthermore, housing projections expect a particular increase in the required households to accommodate childless couples for whom city centre living might be the most typical choice (Couch, 1999). The renaissance in the UK higher education sector, colleges and universities, has also been seen as a major contributor to bringing people back to the heart of cities. A significant share of city centre residents are students either living in privately rented apartments or in student accommodations (Chatterton, 1999).

One of the other factors which helps in recovering city living is the change in culture and hence attitude and preferences towards residing in the core of the city. Experiencing the lifestyle of city living has been an existing popular choice for many young Britons (Nathan et al., 2005). Nowadays new fashionable centres provide a suitable place equally for living, working and going out actively. The final factor that could be offered to explain why city living is prosperous is indeed to some extent the result of the above - safety. Many local authorities' surveys regarding city centre's users and residents perceptions are interested in awareness of neighbourhood safety. The absence of serious crime in the vast majority of British city centres has allowed them to be presented as safe zones, and eventually endorsing relocation (Allen & Blandy, 2004).

3.4.1.2 Residential environment change

Two main factors have contributed to the pace of prosperity in dwelling units marketed in the city centre. First, over the past years, there has been a general shortage in housing in the UK. This has been accompanied by high house prices making the demand for housing ever high. Second, there are unoccupied spaces and derelict buildings in the city core used previously to house factories and warehouses. These brownfield sites have relatively low land value. In consequence, both these factors have been seen as attractions to the developers to invest in the building industry. These new and converted properties have helped in accommodating the growing demand for residing in the centre (Nathan et al., 2005). In Belfast and according to the 2001 Census, the population density in some parts of its city centre are up to four times the Belfast city average of 24 persons per hectare (Belfast City Council, 2006).

3.4.1.3 Policy interventions

As mentioned previously, since the 1990s the national planning policy of the UK Government has resulted in several urban renewal and regeneration schemes and programmes with the ultimate objective of turning urban decline into economic recovery and making city living more attractive, using multi-measures related to renaissance in housing, retail, office and entertainment and other cultural activities. British cities have been interested in constantly promoting employment opportunities in their centres and hence many towns are perceived as places for living and working alike. In addition, local residents are potential customers for local employers in retail, leisure and business sectors (Nathan et al., 2005). These new residents radically add to the city living and hence are themselves an extra attraction factor for others to relocate into centres. They make the local environment appear more safe, vibrant and liveable. Housing policy (PPS 3), on the other hand, has helped in making centres a competitive living option by requiring that planning authorities should offer decent and affordable housing across a spectrum of types and tenure. The objective is to achieve socially inclusive and sustainable living by supporting households with different size, structure and income (DfCLG, 2010).

3.5 City centre living

City centre living has recently been seen as one of the major contributors to the renaissance process of cities and in particular urban centres. Urban growth in the city centre has several positive economic impacts. Residents significantly add to the centre's day time and in particular nightlife vibrancy and economy. Furthermore, wealthy residents also benefit the centre's local shops and markets as good buyers. Finally, the city council tax revenues also benefits from people who live in private dwelling units that have a relatively high land value and council tax.

3.5.1 Demographic attributes

Overall, city centre dwellers could be classified into two main groups. While the first group includes young people seeking a short experience of city centre buzz and lifestyle, the second comprises those who intend to stay for longer periods. Different reasons make people prefer to stay in city centres based on a variety of economic, social and cultural aspects. Generally, the survey-based evidence indicates that those people could be further classified into three sub-groups: first, the wealthy seniors who are mainly attracted by the colourful, cultural nature of city centres; second, the non-traditional lifestyle seekers, such as the gay community; third, those singles seeking places promoting single lifestyles such as single professional adults, young people just starting their careers, divorced, students and lifestyle changers (Allen & Blandy, 2004; Nathan, et al., 2005).

3.5.1.1 Age and gender profile

Generally, statistics, mainly based on the UK 2001 Census, show that a significant portion of the city centre population is young or in their middle age in comparison with the city-wide average. According to the Birmingham City Centre Area Profile and based on 2001 Census, there are about 19,059 people living in the centre with males comprising 52%. About 59% of the residents are within (18 – 44) years in comparison with only 40% in the whole city. The people of working age (16 to pensionable age) are about 74% while the ratio is 60% for the whole city (Birmingham City Council, 2003).

Liverpool is one of the UK's main cities and city centre living has been supported by the council since early 1990s. According to the UK Census, the Liverpool city centre population increased from 10,000 in 1991 to 13,500 in 2001. Statistics from the 2001 Census show that over 60% of the city centre dwellers are (18-34) years old (Nathan & Urwin, 2005).

In the Nottingham city centre living survey, no significant difference regarding respondents gender could be noticed, while 51% of the respondent were males, 49% of them were females. Regarding the age profile of residents, the descriptive analysis also shows that the mean respondent age is 32 years which is well below the mean age (44 years) of the whole of Nottingham City based on 2001 Census statistics (Nottingham City Council, 2007a). This confirms the whole picture in that city centre dwellers are generally younger than others living elsewhere.

Similarly, in Belfast city centre, the 2001 Census figures indicate that while 22% of the Belfast population is within the age group 16 to 30 years, in some city centre parts this proportion could reach up to 42% (Belfast City Council, 2006). Nathan et al. (2005) carried out a descriptive analysis using the 2001 Census database to investigate several city centre living issues in three British cities: Manchester, Liverpool and Dundee. They confirmed that while city centre residents are, broadly speaking, much younger than the rest of the city, they also pointed out that city living does not sound appealing for families with children. In Liverpool and Dundee city centres, the fraction of families is about half the city average while in Manchester city centre it is approximately a sixth.

On the other hand, city living is found to be less attractive for people over 40 years or retirees. In Manchester centre, the number of residents of (45-60) years old in the 2001

Census is about 50% less than what it was in 1991. Concerning inhabitants in the pension age (65+), while in Scotland the average is just under 16%, in the Dundee city centre it is 4.4%. Likewise, while the figures in Manchester and Liverpool are 5.6% and 7.9% respectively, the corresponding average in the whole of England is almost 16% (Nathan et al., 2005).

3.5.1.2 Household size and composition

Overall, city centre living is proven to be more appealing for those who live alone and childless couples. This could be attributed to the substantial presence of students and young professionals. According to the 2001 Census statistics, the average household size in Birmingham city centre was about 1.73 (BCC, 2003); moreover, areas with a high proportion of one-person households mainly include areas in and around the Birmingham city centre (MacDonald, 2003). The 2001 Census also shows that 75% of Liverpool centre adults are single (Nathan & Urwin, 2005, p3). While this is approximately the same fraction in Manchester centre, in Dundee, this rises to 85%. It is worthwhile mentioning that the average percentage of people living alone nationwide is around 30% (Nathan et al., 2005). Based on the Nottingham city centre living survey, only 4% of the respondents stated that they live in households consisting of three people. The vast majority are living either alone (49%) or with one other adult (47%)(Nottingham City Council, 2007a). According to the Bristol City Council statistics, the Bristol city centre population is just over 9,000 residents living in 4,400 households. About 55% of these households are occupied by adults living alone; in contrast, the figure is 33% in the whole city of Bristol.

On the other hand, regarding children, the fraction of households with children living in the property is small at only 3% (Nottingham City Council, 2007a). In the same context, in Manchester city centre, couples living together without children comprise around 14% of the population.

3.5.2 Socioeconomic attributes

3.5.2.1 Income and car ownership

Generally, people residing in city centres have a wide spectrum of incomes. This simply reflects the varying economic status of those groups ranging from students with limited financial ability to young professionals with high wages. Unfortunately, there is a lack of enough information about city centre inhabitant's incomes. This is because this question was not included in the UK Census questionnaire form. In contrast, the limited number of surveys in city centres carried out/sponsored by local government or other independent agencies either fail to ask about the income variable or the typical reluctance of respondents leads to too low a response rate to make this variable representative for further analysis.

In the Nottingham city centre living survey, 36% of working respondents have an annual income less than £19,999 while 55% earn between £20,000 and £59,999. The remaining 11% earn over £60,000. For those who have been classified as high earners (earning over £40,000), survey figures show that 33% are male compared to 15% females (Nottingham City Council, 2007a). Regarding car ownership, the 2001 Census statistics demonstrate that about 60% of Birmingham city centre dwellers are without auto in comparison with only 38.5 in the whole city. City centre households with one car are 29% while those with two or more cars are as low as 5.4% in contrast to about 20% in the citywide (Birmingham City Council, 2003).

3.5.2.2 Employment status

According to the 2001 Census statistics, almost 46% of Birmingham city centre dwellers are in employment and 29% are full time students. Of all (16-74) years residents, just over half are economically active[7]. Retirees form 14% of the economically inactive people in the centre in contrast to approximately 31% in Birmingham city (Birmingham City Council, 2003).

Based on the 2001 Census, 47% of the Liverpool city centre population are students (Nathan & Urwin, 2005). In the Dundee city centre students play a major role in the demographic fabric, they form around 56% of residents. While in Manchester city centre, a mature vibrant centre, students make up only 37% and economically active people in work add more to the social fabric (Nathan et al., 2005).

People with professional or associated professional occupations make up almost 40% of the Liverpool city centre residents. Those who are at the top of the occupational ladder (managers and senior officials) form just over 10% (Nathan et al., 2005). In Belfast city centre, the statistics show that while the concentration of people with managerial and professional occupations is about 25% in the Belfast, in central areas this ratio jumps up to 52% in some parts of the city centre (Belfast City Council, 2006). Recently, the employment

[7] Often defined as people in the working age (16-74) and physically able to work or study.

rate in city centres has substantially increased. This might reflect the success of the part of urban regeneration programmes dealing with promoting more job opportunities. Based on the household survey in Nottingham city centre, 82% of respondents are in employment either full or part time. Of the 12% not in work, just under two-thirds of them are full-time students while only 14% are retirees (Nottingham City Council, 2007a).

Finally, regarding academic qualifications, the 2001 Census factsheet indicates that 26.5% of the Liverpool city centre population aged (16-74) are graduates (Nathan & Urwin, 2005).

3.5.3 Housing

According to the 2001 Census statistics, about 79% of Birmingham city centre dwellers reside in households while the other 21% are in community establishments. Regarding the type of dwelling unit occupation, while about 29% are privately owned or rented about 64% are rented from local authority or housing associations (Birmingham City Council, 2003). City centres are one of the places in the Birmingham area with a major concentration of flats, with over 70% of households being accommodated by flats (Birmingham City Council, 2003; MacDonald, 2003). The surprisingly higher proportion of social housing could also be more tangible in Liverpool city centre. The 2001 Census results point out that the vast majority (73%) of the dwelling units are rented with 47% of them being from the social sector while the rest (26%) are privately rented (Nathan & Urwin, 2005). In Dundee and Manchester city centres, for the same 2001 Census results, the proportions of social housing are about 20%.

It is worthwhile mentioning that these figures are more than 10 years old and it is likely that there has been a continuing increasing in the numbers of apartments that are being built by the private sector where the prevailing tenure type is privately owned or rented. For example, according to the city centre living survey commissioned by Nottingham City Council (Nottingham City Council) in 2006, about 87% of the properties in the survey sample were privately owned or rented while only 10% were rented from the council or housing association (Nottingham City Council, 2007a). Also according to the Liverpool city centre living update, the current governing attitude in the house building industry is towards the private rental market (Liverpool City Council / Liverpool vision, 2010).

In Belfast city centre, the 2001 Census shows that about 50% of the housing stock is terraced houses followed by apartments (38%). However, during 2002-2005 there was an increase in the new build apartment building reflecting the high demand resulting from continuous relocation to the centre (Belfast City Council, 2006).

Finally, regarding dwelling unit type, it is obvious from observation that almost the vast majority of housing properties in centres are flats. According to Nathan et al. (2005), while almost a fifth of the British population are accommodated by apartments or flats, in the city centres of some British cities the figures are much higher, such as Manchester, Liverpool and Dundee at 78%, 62% and up to 95% respectively.

3.5.4 Attitude and preferences

Nathan and Erwin (2005) have run three focus groups in Liverpool city centre. Regarding the reasons for selecting the centre as a living place, convenience, closeness and buzz were the key reasons. While those who in essence live in Liverpool opted to stay to be near their families and friends, students from outside opted to locate in the centre to enjoy the nightlife. The elderly who spent several decades in the centre found it irrational to move out. Palfrey (2009) in his survey pointed out that among Liverpool city centre inhabitants, almost three-quarters (73%) agree that pedestrian areas are well lit at night; however, according to the survey figures women were more conservative (61%) than men (88%). For travel by bike, two-thirds of the residents agreed that cycle paths in the city centre area are well lit at night. Regarding how safe the pedestrian crossing is, 91% of the residents rated in favour of their safety. For transit accessibility, among people living in the centre 80% agree on the good accessibility to public transport.

In Belfast city centre, the same picture could be seen; survey-based evidence also states that issues such as closeness, general convenience and location attractiveness were mentioned by almost 60% of the residents as positive characteristics of city centre living (Bromley, et al., 2005; Tallon & Bromley, 2004). In the Nottingham city centre survey, the respondents have also pointed out that convenience for leisure (66%), convenience for work or university (27%), general convenience of location (23%) and good transport links (22%) are the most liked aspects of city centre living. On the other hand, issues such as noise, cleanliness, and parking availability and affordability are the least liked aspects (Nottingham City Council, 2007a). Regarding transit accessibility, the vast majority (91%) of respondents agree that there is good access to public transport (Nottingham City Council, 2007a). Where respondents were asked about the most important factors which made them decide to relocate to the centre, work or study related reasons (49%) and city centre living (48%) are the most common reasons. Issues like better accommodations (27%) and neighbourhood (20%) are also important (Nottingham City Council, 2007a).

3.5.5 Travel patterns and behaviour

According to the literature, residential location decisions have considerable impacts on personal mobility. However, issues such as amount, type and significance of these impacts are not totally understood (Bagley & Mokhtarian, 2002).

The spatial location of residence with respect to the city centre or the CBD has been investigated by several researchers in their meso- (citywide) or macro-level (regional) travel analyses. The general objective is to examine the potential effect of location on several travel behaviour aspects. The most frequent travel aspects are trip frequency, travelled distance, mode share and transport-related energy use. Overall, homes located far away from the urban centre (in suburbs, exurbs or out of town) are typically associated with higher travel distance, more car dependent and increasing transport energy consumption. The elasticity of number of trips taken with residence location is generally not noteworthy. This idea is well supported by several researchers; for example, Stead (2001) who reviewed many studies in an attempt to examine the relationship between residential location and people's travel patterns; as well as Naess (2005), Nathan et al. (2005) and Litman (2011) who presented literature-based evidence.

However, it is worthwhile mentioning that generally European city centres have a more compact urban form with a narrow and winding local street network. These sort of built environment features could, on the one side, add in hindering motor vehicle use in comparison with the grid-like street network in North-American cities and on the other make the variation in car use between the city centre and outer areas more distinct (Schwanen, Dijst, & Dieleman, 2002; van Acker, et al., 2007).

Naess (2005) has carried out a comprehensive household travel survey in the Copenhagen metropolitan area, in Denmark. The central focus was to investigate the effect of residential location with respect to downtown Copenhagen and lower-order centres on the respondents' travel pattern. The survey sample includes 1932 respondents in 29 residential developments; the self-completion questionnaire form technique was mainly adopted for contact. Travel diaries were sent to 273 inhabitants whilst 17 households were interviewed. The study quantitatively shows how weekday travel distance using three modes of conveyance (car, on foot and bike) vary within people living in different distances from the main city centre of the Copenhagen Metropolitan Area (Figure 3-2). Results point out that city centre and inner city dwellers travel considerably shorter distances by car than those living far from the centre. Moreover, people living in the city centre are using active transport (walk/cycle) for undertaking most of activities up to almost 20 km, but suburbanites and exurbanites, in opposition, often walk/bike for activities in destinations less than 5 km around their homes. The regression analysis also confirms the strong and significant impact of residential location on people's travelled distances (Naess, 2005). For the British cities' experience, compared to the UK as a whole, more than twice as many people in Manchester and Liverpool city centres reside within 2 km from their working destinations. In addition, more than 33% of employed inhabitants in Manchester and Liverpool city centres commute to their job on foot. This compares to less than 12% nationally. Conversely, the percentage of people who drive to work in these two city centres is low compared to national averages (Nathan et al., 2005).

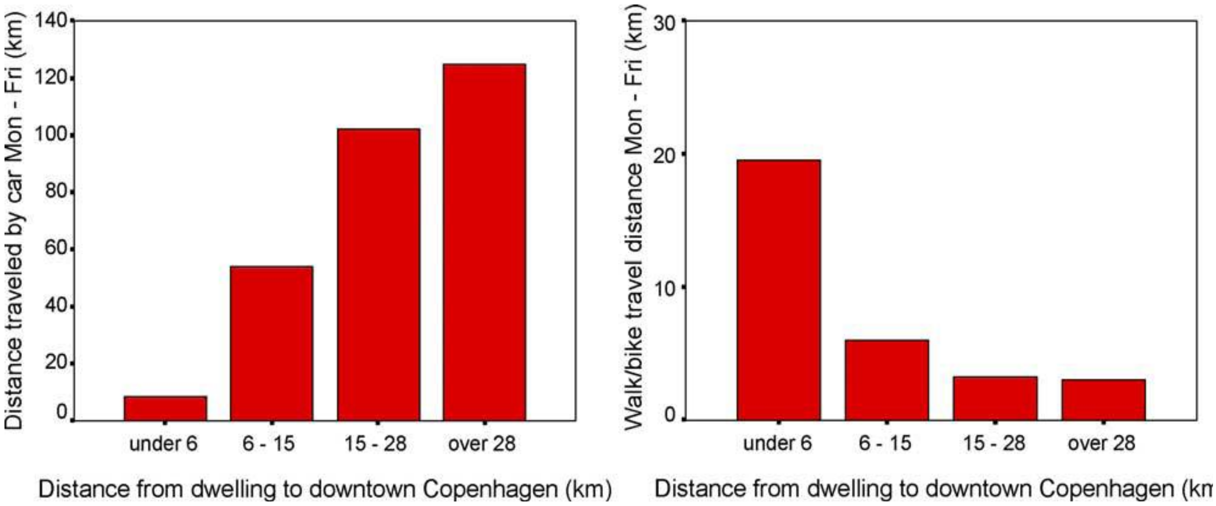

Figure 3-2: Variation in median travel distances by car (left) and by walk/bike (right) for residents living in different distance from the city centre of Copenhagen (Source: Naess, 2005, p194).

In an attempt to better understand transport-related housing location consequences, Naess (2006a) examined the residential location impacts on several characteristics of daily-life journeys in Copenhagen such as trip length and trip frequency. Regarding trip length, statistical analysis indicates that the weekend leisure trip distance increases with increasing the housing distance from the urban centre (Figure 3-3; left-hand side). This pattern can also be noticed for the working trips even after controlling for socioeconomic and attitudinal variables (Figure 3-3; right-hand side). This could be attributed to the numerous, concentrated entertainment and social places (cafes, bars, restaurants ...etc.) and the proximity and availability of employment opportunities in the city centre (Naess, 2006a; Nathan et al., 2005).

Regarding trip frequency, after controlling for non-urban structural variables such as demographic, socioeconomic and attitudinal factors, analysis results indicate that people living in outer areas undertake more weekday total trips than those living in or surrounding the downtown (Næss, 2006a). One possible explanation of that is the nature of the city centre built environment, in particular compactness and land use diversity which enable residents to undertake several errands within one journey (trip chain). However, at weekends, the opposite appears to be more evident; city centre dwellers do more trips than their counterparts in outer areas (Naess, 2006a).

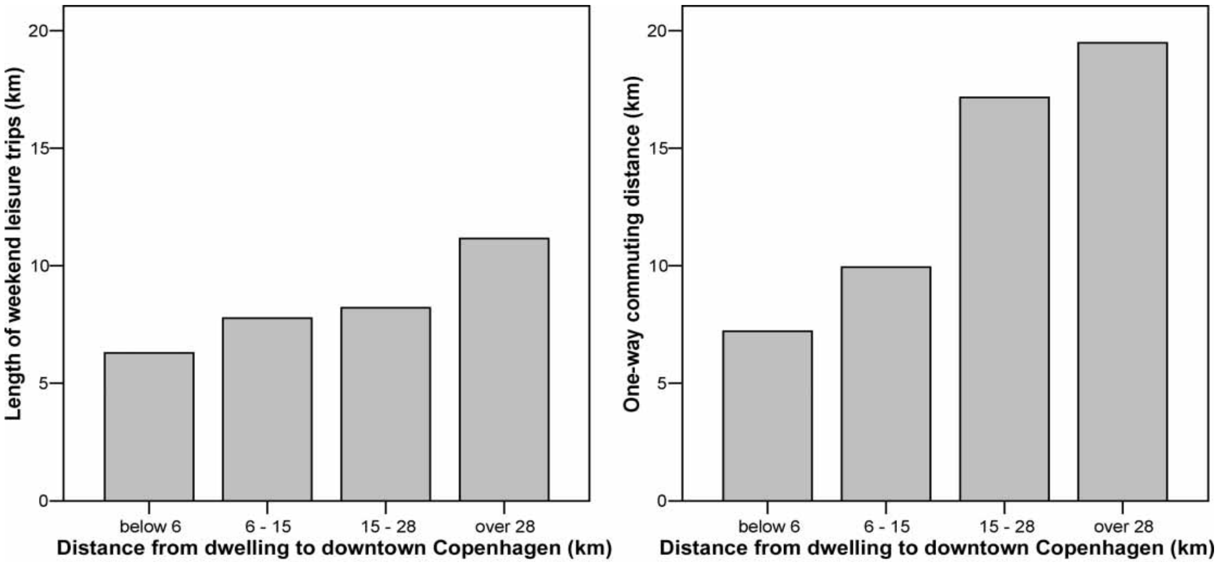

Figure 3-3: Variation in mean leisure trip lengths at the weekend (left; p = 0.005) and working trips (right; p = 0.000) among respondents living within different distance from downtown Copenhagen (source: Naess, 2006a, p640).

According to Nathan et al. (2005), the focus groups-based findings in their survey indicate that many dwellers prefer to escape the city, driving at the weekend. The majority carry out their main shopping weekly at supermarkets, and private vehicles seem the most eligible mode**.** The concentration of a variety of social places in the town in addition to the characteristics of most town residents; single or childless couples would also highly facilitate going out on journeys. The relative influence of demographics characteristics of city centre's residents on their several distinct travel patterns, in particular, car use, has recently been questioned (Sun, Waygood, Fukui, & Kitamura, 2009).

Regarding the impact of a city centre housing location on transport energy use, Perkins et al. (2009) have studied the transport operational energy use for 41 apartments in the city centre of Adelaide, Australia in comparison with suburban households. The descriptive analysis for the variation in trip frequency among dwelling units in city centre, inner and outer suburbs for different transport modes is in agreement with the typical whole picture (Figure 3-4). City centre living promotes non-motorised travel and reduces car dependency. In addition, in line with Litman (2011), city centre living encourages transit use as an alternative to driving. The Perkins' study findings also state that living in downtown could reduce travel distance, while 80% of trips carried out by city centre respondents are less than 5km, the corresponding figures for inner and outer suburbanites are 75% and 50% respectively. Having said that, it is not surprising to find that transport energy consumption by city centre apartment dwellers is much less than their counterparts in the suburbs.

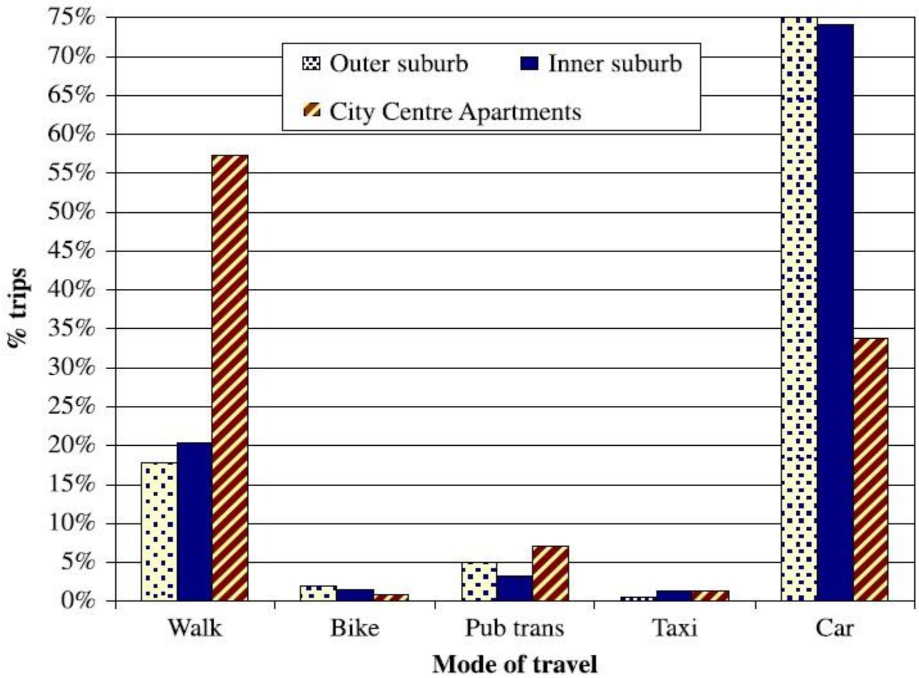

Figure 3-4: Proportions of trips by mode—comparison of the three samples
(Source: Perkins (2009, p.387))

In response to some critiques that the impacts of built environment factors on travel behaviour could be overestimated by researchers who ignored the influences of self-selection, Naess (2009) has found empirical-based evidence that counters this hypothesis. Using data from the Copenhagen survey and conducting multiple regression analysis, he studied the impacts of housing location on the distance travelled by car on weekdays among people with different residential preferences. The regression model parameters regarding location of residence relative to Copenhagen downtown have only slightly changed after controlling for the self-selection (Naess, 2009).

Adopting another case study, Hangzhou Metropolitan Area, China, Naess (2010) has almost replicated the methodology and analysis that was adopted in Copenhagen. However, the analysis results and findings are, in general, similar. Location of the respondent's home relative to the city centre exerts considerable impact on several aspects of travellers' decisions. Overall, respondents located in the city centre of Hangzhou or within its immediate surroundings carry out less travel, with a higher non-motorised transport share, and contribute to lower transport energy expenditures. The study recommends that in order to reasonably minimise motorised transport, China should avoid urban sprawl.

Taking Santiago de Chile as a case study, Zegras (2010) looked at the potential influence of the relative housing location to the CBD area (as one of the meso-level urban form features) on car use and ownership. Regarding household motor vehicle use, the regression analysis parameters show that VKT by car increase by 530 metres with each 1km increase in the distance from the CBD. The study proposed that this could confirm the structural idea of the ability of the concept of the compact city in reducing the amount of travel. Concerning car ownership, on the other hand, a multinomial logit model was developed and shows that while the propensity of owning a vehicle is higher in households residing relatively far from the city centre, this trend decreases for those living too far from the downtown. One of the possible reasons is the presence of other suburban or town centres in the region which might work similarly, at least to some extent, to the city centre in reducing car dependency; or the urban region is simply multicentric (Zegras, 2010; Stead, 2001). Actually, this could question the adequacy of using location of residence relative to the city centre as a proxy of the remoteness of a development in monocentric urban areas.

Recently, Naess (2011) has conducted an empirical study with objective of comparing the impacts of macro-level (regional or citywide) and micro-level (typically neighbourhood level) urban spatial environment features. The study findings indicate that metropolitan-scale urban structural characteristics have greater impact than neighbourhood-scale characteristics on people's travel patterns. Residential location relative to downtown is found to be one of the most influential spatial attributes.

In England, according to the focus group survey conducted by Nathan and Erwin (2005) in Liverpool centre, while the vast majority of employed people have a job destination within the centre, less than half of them commute by walking. Regarding shopping activity behaviour, a difference is noticed based on the car availability. Those without a car as an option to travel often use shops inside the centre while the presence of a car makes most people opt to head to supermarkets out of town. According to a Liverpool city centre perception survey, more Liverpool residents were in the city centre to shop (46%) than non-residents (39%). Non-Liverpool residents were more likely to be in the city centre for leisure (20%) than Liverpool residents (13%) (Palfrey, 2009). In Palfrey's (2009) survey, both city centre dwellers and users were interviewed. One of the interview questions was about how people usually travel in and around Liverpool city centre. The respondent's replies stated that while non-residents form 33%, the dwellers comprise only 16% of those more likely to make their journeys by car, van or motorcycle. For bus transport, almost 60% of the centre dwellers use buses compared to only 21% of non-residents.

Based on the 2001 Census results regarding Leeds city centre resident's travel behaviour, the findings show that commuting to work on foot is the most common mode of travel while car commuting is not common (Clark & Mckimm, 2003). Two reasons may justify this behaviour; the first is the continuous increase in residential developments in the centre while the other is the concentration of employment opportunities in the centre.

3.6 The UK national planning perspectives: city centres

According to (Couch, 1999), the shrinkage in the inner city population was formally quantified in the time of the 1971 Census when the symptoms of urban decline in several British cities became evident. As highlighted previously, in response to this continuous decline and decentralisation in British cities and in particular their centres in 1980s and 90s, the UK government asked the Urban Task Force to undertake a study looking at urban policy. The commissioned report, Towards an Urban Renaissance (DETR, 1999), was partly formally adopted by the government via its well-known Urban White Paper (UWP) - Our Towns and Cities: The Future (DETR, 2000).

Several essential challenges to the vision of urban renaissance in towns and cities were made clear in the UWP; in general, they could be summarised in the desperate need to:

‘ *encourage people to remain and move back into urban areas, particularly the centres of our major cities and conurbations, by making them places which offer a good quality of life. This means having an attractive urban environment employment opportunities and good quality services, ..., to tackle the poor quality of life and lack of opportunity in certain urban areas as a matter of social justice,..., to strengthen the factors in all urban areas which will enhance their economic success,...., and to make sustainable urban living practical, affordable and attractive to enable us to reduce the emissions, ..., and other local and global environmental impacts’*(DETR, 2000, para. 2.36).

It appears clear that the UWP calls for making the city centre an attractive place to live and work alike. In doing so, it emphasises the importance of achieving the three essential corners for sustainable urban regeneration – environment, economy, and community. According to Richard Rodgers (the chair of the Urban Task Force), there have been evidences that the implementation of the strategies of urban renaissance proposed in the UWP is working. He added that there has been a considerable change towards moving back to the city after the decentralisation following the postwar boom years; *People have started to move back into city centres*. He showed two evidences; the first is that the Manchester central population has exploded between 1990 and 2005 while the second is the quadruple increase in central Liverpool population during the same period (Urban Task Force, 2005). In the same context, Bristol city council in its report ‘The Population of Bristol’, based on the ONS Small Area Population Estimates Experimental Statistics, indicates that the areas of highest population growth, during 2001 and 2007, are all concentrated around the City Centre. Moreover, the report stated that two of the key reasons for this growth are the high levels of residential development taking place and the increase in student accommodations since 2001 (Bristol City Council, 2009).

Recently, issues of promoting sustainable urban renaissance in urban centres have explicitly appeared in several planning policy statements (PPS). According to the first statement (PPS1) – Delivering Sustainable Development- these governmental planning documents set out the official national policies on various aspects of spatial planning in England. Their holistic prospect is that adequate planning is the ideal vehicle for carrying the wider governmental, social, environmental and economic objectives and for sustainable communities. These policies are supposed to be considered by the regional and local planning bodies and authorities respectively (ODPM, 2005a). Regarding centres, the ODPM assigned PPS6 to look at adequate planning policies for promoting centres, in particular, city, town, district and local centres (ODPM, 2005b). This statement was replaced by the contemporary PPS4 Planning for Sustainable Economic Growth (DfCLG, 2009a). However, the vast majority of planning policies remain unchanged.

PPS4 reports that the Government's overarching goal is sustainable economic growth; '*growth that can be sustained and is within environmental limits, but also enhances environmental and social welfare and avoids greater extremes in future economic cycles*' (DfCLG, 2009a, p3). To achieve a prosperous economy, the current National Planning Policy Framework (NPPF) has set several Government objectives that planning is supposed to meet. In the city centre context, adequate planning should promote the vitality and viability of city and town centres as essential places for communities. In so doing, the main uses in centres such as offices, retails and leisure should be sustainably promoted, high-density and accessible development are encouraged, and mixed-use building such as residential or office development above ground floor retail, leisure or other facilities within centres are recommended.

With respect to housing, the policy states that providing a proper living district can significantly add to maintaining and enhancing the vitality and viability of city centres, to be addressed as part of a proactive planning approach for these centres. Adding to this point, the planning policy confirms that promoting centres as places to live and work could escalate local demand and hence promote a 24 hour city centre vitality (DfCLG, 2009b, p.21). In response, many British local planning authorities have considered essential improvements and growth in city centre housing. For instance, Birmingham City Council (BCC) in its Economic Review and Prospects publication promotes constructing more residential developments in the centre for attracting more young professionals and to increase the liveliness of the cultural life (Birmingham City Council, 2005)

On the other hand, regarding transport services and infrastructure, the PPS4 calls for planning for sustainable transport. That is, spatial planning that reduces the need of people to travel. This is in addition to working on reducing car dependency and responding to climate change concerns (DfCLG, 2009a). Furthermore, PPS4 asks regional planning bodies and local planning authorities to encourage development to be accessible by public transport, walking and cycling. In addition it calls fo--r city centre planning that adequately addressed transport issues associated with the growth and management of city centres (DfCLG, 2009a), for example the amount of travel generated by new developments (DfCLG, 2009a). It is worth while mentioning that the policy statement also calls for information to establish an evidence base for the development plan and management in addition to checking the impacts of the adopted plans in the sustainability appraisal. Included in this information is the travel to work patterns including the commuting mode (DfCLG, 2009a).

3.7 Summary

Based on the relevant available literature, this chapter shed a light on the UK city centre living from a travel behaviour perspective. It started with presenting typical definitions regarding city centre (downtown) and its complementary part, the central business district (CBD). Thereafter, the chapter reviewed how the technological developments in the transport technology, especially the presence of the private car, have played an essential role in shaping the dormant and vibrant stages of the city centre. In the same context, the chapter also highlighted some of the recent urban regeneration aspects in the UK cities. The discussion revealed that reviving the residential sector is an effective tool in the renaissance agenda of a city centre.

Next, the chapter examined the potential reasons of the recent relocating/moving back of people to the UK city centres. The discussion demonstrated three noteworthy reasons; first, the change towards city living lifestyle; second, the interest of developers in investing in urban centres and thirdly, the significant policy interventions that aim to make city centres attractive neighbourhoods for living, working, shopping and entertaining.

Subsequently, the chapter investigated the recent relevant literature regarding the characteristics of city centre living from personal mobility perspective. Several influential personal characteristics of the city centre residents have been examined in addition to their travel patterns. These characteristics are; demographic, socioeconomic and attitudinal attributes. Finally, the chapter has ended with reviewing the aspirations and recommendations of the recent UK national planning policy regarding city centres. The review have covered three essential relevant issues; sustainable development, housing and transport.

CHAPTER 4: DATA AND RESEARCH METHODOLOGY

4.1 General

This section endeavours to illustrate the overall research strategy that has been chosen to integrate the various components of the research process conducted in the thesis in a consistent and logical way. In so doing, the theoretical framework underlying the travel analysis and modelling is discussed in Section 4.2. Thereafter, the sources of data required to operate the planned analysis have been shown in Section 4.3. For each dataset, background information and several survey design related issues have been discussed. Section 4.4 presents a concise discussion regarding a number of central methodological issues. Such issues include the data sources employment strategy (Section 4.4.1) and the research design and analytical strategy (Section 4.4.2). Thereafter, Section 4.4.3 presents a brief review about the univariate and multivariate statistical inferential techniques employed in the study. Additionally, further statistical-related issues have been highlighted in Section 4.4.4. Finally, the chapter ends with a concluding summary section (Section 4.5).

4.2 Conceptual framework

This section aims to demonstrate the underlying conceptual framework of the models and analysis conducted in this study. The conceptual framework has been shaped in accordance with the major objective of understanding the travel behaviour of people residing in UK urban centres. General details regarding this objective have been stated in Chapter 1, whereas specific details will be presented at the beginning of the three analytical chapters 5, 6 and 7. There are two main approaches in travel demand/behaviour modelling; trip-based and activity-based. The first of these has been adopted in this work mainly because of the data-intensive nature of the activity-based approach; it necessitates time-use survey data for both the indoor and outdoor activities of people (Bhat & Koppelman, 2003). Furthermore, most of the recognised and recommended UK transport survey databases (for example, TRAVL, TRICS, GB NTS and NTEM) do not offer such a form of data.

Before presenting the underlying conceptual model adopted in this study, it is sensible to highlight some relevant outputs from the literature reviewing process conducted for the research purposes of the current study. First, 'Travel Demand Model' is a generic term used in the literature to stand for all the travel demand/behaviour models linking one or more of the mobility measure outcomes to one or more of the land-use, transport system, and/or traveller characteristics. Nevertheless, a distinction has also been found whereby 'travel demand' is utilised when the central objective is to quantify and forecast whereas 'travel behaviour' is utilised when the central objective is to investigate and explain. Another distinction is that while travel demand models are typically aggregate, travel behaviour ones are typically disaggregate. Having said that, all the travel models developed in this study are actually travel behaviour models in terms of the general aim of understanding people's travel behaviour. However, with respect to the level of analysis, all the models developed in the Chapter 5 are relatively at an aggregate level while those in Chapter 6 and Chapter 7 are strictly at the disaggregate level.

Second, overall, transport modelling research can be divided according to the adopted modelling design and strategy into two groups. Whereas the first group only contains statistical models, the second group has a clear conceptual model that rationally justifies the subsequent statistical modelling issues including model specification and the analytic strategy utilised. The vast majority of the recent transport modelling research can be listed under the second group in which several underlying travel behavioural theories can be noticed. Examples are; demand for travel is derived, people make their travel-related decisions rationally, and whether travel behaviour is planned or habitual.

Regarding the current study, all the travel modelling follows a conceptual framework which is based on the traditional philosophy in that the travel demand for most trip purposes is derived (Crane & Crepeau, 1998; Mokhtarian & Salomon, 2001). People typically travel not for the sole sake of travelling but rather to reach other locations, usually spatially distributed, to pursue their activities there. Typical activities include work, study, shopping and leisure. In addition, it is assumed that individuals follow a rational decision making process. For instance, the commuter will repeat his or her mode choice under identical circumstances (Ben Akiva and Lerman, 1985). Finally, the underlying theoretical framework for the current study follows the general principles of the theory of planned behaviour. That is, broadly speaking, the attitudes, preferences and perception of people might shape their intentions and eventually their actual behaviour (Chen & Chao, 2011).

The schematic illustration shown in Figure 4.1 represents the overall underlying conceptual model for the travel behaviour analysis and modelling conducted in this study. Broadly speaking, this is recognised in most of the recent transport studies that model people's travel behaviour within a behavioural framework. The model implies that the negative consequences of road transport, such as energy consumption and emissions, are expected to be a result of people's travel behaviour (TB); in particular, the vehicle distance travelled. The travel behaviour is, in turn, expected to be affected by several socioeconomic (SE), demographic (DG), built environment (BE), attitude (Att.) and preferences (Pre.) in addition to the travel cost indicators.

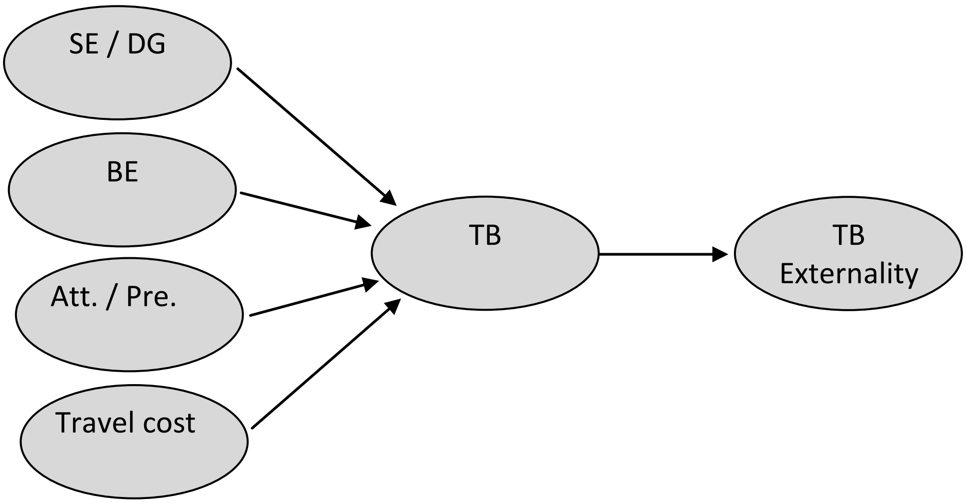

Figure 4-1: The general conceptual framework of the study.

Following (Boarnet & Crane, 2001a; Boarnet & Greenwald, 2000; Boarnet & Sarmiento, 1998; Cervero, 2002), the behavioural framework of the travel demand models in this study complies with the traditional behaviour theory in microeconomics related to consumer demand and choice (comprehensive background is found in (Ben Akiva and Lerman, 1985)). In general, it is hypothesised that consumers attempt to make a logical decision in choosing a particular choice. In the transport context, choices relate to travel purpose, frequency, timing, destination and mode choice. According to this theory, the rationality involves that consumers (travellers) make a balance between their preferences/tastes and expenditures (travel cost/price) by maximizing their utility and benefits but subject to their budget constraints (income). Hence, the travel behavioural models developed for the research in this study are specified to be consistent with the theory of consumer demand and choice in that they typically include variables that reflect service prices and traveller income (Ben Akiva & Lerman, 1985; Domencich & McFadden, 1975).

Having said that, the adopted generic mathematical form for the travel behaviour model that links a specific travel outcome to relative mode costs, traveller income and other socioeconomic characteristics, is:

$$T = f\,(P, I; S), \tag{1}$$

where T is a certain measure of trip making behaviour such as number of trips taken by an individual, P is the vector of relative time costs (or prices) of the taken trips, I is the individual's income, and S represents a vector of sociodemographic (taste) variables.

The inclusion of income and socioeconomic/demographic factors in Figure 4-1 and Eq. (1) has both theoretical and empirical bases. Theoretically, the inclusion of income is central in any utility-based travel demand behavioural model in that it reflects the resource aspect of the consumer (traveller) (Ben Akiva and Lerman, 1985). Other traveller's socioeconomic and demographic traits such as age, gender and education aim to quantify tastes and feelings of individuals towards specific goods and services. According to Ben Akiva and Bierlaire (1999), their inclusion is a necessity to explain the variation in preferences among decision-makers. In practice, there is sound empirical evidence that traveller's socioeconomic and demographic characteristics have a significant impact on people's travel decisions.

Now, statistically speaking, in order to fit Eq.(1), the price variable P should first be specified. Generalised travel cost (travel expenses) typically includes time and money. Two cost-related points were made clear by Boarnet and Crane (2001a): first, there is no straightforward measure to quantify the unit price of travel; second, adding more travel cost variables may confuse (clutter) the analysis for no extra benefit. However, in the relevant literature, three proposed modelling strategies to specify how land use patterns could reflect travel costs can be recognised. Actually, this explains the inclusion of urban form variables in Figure 4-1. In the first proposed specification, Boarnet and Sarmiento (1998) suppose that spatial patterns of land use (L) could mirror travel cost, thus this implies that Eq.(1) could be re-specified as follows:

$T = f\,(L, I; S),$ (2)

This sort of specification is adopted by several researchers, among them (Boarnet and Sarmiento, 1998; Boarnet and Crane, 2001a: Greenwald and Boarnet, 2001: Snellen et al., 2002; Boarnet and Greenwald, 2000; Cao et al., 2009b; Boarnet et al., 2011). The simplification in this specification may reduce the power of a model to reflect travel prices. However, when the required data are unavailable, it at least rules out the need for a clear justification of the possibility of potential endogenous travel cost impacts in travel demand models (Cao, Mokhtarian, & Handy, 2009a). This specification is adopted in this study.

A second specification is proposed by Crane and Crepeau (1998). They claimed that the inclusion of a price variable as well as urban form characteristics in the demand model would enhance its specification.

$T = f\,(P, L, I; S)$ (3)

In order to make the model in Eq. (3) more straightforward regarding specification and more sensitive for policy interventions, it is assumed that the time-cost variable (P) may be captured by trip distance (d) and trip speed (v). Accordingly, Eq. (3) can be rewritten as follows:

$T = f\,(d, v, L, I; S)$ (4)

This type of specification, or one equivalent to it, is also used by several researchers, among them Crane and Crepeau (1998); Handy & Clifton (2001); Boarnet and Crane (2001a); Greenwald and Boarnet (2001); Boarnet and Greenwald (2000); Chao and Qing (2011); Rietveld & Daniel (2004).

In the third specification, Boarnet and Crane (2001a) pointed out that, to eliminate any doubts about model bias, it is preferred to specify the demand model in a two-step procedure. In the first step, trip distance and speed are regressed on land use features (see Eqs. 5 &6 below) and then in the second step Eq. (6) is substituted in Eq. (1) to yield Eq. (7):

$d` = f\,(L)$ (5)

$v` = f\,(L)$ (6)

$T = f\,(d`, v`, I; S)$ (7)

This specification, unlike the first two, is not frequently utilised in the literature. Furthermore, it obviously shows no direct link between land use variables and the specific travel outcome. On one hand, this would make the demand model hard to interpret and on the other hand this would complicate planning policy intervention - for example, travel demand management regarding manipulating urban form characteristics. For these reasons, the third specification is ruled out in this study.

Table 4-1 represents the expected effects of urban form on the elements of generalised travel costs (Cao et al., 2009a). It shows the expected notable impact of the spatial features on active transport in terms of time and psychological effects. In comparison, the table also shows that the corresponding impacts on motorised transport are either small or fair. This table could highlight a possible deficiency of the initial consumer theory (without spatial features) in modelling active travel mode choice behaviour.

Table 4-1: The Influence of the built environment on elements of generalized travel costs. (Source: Cao et al. (2009a, p 550)).

Mode	Time	Monetary expenditures	Psychological effect
Car	Moderate	Moderate	Minor
Walk/Bike	Strong	N.A	Strong
Transit	Minor	No(flat-rate): Minor(non-flat rate)	Moderate

In practice, the inclusion of urban form attributes in travel demand models has recently witnessed a wide popularity (Joh, 2009). That is especially after the interesting work done by Newman and Kenworthy (1989). Their international evidence-based findings about how higher density development consumes less energy have motivated researchers to investigate several urban form characteristics in addition to density.

In the policy context, researchers are also urged to develop models that are policy-sensitive by incorporating variables that are controllable by the policy makers. According to Domencich & McFadden (1975), examples of these variables are population density, land use diversity, and characteristics of the transit system. Furthermore, the recent emergence of spatial policies, such as New Urbanism in the USA and the Compact City in Europe as potential scenarios for tackling car dependency, have boosted the rationale towards the need of incorporating such variables (Bohte et al., 2009).

Finally, the inclusion of the attitudinal variables in Figure 4-1 is actually a step further beyond the traditional utility model. As stated previously, an individual's perception towards several housing and travel aspects is an interesting travel behaviour line of research that has only recently emerged. Handy (1996a,b) is credited for her pioneering works regarding the potential importance of the attitudinal factors. More information that is relevant has already been mentioned in Section (2.4.3). In brief, it is argued that deep insights into the role of perception and preferences could help in reducing travel impacts and increase the ability and flexibility of policy interventions.

To sum up, as shown in Figure 4-1, three main groups of determinants – built environment, traveller socioeconomics/demographics, and attitude and preferences – have been chosen to investigate their impact on several travel outcomes of city centre residents. Additionally, the inclusion of travel price variables in the behavioural travel demand models is considered.

4.3 Data sources

Obtaining travel dataset(s) for conducting the required exploratory and modelling analysis is a vital stage in each empirical travel behaviour study. Several features can be considered as essential to attain the sufficiency and efficiency of a travel dataset. Five of these features have been considered central in the dataset selection process due to their relevance to the scope of the current study. First and foremost, the spatial coverage and area type; urban centres, in the case of this study. Second, the availability of the raw dataset for public use or the ease of obtaining it. Third, the age of the data source; how up to date it is. The fourth is the adequacy and compatibility of the databank with the research objectives. That is typically in terms of the width, depth and aggregation level of the measured characteristics available. Lastly, the fifth is the adequacy of the dataset according to the conceptual and methodological framework; accordingly, this without doubt includes the statistical modelling. This could be usually seen in terms of the availability and eligibility of the explanatory and outcome variables in addition to the overall sample size.

Having reported that, the 2001 and 2011 UK Census data in addition to national travel surveys such as the GB National Travel Survey, National Trip End Model (NTEM), and Trip Rate Assessment Valid for London (TRAVL) have been discarded for one or more of the above reasons. This is also true for national surveys with partial travel data including the British Household Panel Survey (BHPS). However, with exception of TRAVL, the key reason for discarding is the (expected) considerably low amount of data (sample size) necessary for travel behaviour modelling in urban centres locations. The TRAVL dataset is a unique, multi-modal trip generation database specifically for London (Hills, 2007). However, it has been discarded because of, as stated in the limitation section, the several unique characteristics of London's residents and its transport system.

It is sensible here to report that in spite of the best endeavours to find an appropriate household travel survey in a UK urban centre, the search has failed. In consequence, the compass of the focus is imperatively directed to two possible alternatives. First, general national household or travel surveys with a statistically acceptable sample in the urban centres. Second, conducting an original household travel survey with a travel diary part in a recognised UK city centre. Regrettably, only two recognised national datasets have been found, at least reasonably, holding the above five features. These are the Trip Rate Information Computer System (TRICS) and the Scottish Household Survey (SHS). Both of these datasets, therefore, have been considered in the current study. Additionally, an original household travel survey has been conducted in Manchester city centre for the purpose of this study.

4.3.1 Trip Rate Information Computer System (TRICS)

This section presents a general introduction for TRICS as a nationally recognised travel database and trip generation system. In contrast, Section 5.3 will be primarily devoted to review the analysis variables. The researcher, as a Ph.D student, was able to access TRICS by using the access details of the University of Salford which has held an educational TRICS user licence for many years.

4.3.1.1 Overview

According to the formal website (TRICS, 2013), TRICS was established and is owned by the TRICS Consortium, which consists of 6 county councils; West Sussex, East Sussex, Surrey, Kent, Dorset, and Hampshire. It is advertised as the national standard for trip generation analysis and as an integral and essential part of the Transport Assessment process. So far, it consists of over 6,300 directional transport surveys at more than 100 types of land uses over the UK and Ireland. TRICS has been adopted to be the source of the housing site's description and transport data used in the travel analysis and modelling of the first analytical chapter (Chapter 5) in the current study. Several reasons are behind this selection:

- TRICS is one of the nationally recognized multimodal trip generation databases; it is often recommended to be used in planning applications in England (DfCLG/DfT, 2007; Transport for London, 2008, 2010), Scotland (Scottish Executive Development Department, 2005) and Northern Ireland (Department for Regional Development, 2006).
- Unlike other similar trip generation databases including the American Institute of Transportation Engineers (ITE) Trip Generation informational report (ITE, 2003) which is paper-based manual, TRICS is a computerised database with an acceptable flexibility for data interrogation.
- It is a multi-modal trip rate databank with sites scattered all over the UK and Ireland.
- It covers several types of residential location, ranging from urban centres to rural areas.

4.3.1.2 General methodological issues

Overall, Trics comprises sixteen different main land uses. These are including, but not limited to, residential, retail, employment, education, health and leisure land uses (TRICS, 2013). For obvious reasons, only the residential (housing) land use is the interest of the current study.

In TRICS (version 2012a), there are thirteen residential land use subcategories (sub land uses) that cover several types of housing including houses privately owned, flats for rent, institutional hostels, sheltered accommodation, student accommodation, nurses homes and retirement flats. Nevertheless, only seven of them were chosen for the travel analysis and modelling of this study. These seven are; Houses Privately Owned (HPO), Houses for Rent (HFR), Flats Privately Owned (FPO), Flats for Rent (FFR), Mixed Private Housing (MPH), Mixed Non-Private Housing (MNPH), and Mixed Private/Non Private Housing (MPNPH).

A full definition of these residential developments is available in the TRICS 2012 Online Help File; however, for the reader's convenience, the full definitions of the selected seven housing sub types have been listed in Appendix-A. However, it is worthwhile highlighting here that the ratio 75% is the key threshold for discriminating housing types and tenure. For instance, Houses Privately Owned are housing developments where at least 75% of units are privately owned and also where at least 75% of these units are houses. Other housing sub land uses were excluded for one or more of the following three reasons: first, the lack of an adequate number of sites (in this study a statistical-based threshold of a minimum 3 sites has been adopted); second, the obvious inconsistency in the nature of the travel behaviour in comparison with the seven already selected; third, due to being out of the research scope and thus there is little expected contribution to the main research objectives.

In TRICS, both the descriptive and traffic site data are stratified into hypothetically non-overlapping (mutually exclusive) categories to produce the corresponding trip rates of the representative sample site(s). This could be seen as the main building block underlying the category analysis model used in TRICS (Ortuzar & Willumsen, 2011).

According to the TRICS Good Practice Guide (TRICS, 2012), users should not mix weekday and weekend surveys together. On the other hand, the Guidance on Transport Assessment (DfCLG/DfT, 2007) states that for residential developments the peak periods occur on weekdays. Therefore, only weekday surveys have been adopted for the analyses in this study. These surveys were based on a 12hr. (7.00-19.00) analysis period for both travel directions (production and attraction trips). Finally, in line with TRICS recommendations listed in the TRICS Basic Tutorial (TRICS, 2005), only the most recent surveys were chosen to avoid any possible bias towards multiple survey sites.

4.3.2 Scottish Household Survey (SHS)

4.3.2.1 Overview

The Scottish Household Survey (SHS) is a major continuous (repeated) cross-sectional survey based on a sample of the general population in private residences in Scotland. Each year, about 15,500 households across Scotland are interviewed. It was started in 1999 and has been commissioned by the Government of Scotland and undertaken by a consortium of research organisations involving Ipsos MORI and TNS BMRB. The general target of the survey is to periodically supply reliable information regarding the features and traits of the Scottish households and individuals. The survey is considered a major supplier for information that supports the efforts of the Scottish Government for setting up policies regarding transport, communities and local government. In addition, the survey is initially designed to enable disaggregating the household and individuals' characteristics geographically (Scottish Government, 2012).

4.3.2.2 Survey methodology

The survey sample in the SHS has been designed to be representative on the nationwide scale each quarter and on the small local authority scale each two-year cycle (Scottish Government, 2012).

The SHS uses a questionnaire as its main survey instrument to gather information, utilising the Computer Aided Personal Interviewing (CAPI) technique to retrieve information from the respondents during the face-to-face interviews (Hope, 2010). In order to end up with a sample that is representative of both the Scottish household and individual populations residing in private housing units, the questionnaire has been structured in two main parts. Whereas the first is worded to collect information about the household, the second part of the questionnaire, which contains the travel diary part, is allocated to interview a randomly selected household adult (Scottish Household Survey, 2011). The full survey questionnaire for the 2007/2008 cycle is listed in Hope (2008) however, the main topics covered in this instrument can be seen in (Scottish Household Survey, 2008). It is worthwhile mentioning that the SHS defines a household as one person or a group of people living in accommodation as their only or main residence and either sharing at least one meal a day or sharing the living accommodation (Scottish Household Survey, 2010).

In the first part (usually called the main part), the Highest Income Householder or their spouse/partner is interviewed. In the SHS, this householder is defined either as the person in whose name is the dwelling unit or the household member with the highest income (SHS, 2010). In this part, information is collected about several aspects that address the composition and characteristics of the household. The householder is asked about issues such as household members' socio-economic characteristics, type of property and accommodation, child-care and schooling, household income, car ownership and access to the internet (Hope, 2010; Scottish Government, 2012).

On the other hand, in the second part of the interview, the random adult (aged 16+) is asked about perception towards issues such as local services and neighbourhood in addition to questions regarding demographics, personal travel, health, employment status and participation in culture and sport. However, the essential aspect of this part, which has most relevance to this study, is the travel diary. The interviewer asks the random adult to give quite detailed information about the journeys made on the previous day (Scottish

Government, 2012). This information includes descriptive data about each journey and its stages for multi-stage journeys; for example, origin and destination of each journey stage, travel mode, end and start travel time and journey purpose.

4.3.2.3 The SHS travel diary

In contrast to the main part of the questionnaire in which the householder is interviewed, the second part is often called the travel diary which is answered by the random adult is interviewed. The travel diary covers journeys made by the respondent for private purposes, work or education, taking into account that the main reason for the journey is not in the process of business (like a taxi driver), but it is the own intention of the traveller to reach the destination. In doing so, the travel diary comprises personal trips made for domestic, social or recreational purposes in addition to trips for taking or accompanying someone else (SHS, 2011). For travel analysis purposes, in the SHS travel diary a journey is the basic unit of travel. A journey is defined as a one-way course of travel having a single main purpose. Outward and return halves of a return journey are treated as two separate journeys. Furthermore, a journey could consist of one or more stages. A new stage is primarily triggered when there is a change in the travel mode (SHS, 2010). However, single stage journeys encompass 98.75% of the journeys recorded in 2007/2008 (SHS, 2011, p.5).

When a journey is conducted using more than one transport mode, only the main mode of travel is recorded. The main mode is that one that is utilised for the longest (in distance) stage of the journey (SHS, 2011, p6). With respect to walking, in the SHS travel diary it is only defined as a mode of travel if it is the sole mode used in travel; for example, walking the dog and walking to the corner shop (SHS, 2011, p.5). The length of any journey stage is the calculated straight-line distance, as the crow flies, based on the grid coordinates of the postcodes of the origin and destination of that certain journey stage (SHS, 2010, p.A36). For missing and illogical data, an imputation process has been adopted to get around such issues, details are listed in travel diary user guide (SHS, 2011). A complete list of the SHS travel diary variables and the SHS travel diary questionnaire can also be found in the travel diary user guide.

The 2007/2008 cycle of the Scottish Household Survey has been chosen as the master dataset for the research of the present study whereby the characteristics of the households residing in the city centres of four large Scottish cities would be extracted. These four cities are Glasgow, Edinburgh, Aberdeen and Dundee. The main reason behind choosing this specific dataset is that it was the most up to date and publicly available dataset at the time of applying the formal SHS Special Dataset Request[8]. The details regarding the approach adopted in identifying such households is explained later in Chapter 6 (Section 6.3). It was initially planned to also include the city centre households in the 2005/2006 cycle to maximise the number of cases and hence enhance the sample size required for statistical analysis. Another reason for the inclusion of another dataset is that while prior to 2007 all the households selected for the main SHS were included in the Travel Diary section, from 2007 onwards, this was reduced to only three-quarters of them (SHS, 2010).

However, there have been several reasons to disregard such intention. Generally, they are regarding the changes that have been made in the survey methodology of the 2007/2008 data cycle. SHS (2010) has explicitly expressed this awareness regarding using data from both prior and post 2007 datasets. The following are the main relevant ones (Scottish Goverment, 2009b, p.3):

1. Walking journeys less than ¼ mile or shorter than 5 minutes have been considered. This has resulted in an increase in the proportion of walking journeys with corresponding decreases in the proportion of journeys by other modes. This led to add a new purpose category (go for a walk) from 2007 onwards.
2. Modifications in the wording of questions; this would trigger the problem of combining responses from non-identical survey instruments.
3. From 2007 onwards, the duration of journey is directly obtained from the respondent, while prior to 2007 it was calculated depending on the reported start and end times of each journey stage.

This relates to the fact that the purpose of a journey is usually recorded depending on the activity at the destination. In the years preceding 2007, the journey of going back home was defined by the purpose at the origin of the journey – for example, a journey from workplace to home would be defined as going to work. Nevertheless, from 2007 onwards only the direct reverse journey of the outward journey is classified depending upon the purpose of the origin. In contrast, non direct return journeys are classified according to their own purpose. Hence, from 2007 onwards, a new purpose category (go home) has been listed.

[8] The first formal contact with the SHS Project Manager was on 14 March 2011.

The travel behaviour measures and household and individual characteristics included for the travel analysis carried out for the objectives of this study are reviewed later in Ch. 6.

4.3.3 Manchester city centre household travel survey

The third employed dataset in this study has been obtained by conducting an original household travel survey in Manchester city centre. For the reader's convenience and for the sake of coherence, the survey will be thoroughly described in the third analytical chapter (Chapter 7) where it has been used (Section 7.6.2). The description includes issues regarding survey design and methodology including sampling design, questionnaire design, survey administration and data processing.

4.4 Methodological framework

The following sections will highlight the key methodological issues of the research carried out for this study. More detailed and complementary information is listed in Appendix-B.

4.4.1 Strategic roles of the three data sources for developing the study

Each travel data source of the three employed in the current study has been individually utilised to address certain research question(s); however, they have collectively been utilised to attain the main second and third objectives of the thesis (see Section 1.5). In addition, the order of using these data sources – TRICS, SHS and then Manchester city centre survey – has been arranged so to consider the rational development of the thesis research questions correspondingly.

Having said that, the UK TRICS database will be firstly utilised to address the primary second objective of whether the location of a residential site has a notable influence on its households' travel characteristics. That is, whether sites in city/town centres have different mobility activities from those located out-of-centres. However, TRICS is not adequate for household or individual-level travel behaviour analysis (more details will be seen in Chapter-5). Therefore, the Scottish Household Survey has been mainly employed to address the third main objective of understanding the mobility behaviour of households and adults that live in the centres of three Scottish cities and the consequent implications for the sustainability agenda.

Finally, the household travel survey conducted in Manchester city centre has been, as with the SHS, also employed to consider the main third objective for three different but related reasons. First, there has been a need to acquire a travel survey that has been originally designed for the research purposes of this study and hence capable of addressing all the essential research questions entirely and effectively with special focus on the impact of attitude. Second, while the TRICS dataset contains a mix of town and city centres and the SHS dataset comprises only city centres, the conducted survey covers a mature and regionally recognised urban centre; Manchester city centre. Third, the survey is a prompt response to the overarching goal set by the local planning scheme in the city of Manchester about implementing a sustainable urban regeneration in the city centre. Therefore, the importance of understanding personal mobility of the city centre's residents is central and recognised. Figure 4-2 depicts the progress of travel analysis and modelling using the three main databases; that is by highlighting the main issues that each data source has been mainly employed to deal with.

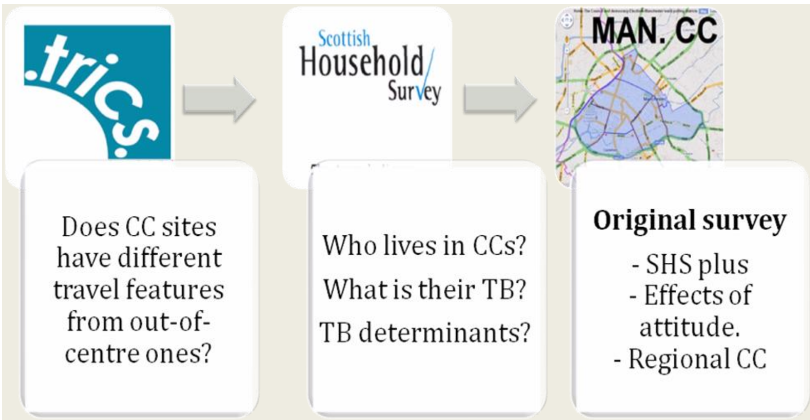

Figure 4-2: The progress of travel analysis and modelling using the three main databases.

The specific objectives and relevant research questions that each data source has been used to address will be clearly stated later in the beginning of each one of the three analytical chapters.

4.4.2 Research design and analytical strategy

The essential distinction between experimental and non-experimental research design is whether the independent variable(s) is manipulated by the researcher (see for example Tabachnick and Fidell, 2007). Accordingly, recalling that the main databases of the research conducted for the current study are coming from surveys, therefore, it is evident that the design of the current research is nonexperimental (correlational). It is worthwhile mentioning here that regardless of the statistical technique adopted, in correlational research it is tricky to imply cause and effect linkage between the independent and dependent variables. Hence, it is more appropriate in correlational research to call the independent variable as the predictor and the dependent as the response or outcome (further details can be seen in Appendix-B, Section B.1).

With respect to the data analysis strategy, it is reasonable to at first report here that the statistical software package IBM SPSS Statistics (v20) has been used to conduct the analysis and estimate the travel behaviour models. Table 4-2 highlights the key overall stages of the analytical framework adopted in the study.

Table 4-2: The main stages of the statistical analysis framework

Stage	Brief comment	
1. Data acquisition / collection	TRICS 2012a Scottish Household Survey (2007/2008) Manchester City Centre Household Travel Survey	
2. Data cleaning and screening	Exploratory data analysis	
3. Model specification	Based on research question/objectives	
4. Statistical technique selection	Research question formulation Number, types &distribution of variables. Sample size and specific model assumptions	
5. Model estimation	Ordinary least squares; maximum likelihood	
6. Analytic technique	General Linear Models	ANOVA, Multiple Linear Regression
	Generalised Linear Models	Binomial Logistic Regression Multinomial Logistic Regression Poisson Regression Negative Binomial Regression
	Principal Components Analysis	
7. Model evaluation and testing	Sum of squares (SS); Log likelihood (-2LL) Significance tests (t-, F- and χ^2)	

The selection of the approach and type of the statistical analyses employed has depended on several decisive factors. For the current study, the intention of studying a number of aspects regarding city centre living and personal mobility using three different household surveys was the trigger for the need to use several quantitative statistical techniques. This is in addition to the measurement scale and numbers of the dependent (outcome) and independent (predictor) variables (further details can be seen in Appendix-B, Section B.2).

4.4.3 Statistical techniques employed

4.4.3.1 Descriptive statistics

The purpose of conducting the exploratory data analysis in the current study is twofold. The first is statistical-specific; that is, for screening and cleaning data before conducting the required inferential analysis. The second is research-related; that is to address some of the minor research questions. Descriptive statistics techniques are the typical tool for conducting the exploratory data analysis (more details can be seen in Appendix-B, Section B.3).

The general merit of the descriptive analysis is to describe the analysis variables in order to get some preliminary answers in terms of how, where and when and, thereafter, to present the analysis results in a convenient, usable, and understandable form. Accordingly, inferential data analysis can be informed in terms of technique type and analysis variables included based on the output of the descriptive analysis.

Several traditional descriptive analysis methods and tests have been used in the current study including bar charts, frequency tables, percentile analysis, contingency tables and the Chi-square test for independence. In addition, the more sophisticated technique of Principal Components Analysis (PCA) has also been employed for handling attitudinal variables. More thorough discussion can be seen in Appendix-B (Section B.3.1) that covers the general sequential steps of applying the principal components analysis adopted in this study along with several interesting comments.

4.4.3.2 Inferential statistics

Inferential statistical techniques address the problem of making inferences from sample data to the whole population; this is typically by testing hypotheses about differences in populations on the basis of measurements made on samples of subjects (Tabachnick and Fidell, 2007; Ho, 2006). In this study, the method of analysis is quantitative. Several quantitative statistical techniques have been employed. These techniques can be generally classified into two fundamental groups; General Linear Model (GLM) and Generalised Linear Model (GsLM).

The general linear model is a general procedure that is typically employed for conducting several statistical techniques such as analysis of variance and covariance, multiple linear regression and factor/components analysis (Cohen et al., 2003; Tabachnick and Fidell, 2007; IBM Corp., 2011a). A brief review of ANOVA and multiple linear regression has been given in Appendix-B (Section B.4.1).

On the other hand, the Generalised Lineal Model GsLM is typically appraised as a generalisation to the General Linear Model (GLM). This generalisation may be outlined by two essential issues; first, the generalised linear model allows for modelling discrete response variables in addition to continuous variables. Second, it relaxes the strict assumption of the GLM in that the dependent variable should have normally distributed errors with a constant variance (Cohen et al., 2003; Freund et al., 2006). The mathematical form of a generalised linear model typically consists of three components; random, systematic and the link function (Agresti, 2007; Freund et al., 2006). First, the random component identifies the mean value of the response (dependent) variable y; second, the systematic component specifies the linear predictor and is usually referred to as (η) and third, a link function g() that linearly links the mean response variable (μ) to the linear predictor (η), usually written in terms of μ, $g(\mu)$.

In this study, in addition to the OLS multiple regression, four statistical regression models that are components of the GsLM package are employed to develop the required travel behaviour models. These are binary logistic regression, multinomial logit regression, Poisson regression, and negative binomial regression. In Appendix-B (Section B.4.2), a quite comprehensive outline of the discrete models employed in the travel modelling for the current study has been presented.

4.4.4 Further methodological issues

In order to ensure carrying out robust analysis and ending up with reliable results and hence findings, two extra essential statistical precautions should be taken seriously. The first includes the rules and recommendations adopted in the study to determine the sample sizes required for acceptable statistical modelling. The second precaution tackles the critical requirements and assumptions that underline regression analyses such as normality, Independence of errors and multicollinearity. In Appendix-B (Section B.5), proper discussion about these extra methodological precautions has been presented.

4.5 Summary

This chapter discussed the overall research strategy employed in the study. With respect to the conceptual model, Section 4.2 stated that the principles of consumer demand and choice theory have been employed. Three relevant travel model specifications have been presented and the first has been chosen. Concerning data sources, the search process has shown a significant lack in the availability of travel behaviour surveys for UK city centre residents. The UK TRICS database and the Scottish Household Survey have been utilised to extract the city centre survey samples. In addition, an original travel survey has been conducted in Manchester city centre. On the other hand, it has been stated that the current research study has a non-experimental design; in particular, it employs correlational research with a quantitative analysis method. Most of the descriptive and inferential statistical techniques employed in the study have been briefly outlined. Where appropriate, readers have been referred to Appendix-B for more details regarding statistical techniques employed and other methodological issues such as sample size, regression assumptions and bootstrapping.

CHAPTER 5: AGGREGATE TRAVEL PATTERN ANALYSIS USING THE TRICS DATABASE

5.1 General

It has become obvious that regeneration of city centre areas is taking into account a renewed desire for some people to locate their homes in central areas. This change in land use has an important impact on travel demand and on the need to design, manage and engineer sustainable transport systems. It is, therefore, hoped that the site-based level analysis in this chapter will give a better understanding of the nature of travel patterns for neighbourhoods located within the city centre in comparison with those located in other urban, suburban and outer areas.

This chapter starts by highlighting its travel analysis and modelling objectives and research questions (Section 5.2). A description of the data source adopted (TRICS 2012a) is then presented in Section 5.3. Thereafter, an explanation is given regarding the research methodology adopted to achieve the chapter objectives. Data extraction, the conceptual model, and statistical modelling strategy are the essential issues discussed in the methodology section (Section 5.4). Section 5.5 has been devoted for the analysis, results and discussion of findings. Finally, a concluding summary has been presented in Section 5.6.

5.2 Objectives and research questions

The general purpose of the residential mobility modelling included in this chapter is to enrich the trip making behaviour literature while the particular one is to investigate the characteristics of home-based trips in central areas in comparison with those in outer ones. Hence, this could help in identifying the transport impacts of any potential changes in a residential neighbourhood's features. In line with this, the preliminary objectives are:

a- To identify the distinctive spatial, socio-economic and travel characteristics of housing neighbourhoods located in or nearby the centre in comparison with those located in out-of -centre locations. Three research questions are related to this objective; firstly, do neighbourhood features vary notably across site locations? Secondly, if yes, then do travel behaviour indicators also vary notably across site locations? Thirdly, if yes, then what are the neighbourhood and travel behaviour indicators typically seen in each site location, in particular in central and outer areas?

b- To examine the specific built environment features and socio-economic traits that might explain why there is a variation in the travel behaviour of people residing in different site locations. The research questions corresponding to this objective are "if there is a significant relationship between people's travel behaviour and their place of residence within the city, then what are the neighbourhood characteristics that might mediate this relationship and hence explain how it has happened? Are these features statistically significant? What is their relative effect size and what is their direction of influence?

c- In line with the previous objectives, the third one is to review the nationally recognised UK database and trip generation system, TRICS 2012. Several cautions for TRICS users are noted and methodological improvements are proposed.

5.3 TRICS database

The overall overview of TRICS as a travel database and system for conducting trip generation analysis has been presented previously in Section 4.3.1. This section, in contrast, is mainly dedicated to shed a light on the variables and factors that have been utilized for the travel analyses planned to achieve the objectives of the current chapter. In TRICS 2012a, there is a relatively wide array of variables and factors that describe the characteristics of a housing development and the site where this development is located. However, with the exception of the household car ownership variable, the vast majority of the other indicators are either to describe the spatial environment or to quantify the residents' trip frequency. The following subsections highlight the variables and factors listed in TRICS 2012a and which have been included in the travel analysis.

5.3.1 Urban form features

These features describe the spatial characteristics of housing development sites listed in TRICS. These characteristics originally address diverse features; however, in order to be more consistent with the present analysis context, they have been re-categorised into five groups. These are land use variables, site location, public transport indicators, urban design features and parking details.

5.3.1.1 Land use variables

(A) Population density

As shown previously in Section 2.4.1.1, the effect of site population density on trip generation, in particular, and on other travel behaviour aspects, in general, is still a controversial issue. However, it is still one of the land use variables which is most frequently adopted in travel behaviour modelling analysis.

In TRICS 2012a, the population factor is provided in terms of its density within three given radii of the site boundaries based on the UK 2001 Census output levels. The three options are: population within 500m, population within 1mile and population within 5 miles. For the TRICS user, analysing this factor could assist in answering how beneficial it is to disaggregate sites according to their population density levels. In the planning policy context, this could help in shedding some light on the prolonged question about whether densification of an area could reduce its resident’s mobility. Only the population within 500m has been considered since it is the most eligible one to be a reasonable indicator due to the obvious high aggregate level of the others.

(B) Site area

TRICS quantifies the area of the development site as the total site perimeter area, measured in hectares, up to the outermost boundaries of the site, including parking areas etc. This field variable is measured twice; the first includes the public open space for the site while the second excludes it.

(C) Housing density

In the TRICS, this variable is defined as the total number of occupied dwellings divided by the site area. This land use variable reflects the concentration of the housing units in a specific residential development. However, in TRICS 2012a there are two proposals in defining this variable depending on the way in which the site area is calculated. When the area of the site includes the open public space, then the concentration of the units over it is called the unit density. In contrast, when the public space is excluded (the net area), then the calculated density is designated as the housing density. While housing density sounds more precise than unit density, the use of the former is only utilised in the exploratory analysis due to the large number of missing values for the net area of sites.

(D) Housing unit type

The number of site dwelling units in TRICS is broken down according to the type of the residential unit. The field measurements in Trics recognises four types of housing units ; namely, houses, flats, bungalows and townhouses. According to the initial exploratory analysis that has been conducted, it was expected to find that the two main types of housing units are houses and flats. It is worthwhile mentioning that other types of units (bungalows and townhouses) are excluded for their relatively low weight and for being out of the scope of the current study.

(E) Housing unit tenure and bedrooms

TRICS also distinguishes between the housing units in a site according to the way these units are possessed (the tenure). In each site, the tenure details are included by listing the number of units that are Privately owned and those Non-Privately owned. The Non-Privately owned units are those that may be council rented or housing association rented/part-owned. In order to make the tenure variable more adequate for the planned statistical analyses, a new quantitative equivalent variable called (private ratio) has been created. The Private ratio variable represents the number of the privately owned housing units in a site divided by the total number of the units in the site. Furthermore, in residential development sites, the total number of bedrooms within the site is one of the listed field data in TRICS.

(F) Household space type

TRICS also classifies houses according to their structural form into the common three types, namely; detached, semi-detached and terraced. Similar to the statistical reason mentioned above, three equivalent variables are created. These new variables are Detached ratio, Semi-detached ratio and Terraced ratio; they have been computed as the number of each type divided by the total number of dwelling units in a site. The division by the total dwelling units rather than the total houses is employed to avoid the mathematic dilemma of division by zero in sites which only have flat units such as blocks of apartments.

5.3.1.2 Site location – place of residence

The influence of the location of a housing development site with respect to the city/town centre on its residents' travel behaviour has strong empirical-based evidence according to the literature (See section 3.5.5).

This influence has also been highlighted in the TRICS good practice guide (TRICS, 2011, pp4). The guide points out that site location type is one of the vital data fields when seeking site selection compatibility. It further states that development sites located in a town centre with an acceptable level of local public transport accessibility will most probably experience a modal split different from another site in rural areas without any substantial public transport services. However, no relevant dedicated statistical study has been found in the TRICS library that tackles this interesting point in detail.

As an attempt to attach a spatial dimension to the trip generation analysis, TRICS, in line with planning policy statement 6 (PPS6), assigns main location definitions as a descriptive spatial characteristic for each development site. These location categories are basically used as a proxy measure of both how far the site is from the town/city centre and the availability of local public amenities in the development site. In TRICS these categories are designated as; Town centre TC, Edge of town centre ETC, Neighbourhood centre NC (Local centre), Suburban area SA (Out of centre), Edge of town ET and Free standing centre FS (Out of town) (see Figure 5-1).

Due to a sample size issue, the Free standing location has been excluded from the analysis. Furthermore, the Neighbourhood centre location (Local centre) has also been excluded from all the travel analysis for two reasons. Firstly, this location is defined in the TRICS as a Local centre such as a small district or village; however, it is not a city or even town centre. Hence, its characteristic is expected to be arbitrarily oscillating between town centre and suburban area. The preliminary exploratory analyses of the neighbourhood features within location have confirmed this. In consequence, it is expected that its inclusion would confound the objective regarding the investigating of variation in travel behaviour for people residing in well-defined and almost mutually exclusive locations. Secondly, the limited number of sites located in such locations (only seven in the TRICS 2012a database) makes it statistically vulnerable to examine these sites separately.

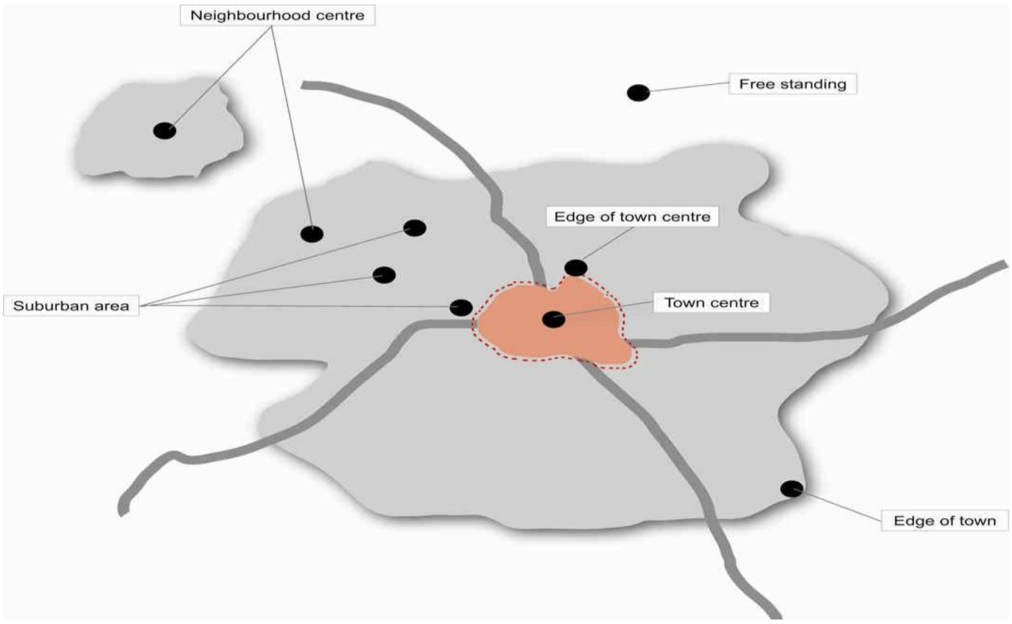

Figure 5-1: The Trics definition for the main location types.

5.3.1.3 Public transport indicators

(A) Public transport services

A summary of the availability and frequency of transit services near a residential site is often tabulated in the 'Main Details' screen of each site. The table lists the total number of bus/tram and train services that stop near the site on a weekday (Monday – Friday), Saturday and Sunday for selected time periods. Three periods are usually displayed; 7.00am-7.00pm, 7.00am-10.00am and 4.00pm-7.00pm. In line with the objectives and scope of the current study, the transit frequency figures corresponding to a 12hr (7.00am-7.00pm) typical weekday are the only ones chosen to be included in the travel analysis.

It is worthwhile reporting that only the buses and trams with a stop within 400 metre radius of a site access are considered in the table. Similarly, only train stations within 1 kilometre are included. For buses and trams, the figures displayed in the transit provision table are the total two-directional number of all buses and trams that stop within 400 metres of a site access. For trains, the number listed is the total two-directional number of all trains that stop within 1 kilometre of a site access.

(B) Public transport infrastructure

TRICS 2012 also provides qualitative information about the availability of certain transit infrastructure around the development site. In addition, TRICS gives information regarding the accessibility to these transit provisions. Some of this information has only recently been added and thus no adequate sample size is available for proper statistical analysis. Hence, four explanatory features of transit provisions near the certain residential site have been chosen. These includes two indicators about the availability of a bus stop and train station within 400m and 1km from the site respectively, and two indicators to state whether there is a satisfactory pedestrian crossing to access the bus stop or the rail station,

5.3.1.4 Urban design features

According to the TRICS 2012 database, pro-walking design features encompass the existence of one or more of the following design elements within the site: footpath links, covered walkways, internal crossings of vehicle paths and speed humps. Pro-cycling design features include for example: on-site cycle-ways, cycleway connections offsite, secure cycle parking, and shower facilities. In contrast, pro-transit design features include several site characteristics such as; service information provided on-site, special ticket deals for employees/visitors, park & ride on or near site and in close proximity to local bus routes or rail station.

A fourth indicator has been created for the current analysis depending on the previous design features information listed in TRICS. This fourth indicator, namely pro-non car modes, is supposed to collectively cover the previous three with the interaction effect taken into account. The pro-non car mode indicator has been created as a nominal variable with three levels; full, partial and none. The level “Full” is granted when there is at least one design feature that supports each of the previous three indicators. In contrast, the level “None” is chosen when none of the previous three design features exists at the specific site.

5.3.1.5 Parking details

Recently, TRICS has dedicated a specific screen called Parking Details to list the information about parking in housing developments. In this screen, there is a mix of quantitative and qualitative information about both the on and off-street parking facilities.

(A) On-site parking

Regarding on-site parking, the total number of parking spaces within the site is displayed. This total is also broken down into four parking types; namely, on-street, driveway, garages and communal parking spaces. In addition, the parking density in terms of both the site area (in Hectare) and site dwelling units are also available. In the statistical analyses, the numbers of garages and driveway parking spaces have been combined for two reasons. Firstly, there is no reasonable expected research benefit from examining each of them separately. Secondly, combining them will increase the number of cases per variable, hence making it more likely that the statistical criteria about sample size will be met. Only the parking density in terms of number of dwelling units has been analysed.

(B) Off-site parking

Where full off-site parking details are available for a site, it includes brief information about on and off street parking. These field measurements typically include availability, existence of controlled parking zone (CPZ) and parking charges.

Likewise, to address the set research questions and to consider the sample size issue, only three variables are chosen to be included in the planned analyses. These variables are: availability of off-site parking, availability of free nearby on-street parking and the existence of a controlled parking zone policy. In the TRICS database, the availability of off-site parking is accepted if there is a possibility for people visiting the site to park in any on-street or off-street off-site parking areas.

5.3.2 Socioeconomics – Car ownership

Car ownership is the only explicit socioeconomic variable listed in the TRICS database up to date. TRICS introduces car ownership as the number of vehicles owned per household within a 5-mile radius of the boundaries of the site. TRICS originally measures the household car ownership variable in categorical scale with numerical ranges. The statistics are mainly extracted from the 2001 UK Census. The ranges available for this parameter are; <= 0.5, 0.6 – 1.0, 1.1 – 1.5 and >= 1.6. For statistical reasons regarding this study, this variable has been reformed as a continuous variable by replacing each range by its corresponding mid-point. For the selected sites, the last range has been found to be (1.6 – 2.0).

5.3.3 Trip making behaviour indicators

Being originally created as a trip generation analysis system and taking into account its aggregate level nature, only two travel behaviour indicators have been found viable for statistical analysis. These are trip rate and mode share.

(A) Trip frequency

As highlighted previously, TRICS includes two main types of surveys; traffic surveys and multi-modal surveys. While traffic surveys are limited to the counts of vehicles entering and exiting a site, the multi-modal surveys are open to include several modes of travel.

Hence, in order to understand how the location of a residential site might influence peoples' trip rates using several modes of travel, the multi-modal survey counts have been considered. It is worthwhile noting that in this count only the main method of transport (by distance) is recorded. Seven travel counts have been selected to be analysed; namely, Total people, Vehicle occupants, Public transport users (PTUs), Cyclists, Pedestrians, Total vehicles and Total motor cars. According to TRICS 2012(a) help file, the total people travel count is defined as the sum of vehicle occupants, transit users, cyclists and pedestrians. That is, the total person trips generated from (produced or attracted to) a site. Vehicle occupants are defined as the total occupants of cars, taxis, motorcycles, light goods vehicles and other goods vehicles entering and exiting the site at any access point, or being dropped off by vehicles outside or near the site. This excludes taxi drivers and drivers of other vehicles dropping off/picking up passengers inside or outside the site. The transit users count includes all the users of common modes of road public transport; i.e, bus/tram passengers, train passengers, and coach passengers counts. On the other hand, total vehicles comprise all vehicles accessing the site. Motor cars count is usually given indirectly as a percentage of the total vehicles. Generally, the trip rate figures that have been utilised in the analysis are the total (arrivals and departures) 12hr. (7:00-19:00) trips per each dwelling unit.

(B) Mode share

One of the most important merits of adopting the multi-modal survey counts rather than the traffic counts is the potential possibility of investigating the variation in travel mode selected by people in a specific location and between similar locations. Recalling that the total people mobility in TRICS is broken down into four travel counts (Vehicle occupants, PTUs, Cyclists and Pedestrians), then it is possible to investigate the modal split in a specific location.

5.4 Methodology

5.4.1 Using TRICS

As highlighted in Section 4.3.1, TRICS is a computerised database and system for trip generation analysis. This computer-based design of TRICS usually grants the user some degree of flexibility in selecting an array of field data that may allow the investigator to end up with the desired representative site or sites. For example, utilising the embedded search technique to set the proper range for the parking spaces and/or site areas; or using the provided check boxes to select the appropriate main site location and/or population density.

Nevertheless, the priority of which site parameter should be first adopted in the filtering process of the sites is quite rigid; i.e., it is not always a user-specified option. One of the most evident and important examples is the unavoidable required selection of the secondary land use for each main land use. For example, if a TRICS user wants to calculate the trip rate for a residential development site, then it is unavoidable at the first place to choose at which secondary residential land use category this site is based (or expected to be based). An example of these secondary housing land use types can be seen in the first column of the Table 5-1.

It follows that, in order to respond to this chapter's general objective to examine the impacts of site location on people's mobility behaviour, it is a necessity to cross-tabulate the sites in each selected housing land use with the TRICS site main location definitions. In doing so, Table 5-1 has been created to show the available number of multi-modal survey sites with specific residential land use and location type. Sites with travel surveys conducted on weekend or sites located in Greater London are excluded.

Taking into account the essential requirement of having a statistically adequate sample size, only categories with more than three sites are considered in the analysis. One of the reasons for this threshold is that objective normality tests such as Shapiro-Walk and Kolmogorov-Smirnov request at least three cases in the tested variable. Unfortunately, the cross-tabulation reveals that most of the cells are ineligible for statistical analysis according to this basic study threshold. Moreover, it is evident that this could become even worse when it is planned to control for some variables (as covariates) since this would obviously mean further categorisation and hence ending up with more problematic cells.

To avoid this problem in the planned statistical analysis, a thorough site-by-site data extraction has been carried out to create the main MS-Excel dataset which contains all the required travel analysis variables and factors. This master file contains most of the statistically analysable field data regarding land use, public transport, urban design, parking, socio-economic status and travel patterns.

Table 5-1: TRICS 2012a multi-modal counts sites cross classified by both residential land use and location types.

Land use / Location Types	TC	ETC	NC	SA	ET	FS
A. Houses Privately Owned	0*	7	4	40	39	0*
B. Houses for Rent	0*	2*	0*	6	1*	0*
C. Flats Privately Owned	5	10	1*	20	1*	0*
D. Flats for Rent	0*	8	0*	11	6	0*
K. Mixed Private Housing	1*	3*	0*	14	5	1*
L. Mixed Non-Private Housing	0*	2*	0*	0*	2*	0*
M. Mixed Private/Non-Private Housing	0*	0*	2*	11	9	0*

* Not sufficient for statistical analysis.

TC: Town centre ETC: Edge of town centre NC: Neighbourhood centre SA: Suburban area ET: Edge of town FS: Free standing

5.4.2 Conceptual framework and model specification

To achieve the objectives previously set up for this chapter and to answer the relevant research questions, the conceptual analytical structure could be divided into two main stages. Firstly, exploring the variation in the neighbourhood features between different locations. These features include the spatial, socioeconomic and travel characteristics of the housing development. Statistically speaking, this objective could be tackled by examining the direct effect of location on these neighbourhood features. Figure 5-2 (a) displays the schematic model for this objective. The arrows generated from the site location and heading towards the other neighbourhood features simulate that intention of studying the direct potential association between the location (as the indicator) on each feature (as an outcome).

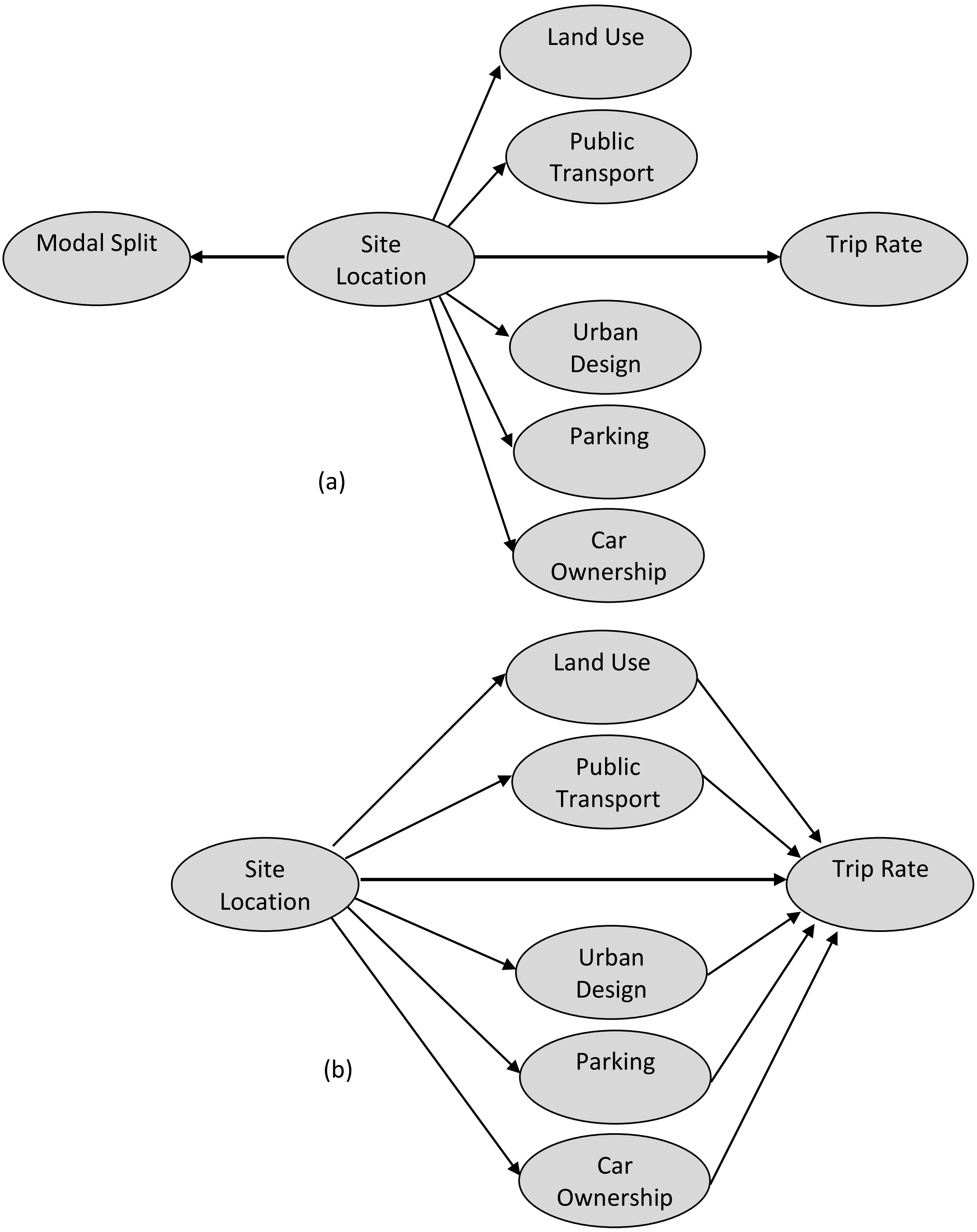

Figure 5-2: The conceptual framework of the travel analysis using the Trics2012a: (a) Shows the direct effect of site location on several neighbourhood characteristics, (b) Shows the direct and indirect effect of site location on the people's trip rates.

Thereafter, secondly, if the analyses undertaken for the first objective above proved the significant effect of the site location on a travel behaviour aspect, then the research question would be; what are the intervening variables that could explain why in essence there is such effect. This proposition stems from a reasonable and evident assumption that if the location of a housing site affects the mobility behaviour of its residents, in that case there is a high possibility that it does so because of the specific characteristics of the residential development located in that site.

Bagley and Mokhtarian (2002), for example, explicitly reported that it is the overall features of a development that are actually important rather than merely the geographic location per se; while Litman (2011) classified land uses into central, suburb and rural according to ten land use features where the distance to the downtown is only one of them. In a statistical language, this is equivalent to examining the influence of the location on the travel indicators when the neighbourhood features are controlled for. Figure 5-2 (b) represents the conceptual model for the second stage of analysis. The statistical mechanism “mediation” employed to undertake the analyses has been reviewed in Section 5.4.3.2.

With regard to the model specification, all the relationships between the outcome variable and the predictors are assumed linear and hence all the developed statistical models are linear models. This assumption in travel behaviour modelling studies is acceptable and widespread. Furthermore, two essential criteria have been followed in the inclusion of variables in the travel analysis; firstly, the relevance of this variable (its contribution) to the set objective or its relevant research question; secondly the availability and statistical adequacy of this variable in the TRICS database. As will be shown in detail, in Section 5.4, the variables and factors included in the analyses can be categorised into seven categories. These are land use, site location, public transport, urban design, parking, car ownership and travel behaviour indicators.

The purpose of the inclusion of land use and urban design indicators is to examine how development within a different built environment might lead to different travel decisions. Likewise, the inclusion of indicators regarding transit and parking could highlight the effectiveness of management strategies regarding them. Only household total generated trip rate and mode choice are available and eligible as travel behaviour indicators.

Table 5-2 lists the variables included in the travel analysis with the corresponding mean/median and standard deviation. The mean is not computed in favour of median when the variable contains outliers and hence displays a skewed distribution. However, when there is a variable with the vast majority of its scores having the same value, the mean is adopted.

Table 5-2: The key statistics of the quantitative variables and factors extracted from the TRICS 2012a.

Analysis variable	Median or Mean*	Std. Deviation
Land use		
Population density (within 500m radius)	1780.000	1328.359
Private housing ratio	0.759*	0.375
Detached houses ratio	0.147*	0.292
Semi-detached houses ratio	0.225*	0.327
Terraced houses ratio	0.188*	0.294
Average number of dwelling bedrooms	2.430	0.799
Unit density (hh/ha)	38.660	59.913
Housing density (hh/ha)	47.89	128.341
Flat ratio	0.135	0.439
Site area (ha)	1.370	3.468
Area net (ha)	0.910	2.329
Public Transport		
Bus Stop (Ref. Cat. = Yes)		
Pedestrian Crossings (Ref. Cat. = Yes)		
Rail Station (Ref. Cat. = Yes)		
Bus Services (Monday-Friday)	106.000	179.275
Train Services (Monday-Friday)	35.440*	68.096
Public Transport Services (Monday-Friday)	134.000	216.730
Urban Design		
Pro-walking design features		
Pro-Cycling design features		
Pro-public transport design features		
Parking		
Parking Density (parking/hh)	1.500	1.120
On-Street parking	4.000	117.124
Garage &Driveway parking	26.000	141.182
Communal parking	10.000	62.064
Off-site parking (Ref. Cat. = Yes)		
Socioeconomics		
Car Ownership	1.250	0.285
Housing Location		
Town Centre		
Edge of Town Centre		
Suburban Area		
Edge of Town		
Trip rate measures		
Total People	7.500	3.338
Total Vehicles	4.285	1.821
Total Motor Cars	3.565	1.656
Vehicle Occupants	5.512	2.621
Public Transport User	0.143	0.402
Cyclists	0.125	0.281
Pedestrians	1.500	1.545

*hh: no. of household ha: hectars

5.4.3 Statistical modelling strategy

After identifying the objectives and setting up the conceptual model, the next logical step for a typical research study with empirical design is to choose the appropriate statistical modelling approaches and mechanisms that could effectively address the developed research questions. In doing so, two main statistical data analysis strategies have been employed: firstly, an exploratory analysis for the neighbourhood features; secondly, a mediation process.

5.4.3.1 Exploratory analysis

The research intention accompanied with this analysis is to address the first research question regarding to objectively determine the spatial, socioeconomic and travel characteristics of the TRICS' four main residential locations adopted in this study.

Regarding the spatial (built environment) information, the TRICS database, particularly version 2012a adopted in this study, relatively contains a fruitful array of spatial variables and features. According to the research scope of this study, these data have been extracted and organised into four groupings: land use variables, public transport services features, urban design variables and parking characteristics.

On the other hand, according to the breadth and depth of the TRICS dataset, household car ownership is the only explicit socioeconomic variable. However, the number of bedrooms in a housing unit might be a reasonable proxy for the household size. Similarly, variables such as type of housing (full/semi detached and terraced) and type of possession (privately/ for rent) may be sensible indicators for the household income. Finally, concerning travel characteristics, the potential variations in total trip rates between town centre and other housing locations are investigated for seven different road transport counts: total people, total vehicles, motor cars, vehicle occupants, PT users, pedal cycles (bikers) and pedestrian.

Depending on the type (scale) of the predictors and the outcome (nominal vs interval), both the chi-square test of independence and the analysis of variance technique have been used. The objective is to investigate whether a particular site feature varies significantly between the centre of a city/town and other out of centre locations. While the predictor variable (location categories) is a nominal variable, the outcome variables (site features) are a mix of categorical and numerical variables. Hence, the chi square test has been employed when the dependent variables are measured using a nominal scale and the ANOVA has been used when the outcome is with a continuous scale. It is worthwhile mentioning that despite this the analyses are mainly inferential, it was planned to display the outputs with a descriptive nature to achieve the specific main goal of exploring the features of housing development dependent on location. Finally, the statistical analysis results and the corresponding interpretations of findings are displayed in Section 5.5.1.

5.4.3.2 Mediation analysis – Definition, Purpose and Design

The mediation process implies a causal hypothesis regarding the effect of an indicator variable X on an outcome Y; this hypothesis proposes that this effect could be explained by some intervening variable M (Shrout, 2002). In other words, this intervening variable (the mediator) is postulated to transmit the effect of an independent variable to a dependent variable (MacKinnon et al., 2002). Figure 5-3 shows the path diagram for a standard mediational model. Whereas the path c' indicates the direct effect of predictor X on the outcome Y, the paths d and b represent the indirect effect on it. The terms e_1, e_2 and e_3 are the measurement errors; X, Y and M represent the predictor, outcome and mediator variables respectively. The variable X could be a predictor in a correlational study or an independent variable in an experimental study (Shrout, 2002).

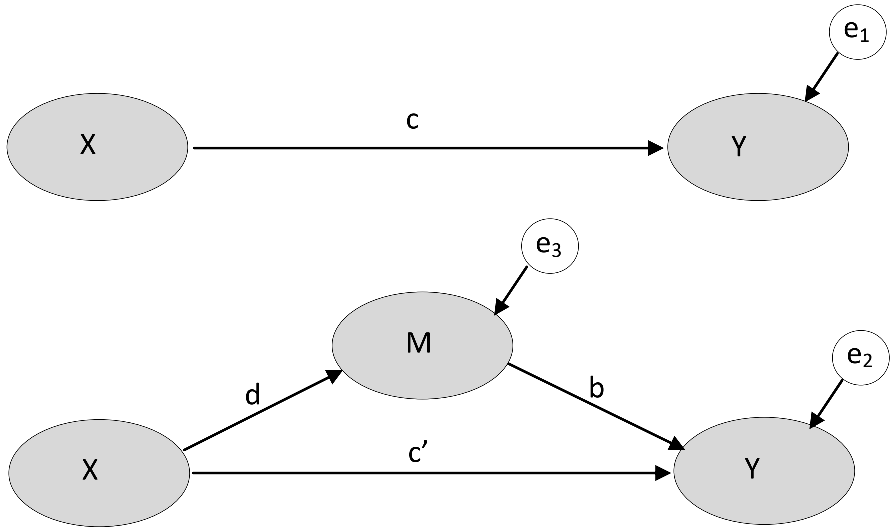

Figure 5-3: The diagrammatic illustration of the mediational process in terms of the total effect (upper model) and the mediated effect (lower model).

As the definition implies, the typical purpose of conducting a mediational analysis is to tackle research questions about "how" or "why" one variable predicts/causes the outcome variable. Specifically for correlational studies, this is equivalent to investigating why an association between a predictor and outcome is observed (Frazier, 2004). Mathematically, this hypothesised conceptual model of the mediation effect is traditionally represented and tested by constructing three algebraic equations (see for example, Baron and Kenny, 1986; MacKinnon, 2002 and Hayes, 2012):

$$Y = a_1 + cX + e_1 \tag{8}$$

$$M = a_3 + dX + e_3 \tag{9}$$

$$Y = a_2 + c'X + bM + e_2 \tag{10}$$

Several strategies have been developed to test the hypothesis about the influence of the mediating variable; the common three, namely Causal Steps, Difference in Coefficients and Product of Coefficients, have been extensively and comparatively discussed by (MacKinnon, 2002). Although the former approach, Causal Steps, has been designated by some researchers as less powerful than the others; it has been adopted in this chapter for two reasons. Firstly, its popularity: this method has been popularised by Baron and Kenny (1986) and ever since it has been extensively used. The Causal Steps approach has been described as influential and frequently used by several researchers; see for example, Hayes, 2009; Frazier, 2004; Mallinckrodt et al 2006 and Shrout, 2002. Secondly, the mediating model set up for this chapter is quite complicated (see Figure 5-2). On the one hand, it contains multiple mediators (specifically nineteen as will be seen later in this chapter); on the other hand, the predictor (site location) is a categorical rather than continuous variable. Only one research paper has been found addressing these two issues. However, this paper, written by (Hayes, 2012) is still a white paper (in press) during the period of conducting the statistical analyses for this chapter.

In the Causal Steps approach, the researcher should estimate the paths in the model and thereafter appraise to what extent a variable could function as a mediator by examining a certain statistical criteria. Overall, in this approach, there are four conditional steps that should be met before establishing that the influence of the predictor on the outcome variable is intervened by the mediator (Baron and Kenny, 1986: MacKinnon, 2002 and Frazier, 2004):

Step 1*:* To show that the initial predictor is significantly related with the outcome; i.e., variations in the levels of the predictor variable significantly account for variations in the outcome (the null hypothesis is Ho: c = 0). The logic behind this step is that there is in essence an effect which might be intervened (see Path c in Figure 5-3). Statistically, this relation can be developed and tested by linearly regressing the outcome on the predictor (see Eq. 8). In the context of this chapter analysis, this step is equivalent to regressing each trip rate count (Total people, Total vehicles ... etc.) on the site location categories.

Step 2*:* To show that the initial predictor is significantly related with the mediator (see Path d in Figure 5-3); i.e., variations in levels of the independent variable significantly account for variations in the supposed mediator (Ho: d = 0). Statistically, this relation can be developed and tested by linearly regressing the mediator (as an outcome) on the initial predictor (see Eq. 9). This is equivalent to regressing each of the quantitative site features on the location categories.

Step 3*:* To show that the mediator is significantly related with the outcome (see Path b in Figure 5-3). That is, variations in the mediator significantly account for variations in the dependent (outcome) variable (Ho: b = 0). Statistically, this relation can be developed and tested by linearly regressing the outcome on the mediator after controlling for the effect of the initial predictor (see Eq. 10). The multiple regression technique is adequate for such sort of analysis. It is worthwhile highlighting here that the aim of ruling out (controlling for) the effect of the predictor is to eliminate the possible effect of confounding, resulting from the base that both the outcome and the mediator are related with the predictor. This step is equivalent to regressing the trip rates on the residential site features after controlling for the site location factor.

Step 4*:* The aim of this complementary step is to statistically evaluate the impact of mediation. Typically, this is evident if the strength of the initial relation between the predictor and the outcome is reduced significantly after including the mediator (Path c’). The mediator is designated as complete if the parameter c’ is no longer significantly different from zero (Ho: c’= 0 is not rejected). Whereas it is designated as a partial mediator if the parameter c’ is still significant but with less absolute magnitude than the parameter c (i.e.,|c’| < |c|).

It is useful to highlight here that mediational analysis can be conducted using the statistical data analysis approach Structural Equation Modelling (SEM) in addition to the frequently used multiple linear regression technique (Shrout, 2002; Hayes, 2009). There is literature-based evidence that when the assumptions and requirements of both methods are met, then SEM is preferable over regression analysis. According to Frazier (2004), three key reasons could be the corner stone behind this preference; firstly, unlike regression analysis, in the structural modelling approach the measurement error is accounted for. Secondly, it shows indications about the goodness of fit for the entire model. Thirdly, it is considered more flexible than regression in conducting complex mediational analysis; that is, for example, by conducting multivariate analysis with multiple predictors and several mediators.

It was initially planned to employ these common features of the structural modelling approach in conducting this chapter's mediational analysis. However, it was found that it required quite a large sample size. This difficult requirement is well known and recognised by several researchers, for example Kline (2011) designates it as a large sample technique whereby inadequate sample size may affect both the conducting of the analysis and the estimates (such as standard errors). Even larger sample sizes are needed when basic assumption of the multivariate normality is not met (which is the case for the sample in the analysis in this chapter). Byrne (2010, p.105) reported that an extremely large sample size (1000-5000) is needed to perform the analysis when normality is not satisfied.

Having mentioned that, for the current planned study, it is evident that the use of regression is a necessity to carry out the analysis and to end up with models of acceptable statistical power taking into account the available moderate sample size extracted from the Trics2012a (about 200 sites). The implementation of the regression analyses and the interpretation of the mediating analysis results are shown under Section 5.5.2.

5.5 Analysis results and discussion

This section deals with the key results of the analyses and its findings. The discussion of these findings and its planning-related implications is also reviewed. According to the modelling approach adopted in this chapter, this section is divided into two main subsections; while the first is devoted to the results of the exploratory location analysis, the second is devoted to the mediation analysis outputs and the corresponding travel behaviour models.

5.5.1 Exploratory residential location analyses

As stated in Appendix-B, since ANOVA is a parametric test and one of the General Linear Model family techniques, the assumptions of normality and homogeneity in variances are central and hence have been considered here. Table 5-3, lists a number of probability values (p-values) accombined to the null hypothesis of there is no significant difference between the distribution of the specific variable and the normal distribution. However, the table shows that almost all the site features with an interval scale have violated the normality assumption. The Shapiro-Wilk normality test has been used as an objective technique to appraise the variable normality at the 5% level of significance.

Table 5-3: The P-values of the normality test for several site characteristics.

Variable	TC	ETC	SA	ET
Car ownership	0.00 (0.00)[a]	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Housing density	0.91 (0.18)	0.00 (0.15)	0.00 (0.02)	0.00 (0.02)
Pop. density	0.01 (0.02)	0.01 (0.08)	0.00 (0.00)	0.00 (0.05)
Detratio	NA[b] (NA[b])	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Semratio	NA[b] (NA[b])	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Terratio	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Flatratio	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Privratio	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
AvgBed	0.18 (0.10)	0.07 (0.07)	0.02 (0.01)	0.04 (0.00)
SArea	0.08 (0.17)	0.00 (0.12)	0.00 (0.05)	0.00 (0.01)
PTMF	0.01 (0.12)	0.02 (0.00)	0.00 (0.00)	0.00 (0.00)
TrainMF	0.01 (0.40)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Bus MF	0.03 (0.10)	0.02 (0.00)	0.00 (0.00)	0.00 (0.00)
PkDen	0.53 (0.00)	0.10 (0.10)	0.00 (0.00)	0.00 (0.08)
OnStPk	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
DwayPk	NA[b] (NA[b])	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
ComPk	0.04 (0.30)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Garages	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
GrgDwayPk	0.00 (NA[b])	0.00 (0.90)	0.00 (0.03)	0.00 (0.40)

a Figures in parentheses represent the p-values of the log transformed variables.
b Not applicable since ratio of detached houses is constant in town centre locations.

The table also proves that this is the case even after transforming these variables using the logarithmic function (y = ln x). In consequence, the bootstrap technique has been employed for such variables in order to obtain robust estimates.

Finally, it is worthwhile reporting that, for all ANOVA models performed in this work, the level of significance is 5% unless otherwise stated. The abstract null hypothesis (Ho) is that there is no significant difference in the specific variable between the four main TRICS location categories.

5.5.1.1 Urban form variables

(A) Land use variables

1) Population density

Figure 5-4 shows that there is no clear variation in the population density between sites with different spatial locations. Statistically speaking, the ANOVA model for the population density is non-significant and with P-value equal to 0.486. That is, the null hypothesis (Ho: there is no significant difference in population density between sites with various locations) is not rejected.

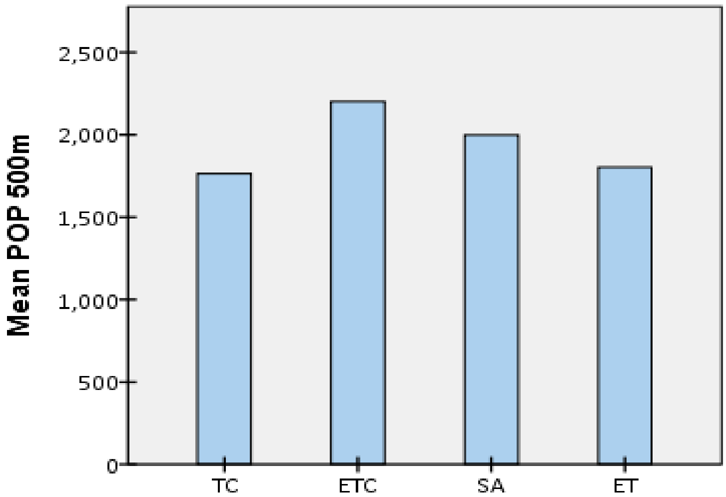

Figure 5-4: Variation of population density by residential location.

One of the reasons behind the non-significant influence of the population density is its measurement scale (Census output area level). That is, the population figures are not the site population but instead they are population densities within 500m from the site boundary. Pursuing this further by doing simple mathematics, the equivalent area for this factor is [Area (500m) = πr^2 = 785000 m^2 = 78.5 hectare] which is over 6 times bigger than the largest site area in TRICS 2012a database (12.7 ha); whereas the average site area is only about 4.2 ha! Hence, most probably, the site density is masked by one or more adjacent sites lying within the same 500m radius zone (78.5/4.2 = 18.7 sites).

2) Flats ratio

Figure 5-5 illustrates the distribution of the two main types of housing unit (house and flat) in terms of the percentage of flats within the four location groups. The exclusion of other types of housing units like bungalows and townhouses explains why that in some categories (namely edge of town and suburban area) the summation of the houses and flats ratios is not exactly 100%.

Graphically, it is evident that the vast majority of dwelling units in central location are flats/apartments (about 92% in the town centre and 71% in the edge of town centre). In contrast, the vast majority of housing units are houses in residential developments located in out-of-centre locations (about 74% in the edge of town and 55% in the suburbs). Furthermore, the analysis of variance results confirm that this difference in the ratio of flats is significant, that is, it is unlikely to be happened by chance (p-value = 0.00). According to the 2011 Census: Key Statistics for England and Wales (ONS, 2012b, p.20), the houses comprise about 78% of accommodation type in England and Wales; flats comprise only 16.6%.

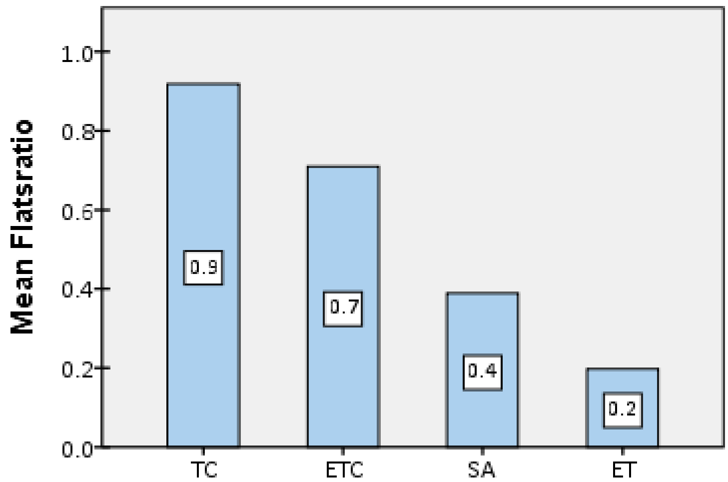

Figure 5-5: Variation of flat ratio by residential location.

Two primary reasons might be attributed to this rise in flats in central location generally and in the downtown particularly in comparison with the outer locations. The first is the typical high land cost in the downtown which makes it more practical and feasible for the government and private developers alike to invest in flats rather than houses. The second reason, however, is the recent spatial planning policy in the UK that encourages and recommends the compactness of city centre. One of the recommended strategies to promote this compactness is the utilising, refurbishing and transforming old and derelict building to be residential land uses instead of constructing new ones.

3) Housing density

Figure 5-6 shows the variation in the housing densities (households/hectares) between the location categories. The figure clearly indicates that neighbourhoods located in city centre locations have higher housing densities than those located outside the centre and in particular in the edge of town. Furthermore, statistically speaking, this dissimilarity in site residential densities has been found to be significant using the ANOVA technique (p-value = 0.00).

This analysis finding is consistent with the literature. One of the obvious reasons for the high density of housing units in the core of the city is that the typical type of dwelling units there is “flat/apartment” rather than “house”. Therefore, multi-story residential buildings (blocks of flats/apartment blocks) represent an iconic design feature in most centres nowadays.

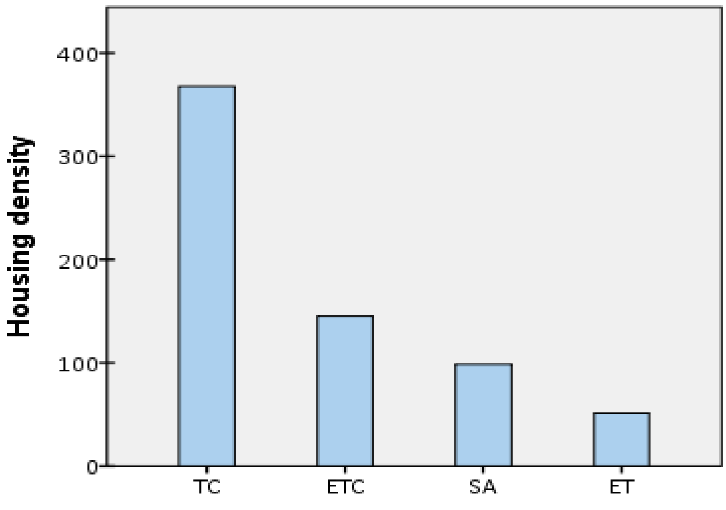

Figure 5-6: Variation of housing density by residential location.

4) Private housing ratio

The particular objective of this analysis is to investigate whether housing tenure varies within the locations of the residential development sites. In so doing, the ratio of private housing is computed as the number of units owned or rented privately divided by the total number of dwelling units. Figure 5-7 displays the proportional distribution of the private and social housing between the four location categories. The figure states that the highest proportion of private housing is in the city centre (98%) while the lowest one is in the edge of town centre (65%). The ANOVA model, however, states that this difference is not significant (p-value = 0.206). The descriptive results are unsurprising. Over the past twenty years, the UK planning policy has been promoting the sustainability concept as a criterion for successful planning. Hence, while high private housing in the downtown may speak to the economic dimension of the sustainability (sustainable development), the high social housing in the edge of city centre would address the social dimension of it. As a comparison, the UK 2011 Census shows that over England the total percentage of privately owned and rented units is just over 82% (ONS, 2012a).

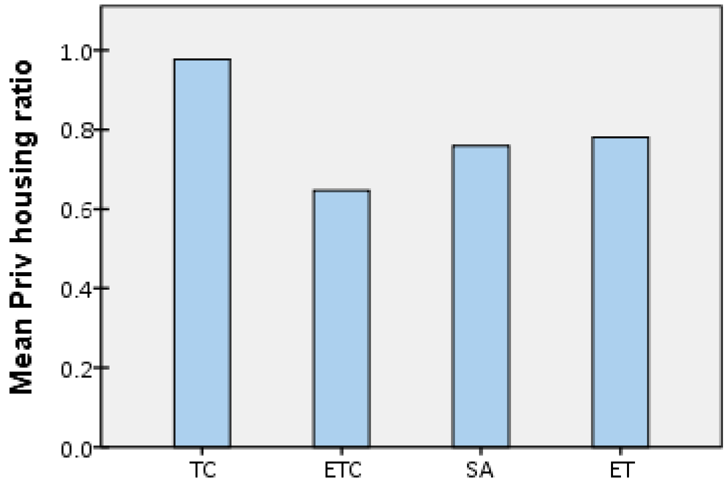

Figure 5-7: Variation of private housing by residential location.

5) Household space type

This analysis aims to address the question of whether the type of houses (detached, semi-detached and terraced) vary with the site location. That is, is there a specific type of house that is common in a specific site location? Figure 5-8, Figure 5-9 and Figure 5-10 describe schematically the variation in the ratio of detached, semi-detached and terraced houses within the four TRICS location groups respectively. Figure 5-8 and Figure 5-9 show that both detached and semi-detached houses are mostly concentrated in outer locations and particularly in the edge of town. This distribution pattern has also been found statistically significant using the analysis of variance method (p-value = 0.00).

On the other hand, Figure 5-10 shows that there is no specific location where terraced houses are notably concentrated although their concentration in the suburbs is

moderately higher than in other places. However, this variation in concentration is not significant according to the ANOVA output tables (p-value = 0.328).

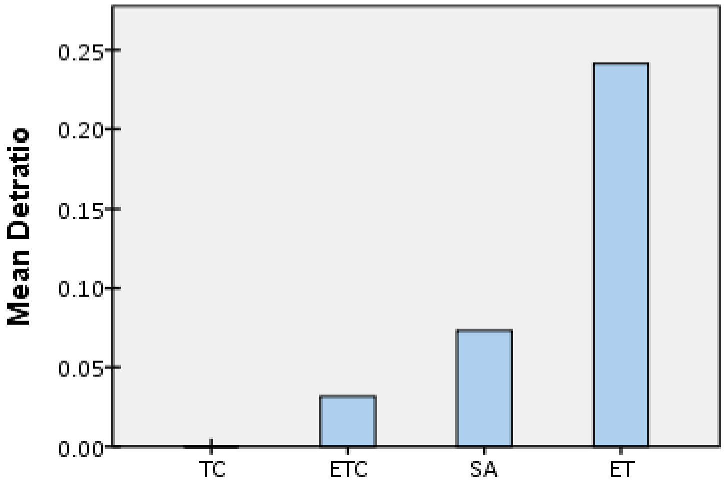

Figure 5-8: Variation of detached houses by residential location.

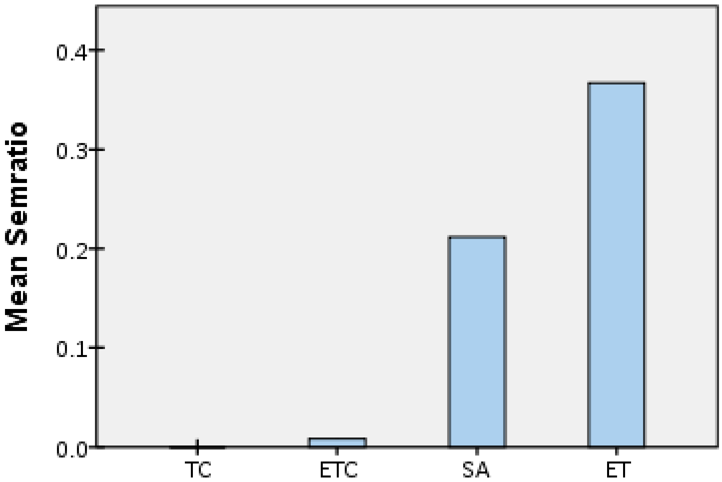

Figure 5-9: Variation of semi detached houses by residential location.

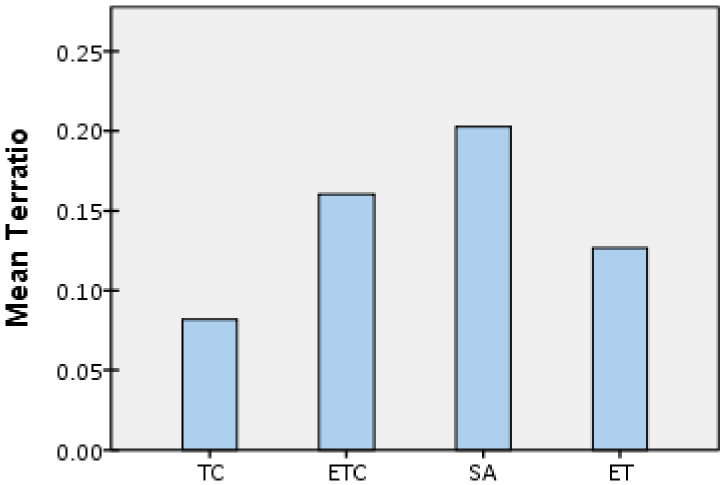

Figure 5-10: Variation of terraced houses ratios by residential location.

6) Housing unit bedrooms

Intuitively, there are two expected reasons that could mainly shape the decision of an individual (or a household) about their required number of bedrooms. These reasons are: the number of household members (preference) and the household economic status (budget/constraint). Hence, the average number of bedrooms in a dwelling unit for a given site may work as a reasonable indicator (proxy) for the household size and income. For instance, those who live in a one-bedroom dwelling unit probably do so because they are not in need of more space and/or they can not afford a unit with more bedrooms.

Taking the above into account, the variation in the average number of bedrooms per unit within a residential neighbourhood has been investigated in order to explore any potential link between the number of bedrooms and the site location. Figure 5-11 shows that the mean number of bedrooms in a unit for sites located in out-of-centre locations is higher than the corresponding number in units located in the central area. Statistically speaking, this difference is significant (p-value = 0.00). Based on the previous literature-based evidence, this finding may address the relatively low household size of people living in the downtown. As a comparison, the 2011 Census statistics (Table KS403EW) for England and Wales reveal the average number of bedrooms per household in England is 2.7 (ONS, 2012a).

In order to explore this indicator further, Figure 5-12 has been constructed to investigate the potential association between the number of bedrooms in a unit and housing categories. In this figure, it can be clearly seen that the highest number of bedrooms exists in the Houses Privately Owned category while the lowest number is in the Flats For Rent (social housing) category. The results of the ANOVA states that this difference is significant (p-value = 0.00). This finding might clearly address the income hypothesis above in that low income people (such as those living in social housing) usually opt to live in flats and/or houses with fewer bedrooms than high income people (such as those who own their homes).

7) Site area

Figure 5-13 shows that according to the TRICS 2012a database the areas of the residential sites in the suburbs and exurbs are larger than the areas of those sites that are located in or near the centre. The ANOVA results confirms that this variation in the site area is statistically significance (p-value = 0.00).

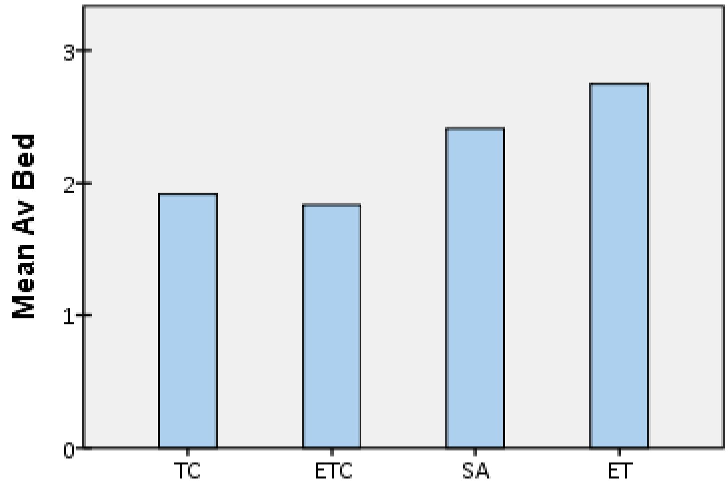

Figure 5-11: Variation of average HH bedrooms by residential location.

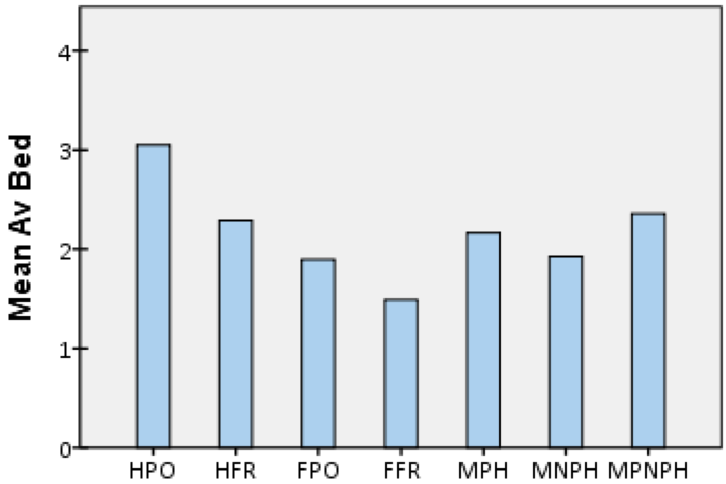

Figure 5-12: Variation of average HH bedrooms by residential land use groups.

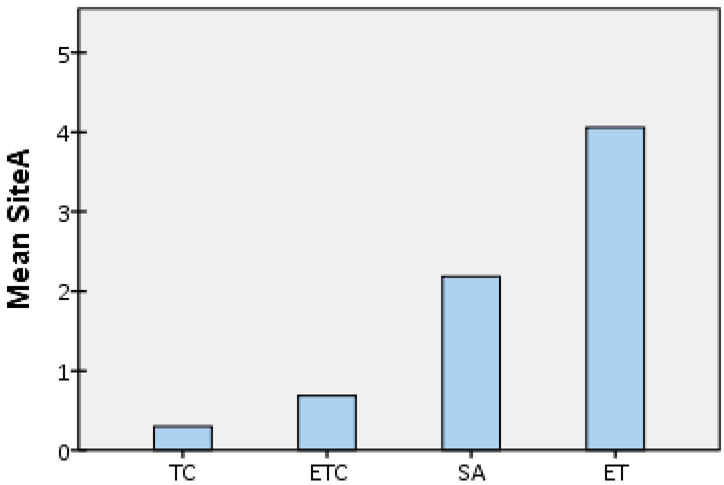

Figure 5-13: Variation of housing site area by residential location.

(B) Public transport services & infrastructure

1) Public transport services

The current analysis attempts to investigate whether the frequency of buses, trams and trains services differ notably within the location of the housing site. This would help in diagnosing the locations that typically have good and poor transit services. The general concept, based on the literature, is that neighbourhoods located in/near the CBD areas usually have good public transport in terms of availability and frequency; however, this is often not the case in the suburban and rural locations.

The bar charts in Figure 5-14, Figure 5-15 and Figure 5-16 display the mean total number of bus/tram (Bus MF), train (Train MF) and total public transport (PT MF) services that stop close to the site for a weekday (Monday to Friday) respectively. All the three figures show a pattern of variation in the transit services that is consistent with the literature. Central locations, especially centres, are typically provided with transit services (bus/tram and/or train) that are higher than those in other areas such as the edge of town. Furthermore, the three graphs show that there is an evident association between the decrease in the provision of transit services and the distance from the city centre. The ANOVA have been found significant for the bus/tram, train and transit models with p-values of 0.025, 0.000 and 0.001 respectively.

2) Availability and accessibility of bus/tram stops

The four transit-related indicators displayed in Table 5-4 have been found adequate to be considered in a statistical analysis. These indicators are bus stop availability, bus stop accessibility, rail station availability and rail station accessibility.

Table 5-4 is the contingency table that presents a cross tabulation for these four transit indicators with the four typical TRICS site locations. A Pearson Chi-square test of independence has been employed to investigate if there is any potential association between any indicator and the location factor. The typical null hypothesis (Ho) is that there is no such association and the variables are independent. The level of significance (α) associated with the set Ho is 0.05. To show whether this association is significant, i.e. to test the null hypothesis, the computed p-value is listed in the table as well. Finally, the last column in the table quantifies the degree of the association utilising Cramer's V statistic.

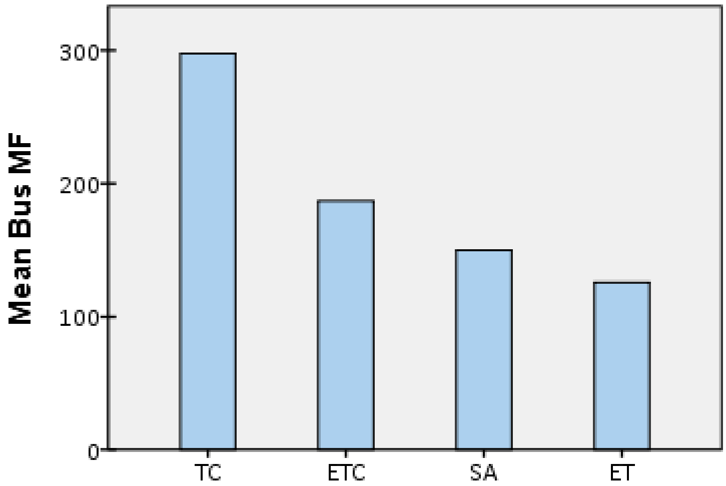

Figure 5-14: Variation of weekday buses frequency by residential location.

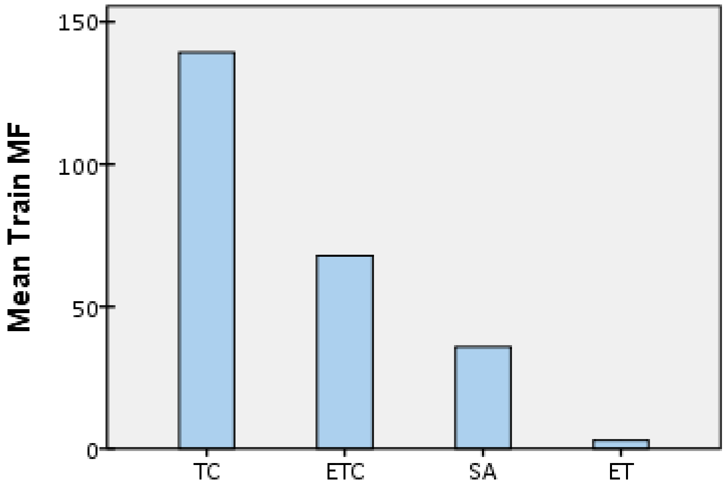

Figure 5-15: Variation of weekday train frequency by residential location.

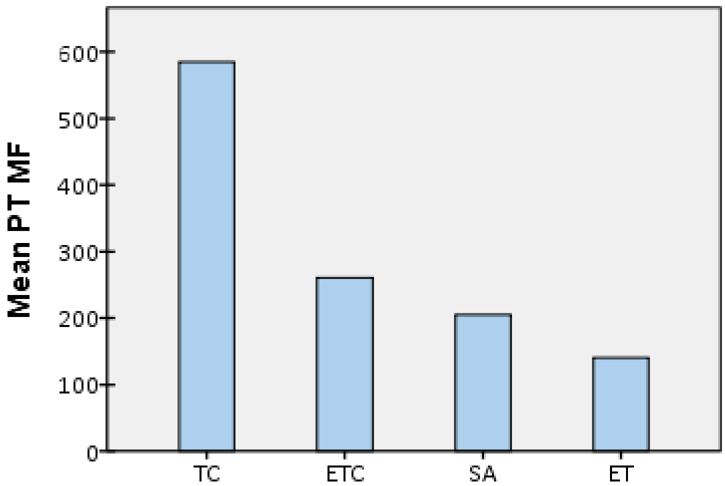

Figure 5-16: Variation of weekday transit services frequency by residential location.

The cross tabulation and the Chi-square analysis results displayed in Table 5-4 show that the availability of bus/tram stop factor is independent of the site location (p-value = 0.687). This might be attributed to two reasons: the first is the sufficient spread of bus/tram stops over the studied sites. The second is the way in which TRICS 2012a defines the availability of stops. In fact, TRICS confirms the existence of stops nearby the site (specifically within 400m radius) even when actually only one bus/tram stop is available. In consequence, TRICS show no difference between a site with say five stops around it and a site with just one stop; since in both cases only a "tick" will be presented. Regarding the bus/tram stop accessibility, as stated previously TRICS defines this as the availability of a conveniently placed crossing facility. The analysis results listed in Table 5-4 confirm that there is no significant link between the stop accessibility and the location categories (p-value = 0.471).

Table 5-4: Availability and accessibility of bus stops and rail station by residential location in terms of the percentage number of sites.

Indicator[x]	Level	Location category				Pearson's χ^2 P-value	Cramer's V
		TC	ETC	SA	ET		
Bus stop	Yes	100	92.9	95.3	91.4	0.687	0.086
Bus stop access	Yes	50.0	42.9	50.5	37.9	0.471	0.113
Rail station	Yes	100	57.1	34.6	8.6	0.000	0.423
Rail sta. Access	Yes	83.3	53.6	32.7	8.6	0.000	0.378

[x] N of valid cases = 199

3) Availability and accessibility of train station

Similarly, the TRICS 2012a addresses the availability of rail station as the existence of at least one train station within 1 km radius of the site. The crosstabs shown in the contingency table (Table 5-4) obviously demonstrate the large and significant discrepancy in rail stations provision between the location categories (p-value = 0.000). In particular, while all the sites (100%) located in the centre benefit from at least one station in proximity, such percentage shrinks with moving outside the centre. Distinctively, only 8.6% of the sites in the edge of town have at least one rail station within 1km radius. The relatively high Cramer's V statistic (0.423) concludes that availability of rail station and location are correlated variables.

Finally, the exploration of the existence of a probable link between the availability of a satisfactory pedestrian access to a train station and the site location is also examined. The crosstabs results show that central locations are mainly (83%) characterised with stations of adequate pedestrian accessibility; however, this is not the case in the suburbs and the edge of town (see Table 5-4). This link between the provision of adequate pedestrian access and site location category is found to be significant (p-value = 0.00) and relatively strong (Cramer's V = 0.378).

(C) Urban design features

According to the context of this study and based on the relevant literature reviewed, low emissions road transport modes include active transport (walking and cycling) and public transport modes. This part of the analysis attempts to answer the question of whether the spatial design features of a neighbourhood that support a specific mode of travel may vary depending on the location of that neighbourhood. In so doing, Table 5-5 represents a contingency table has been formed to crosstabulate the availability of the design features (see Section 5.3.1.4) that support three travel modes by the location categories. The three low emission modes of travel that have been selected are walking, cycling and transit. The analysis results point out that, in general, all the four employed indicators are highly likely to be seen in city/town centres but occasionally in outer areas. This leads to an impression that unlike edge of town locations, downtowns are often areas where non-car (low emissions) modes are well supported by site design features. However, the inferential statistics for all the four indicators show that this variation in the design characteristics is not statistically significant (p-value > 0.05).

One of the most expected and logical reasons is the qualitative rather than quantitative manner of including these factors in TRICS. For instance, including specific geometrical features about the available footpath or cycleway such as width and length would be more distinguishing than merely highlighting their existence.

Table 5-5: Availability of pro-walking, cycling and transit modes design features by residential location.

Indicator[x]	Level	Location category				Pearson's χ^2 P-value	Cramer's V
		TC	ETC	SA	ET		
Pro-walking DF	Yes	100	53.6	57.9	53.4	0.172	0.159
Pro-cycling DF	Yes	66.7	35.7	37.4	22.4	0.074	0.187
Pro-transit DF	Yes	100	67.9	78.5	65.5	0.115	0.173
Pro-non car modes DF	Full	66.7	25.0	27.1	17.5	0.149	0.155

[x] N of valid cases = 199

(D) Parking

The availability, affordability and operation of parking have an undoubted impact on people's travel decisions. Hence, it is important to shed light on the specific parking characteristics that might be associated with site location categories. While both on site and off site parking facilities have been considered, only characteristics listed in TRICS 2012 that have a statistically adequate sample size and in line with the study objectives have been considered.

1) On site parking density

Using the TRICS 2012 parking details, parking density can be calculated as the sum of the on site on-street, driveway, garages and communal parking spaces divided by the number of occupied site dwelling units. From Figure 5-17, there are two important points that can be clearly seen; the first is that on site parking density is low in the city centre. The second is that the number of parking spaces in a housing site increases steadily with the distance from the centre. This difference in the provision of parking among location categories is found to be significant using the analysis of variance method (p-value = 0.000).

One of the most reasonable reasons for this variation is that unlike suburban and rural areas, there are limited parking options in the core of the city in general and in the centre in particular. This justification can be statistically quantified and clarified in the next three sections. This limit in the provision of parking facilities, especially affordable ones, may be in turn attributed to the strict parking strategies and schemes adopted by the recent planning policy road map to alleviate congestion in the centres.

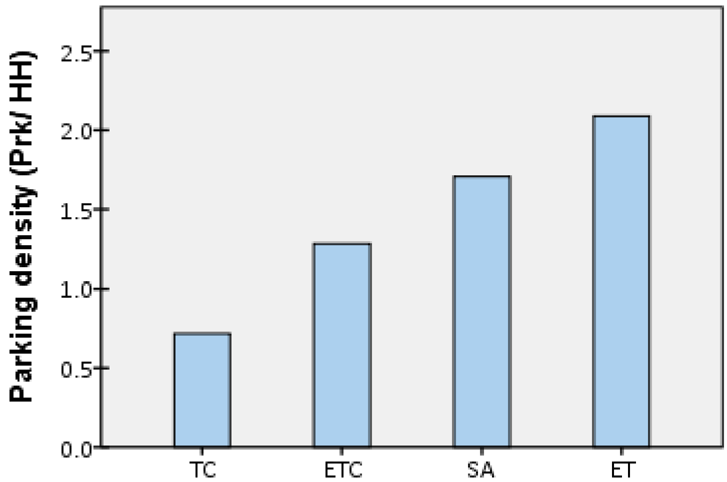

Figure 5-17: Variation of parking density by residential location.

2) On site on-street parking

Figure 5-18 points out that the availability of on-street parking varies with the location of the residential site. Sites that are located in central locations have much less on-street parking spaces than those residential sites in out-of-centre locations and especially edge of town. The analysis of variance model has also been found as significant with p-value equal to 0.002. Again, the strict parking strategies in city centre in terms of the availability and affordability of parking facilities can be seen as a major cause for these low figures in the central areas. In addition, the typical urban design of downtowns has a probable influence. The presence of apartment blocks instead of houses along with the typical condensed urban fabric in the centre may also hinder the number of on-street parking spaces.

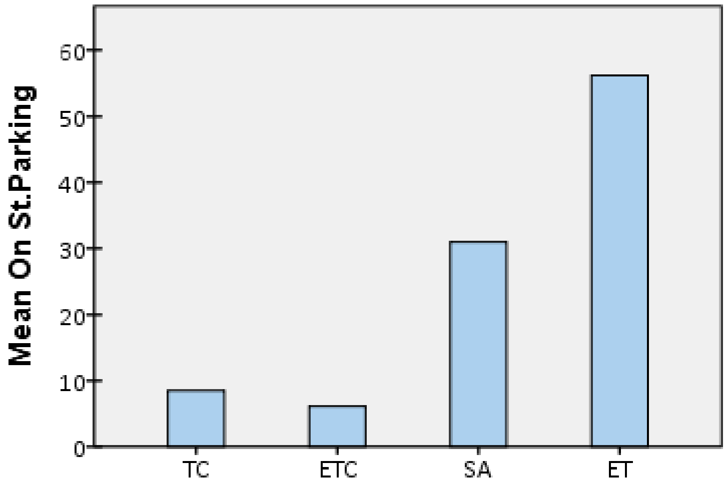

Figure 5-18: Variation of on-site street parking by residential location.

3) On site Garages and driveway parking

Based on the bar charts in Figure 5-19, the very low number of garages and driveway parking spaces is mainly connected to the low number of houses in a typical city/town centre. In contrast, the high percentage of semi- and full-detached houses in the edge of town can explain the evident presence of such type of off-street parking there. The null hypothesis that the differences in garages and driveway parking between location may be solely due to chance is rejected using the ANOVA approach (p-value = 0.000).

4) On site Communal parking

Communal parking is usually a common parking area with/without designated spaces and serves either several houses or a specific block of flats. The variation in the provision of communal parking over location categories is statistically significant according to the ANOVA results. The parabolic shape of the bar charts in Figure 5-20 probably encompasses two issues. The first is the increase in parking when moving from the town centre to the edge of town centre location. This increase could be explained as although communal parking is very common in the centre and to lesser extent in edge of centre due to the high percentage of multi-story housing buildings, the parking planning and management policies are stricter in the centre than in the edge of the town centre. On the other hand, the steady decrease in communal parking from the edge of town centre category to the edge of town is strongly expected to be because of the same steady increase in houses with garages as well as on-street parking options being conveniently available.

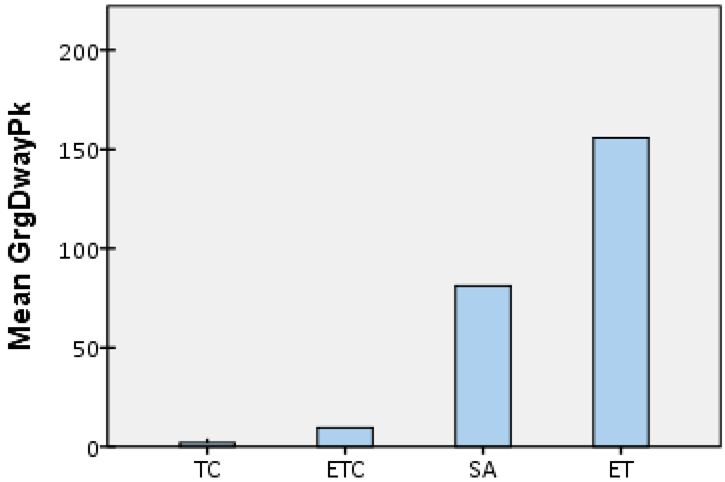

Figure 5-19: Variation of garages and driveway parking by residential location.

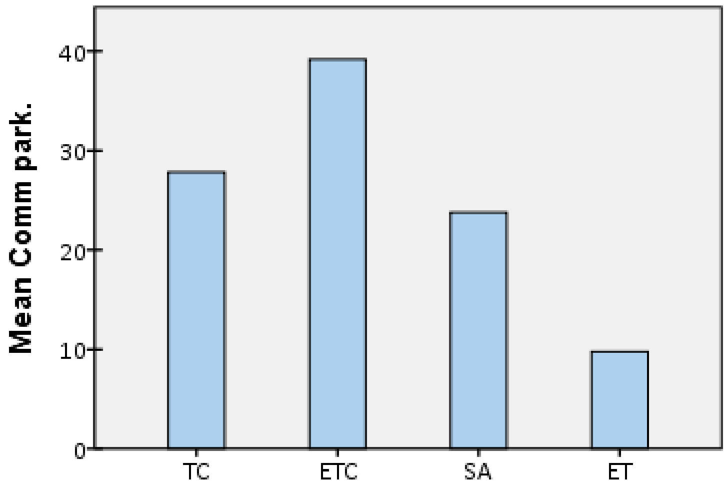

Figure 5-20: Variation of communal parking by residential location.

5) Availability of off-site parking

TRICS addresses the availability of off-site parking as the possibility for people visiting the site to park in off-site parking areas, not necessarily specific off-site parking for the site itself. This parking option includes on-street and off-street parking. The cross tabulation analysis displayed in Table 5-6 shows that there is no obvious distribution pattern for the presence of the off-site parking over the four location categories. Furthermore, based on the Chi-square output results, there is no significant difference between categories (p-value = 0.607).

Table 5-6: Availability and affordability of parking by residential location.

Indicator	Level	Location category				Pearson's χ^2 P-value	Cramer's V
		TC	ETC	SA	ET		
Off-site parking[x]	Yes	83.3	75.0	82.2	74.1	0.607	0.096
Free off-site parking[y]	Yes	20.0	63.6	88.0	82.2	0.000	0.345
Controlled parking zone[z]	Yes	100	68.2	24.2	13.3	0.000	0.461

[x] N = 199, [y] N = 164 [z] N = 163

6) Affordability of off-site parking

The influence of parking charges on people's parking behaviour is found to be significant in the literature. Recently, TRICS has considered this factor by stating whether there is a free on-street parking available nearby (off-site). Table 5-6 indicates that for city/town centres there is a shortage in the availability of free on-street parking that is available in the local area near the site. In contrast, the presence of free of charge parking appears clearly in other locations and especially in suburban and outer areas. The contingency table also confirms that the association between the presence of free off-site parking and site location is significant and not weak (p-value = 0.000, Cramer's V = 0.345).

7) Availability of off site parking restrictions (controlled parking zone cpz)

As stated previously, parking management is one of the policy's arms in achieving the national and local planning goals. This is especially true in congested urban areas such as the CBD areas in city centres. Parking restriction mechanisms such as setting up Controlled Parking Zones (CPZ) is one of the common parking supply management techniques used in city centres. In the TRICS 2012a database, the initial analysis finds that about 75% of the sites selected for analysis in this chapter are provided with details about whether or not the local area is subjected to a controlled parking zone. The crosstabs results listed in Table 5-6 demonstrate that there is a statistically significant and strong link between the presence of the CPZ and the site location (p-value = 0.000, Cramer's V = 0.461). The likelihood of there being controlled parking zones is found to decrease sharply with an increase of distance from the centre.

5.5.1.2 Socioeconomics

(A) Car ownership

Figure 5-21 displays the descriptive part of the ANOVA analysis. As can be seen, there is no clear difference in the mean of car ownership levels between the four selected location groups. This was also confirmed by the analysis of variance results, in that the null hypothesis of the absence of significant difference has been not rejected (p-value = 0.170).

This finding is quite contradictory with the literature where it was mentioned that normally households located in outer locations own more cars than those who live in or around the centre. The most probable main reason for this discrepancy between current finding and the majority of the literature is the level of measurement. The aggregated level of car ownership measurement (5 miles) is too fuzzy to capture differences between sites rather than households. This could be clearly seen by investigating the range of variation in car ownerships in Figure 5-21; the minimum is 1.00 and the maximum is only 1.20. It is worthwhile reporting here that this could provide a warning sign for TRICS users such as developers, urban planners and researchers that analyses utilising the variable car ownership in its current scale should be interpreted with caution.

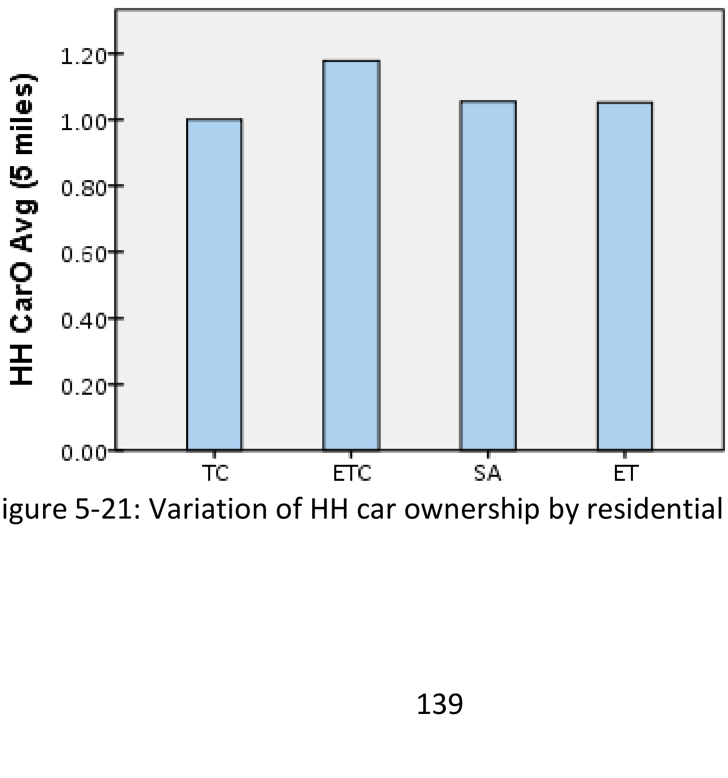

Figure 5-21: Variation of HH car ownership by residential location.

5.5.1.3 Trip making behaviour indicators

Likewise, in this section a thorough investigative analysis has been conducted to explore the possible variation in the observed travel behaviour between city/town centre and other location categories. Further more sophisticated confirmatory analysis will be shown in Section 5.5.2. According to the TRICS 2012a database, only trip frequency and mode share have been utilised as indicators for people's travel behaviour.

(A) Trip frequency

1) Total people

Figure 5-22 shows the variation in the total person trip rate (TPtrHH) among the four location categories. In particular, the figure shows that the mean trip rates in suburban and edge of town locations are larger than those rates in the centre and its vicinity. It is important to recall that this travel indicator (total trip rate) actually quantifies the travel for a household. Thus, the difference in the trip rates could be attributed to the variation in household size. As shown previously, unlike centres, outer locations are usually characterised as places with a high ratio of houses (especially semi- and full-detached) and a high ratio of the number of bedrooms in a dwelling unit. Hence, the concentration of detached houses with high number of bedrooms in these areas give a reasonable evidence that the residents there are typically families with a relatively high number of household members.

2) Total vehicles

This count includes all vehicles entering and exiting the site at any access point. Figure 5-23 shows that, in general, there is an increase in the total generated vehicles (TVtrHH) as site distance from the CBD increases. As with the previous category, increases in household size may account for some of this effect. Furthermore, the finding is in agreement with the conclusions of most researchers mentioned in Sec 3.5.5 (e.g., Naess, 2005, 2006; Perkins et al., 2009; Litman, 2011). The absence of an ability for filtering trips by their purpose (commuting, shopping, leisure ...etc.) using the TRICS 2012a database makes it complicated to accurately propose what factor(s) might be behind this evident variation in vehicle use. However, in general, the possible reasons are the lack in transit provisions and/or lack in nearby public amenities and work opportunities within reach by walking or cycling (poor land use diversity).

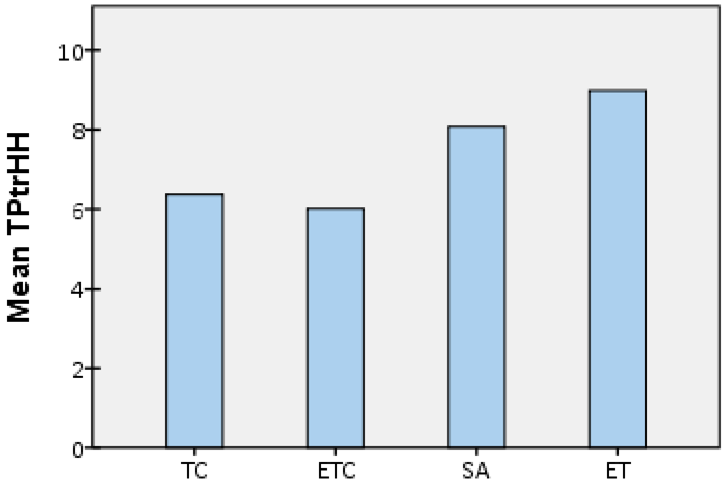

Figure 5-22: Variation of total people trip rate by residential location.

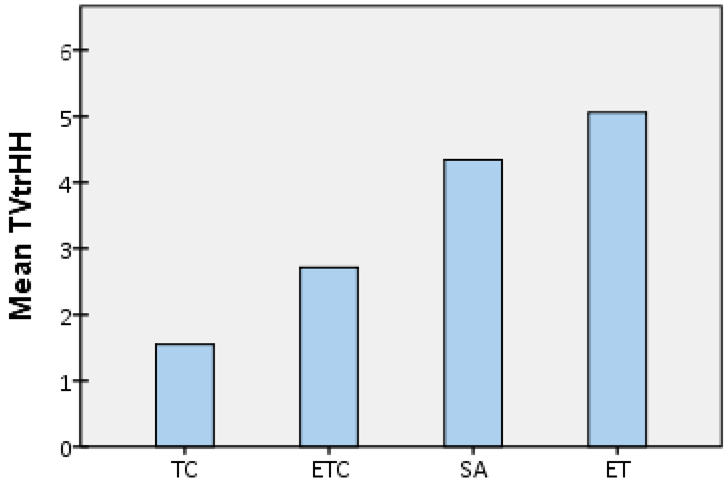

Figure 5-23: Variation of total vehicles trip rate by housing location.

3) Motor cars

This count contains all cars including light vans and three wheeled cars. As in the total vehicles count and in harmony with the most relevant literature, the descriptive analysis shown in Figure 5-24 confirms that those who live in the town centres use motor cars much less than others who living in out-of-centre locations especially in the suburbs and edge of town. The same possible reasons listed above in the analysis of the total vehicle trip rate can be repeated here to justify the noteworthy variation in the motor car use.

4) Vehicle occupants

This count quantifies the average household number of the occupants of cars, motorcycles and goods vehicles (VOtrHH). Figure 5-25 indicates that vehicle occupants in inner areas, in particular centres, are substantially fewer in number than those in outer areas, in particular edge of town.

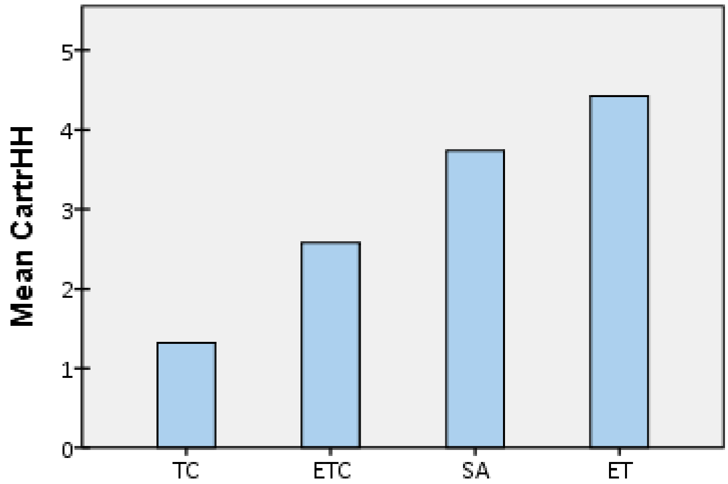

Figure 5-24: Variation of motor cars trip rate by residential location.

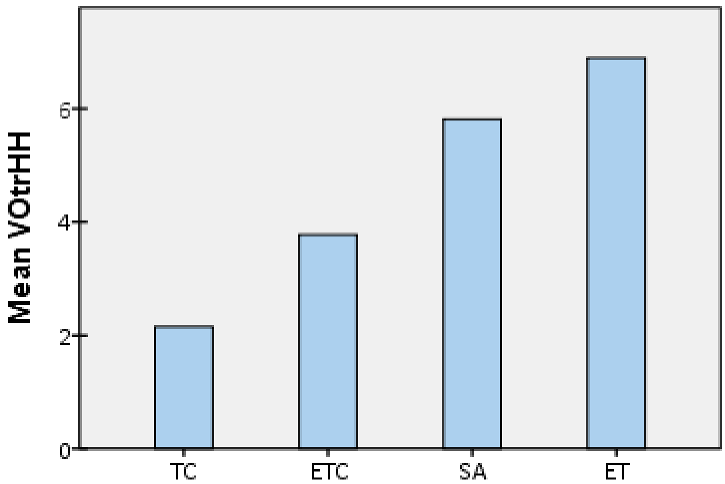

Figure 5-25: Variation of vehicle occupants trip rate by housing location

5) Public transport users

In TRICS, public transport users are those passengers who travel by bus/tram, train/metro/underground, and coach/minibus. Figure 5-26 makes it obvious that there is no evident pattern of the variation in the transit users' trip generation rates (Mean PTUtr) within the studied site location categories. However, the public transport trips are relatively not as common in the edge of town or edge of town centre as in the centre and suburbs. Nonetheless, it is not clear at this stage what reasons are behind this fluctuation in trip making. However, the lack of good public transport provision/services or the high dependency on passenger cars might be reasonable causes behind the low proportions of transit users in the edge of town. On the other hand, the typical proportion of students residing in the centre may partly explain the relatively high trip rate in the centre.

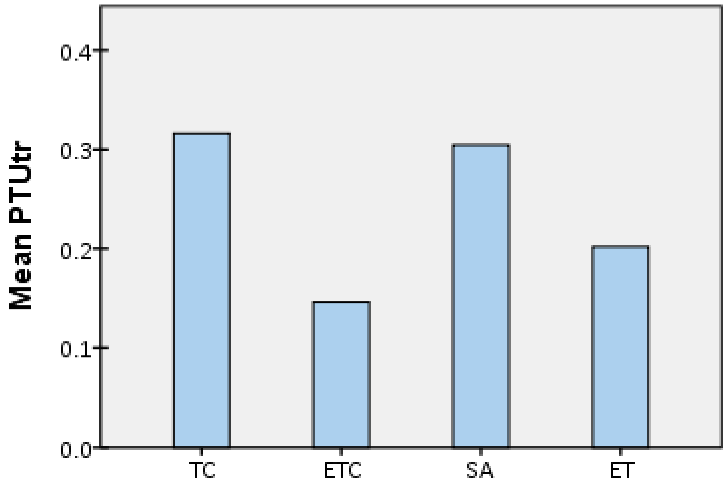

Figure 5-26: Variation of public transport users trip rate by residential location.

6) Cyclists

As with the transit users, according to Figure 5-27, the cyclists analysis shows no clear pattern or considerable variation in the trip rates of pedal cycle's users (Mean Cyctr). Statistically, the null hypothesis of the absence of significant variation is not rejected (p-value = 0.498).

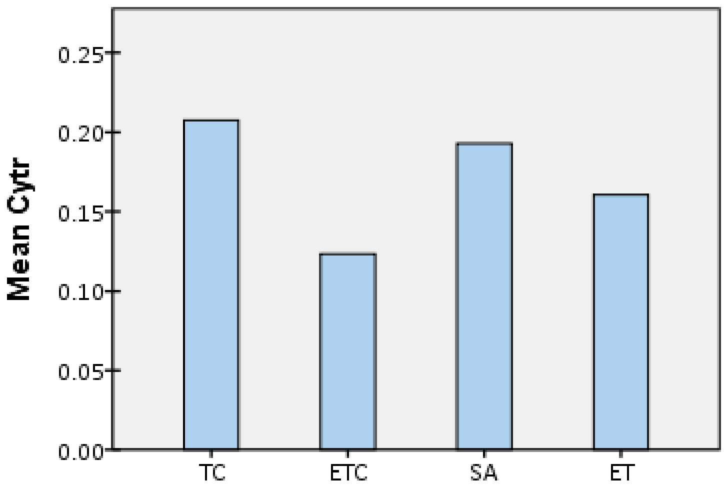

Figure 5-27: Variation of cyclists' trip rate by residential location.

7) Pedestrians

Figure 5-28 indicates that the pedestrian trip rate (PedtrHH) in city/town centres is evidently higher than that in other out-of-centre environments, in particular the edge of town areas. In light of this, it is logical to point out that people living in or nearby downtowns would prefer to accomplish their travel needs by walking more than those who live far from town/city centres. One of the probable reasons for this is the availability and diversity of public amenities that can be accessed on foot in central areas compared to the situation in outer areas.

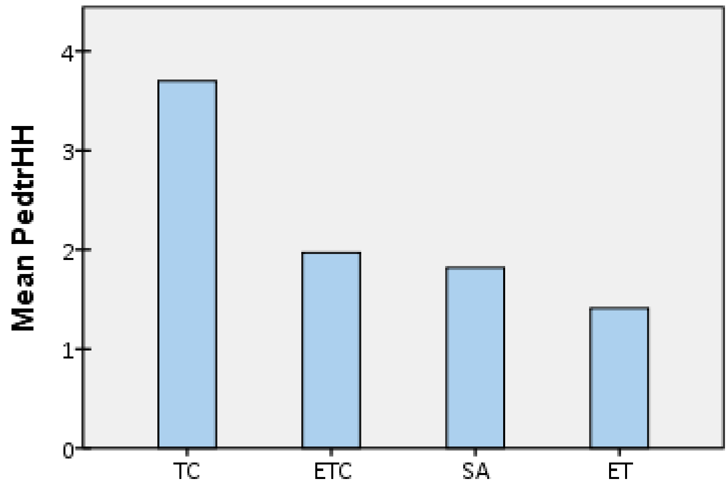

Figure 5-28: Variation of pedestrian trip rate by residential location.

(B) Mode share

The previous bar charts have collectively presented an empirical-based impression about the distribution pattern of each trip rate account with the four site locations. Now, extra empirical evidence will be presented to demonstrate the use of the TRICS 2012 database to produce the distributional patterns of the trip rate counts within each single site location. The general goal is to explore what is the most common travel mode in each location. Figure 5-29 shows the total people trip rate mean (6.4) for households in the centre has four trip rate components which form this count; total vehicle occupants (2.2), PT users (0.3), cyclists (0.2) and pedestrians (3.7).

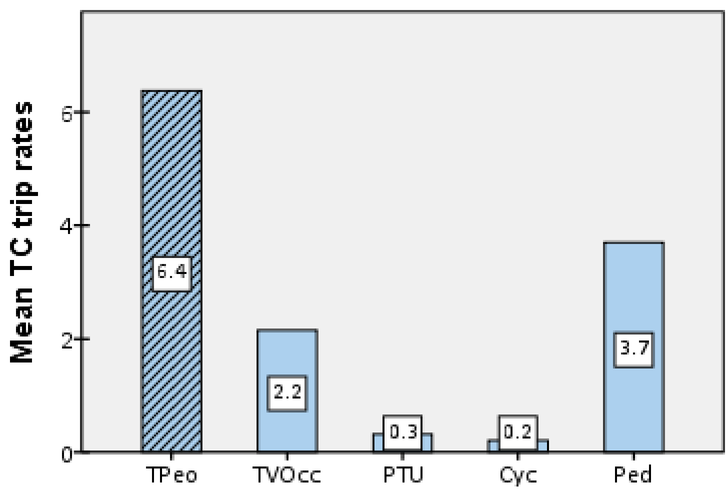

Figure 5-29: The variation in modal trip rate patterns in the city centre location.

One of the most interesting points that can clearly be shown by the figure is that walking is the most common mode of travel for the centres' residents. On average, pedestrians form nearly 58% (3.7/6.4) of the total people entering or exiting a site in the centre from 7.00am to 7.00pm. This is then followed by the total vehicle occupants, which represent almost 34% of the total travelling people. People travelling using the transit system or biking form only about 8% of the total people. Table 5-7 illustrates the pattern of modal share variation for the total people count and its four components for each housing location category. This variation has been quantified using the mean household trip rate counts for each mode. One of the important points the table informs is that while the most common travel mode in the centre is the walking, in all other out-of-centre locations the vehicle is the most utilised travel option. Another worthwhile highlighting point is that on foot and by vehicle are the prevailing modes of travel in all the included residential sites regardless of location[9].

Table 5-7: Summary of people's trip rates by mode share (%) by site location.

Travel mode	Location category			
	TC	ETC	SA	ET
Total people	6.38 (100.0)[S]	6.01 (100.0)	8.23 (100.0)	8.90 (100.0)
Vehicle's occupants	2.16 (33.8)	3.77 (62.7)	5.69 (69.1)	6.82 (76.6)
PT users	0.32 (5.0)	0.15 (2.5)	0.35 (4.3)	0.25 (2.8)
Cyclists	0.21 (3.3)	0.12 (2.0)	0.22 (2.7)	0.22 (2.5)
Pedestrians	3.70 (58.0)	1.97 (32.8)	1.97 (23.9)	1.61 (18.1)

[S] Figures in round brackets are percentages of modes in each location.

The current comprehensive exploratory location analyses (Sections 5.5.1) have presented empirically based evidence regarding two different but interrelated interesting findings. A mix of descriptive and preliminary predictive statistical analyses have been employed. The first finding is the indication and quantification of several distinguishing characteristics that are associated with each residential site location; especially the city/town centre. These characteristics include several built environment factors such as transit provisions, parking and land use in addition to household car ownership. The second main finding is the proof of presence of a quite statistically significant linkage between the location of the housing development and people's trip making characteristics. Trip making behaviour has been quantified using two indicators; trip frequency and the modal share.

[9] Both the above figure and summary table are constructed based on the raw data; no systematic outliers detection approach has been employed.

Having conducted these analyses and reached the results identified above, the next step is to address the second objective of this chapter (or to answer the second main research question). That is, if the location of a neighbourhood indeed influences the travel behaviour of its residents, what are the specific neighbourhood and residents' characteristics that potentially inform such an influence? The mediational analysis explained and conducted in the next section is designed to consider this issue.

5.5.2 Mediation analysis

As stated earlier in Section 5.4.3.2, the regression technique has been chosen to verify the conditional steps of the mediational analysis by constructing and testing the paths required for claiming a mediating effect. The analysis results of Step 2 are shown in Section 5.5.2.1 the analysis outputs of the Step 1 & 3 are shown in Section 5.5.2.2.

5.5.2.1 Step 2 – Regressing housing site features on location

For examining Step 2 of the mediation approach, the ordinary least square linear regression technique has been employed to regress the housing site features (outcome) on the TRICS main location categories (predictors). The location categories have been coded as dummy variables with the Edge of Town as the reference category. Providing that the regression equation has only dummy-coded categorical variables, the reference category (edge of town) is the regression constant (intercept) here. Furthermore, whereas the value of the constant quantifies the mean value of the specific site feature in the edge of town location, the values of the regression coefficients represent the differences in the mean of this feature between each specific location and the edge of town (reference category). It is worthwhile noting that for these site features measured on a nominal rather than quantitative scale, the analysis results of the Chi-squared test of independence carried out earlier have been utilised (See Table 5-4, Table 5-5 and Table 5-6).

The multiple regression analysis outputs of the IBM SPSS (20) package have been trimmed and efficiently tabulated in condensed tables for avoiding unnecessary statistics (see Table 5-8 to Table 5-13). Each regression output table contains key statistics about both the regression model parameters (upper part) and the diagnostics statistics of the model (lower part). In the upper part, information is provided about the estimates of regression constant (a) - also known as the intercept, regression coefficients (b-values), standard errors (SE) and the statistical significance (2-tailed P-value) of these parameters. It is worthwhile recalling that the null hypothesis is that the regression parameter is not significantly different from zero (Ho: B = 0). The level of significance (LOS) is 5% unless otherwise stated. On the other hand, the lower part of each table provides influential information about the strength and reliability of the regression model such as the adjusted multiple coefficient of determination and the p-value of the analysis of variance. In addition, several key statistics about the regression assumption and residual analysis are also provided. For instance, statistics about, Durbin-Watson test, minimum tolerance and maximum standard residual. An adequate overview of these statistics and other relevant ones has been given in Appendix-B (Section B-5).

However, it is beneficial to mention here that regarding regression outliers, the Casewise Diagnostics option in SPSS has been employed to identify cases of standardised residuals of more than 3.29 (equivalent to 95% level of significance). Hence, several rounds of regression analysis have been carried out for some variables in order to end up with no severe outliers. For instance, the tabulated regression results for the unit density, communal parking, site area and on-street parking represent the second, third, fourth and fifth round of the regression analysis respectively. Also, it is important to recall that a bootstrap technique has been used to fix normality and heteroskedasticity issues, hence all the estimates of the regression parameters standard errors and their equivalent p-values are bootstrapped statistics. Overall, the statistical results concerning the linkage between the residential development characteristics and the place of residence are consistent with the exploratory analysis carried out earlier.

Table 5-8 displays the outputs for both the population density and the detached houses ratio. As in the exploratory analysis, the ANOVA statistic indicates that the population density regression model is non-significant (p-value = 0.486). Furthermore, the analysis shows that all the location regression coefficients are also non-significant (p-value (TC) = 0.916, p-value (ETC)= 0.164, p-value (SA)= 0.295). That is, the differences in mean population densities between each of these three locations and the ET location (regression coefficients; -39.3, 398.5, 194.2) are not statistically significant. As stated earlier, the inadequacy of the level of measurement of this variable is the most likely reason for this insignificance. In contrast, the ratio of detached houses shows significant variation between site locations, both the model (p-value = 0.000) and the location coefficients (p-values = 0.001) are statistically significant. The indicators of the regression assumption and residual analysis show no discrepancy from their corresponding typical thresholds and ranges.

Table 5-8: The analysis outputs of regressing population density and detached houses ratio on the location categories.

	Population Density			Detached ratio		
	B	SE	Sig.	B	SE	Sig.
Constant	1803.31	143.162	0.001	0.241	0.045	0.001
Town Centre	-39.310	448.127	0.916	-0.241	0.045	0.001
Edge of Town Centre	398.511	288.412	0.164	-0.210	0.04	0.001
Suburban Area	194.199	184.903	0.295	-0.168	0.047	0.001
R^2 adjusted		0.003			0.106	
ANOVA – p-value		0.486			0.000	
Durbin-Watson		1.646			1.724	
Max. Std. Residuals		3.122			3.274	
Min. Tolerance		0.763			0.770	

In a similar way, according to Table 5-9, the results of regressing the private housing ratio on location shows that only the town centre has a significant coefficient (b= 0.196; p-value = 0.002). In other words, the difference in private housing ratio between town centre and edge of town locations (0.196) is significant.

Table 5-9: The analysis outputs of regressing private housing ratio and average unit bedrooms on the location categories.

	Private housing ratio			Avgerage bedrooms		
	B	SE	Sig.	B	SE	Sig.
Constant	0.781	0.047	0.001	2.747	0.095	0.001
Town Centre	0.196	0.052	0.002	-0.829	0.129	0.001
Edge of Town Centre	-0.134	0.094	0.160	-0.910	0.155	0.001
Suburban Area	-0.021	0.060	0.735	-0.335	0.123	0.005
R^2 adjusted		0.008			0.128	
ANOVA		0.206			0.000	
Durbin-Watson		0.336			1.021	
Max. Std. Residuals		< 3.29			< 3.29	
Min. Tolerance		0.760			0.760	

In contrast, the location of residence has been a good indicator to explain the variation in the average number of household bedrooms. All the location coefficients are significant at 5% level of significance. While the Durbin-Watson statistic falls out of the typical range (1 –

3), Tabachnick and Fidell (2007, p.128) reported that autocorrelation is an important issue in regression with time-series data. Hence, no further action has been planned.

The regression results of regressing unit density and flats ratio, separately, on location types can be shown in Table 5-10. The location coefficients for both of them are significant at 5% level of significance. Other model and residual statistics are within the acceptable limits.

Table 5-10: The analysis outputs of regressing unit density and flat ratio on the location categories.

	Unit Density			Flat Ratio		
	B	SE	Sig.	B	SE	Sig.
Constant	37.380	3.320	0.001	0.197	0.046	0.001
Town Centre	261.190	50.692	0.001	0.721	0.093	0.001
Edge of Town Centre	60.673	13.022	0.001	0.512	0.091	0.001
Suburban Area	16.703	5.021	0.002	0.191	0.064	0.002
R^2 adjusted		0.420			0.161	
ANOVA		0.000			0.000	
Durbin-Watson		1.311			0.473	
Max. Std. Residuals		3.084			< 3.29	
Min. Tolerance		0.779			0.761	

Table 5-11 indicates that all the coefficients of the location factor are significant (p-values < 0.05) when it is modelled with the housing site area. For the parking density, on the other hand, all the location coefficients are also significant with except the Suburban Area location type (p-value = 0.165).

Table 5-11: The analysis outputs of regressing site area and parking density on the location categories.

	Site Area			Parking Density		
	B	SE	Sig.	B	SE	Sig.
Constant	3.553	0.390	0.001	1.969	0.141	0.001
Town Centre	-3.255	0.402	0.001	-1.251	0.234	0.001
Edge of Town Centre	-2.867	0.403	0.001	-.687	0.179	0.001
Suburban Area	-1.456	0.444	0.002	-.235	0.169	0.165
R^2 adjusted		0.154			0.071	
ANOVA		0.000			0.001	
Durbin-Watson		1.463			1.167	
Max. Std. Residuals		3.199			3.310	
Min. Tolerance		0.747			0.756	

According to Table 5-12, similar to the parking density model, the on-street parking model demonstrates that all location coefficients significantly differ from zero except the suburban area (p-value = 0.382). The same table confirms that all the location types are significant in the garage-driveway parking model. Both tables show no unusual statistics regarding regression diagnostics statistics.

Table 5-12: The analysis outputs of regressing on-street and garage-driveway parking on the location categories.

	On Street Parking			Garage/Driveway Parking		
	B	SE	Sig.	B	SE	Sig.
Constant	37.208	7.498	0.001	137.089	19.173	0.001
Town Centre	-28.708	11.831	0.014	-135.09	19.302	0.001
Edge of Town Centre	-31.100	7.994	0.001	-127.48	19.356	0.001
Suburban Area	-7.846	8.865	0.382	-65.680	21.877	0.005
R^2 adjusted		0.036			0.117	
ANOVA		0.019			0.000	
Durbin-Watson		1.645			1.551	
Max. Std. Residuals		3.304			3.287	
Min. Tolerance		0.740			0.754	

The regression analysis outputs of the communal parking model are displayed in Table 5-13; apart from the Town Centre, all other location types are significantly larger than zero (α = 0.05). The same table illustrates that while transit services decrease with the distance from the centre, only the Edge of Town Centre location type is with significant coefficient (p-value = 0.009).

Table 5-13: The analysis outputs of regressing communal parking and public transport on the location categories.

	Communal Parking			Public Transport.		
	B	SE	Sig.	B	SE	Sig.
Constant	9.786	2.296	0.001	136.65	15.164	0.001
Town Centre	18.048	15.743	0.225	277.01	204.09	0.175
Edge of Town Centre	25.659	7.432	0.002	110.84	43.168	0.009
Suburban Area	11.418	3.670	0.003	30.413	20.565	0.160
R^2 adjusted		0.066			0.090	
ANOVA		0.001			0.000	
Durbin-Watson		1.806			1.700	
Max. Std. Residuals		3.437			< 3.29	
Min. Tolerance		0.760			0.773	

In the final table (Table 5-14), it can be clearly seen that the household car ownership model is non- significant (p-value = 0.170) at the 5% level of significance; however, the Edge of Town Centre location has a significant coefficient at the same threshold level (p-value = 0.041).

Table 5-14: The analysis outputs of regressing household car ownership on the location categories.

	Car Ownership		
	B	SE	Sig.
Constant	1.052	0.034	0.001
Town Centre	-0.052	0.118	0.639
Edge of Town Centre	0.127	0.064	0.041
Suburban Area	0.003	0.043	0.950
R^2 adjusted		0.010	
ANOVA		0.170	
Durbin-Watson		1.776	
Max. Std. Residuals		< 3.29	
Min. Tolerance		0.760	

To sum up, the analysis of variance results for the quantitative neighbourhood features shown in Table 5-8 to Table 5-14 show that only population density, private housing ratio and car ownership variables have no clear relationships (variations) with the location. On the other hand, regarding neighbourhood features with categorical variables, the Chi-squared test of independence has already proved that the availability and accessibility of bus stop, urban design variables and off-site parking availability also have non-significant relationship with the site location factors (see Table 5-4 to Table 5-6). Hence, there is a weak possibility for these variables and factors to function as mediators due to failure in meeting the second condition (Step 2) of the mediation approach. Nevertheless, there is still a probability for these features to influence the resident's trip rates; therefore, they have been included in the second block of the sequential regression conducted for examining Step 3 as covariates, that is, to rule out their influence on the trip frequency behaviour. The including of covariates in a mediation analysis is legitimate and recommended.

5.5.2.2 Steps 1 and 3: Direct and indirect effect of location on trip rates

Step 1 and Step 3 of the intervening analysis have been investigated jointly using the sequential approach of multiple linear regression. In the first block (location model), the multi-modal trip rates have been regressed on the main location types (Step 1); while in the second block (full model) the trip rates have been regressed on the neighbourhood characteristics in addition to the main location types (Step 3).

As in the Step 2, indicators with categorical level of measurement have been coded as dummy variables. These include the urban design factors, indicators of transit infrastructure provision and availability of off-site parking. As stated previously, in order to obtain clearer understanding of people's travel behaviour, seven different counts of trip rates are included: total people, total vehicles, motor cars, vehicle occupants, public transport users, cyclists and pedestrian. For the same reason, a wide set of neighbourhood features are investigated.

The purpose of employing regression with a hierarchical approach is to investigate what specific spatial or socioeconomic features (as mediators) might be efficient to indirectly explain the total effect of the housing development location on the people's trip frequency patterns after controlling for the direct effect between them. In line with the philosophy of mediation and using the sequential approach of regression analysis, if the inclusion of the neighbourhood explanatory variables converts a location parameter from statistically significant to non-significant, this indicates the existence of a mediation effect. Furthermore, this proposes that the housing development characteristics intervene in the influence of the place of residence on its resident's trip making behaviour. On the other hand, if the location parameters preserve their significance even after the inclusion of the neighbourhood features, this would indicate the existence of other exogenous (hidden) variables that are not included in the model which might intervene in the trip frequency-location relationship.

While the change in the coefficient of determination (R square) quantifies the contribution of predictors in explaining the outcome variance, its role in mediation is not crucial. There is a high correlation ($r = 0.95$) between rail station availability and rail station accessibility. This might explains the high Variance Inflation Factor ($VIF > 10$) of both of them (about 13.5). Hence, it was decided that one of them should be removed to fix this multicollinearity issue. Based on the exploratory analyses carried out earlier, the rail accessibility variable has been removed due to its relatively low association with housing location (see Table 5-4).

The sequential regression analysis output using IBM SPSS contains many tables; therefore and for the convenience of the reader in presenting more clear and informative tables, only the most interesting outputs have been selectively aggregated and re-tabulated in typical condensed and separate tables (Tables 5-15 to 5-21). As in Step 2 (Section 5.5.2.1), the statistics regarding the assumptions of multiple regression and error analysis are listed in the lower part of each table. According to the limits and thresholds stated in Appendix-B, all these statistics are acceptable and hence the regression analyses are legitimate and the results can be reliable. Again, the bootstrap technique has been utilised to deal with the normality issue. It is worthwhile mentioning that almost all the regression outputs shown in the following tables represent the second or the third round of analysis because one or two assumptions were violated in the first rounds. The presence of outliers is the main cause of these violations and hence excluding them was the most powerful remedy.

Finally, it is useful to recall that two different null hypotheses (Ho) have been set for each regression model. The first one concerns the significance of the whole model which is that there is no such model for the population and that this model is not significant and only existed due to chance. On the other hand, the second null hypothesis regards the parameters of the regression coefficients. It postulates that a regression coefficient is not significantly different from zero. Both hypotheses have been set up with a 5% level of significance LOS (i.e., $\alpha = 0.0$).

(A) Total people

As stated previously, this count quantifies the total people entering or exiting a specific housing site using any means of transport. That is, it could be seen as an indicator of the total amount of travel generated from a specific site. The key results of the hierarchical regression analysis conducted for the mediation study are shown in Table 5-15 for both the location model (Step 1) and the full model (Step 3) whereby the neighbourhood features are included. Concerning the location model, the ANOVA analysis shows that the model is significant (p-value = 0.000). Furthermore, it can be seen that all the regression coefficients for the three included location categories (TC, ETC and SA) are negative. Given that these coefficients, here, represent the differences between the mean trip rate of a specific location and the mean trip rate of the ET location (the reference category), so the total amount of daily travel in these locations is less than that in the edge of town. Regarding the coefficients' magnitudes, the table indicate that total travel in or near the core of the city is much less than in the edge of town in comparison with the suburban locations.

Table 5-15: Bootstrapped regression parameter estimates and statistics for the total people trip rate models.

Variables	Model No. 1			Model No. 2		
	B	SE	Sig.	B	SE	Sig.
Constant	8.410	0.418	0.001***	10.337	1.700	0.001***
Housing Location						
Town centre	-2.034	0.692	0.003***	1.099	1.080	0.260
Edge of town centre	-2.695	0.574	0.001***	-0.451	0.707	0.533
Suburban area	-0.518	0.520	0.329	0.243	0.457	0.617
Land Use						
Population density				<.001	<.001	0.098*
Private housing ratio				-0.877	0.593	0.142
Detached ratio				1.072	0.871	0.223
Avg. bedrooms				0.087	0.428	0.844
Unit density				-0.001	0.004	0.756
Flat ratio				-3.378	0.857	0.001***
Site area				-0.015	0.132	0.914
Public Transport						
Bus stop (Ref. Cat. = Yes)				-0.090	1.242	0.937
Ped. cross (Ref. Cat. = Yes)				0.600	0.381	0.129
Rail station (Ref. Cat. = Yes)				-0.386	0.445	0.375
PT services (Mon-Fri.)				-0.002	0.001	0.067*
Urban Design features						
Pro-walking(Ref. Cat. = Yes)				-0.421	0.405	0.298
Pro-Cycling (Ref. Cat. = Yes)				-0.225	0.440	0.624
Pro-PT (Ref. Cat. = Yes)				-0.326	0.528	0.538
Car parking						
Parking Density				0.296	0.253	0.209
On-Street parking				0.002	0.003	0.583
Garage/Driveway parking				-0.002	0.002	0.362
Communal parking				-0.005	0.003	0.024**
Off-site park (Ref.Cat.= Yes)				-0.432	0.434	0.323
Socioeconomics						
Car Ownership				-0.861	0.652	0.199
R^2 Adjusted		0.083			0.452	
ANOVA		0.000			0.000	
Durbin-Watson					1.950	
Max. Std. Residuals					3.243	
Max. Cook's/ Leverage dis.					0.059/0.251	
Max. DFFIT/ DFBETA					1.180/0.340	
Min. Tolerance		0.758			0.187	

* significant at 10% level of significance (LOS); ** at 5% LOS; *** at 1% LOS.

In the context of mediation, the final notable issue in the location model besides the significance of the ANOVA, is the significance of the regression coefficients. It can be observed that the regression coefficients of both the town centre and edge of town centre regression parameters are statistically significant. Hence, this implies a statistical support that the first conditional step in Baron and Kenny causal approach has been met. That is, there is an association between people's trip rates and their residence location which might be intervened by some neighbourhood features.

Having reported that and to find out which neighbourhood features in particular are the reason for this association, the second regression model has been run to examine the third step in the mediation process. Firstly, the results show that the second regression model, the full model, is significant with p-value equals 0.000. Moreover, the inclusion of the neighbourhood features has turned the coefficients of the three location categories (TC, ETC and SA) to be non-significant (p-value > 0.05); i.e., the differences of their mean trip rates from the ET location have now become not statistically significant. This obviously implies that the fourth step of the mediation mechanism has been met and hence postulates that one or more of the included neighbourhood features function as mediator. In consequence, these features could be the reason behind the observed variation in trip behaviour with the housing location in the first model.

According to Table 5-15, only four neighbourhood features are significant; communal parking and flats ratio at level of significance of 5% whereas population density and public transport services only significant at level of 10%. Recalling that population density has no significant variation over site locations (see Table 5-8), thus, its influence as a mediator is not statistically supported. It is worthwhile reporting that among the remaining three variables only the ratio of flats has a regression parameter with a considerable magnitude (3.378) while the parameters' magnitudes of the other two are negligible. The ratio of flat parameter is the largest among all other regression parameters in the model. This reflects its large influence in transmitting the impact of the site location on the people personal mobility. The influence direction of the flat ratio parameter is negative (-3.378). In other words, neighbourhoods located in areas with low flat ratio (high percentage of houses) are associated with high (7.00-19.00) daily total amount of travel. Recalling that a low flat ratio neighbourhoods are typically located in out of centre areas (see Figure 5-5); therefore, the model result is supported by the exploratory analyses carried out earlier in that the total people travel generally increases with the distance from the centre (see Figure 5-22).

The inclusion of the housing development features has noticeably increased the adjusted R-square value from just over 8% to 45%. This typically reflects the added contribution of the development features in explaining the variation in the trip rates. Finally, urban design factors and household car ownership have no statistically approved impact on the people's trip rates.

(B) Total vehicles

This travel behaviour indicator is important in quantifying the total vehicular movement that is generated from a specific residential land use. The statistical results of the sequential regression models (location and full models) displayed in Table 5-16 present evidence about the existence of a mediation effect. This could be seen by noticing the change in the significance status of the location categories from highly significant in the location model to highly non-significant in the full model. That is, the inclusion of the neighbourhood characteristics has turned the regression coefficients of the location model to be non-significant. Of all the housing neighbourhood features examined, only four urban form variables have been found to be statistically significant. While flats ratio, public transport services, communal parking and the parking density are significant at 5% level of significance, the housing unit density is only significantly different from zero at 10% level. According to the analysis conducted for the second step of the mediation process (See Table 5-10, Table 5-11 and Table 5-13), all these variables have significant relationship with at least one category of the four location categories. Hence, according to the Baron and Kenny mediation approach, it can be hypothesised that these four variables are mediators.

Having stated that, it can be specified now that the significant increase in vehicular trips in the outer areas in comparison with inner ones is actually because of the considerable variation of these four variables between inner and outer areas. Unlike the housing density, communal parking and the transit services, the flats ratio and the parking density have relatively large parameters; -1.313 and 0.288 respectively. Furthermore, all the signs and magnitudes of these parameters are logical. The flat ratio parameter with its negative sign may speak to the generally accepted behaviour in that people living in houses travel more than those in flats/apartments.

Table 5-16: Bootstrapped regression parameter estimates and statistics for the total vehicle trip rate models.

Variables	Model No. 1			Model No. 2		
	B	SE	Sig.	B	SE	Sig.
Constant	5.005	0.220	0.001***	4.260	0.826	0.001***
Housing Location						
Town centre	-3.453	0.454	0.001***	-0.463	0.526	0.309
Edge of town centre	-2.293	0.327	0.001***	-0.343	0.357	0.343
Suburban area	-0.733	0.281	0.009***	-0.004	0.223	0.988
Land use						
Population density				<.001	<.001	0.978
Private housing ratio				-0.118	0.292	0.686
Detached ratio				0.672	0.472	0.169
Avg. bedrooms				0.281	0.209	0.183
Unit density				-0.004	0.002	0.085*
Flat ratio				-1.313	0.432	0.004***
Site area				0.051	0.069	0.428
Public Transport						
Bus stop (Ref. Cat. = Yes)				-0.416	0.607	0.467
Ped. cross (Ref. Cat. = Yes)				0.194	0.176	0.278
Rail station (Ref. Cat. = Yes)				0.154	0.215	0.488
PT services (Mon-Fri.)				-0.001	0.001	0.039**
Urban Design features						
Pro-walking(Ref. Cat. = Yes)				0.034	0.201	0.866
Pro-Cycling (Ref. Cat. = Yes)				0.001	0.216	1.000
Pro-PT (Ref. Cat. = Yes)				-0.058	0.252	0.835
Car parking						
Parking Density				0.288	0.145	0.047**
On-Street parking				-0.001	0.002	0.450
Garage/Driveway parking				-0.001	0.001	0.672
Communal parking				-0.004	0.001	0.002**
Off-site park (Ref.Cat.= Yes)				0.063	0.209	0.753
Socioeconomics						
Car Ownership				-0.405	0.327	0.230
R^2 adjusted		0.226			0.646	
ANOVA		0.000			0.000	
Durbin-Watson					1.792	
Max. Std. Residuals					< 3.0	
Max. Cook's/ Leverage dis.					0.147/0.343	
Max. DFFIT/ DFBETA					1.004/0.792	
Min Tolerance		0.765			0.185	

* significant at 10% level of significance (LOS); ** at 5% LOS; *** at 1% LOS.

As mentioned earlier, the expected large household size for families living in houses is the most probable reason. On the other hand, the positive sign of the parking density (0.288) proposes that neighbourhoods with high parking density generate high vehicular traffic. According to Figure 5-17, these neighbourhoods are typically concentrated in out of centre locations. Hence, the model is generally consistent with the descriptive analysis shown in Figure 5-23. Finally, the inclusion of the neighbourhood variables and factors has largely contributed in accounting for the variation in the vehicle trip rates. This is clearly seen by noticing the large increase in the multiple coefficient of determination (adjusted R-square) from 22.6% to 64.6%

(C) Motor cars

This count is often the major part of the total vehicle count; typically, the vast majority of the vehicles are motor cars. Therefore, the regression analysis results of this count are quite similar to the results of the total vehicle analysis. Examining this travel count helps in exploring the passenger car use in terms of trip frequency excluding other vehicle types such as vans and trucks.

The mediation analysis results listed in Table 5-17 indicate that the regression coefficients of all four location categories become largely non-significant upon including the neighbourhood characteristics in the second block of the sequential regression analysis. As stated earlier, this change in the significance implies the existence of the mediation. As shown in the table, four built environment variables have the potential to be mediators. Flats ratio and transit services are significant at 5% level of significance whereas parking density and communal parking are both only significant at level 10%. The analyses relating to the second step of the mediation process show that there is a relationship between each one of these four features and the location of housing development. At least one location category has been found to have a significant regression coefficient with each one of them.

As a result, these four features could be designated as mediators. Hence, the increase in the people's car trip frequency in the suburbs and rural areas relative to the corresponding frequency in or near the centre could be attributed to the significant difference between these four features across these locations. However, only the flat ratio and parking density have coefficients with quite considerable magnitudes; -1.128 and 0.269 respectively.

Table 5-17: Bootstrapped regression parameters estimates and statistics for the motor cars trip rate models.

Variables	Model No. 1			Model No. 2		
	B	SE	Sig.	B	SE	Sig.
Constant	4.413	0.205	0.001***	3.835	0.788	0.001***
Housing Location						
Town centre	-3.092	0.419	0.001***	-0.318	0.531	0.474
Edge of town centre	-2.014	0.311	0.001***	-0.218	0.337	0.522
Suburban area	-0.729	0.281	0.008***	-0.053	0.207	0.808
Land use						
Population density				<.001	<.001	0.840
Private housing ratio				-0.011	0.282	0.971
Detached ratio				0.753	0.455	0.115
Avg. bedrooms				0.221	0.193	0.259
Unit density				-0.003	0.002	0.127
Flat ratio				-1.128	0.411	0.013**
Site area				0.083	0.087	0.318
Public Transport						
Bus stop (Ref. Cat. = Yes)				-0.348	0.588	0.518
Ped. cross (Ref. Cat. = Yes)				0.150	0.164	0.385
Rail station (Ref. Cat. = Yes)				0.114	0.195	0.574
PT services (Mon-Fri.)				-0.001	0.001	0.027**
Urban Design features						
Pro-walking(Ref. Cat. = Yes)				0.123	0.182	0.474
Pro-Cycling (Ref. Cat. = Yes)				-0.032	0.198	0.876
Pro-PT (Ref. Cat. = Yes)				-0.074	0.228	0.737
Car parking						
Parking Density				0.269	0.150	0.066*
On-Street parking				-0.002	0.002	0.288
Garage/Driveway parking				-0.001	0.001	0.649
Communal parking				-0.002	0.001	0.053*
Off-site park (Ref.Cat.= Yes)				0.157	0.198	0.430
Socioeconomics						
Car Ownership				-0.477	0.315	0.130
R^2 adjusted		0.207			0.623	
ANOVA		0.000			0.000	
Durbin-Watson					1.751	
Mam. Std. Residuals					3.150	
Max. Cook's/ Leverage dis.					0.147/0.401	
Max. DFFIT/ DFBETA					1.004/0.792	
Min Tolerance		0.769			0.187	

* significant at 10% level of significance (LOS); ** at 5% LOS; *** at 1% LOS.

The coefficients of public transport (-0.001) and communal parking (-0.002) are too small to be influential. Nevertheless, their signs sound logical. For instance, the negative sign of the public transport indicates that car trip rates are low at neighbourhoods with an adequate provision of transit services.

According to Figure 5-14, these places are typically located in the centre and hence low car trip rates are expected at those locations and supported by the descriptive analysis shown in Figure 5-24. Similarly, the negative sign of the communal parking variable suggests that neighbourhoods with high communal parking are usually associated with low car trip rate. The last sentence becomes more reasonable when recalling that the concentration of communal parking can be observed in the central locations (see Figure 5-20) whereby the exploratory analysis shown in Figure 5-24 confirms the low car trip frequency over there[10].

On the other hand, the interpretation about the influence of flat ratio and parking density is that the same as the one in the previous section; Total vehicles. That is, briefly, neighbourhoods with a high percentage of houses and high parking density are found to be correlated with high car trip rates. A rise of about 42% in the adjusted R-square has been gained from the inclusion of the neighbourhood features in the full model.

(D) Vehicle occupants

This analysis attempts to explore whether the location of a housing development could influence the number of vehicle occupants per household; and if so, what are the neighbourhood features that might predict/mediate this travel behaviour.

According to Table 5-18, the location model is statistically significant with ANOVA p-value equal to 0.000. The values and signs of the location coefficients are consistent with the graphical presentation of the variation in vehicle occupants over locations shown previously in Figure 5-25. That is, the average number of vehicle occupants per household for sites in outer areas is much larger than in inner areas.

[10] To make this sort of interpretation more sensible, it is important to recall that this is an observational study not an experimental study. Hence, it is controversial to infer about causality in spite of the adoption of the causal approach in the mediation process. Instead, making notes about the observed association between any two variables could be appraised as more rational and conservative. Moreover, it is not true to infer that increasing the communal parking would decrease the motorised travel and hence recommending the local planning authority to provide more communal parking in rural area to reduce car dependency. Instead, what is acceptable is to suggest that creating urban environments such as those in central locations, where there are high communal parking, may decrease the dependency on motorised travel.

Table 5-18: Bootstrapped regression parameters estimates and statistics for the vehicle occupants trip rate models.

Variables	Model No. 1			Model No. 2		
	B	SE	Sig.	B	SE	Sig.
Constant	6.797	0.359	0.001***	5.773	1.258	0.001***
Housing Location						
Town centre	-4.643	0.624	0.001***	-0.553	0.781	0.419
Edge of town centre	-3.352	0.514	0.001***	-0.841	0.564	0.282
Suburban area	-1.115	0.433	0.011***	-0.058	0.351	0.887
Land use						
Population density				<.001	<.001	0.581
Private housing ratio				-0.475	0.433	0.292
Detached ratio				1.284	0.699	0.077*
Avg. bedrooms				0.397	0.318	0.219
Unit density				-0.003	0.003	0.352
Flat ratio				-1.960	0.658	0.003***
Site area				0.079	0.019	0.448
Public Transport						
Bus stop (Ref. Cat. = Yes)				-0.112	1.069	0.925
Ped. cross (Ref. Cat. = Yes)				0.265	0.260	0.295
Rail station (Ref. Cat. = Yes)				0.297	0.301	0.323
PT services (Mon-Fri.)				-0.002	0.001	0.007***
Urban Design features						
Pro-walking(Ref. Cat. = Yes)				-0.091	0.295	0.728
Pro-Cycling (Ref. Cat. = Yes)				-0.061	0.324	0.848
Pro-PT (Ref. Cat. = Yes)				-0.029	0.391	0.943
Car parking						
Parking Density				0.286	0.203	0.137
On-Street parking				-0.001	0.003	0.693
Garage/Driveway parking				-0.001	0.002	0.753
Communal parking				-0.004	0.002	0.044**
Off-site park (Ref.Cat.= Yes)				0.213	0.341	0.555
Socioeconomics						
Car Ownership				-0.451	0.492	0.375
R^2 adjusted		0.217			0.601	
ANOVA		0.000			0.000	
Durbin-Watson					1.890	
Max. Std. Residuals					< 3.0	
Max. Cook's/ Leverage dis.					0.051/0.308	
Max. DFFIT/ DFBETA					1.280/0.340	
Min Tolerance		0.762			0.185	

* significant at 10% level of significance (LOS); ** at 5% LOS; *** at 1% LOS.

Moreover, all the regression coefficients of the location model are significant at 5% level of significance. This implies that the null hypothesis that these coefficients are not significantly different from zero is rejected in favour of the alternative hypothesis.

However, the inclusion of the development characteristics in the second block of the sequential regression input procedure has completely turned all the location coefficients to be non-significant. Accordingly, the influence of mediation is expected. By inspecting the statistical significance of the neighbourhood variables, four variables are found significant; these are flats ratio, public transport service, communal parking and detached houses ratio. However, the latter is only significant at 10% level of significance (marginally significant). According to Table 5-8, Table 5-10 and Table 5-13, these characteristics features fluctuate significantly over at least one of the main location categories. Consequently, these spatial features intervene in the relationship between site location and vehicle occupants. Unlike the coefficients of the detached ratio (1.284) and flat ratio (-1.960), the values of the public transport (-0.002) and communal parking (-0.004) coefficients are too small to be influential. However, their signs sound reasonable according to Figure 5-14 and Figure 5-20 and they support the exploratory analysis shown in Figure 5-25. Likewise, the interpretation of the effect of concentration of flats or apartments in a housing development is quite similar to what has been stated in the total vehicles and total cars sections (Section (B) and Section (C) respectively).

In contrast, the coefficient of the detached houses ratio is positive with quite a large value (1.284). While the magnitude speaks to its effect size, the sign implies that its direction of influence is proportional with the number of occupants. That is, the regression model suggests that there is a strong association between residential neighbourhoods with a high percentage of detached houses and the number of household vehicle occupants. Taking into account that typically detached houses are concentrated in the edge of town (see Figure 5-8), this finding is supported by the explanatory analysis of vehicle occupants with location shown in Figure 5-25. That is, households living in detached houses are major contributors to the vehicle occupants trip rate. One of the reasonable explanations is that these households are most probably big families often with children and hence it is common to share their household private car for their journeys, especially the non-work journeys. Furthermore, it is worthwhile reporting that the inclusion of the neighbourhood features has raised the adjusted R-square from only about 22% to 60%. That is, their inclusion has contributed towards explaining an extra 38% of the variation in the trip frequency of vehicle occupants. Finally, as previously stated, urban design factors and the presence of the household car appear to have no significant impact on the vehicle occupants.

(E) Public transport users

The specific objective is to develop a travel model that can help in more understanding of neighbourhood characteristics that might affect the transit users' behaviour. The regression models required for the first and third steps of the mediation analysis are shown in Table 5-19.

The location model has been found to be non-significant at the 5% level of significance (p-value = 0.088). In addition, all the regression coefficients of the main location categories are not significantly different from zero. In the mediation approach context, this violates the first condition. Thus, there is no statistical benefit from carrying out the mediation analysis due to the absence of an initial significant relationship between the location and the transit trips which might be intervened. Moreover, the notable low value of the adjusted R-square (2%) strongly supports the last statement. Nevertheless, the full model (location and neighbourhood features) has been run to investigate the statistical importance of each neighbourhood feature on the transit trip rates. In this case the objective is slightly change but still within the mainline of this analysis objective. The particular research question now is that if the location is not an influential factor, what are the neighbourhood features that might still affect the transit use behaviour? According to Table 5-19, almost all of the significant parameters are with small regression coefficients and hence negligible impact. Only the absence of bus stop factor has been found to have a relatively larger coefficient (-0.152). However, this parameter is only significant at the 10% level of significance. The sign of the bus stop factor is logical; in that, the absence of a bus stop near the site would reduce the use of public transport. Again, land use, urban design and socio-economic parameters are found to be non-influential.

(F) Cyclists

Again, the full model has been conducted to investigate the characteristics of housing development that may influence cycling frequency after controlling for the location factor in the first model.

Table 5-19: Bootstrapped regression parameters estimates and statistics for the public transport users trip rate models.

Variables	Model No. 1			Model No. 2		
	B	SE	Sig.	B	SE	Sig.
Constant	0.207	0.036	0.001***	-0.023	0.258	0.933
Housing Location						
Town centre	0.109	0.197	0.587	-0.124	0.151	0.400
Edge of town centre	-0.055	0.046	0.227	-0.125	0.088	0.151
Suburban area	0.102	0.054	0.065*	0.083	0.053	0.243
Land use						
Population density				<.001	<.001	0.158
Private housing ratio				-0.017	0.070	0.828
Detached ratio				0.066	0.016	0.518
Avg. bedrooms				0.034	0.052	0.485
Unit density				0.001	0.001	0.480
Flat ratio				-0.088	0.102	0.386
Site area				0.008	0.018	0.544
Public Transport						
Bus stop (Ref. Cat. = Yes)				-0.152	0.085	0.074*
Ped. cross (Ref. Cat. = Yes)				0.089	0.048	0.075*
Rail station (Ref. Cat. = Yes)				-0.023	0.072	0.731
PT services (Mon-Fri.)				0.001	0.001	0.001***
Urban Design features						
Pro-walking(Ref. Cat. = Yes)				-0.021	0.052	0.692
Pro-Cycling (Ref. Cat. = Yes)				-0.070	0.055	0.206
Pro-PT (Ref. Cat. = Yes)				-0.052	0.049	0.298
Car parking						
Parking Density				0.031	0.048	0.485
On-Street parking				0.001	0.001	0.115
Garage/Driveway parking				-0.001	0.001	0.088*
Communal parking				0.001	0.001	0.045**
Off-site park (Ref.Cat.= Yes)				-0.008	0.057	0.903
Socioeconomics						
Car Ownership				-0.020	0.088	0.880
R^2 adjusted	0.020			0.269		
ANOVA	0.088			0.000		
Durbin-Watson				1.862		
Max. Std. Residuals				< 3.0		
Max. Cook's/ Leverage dis.				0.180/0.361		
Max. DFFIT/ DFBETA				0.260/-0.370		
Min Tolerance	0.732			0.186		

* significant at 10% level of significance (LOS); ** at 5% LOS; *** at 1% LOS.

Only the coefficient of the flats ratio parameter has been found significant and with a relatively large value (-0.147). This parameter implies that housing developments with a high concentration of apartments are usually associated with low cycling trip rates. Finally, the inclusion of the spatial and car ownership features has only raised the model R-square to 9%, which is obviously a weak coefficient of determination.

Table 5-20 lists the key outputs of the analysis results for the cyclists' trip rate models. As in the previous model (transit model), the location model outputs show that the variations in the levels of the main location do not significantly account for variations in the cycling trip rate. The regression coefficients of the location types are also non-significant. This is also supported by the negligible value of the adjusted coefficient of determination (adjusted R-square = 0.001).

(G) Pedestrians

The current analysis attempts to investigate whether there is a considerable impact of site location on the walking trip rates. If such impact is proved, then the analysis goes further to explore if there are any residential development features that transmit the influence of the location factor to the people's walking behaviour.

The sequential regression outputs required to test the steps of the mediation mechanism are listed in Table 5-21. The location travel model and all the regression coefficients are statistically significant at the 5% level of significance. The values and signs of the parameters are highly consistent with the previous exploratory analysis displayed in Figure 5-28. That is, the centre residents carry out more daily trips by walking than those in other locations, especially outer areas. Furthermore, the tabulated output indicates the existence of a partial mediation effect. The inclusion of neighbourhood features has succeeded in turning the previously significant Edge of Town Centre and Suburban Area location categories into non-significant ones. Nevertheless, the Town Centre coefficient has preserved its significance. So far, the analysis results obviously imply the existence of extra hidden variables and factors that might influence the walking behaviour in the centres. On the other hand, according to Table 5-21, eight built environment variables and factors have been found either significant or marginally significant. However, only four of them could be apprised as having relatively non-trivial parameters. These parameters are average bedrooms (-0.364), flats ratio (-1.188), absence of rail station (-0.616) and lack of off-site parking (-0.595).

Table 5-20: Bootstrapped regression parameters estimates and statistics for the total cyclists trip rates models.

Variables	Model No. 1			Model No. 2		
	B	SE	Sig.	B	SE	Sig.
Constant	0.148	0.018	0.001***	0.185	0.173	0.320
Housing Location						
Town centre	0.082	0.088	0.458	0.106	0.153	0.481
Edge of town centre	-0.021	0.037	0.566	-0.009	0.057	0.884
Suburban area	0.029	0.029	0.310	0.019	0.030	0.524
Land use						
Population density				0.000	0.000	0.084*
Private housing ratio				0.006	0.040	0.883
Detached ratio				-0.096	0.065	0.134
Avg. bedrooms				0.011	0.031	0.734
Unit density				<.001	<.001	0.673
Flat ratio				-0.147	0.069	0.039**
Site area				-0.019	0.008	0.022**
Public Transport						
Bus stop (Ref. Cat. = Yes)				-0.022	0.061	0.733
Ped. cross (Ref. Cat. = Yes)				0.047	0.032	0.141
Rail station (Ref. Cat. = Yes)				-0.044	0.040	0.277
PT services (Mon-Fri.)				<.001	<.001	0.279
Urban Design features						
Pro-walking(Ref. Cat. = Yes)				-0.045	0.030	0.133
Pro-Cycling (Ref. Cat. = Yes)				0.010	0.037	0.791
Pro-PT (Ref. Cat. = Yes)				-0.019	0.038	0.605
Car parking						
Parking Density				-0.009	0.018	0.616
On-Street parking				<.001	<.001	0.469
Garage/Driveway parking				<.001	<.001	0.512
Communal parking				<.001	<.001	0.864
Off-site park (Ref.Cat.= Yes)				-0.044	0.037	0.232
Socioeconomics						
Car Ownership				0.086	0.068	0.213
R^2 adjusted	0.001			0.091		
ANOVA		0.498			0.022	
Durbin-Watson					1.497	
Max. Std. Residuals					3.031	
Max. Cook's/ Leverage dis.					0.083/0.301	
Max. DFFIT/ DFBETA					0.160/0.037	
Min Tolerance		0.756			0.187	

* significant at 10% level of significance (LOS); ** at 5% LOS; *** at 1% LOS.

Table 5-21: Bootstrapped regression parameters estimates and statistics for the total pedestrians trip rate models.

Variables	Model No. 1			Model No. 2		
	B	SE	Sig.	B	SE	Sig.
Constant	1.260	0.132	0.001***	4.423	0.872	0.001***
Housing Location						
Town centre	2.438	0.352	0.001***	1.670	0.562	0.002***
Edge of town centre	0.734	0.238	0.004***	0.323	0.314	0.317
Suburban area	0.488	0.190	0.015**	0.217	0.176	0.218
Land use						
Population density				<.001	<.001	0.080*
Private housing ratio				-0.392	0.273	0.152
Detached ratio				-0.182	0.365	0.600
Avg. bedrooms				-0.364	0.195	0.062*
Unit density				0.001	0.002	0.432
Flat ratio				-1.188	0.384	0.004***
Site area				-0.084	0.050	0.078*
Public Transport						
Bus stop (Ref. Cat. = Yes)				0.195	0.394	0.624
Ped. cross (Ref. Cat. = Yes)				0.199	0.186	0.276
Rail station (Ref. Cat. = Yes)				-0.616	0.244	0.013**
PT services (Mon-Fri.)				-0.001	0.001	0.297
Urban Design features						
Pro-walking(Ref. Cat. = Yes)				-0.265	0.206	0.198
Pro-Cycling (Ref. Cat. = Yes)				-0.103	0.193	0.589
Pro-PT (Ref. Cat. = Yes)				-0.227	0.245	0.381
Car parking						
Parking Density				-0.013	0.110	0.907
On-Street parking				0.002	0.001	0.080*
Garage/Driveway parking				-0.001	0.001	0.245
Communal parking				-0.003	0.001	0.014**
Off-site park (Ref.Cat.= Yes)				-0.595	0.199	0.008***
Socioeconomics						
Car Ownership				-0.477	0.343	0.160
R^2 adjusted		0.119			0.324	
ANOVA		0.000			0.000	
Durbin-Watson					1.714	
Max. Std. Residuals					3.210	
Max. Cook's/ Leverage dis.					0.030/0.448	
Max. DFFIT/ DFBETA					0.460/0.355	
Min Tolerance		0.754			0.189	

* significant at 10% level of significance (LOS); ** at 5% LOS; *** at 1% LOS.

According to the previous analyses (see Table 5-9, Table 5-10, Table 5-4 and Table 5-6), only the off-site parking variable has no significant relation with the site location. In consequence, average bedrooms, flats ratio and availability of nearby rail station are mediators according to the Baron and Kenny causal approach of mediation.

The negative sign of the housing unit bedrooms variable points to the negative association between the average housing unit bedrooms for a specific site and the pedestrians trip frequency. This specific result is supported by locational variation of walking frequency shown earlier in Figure 5-28. That is, according to the exploratory analyses carried out before in Figure 5-11 and Figure 5-12, housing units with high number of bedrooms are typically houses that are located in outer areas. In contrast, the negative link between the absence of a nearby rail station and the walking trips would suppose that locations with adequate provision of rail station such as the core of the city are usually accompanied with high walking trips. The negative sign of the off-site parking parameter reflects the observed link between the unavailability of off-site parking options for site visitors and the low walking trips in these development sites. While there is no direct reasonable explanation behind this link, a hidden variable factor could be the reason.

As in all the previous regression models, the value and sign of the flats ratio parameter highlights the impact of the type of housing units (house/flat) on the people's amount of travel. That is, holding all other parameters constant; people living in houses conduct more walking trips than those living in flats. The highly likely, if not the only, reason is that people who opt to live in flats are often with different household size and structure from those living in houses. According to the literature, the former are usually comprised of households with either a single person living alone or couples without children.

Finally, it is worthwhile reporting that the pedestrians count is the only one in which the town centre parameter is still statistically significant even after including the neighbourhood variables and factors. However, the town centre coefficient in the location model (2.438) has reduced to (1.670) in the full model. This obvious reduction implies the partial moderation effect. In consequence, more detailed travel analysis is justified and required for exploring the potential determinants that influence the travel decisions for downtown's residents.

5.5.3 Discussion of analysis findings and policy implications

5.5.3.1 Descriptive analysis

The essential intention of conducting this analysis has been to consider the first objective of the site-based level studies carried out in this chapter. That is to help in examining whether there is any noticeable difference in the neighbourhood features between residential sites in/near the centre and others located in out-of-centre areas. In line with this, the third objective regarding the suitability of the TRICS for travel demand/behaviour studies has also been partially addressed. The statistical analysis results using the Trics2012a dataset have been listed under Sec. 5.5.1.

A summary of analysis findings concerning the variation of the neighbourhood features and its residents' travel behaviour within the main four site locations has been tabulated in Table 5-22. Based on this table, two obviously distinct location categories could be formed. These categories are found to be correlated with several distinguishing urban form features. In addition, the analyses have also shown that the residents of these locations have comparatively several different travel behaviour aspects; in particular, trip rate and mode share. These two location categories are:

1. Central locations (especially city/town centre): The neighbourhoods located in or near the centre have been found to be correlated with several spatial features. For land use characteristics, housing density is very high in the heart of the centre. In addition, there have been a high proportion of flats which are typically with only one or two bedrooms. Housing development sites are typically with a small area in comparison with outer locations. The frequency of public transport (bus, tram and train) is significantly high with a recognised provision of a train station. Regarding parking, the on-street parking is low in the centre; this is also true regarding the garages and driveways parking. The availability of free off-site parking is highly limited in the city centre. The use of parking management such as controlled parking zones is very common in the CBD areas.

In contrast, with respect to personal mobility, the central locations have been found to be correlated with several distinct travel behaviour aspects. Households located in the inner areas generally travel less than those in the outer areas. The centre's households have been observed that they typically conduct more walking and less driving journeys than those in the suburbs and exurbs.

Table 5-22: Summary of the exploratory analyses results.

Factor/Variable		Comment
Neighbourhood characteristics	Population density	It does not significantly vary with site location.
	Housing density	It is very high in TC while very low in the ET.
	Flats ratio	It decreases with the distance from the centre.
	Private housing ratio	It does not significantly vary with site location.
	Detached houses ratio	It highly increases with the distance from the centre.
	Semi-detached houses ratio	It highly increases with the distance from the centre.
	Terraced houses ratio	It does not significantly vary with site location.
	Site area	It increases with the distance from the centre.
	Number of unit bedrooms	It is higher in outer areas than in the central locations. It is higher in houses than in flats.
	Public transport services	It decreases with the distance from the centre.
	Bus/tram stop	It does not significantly vary with site location.
	Bus/tram stop accessibility	It does not significantly vary with site location.
	Train station	It is very high in TC while very low in ET.
	Train station accessibility	It is very high in TC while very low in ET.
	Pro-walking design features	It is moderately high in TC and low in ET.
	Pro-cycling design features	It is moderately high in TC and low in ET
	Pro-PT design features	It is moderately high in TC and low in ET
	Parking density	It increases with the distance from the centre.
	On-street parking	It is much low in TC & ETC relative to SA & ET.
	Garage/driveway parking	It is much low in TC & ETC relative to SA & ET.
	Communal parking	It is relatively very low in the ET.
	Off-site parking	It does not vary significantly with site location.
	Free off-site parking	It is significantly low in TC relative to SA & ET.
	Off-site parking restrictions	It decreases with the distance from the centre.
	HH Car ownership	There is no clear association with the location.
Travel indicators	Total people	It is much lower in TC & ETC than in SA & ET.
	Total vehicles	It increases with the distance from the centre.
	Total motor cars	It increases with the distance from the centre.
	Vehicle occupants	It decreases with the distance from the centre.
	Public transport users	There is no evident pattern over site locations.
	Cyclists	It does not significantly vary over site locations.
	Pedestrians	It is much higher in TC than in other locations.
	Mode share	Walking is the most common mode in TC.

Regarding the modal split, walking is the most common mode in the town centre location. This is probably because of the urban environment nature of the downtown where most of the daily activities are within walking distances.

2. Outer locations (especially edge of town): A correlation has been found between the out of centre locations, specifically the edge of town, and several built environment factors. Housing developments in such locations are often designed with a low concentration of housing units. These units are typically detached or semi-detached houses with two or three bedrooms typically. The availability of transit services is notably less than those in the central location such as TC and ETC. This is also evidently valid regarding the provision of train stations. With the exception of communal parking, the availability of other options of on-site parking is more noticeable in outer locations. Furthermore, parking restriction schemes such as CPZ are not familiar and free off-site parking is widely available.

Similar to the central locations, the out of centre sites have also been shown to link with certain trip making characteristics. Overall, the households of residential neighbourhoods located in such locations are found to have more travel needs and hence conduct more daily journeys. Regarding the road transport modes utilised, there are fewer walk trips and more motorised trips in comparison with those in the centre. Travelling by a vehicle as a passenger is also more common.

Finally, the analyses have confirmed that some of the spatial variables and factors have shown no relation with the site location. Some of these findings are unsurprising in spite of being interesting such as the availability of off-site parking and the private housing ratio. On the contrary, others such as population density and car ownership which were expected to be linked with the location, in fact, have shown inconsequential linking with the location of the housing site. However, as mentioned earlier in Section 5.5.1.1 and 5.5.1.2, the fuzzy scale nature of the way these variables have been measured is probably the most likely reason behind this insignificance.

5.5.3.2 Mediation analysis

The causal steps of the mediation process have been specifically employed to achieve the second objective of this chapter. That is, if the people living in or surrounding the centre have mobility characteristics evidently different from those living in other areas, then the mediation analysis will attempt to answer the question of why such a difference is evident. In doing so, the developed mediation models propose the existence of mediators (development features) that could explain how this linkage between site location and people's trip rate patterns has in essence existed. The statistical analysis results of the sequential regression technique employed to investigate the mediation effect have been listed under Section 5.5.2. However, the following are some of the notes obtained from the statistics of the travel models developed through the overall mediation analysis.

1. Mediation effect: Statistical evidence has been found regarding the existence of mediation effect in the significant relationships (significance level = 0.05) between site location and each one of five trip rate counts. These five multimodal travel counts are Total people, Total vehicles, Motor cars, Vehicle occupants and Pedestrians. That is, some of the neighbourhood features function as mediators and therefore this could imply a statistical justification of why households in central areas accomplish less driving and more walking trips than those living in the suburbs and countryside.

2. Mediators: According to the mediation analyses, urban form characteristics such as land use, public transport and parking are the most common intervening features. In particular, flats ratio, public transport provisions and parking density are the most statistically approved and with tangible impact mediators. The ratio of flats in a residential development as an indicator of the housing unit type is the only common mediator in the five mediational models. In addition, it has been found to be significant and with a relatively large magnitude (effect size) in all these five travel models. Other mediators with less but non-trivial effect size are also available. For example, parking density in the total vehicles and motor cars models, detached houses ratio in the occupant model and number of household bedrooms, rail station availability and the off-site parking in the pedestrians model.

3. Car ownership: The presence of the household car has shown no noteworthy impact on the household's trip frequency as predictor or mediator alike. As reported in Section 5.5.1.2, while this sounds unreasonable especially for total vehicles and motor cars models, the scale of this variable (within 5 miles) in the TRICS dataset could be the most likely reason behind that. Having stated that and taking into account that TRICS is one of the nationally recognised trip generation database in the UK, a re-measuring for this socioeconomic variable using a more disaggregated level of measurement is highly recommended.

4. Urban design features: Three urban design factors have been included in the regression models to reflect the available design features that might encourage walking, cycling and transit modes of travel. Surprisingly, the regression coefficients of all these three factors have been found to be non-significant as predictor or mediator. As stated in Section 5.5.1.1, the qualitative nature of describing the indicators of these factors in TRICS and hence the way they have been specified in the model might have ruined the significance of their impact. Again, more precise quantitative measuring would have clarified the benefit of the availability of such neighbourhood features and hence making TRICS more adequate for travel behaviour research.

5. Flats ratio: The proportion of flats/apartments housing units in a residential development has been as shown statistically significant with a negative sign and has considerable value (large weight) in all the travel counts regression models. The typical statistical interpretation is that, holding everything else constant, households living in houses conduct more trips than those living in flats. One of the reasonable hypothetical causes of this finding is the household size and structure. Houses are typically occupied by large households often with children while flats are in general occupied by single or two person households. In consequence, it is not surprising that large households conduct more daily trips than small ones. The analysis of variance has been utilised to investigate the impact of the housing unit type on the total daily mobility of a household regardless the location of the site. The descriptive part of the analysis has been demonstrated in Figure 5-30. The ANOVA informs that the mean total daily trip rate of households in flats (just under 6 trips), regardless of the tenure type, is significantly less than the one for households in houses (about 9 trips).

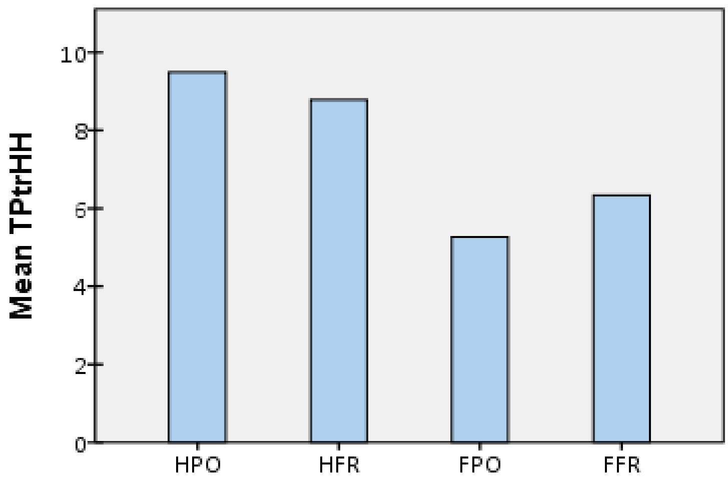

Figure 5-30: The variation in total daily mobility between households in houses and flats .

6. Tenure impact: The mediation analysis has indicated that the type of possession (tenure) of a dwelling unit does not significantly affect the trip rate for all the travel counts. This has also been confirmed by the ANOVA. The post-hoc analysis using the Gabriel approach has shown no significant difference between houses or flats groups with different tenure. The plot of group means of these housing categories is shown in Figure 5-30. This finding could be interesting for local planners and housing policy by helping them to better understand the travel impacts of existing or proposed residential developments. On the other hand, based on the current statistical analysis results, the original seven TRICS 2012a housing subcategories can be safely regrouped after combining the categories which were segregated based on their difference in tenure. With this improved new categorisation, the conceptual framework of the category analysis model implicitly embedded in TRICS is strengthened. Survey time (and hence effort and cost) is saved. In addition, the sample size in each subcategory is increased and hence the database will be eligible for rigorous inferential analyses.

7. The change in significance of the town centre parameter in the pedestrian travel model: The analysis results of the pedestrian trip rate model have shown that the regression coefficient of the town centre variable in the location model has maintained its significance even after the inclusion of the neighbourhood features. However, a clear drop in its value is tangible. Statistically speaking, this interesting finding implies the partial mediation effect. In addition, it indicates the absence of influential variables and factors that are expected to most likely explain the high imprint of the walking trip rates in the centre. Based on the relevant literature and the results of the current analyses, it can be hypothesised that there are three more bundles of variables which could be influential in explaining the walking behaviour of the city centre residents. First, pro-walking design features; second, socio-economic circumstances; and third, travel attitude and neighbourhood preferences.

The current statistical analyses have also confirmed that what is equally important is the adequacy of the levels of measurement and disaggregation of the included variables and factors. As a result, data resource(s) obtained by household/individual-level travel surveys with adequate and sufficient travel behaviour variables and factors are needed for two reasons. The first is related to the general purpose of the current chapter; that is, to obtain better understanding of the determinants influencing walking frequency of city centre dwellers. Whereas the second reason speaks to the main objectives of the whole study and the relevant research questions; which is, in general, to explore the travel behaviour of city centre residents and then the potential determinants behind that behaviour.

8. Adequacy of the TRICS database: Regarding the adequacy of the TRICS 2012a dataset, TRICS is a database and system for conducting trip generation analysis. Therefore and according to the results of this chapter, the use of TRICS for travel behaviour modelling in general and in a specific location such as city centres in particular has been found problematic for three main reasons. Firstly, levels and scales of measurements, while travel behaviour analyses are usually conducted in a disaggregate level (household or individual), most of the variables in TRICS were measured in a site level (aggregate level) and some in a census-tract level. This will mask the variation between households or individuals. Equally important, the existence of some important indicators which are in nominal rather than ordinal or interval scale may, as the analyses proved, make some key parameters becoming inconsequential. Secondly, with the exception of car ownership, the Trics2012a database lacks socio-economic variables. Moreover, there is no existence of any attitudinal factors. The literature review carried out for the current study has highlighted the importance of including them in travel behaviour models and hence it was planned to consider them.

Thirdly, as TRICS was originally designed for trip generation analysis purposes, the information regarding developing travel models for other aspects of people's travel behaviour such as car availability or mode choice is limited whereas data about trip distance, journey duration or journey type does not exist. The development of such models for city centre residents addresses the major objectives of this research. Hence, the deficiency in Trics2012a in coping with the remaining research objectives due to issues regarding the diversity and adequacy of the required dataset makes it inevitable to look for an alternative travel dataset.

5.6 Summary

The strategic purpose of this chapter has been to provide an empirical-based justification for the statistical modelling of the city centre resident's travel behaviour which has been conducted in the next two chapters. In so doing, two objectives have been set to be achieved by the statistical analysis using the Trics2012a. The first objective is to explore what is the package of spatial, personal and travel features that would noticeably vary between residential neighbourhoods with different site locations. Identifying the distinctive characteristic for each location type has enabled qualitative-based conclusions to be drawn about the prevailing travel characteristics in each main location and the corresponding typical neighbourhood characteristics. Exploratory statistical analyses (mainly descriptive) have been employed to achieve this objective. The available travel behaviour aspects were trip rate and travel mode; whereas the locations adequate for analysis in the TRICS 2012a are Town Centre, Edge of Town Centre, Suburban Area and Edge of Town. The analysis results have confirmed that central locations, in particular town centres, have different spatial characteristics from out of centre locations, in particular, edge of town. Similarly, this difference has also been found regarding trip frequency. Households residing in the centre notably walk more and drive less than those living in the edge of town. Furthermore, the prevailing mode of travel in the centre is walking, whereas in the other locations is the vehicle.

On the other hand, the second objective is to answer the research question that if housing developments in different locations do vary in their characteristics and in the trip rates of their residents, then what are the particular neighbourhood features that could explain this variation. What is their statistical significance, their magnitude and their direction of influence? The causal mediation analysis mechanism has been employed using the multiple regression analysis technique and the TRICS 2012a database. The mediation effects have been significantly found in all multimodal travel counts except transit and cyclists. Several neighbourhood features such as flats ratio, transit provisions and parking density helped in explaining the relationship between location and trip rate. For the pedestrian mediation model, the analysis only proved a partial mediation. The town centre coefficient was still statistically significant even after considering the neighbourhood features. This most probably indicates the absence of some influential variables and factors; thus, extra analysis is justified using a more adequate database.

Regarding the adequacy of the TRICS 2012a dataset, TRICS is a database and system for conducting trip generation analysis. Therefore and according to the results of this chapter, the use of TRICS for travel behaviour modelling in general and in a specific location such as city centres in particular has been found problematic for three main reasons: firstly, the aggregate level of most variables; secondly, lack in socio-economic and attitudinal variables. While the third reason is the absence of other travel behaviour indicators such trip distance, journey time and journey purpose. Hence, it is a necessity to find another dataset to consider the remaining objectives of the thesis.

In the next chapter, a dataset extracted from the Scottish Household Survey has been used to study the travel behaviour of people residing in the city centres of Glasgow, Edinburgh and Aberdeen. The travel behaviour analysis generally includes two scenarios. The first is to investigate the personal travel patterns of the residents whilst the second is to determine the spatial features and residents’ personal traits that are most correlated with each travel pattern.

CHAPTER 6: TRAVEL BEHAVIOUR ANALYSIS USING THE SHS DATASET

6.1 General

This chapter examines several aspects of city centre living with particular focus on travel behaviour. The chapter starts with identifying its objectives and the related research questions. In Section 6.3, essential matters about the Scottish Household Survey data set are stated. Such matters include data acquisition, variables and application within the analysis. After that, Section 6.4 is devoted to demonstrating the methodology of this chapter. This includes setting up the conceptual framework and then the corresponding statistical modelling strategy. The key empirical analysis results are listed and discussed in Section 6.5. A summary of these findings with possible policy implications is shown in Section 6.6. Finally, Section 6.7 presents a brief concluding summary.

6.2 Objective and research questions

The overall purpose of this chapter is relatively analogous to that stated in Chapter 5 (TRICS-based analyses) – i.e. enriching the evidence-based findings regarding people's personal mobility in urban centres. However, in Chapter 5, a comparative approach was adopted to examine differences in several characteristics between sites located in city/town centres and others located in out-of-centres areas. In the current chapter, the focus is solely on the urban city centres and their residents' characteristics using households and individuals as the analytical units.

In contrast, the specific purpose is to explore the city living in urban centres and to attempt to understand the transport decisions and patterns of its residents and their propensity towards using sustainable transport options. In line with this purpose, the associated central objectives are:

a- To understand city centre residents' personal mobility by developing travel models that are within the general context of the travel behaviour theory. In so doing, this implies specifying the best set of predictors that significantly associates with the specific mobility measure (response variable). Several travel behaviour measures have been used to quantify people's personal mobility such as car ownership, travel frequency, mode choice and vehicle distance travelled. The specific relevant research questions are: to what extent is the variation in the characteristics of a city centre and its residents related to the variation in a specific mobility indicator? What is the strength and direction of this associative relationship? Moreover, what is its statistical significance? However, to accomplish this primary objective, two relevant secondary objectives should be achieved in the first place:

b- Exploring attributes of the city centres' residents and probing some of the city centre's urban form features. Thereafter, comparing these attributes and features with their corresponding averages over Scotland where appropriate and where such averages are available. Accomplishing this objective might help in answering two research questions. First, what are the main distinctive socioeconomic, demographic and attitudinal traits of people residing in major urban centres? Second, what is remarkable in the city centre spatial features?

c- Identifying the city centre residents' traits and spatial environment features that vary reasonably over their corresponding quantifying variables and factors. This exploration would help in answering the research question about specifying the personal and spatial characteristics that are statistically eligible to be designated within a potential set of predictors for the travel behaviour measures.

6.3 The SHS dataset 2007/2008

6.3.1 Acquiring the SHS city centre sample

The SHS dataset files (as SPSS files) are open to the public and can be accessed using the Economic and Social Data Service (ESDS) website (http://esds.ac.uk). According to this website, the ESDS is a national data archiving and dissemination service which came into operation in January 2003. However, the Scottish Government (the depositor) has specified that registration is required and standard conditions of use apply. The 2007/2008 cycle was the most up to date dataset in time and its latest edition had been released on 02nd June 2010. This dataset was downloaded for use in this study in February 2011. It is worthwhile mentioning that the SHS dataset package consists of six SPSS files: main file, cultural and sports file, journey file, journey stages file, home to work distances file and home to school distances file. The Scottish Household Survey could be considered as a bank of household related variables. For example, the main file, the largest one, of the 2007/2008 cycle dataset contains 2645 variables that describe the living characteristics of 27,238 Scottish households.

After doing the initial exploration of the dataset, unfortunately it was found that the dataset is highly anonymised, in that, there is no geographical identification variable available that differentiates between households located in the city centres of the main four Scottish cities Glasgow, Edinburgh, Aberdeen and Dundee and those households located in other areas.

The Transport Analytical Services (Transport Scotland) was contacted for advice; submitting a special dataset request was recommended. The specific form, called SHS Special Dataset Request Pro-forma, was filled in and submitted to the SHS project manager. A request was made asking for the provision of a variable that states the postcode of each household or a flag variable to discriminate households locating in city centres. Both requests did not work. The first request was refused on privacy and confidential grounds, while the second one due to the complexity of filtering down postcodes to end up with such a flag variable. However, as an offer they highlighted a possibility of doing the second request on condition that the required postcodes would be provided. In response to this offer, contact was made with the planning and regeneration departments (or equivalent units) in the city councils of the four cities (Glasgow, Edinburgh, Aberdeen and Dundee), specifically asking for their help regarding the availability of postcode sector maps of their city centre ward areas and the possibility of providing such maps.

Regarding Glasgow city council, they sent the typical required map. With respect to Aberdeen city council, they sent two files; while the first is the geographical boundary map of the Aberdeen city centre, the second is a huge spreadsheet file including all the unit addresses in the centre. Postcode sectors have been extracted from the addresses. Regarding Edinburgh, the housing and regeneration unit in the city council sent only a boundary map for the city centre without postcodes. To solve this problem, a website called Geoplan (www.geoplan.com) was utilised. For mapping information, this site confirms that they only use the most up-to-date data from Royal Mail and Ordnance Survey. A datasheet, open for public access, of the complete postcode sectors (53 postcodes) in the central area of Edinburgh has been obtained from this website. Thereafter, the Google Maps web service (http:// maps.google.co.uk) in line with the city centre boundary map already obtained from the Edinburgh city council has been used to filter down the 53 postcodes to only 12. In contrast, no reply has been received from the Dundee city council. However, no further action has been taken and it was decided to exclude Dundee city centre from the analysis due to a concern of it being a relatively small town which may not exhibit the sort of characteristics typically observed in other substantial conurbations.

Given that the postcode sectors for the city centres were now ready, the SHS team were contacted again and provided with these postcodes in order to develop a flag variable indicating which households are located in these centres. This request was approved and the flag variable was sent accordingly[11]. The initial exploratory analysis showed that of 27,238 interviewed households, there are only 288 households located in the city centres of the three cities.

6.3.2 SHS variables

The Scottish Household Survey contains a wealth of variables and factors that primarily describe the characteristics of households and secondarily the area where households are located. Nonetheless, in this section only the variables that have been used in the descriptive or predictive analysis have been listed. Overall, these variables have been structured into four groups; socioeconomic and demographic, built environment, attitude and preferences and finally the mobility measures variables. Generally, the variables have been measured at one or more of three disaggregation levels; household, highest income householder or random adult (16 + years).

6.3.2.1 Sociodemographic and socioeconomic attributes

A full list of personal attributes with brief descriptions regarding their measurement and disaggregation level is shown in Table 6-1. Some of these variables (for example, age, economic status, national statistics socioeconomic classification NS-SEC and highest educational qualification) are only available at the individual level (highest income

[11] The whole SHS special data request has taken almost four months.

householder and/or random adult). Others are available at the household level: examples of this are the household working status and the annual household income.

Regarding household type, the SHS classifies the interviewed households according to their size and structure into eight types. These are 'Single adult', 'Small adult', 'Single parent', 'Small family', 'Large family', 'Large adult', 'Older smaller' and 'Single pensioner'. According to Hope (2010) the word ‘single’ refers to one individual households while ‘adult’ refers to the age group which is older than a child but less than the retirement age (16 – 60 Female/65 Male). 'Pensioner' households are based on whether people are of retirement age regardless of their actual economic status. On the other hand, the words ‘parent’ and ‘family’ highlight the presence of children in the household. The household is designated as ‘small’ when there are only two adults; more than two adults means it is ‘large’. An ‘Older Smaller’ household is one with two individuals when at least one of them is of retirement age.

One of the noticeable points in Table 6-1 is the large number of levels (groups) in the categorical variables. For the analyses in this chapter, some of these variables have been re-categorised by either deleting or combining some groups. For instance, while there were originally twelve groups in the economic status variable, these groups have been combined and hence regrouped into eight groups. There are two general reasons for this combining; the first is the very low frequencies in some original categories (such as looking after home/family and at school). The second reason is that some of the groups have little contribution to the global aim and objective of the current study. The same reduction mechanism has been adopted with the educational qualification factor when it is used in the inferential analysis as will be shown later. However, the general rule has been to end up with fewer groups but still generally representing a set of mutually exclusive and collectively exhaustive categories.

Table 6-1: List of the Scottish Household Survey socioeconomic and demographic variables used in the exploratory and inferential analyses.

Variable name	Measurement level		Disaggregation level		
	Num.	Cat.	HH	HIH	RA
Age (in years) 16 – 24, 25 – 34, 35 – 44, 45 – 59, 60 – 74 and 75-plus		√		√	√
Household type Single adult, Small adult, Single parent, Small family, Large family, Large adult Older smaller and Single pensioner		√	√		
Household working status Single working adult, Non-working single, Working couple, Couple, one works and Couple, neither work		√	√		
Annual net household income (£) 0 – 6000, 6001 – 10000, 10001 – 15000, 15001 – 20000, 20001 – 25000, 25001 – 30000, 30001 – 40000 and 40000-plus		√	√		
Economic status Self employed, Full time employment, Part time employment, Looking after home/family, Permanently retired from work, Unemployed and seeking work, At school, Higher/further education Government work or training scheme, Permanently sick or disabled, and Unable to work due to short term illness		√		√	√
NS-SEC (National Statistics Socio-Economical Classification) Higher managerial, administrative and professional occupations Lower managerial, administrative and professional occupations Intermediate occupations Small employers and own account workers Lower supervisory and technical occupations Semi-routine occupations Routine occupations Never worked and long-term unemployed Not classified		√		√	√
Household has access to internet Yes, no		√	√		
Random adult has access to internet at home Yes, no		√			√
Random adult uses internet for grocery shopping Yes, no		√			√

Random adult uses the internet these days No, never use internet Yes, work only Yes, personal use only Yes, both work and personal use		√			√
Highest educational qualification 'O' Grade, Standard grade or equiv (SVQ level 1 or 2) Higher, A level or equivalent (SVQ Level 3) HNC/HND or equivalent (SVQ Level 4) Degree, Professional qualification (Above SVQ Level) Other qualification No qualifications		√			√

6.3.2.2 City Centre Built environment

In spite of the fact that the SHS mainly concerns people's attributes, it contains a limited number of urban form variables and factors. Five of them have been found relevant to the research questions of this thesis; dwelling unit type and tenure, number of dwelling unit bedrooms, bus stop accessibility and frequency of bus services. Table 6-2 lists the mentioned urban form variables along with their type and level of disaggregation.

Table 6-2: List of the SHS urban form variables used in the exploratory and inferential analyses.

Variable name	Measurement level		Disaggregation level		
	Num.	Cat.	HH	HIH	RA
Dwelling unit type House or bungalow, flat, caravan, others		√	√		
Dwelling unit tenure Owner outright, buying with help of loan/mortgage, rent from local authority, rent from housing association or co-operative landlord, rent from private landlord, other		√	√		
Number of unit bedrooms	√		√		
Bus stop accessibility Walking time to the nearest bus stop (in minutes)	√				√
Frequency of local bus services The time headway (in minutes) between two consecutive buses.	√				√

The SHS defines the type of a dwelling unit by four distinct categories; house, flat, caravan or mobile home and other accommodation. In addition, it classifies the residential unit tenure into six categories that mainly speak to how the unit is owned and from where it has been rented. For this study purposes, these two variables has been combined into one factor. This new factor has five distinct categories which are analogous to the TRICS classification. The point is to make the comparison more straightforward. These categories are 'Flats privately owned', 'Flats for rent', 'Houses privately owned', 'Houses for rent' and 'Others'. 'Privately owned' means the unit is either owned or rented from a private landlord, whereas, 'for rent' means the unit is rented from local agency, housing association or any co-operative landlords. While the number of bedrooms variable is essentially continuous, for the descriptive analysis purposes, it has been recoded on a categorical scale. The SHS also provides information regarding the walking time (in minutes) required to reach the nearest bus stop. This data could be seen as quantification of the bus stop accessibility. Finally, the variable representing the frequency of local bus services (in minutes) has also been recoded into categorical for the purposes of descriptive analysis.

6.3.2.3 Attitude and preferences

In the Scottish Household Survey the respondents, specifically random adults, are asked about their preferences, opinions and perceptions towards their neighbourhood and travel options and decisions. However, unfortunately, these stated preference question are normally asked to only part of the survey sample (three-quarters or sometimes even one-half). Hence, most of these attitudinal variables are not eligible for inferential analysis due to small sample size. A list of the available and relevant attitudinal and preference variables that have been included in the analysis can be seen in Table 6-3. Where a variable has been measured on a categorical scale, the associated rating levels are also demonstrated in the table.

Generally, these attitudinal variables can be classified in line with the scope of this research into two main groups. The first incorporates items that ask about the perception of the random adult towards their neighbourhoods. For example, asking about their city centre area as a place to live in and how safe this place is (Hope, 2010). The SHS defines 'neighbourhood' in urban locations as the street the household/individual lives in and the streets nearby (Hope, 2010). The second group of questions attempts to scale the respondents' attitudes about transport-related issues. For example, what issues that drivers might appraise as a problem and to what extent individuals are satisfied with the local transit services (Hope, 2010).

Table 6-3: List of the SHS attitudinal variables used in the exploratory and inferential analyses.

Variable name	Measurement level		Disaggregation level		
	Num.	Cat.	HH	HIH	RA
Thinking now about the neighbourhood you live in, how would you rate it as a place to live? very good, fairly good, fairly poor, very poor		√			√
To what extent would you say you are, or would be, safe from crime when travelling by bus in the evenings? very safe, fairly safe, not particularly safe, not safe at all, don't know		√			√
How safe do you feel walking alone in your neighbourhood after dark? very safe, fairly safe, a bit unsafe, very unsafe, don't know		√			√
Problem recognised by drivers - Too many cars on the road / congestion Yes, no		√			√
Problem recognised by drivers - Petrol prices / cost of fuel Yes, no		√			√
Problem recognised by drivers - Lack of parking spaces Yes, no		√			√
Problem recognised by drivers - Need more lanes/roads Yes, no		√			√
Problem recognised by drivers - Traffic management / speeding measures Yes, no		√			√
How satisfied or dissatisfied are you with the PT services? Very satisfied, Fairly satisfied, Neither satisfied nor dissatisfied, Fairly dissatisfied, Very dissatisfied, No opinion		√			√

6.3.2.4 Travel behaviour indicators

The SHS also provides several personal mobility measures that quantify people's travel behaviour. Whereas only two were measured at the household level, number of cars and bike ownership, all the other indicators were measured at the individual level. Table 6-4 lists the travel behaviour measures that have been used in the statistical analyses conducted for this chapter. Variables with nominal or ordinal measurement have been noted together with their levels.

These mobility measures cover the essential travel aspects that are most frequently investigated in order to understand people's travel patterns and decisions. Examples are; travelling frequency using different modes, car ownership, journey purpose, mode choice, travel duration and journey distance. One of the interesting points that can be noted by Table 6-4 is that most of these indicators are categorical with responses as levels ratings on a Likert-scale. Hence, similar to other categorical variables, most of these indicators have been found to be originally improper for statistical analysis.

Table 6-4: List of the SHS Travel Behaviour indicators used in the exploratory and inferential analyses.

Variable name	Measurement level		Disaggregation level		
	Num.	Cat.	HH	HIH	RA
Total daily trips	√				√
Total daily non-work trips	√				√
Number of household cars	√		√		
Household bike ownership Yes, no		√	√		
Driving licence status A - Currently hold a full driving licence B - Currently hold a provisional licence C - Currently disqualified from driving D - Licence suspended or surrendered on medical grounds E - Never held a UK driving licence F - Did not reapply for licence at age 70 G - Surrendered licence - given up driving		√			√
How often driving a car/van for private purposes every day at least three times a week once or twice a week at least 2 or 3 times a month at least once a month less than once a month Never		√			√
Q2- How often have you used your local bus service in the past month, if at all? Every day Almost every day		√			√

Two or three times per week About once a week About once a fortnight About once a month Not used the local bus service in the previous month		
Q3 - How often have you used a train service in the past month? Every day Almost every day Two or three times per week About once a week About once a fortnight About once a month Not used the train in the previous month	√	√
Q4 - How often, if ever, do you travel by bus in the evenings these days, say between 7pm and 10pm? Most days At least once a week, At least once a month Less than once a month Never	√	√
Q5- How often do you use Public transport? More than once a week About once a week About once a fortnight About once a month About 2-3 times a year About once a year Less than once a year	√	√
Walking (at least 30 minutes for recreational purposes) during the last four weeks. Yes, no	√	√
Cycling (at least 30 minutes for recreational or health purposes) during the last four weeks. Yes, no	√	√
How often use the following different service: Post office, Cash machine or ATM, Banking services, Doctor's surgery, Small amount of grocery or food shopping, Pharmacist, Hospital Outpatients department, Petrol station, Dentist. more than once a week about once a week about once a fortnight about once a month about 2-3 times a year about once a year less than once a year don't know	√	√

What mode of transport is normally used for most of the journeys? Walking, Driver Car/Van, Passenger Car/Van, Motorcycle/ Moped, Bicycle, School Bus, Works Bus, Ordinary (Service) Bus, Taxi/Minicab, Rail, Underground, Ferry, Aeroplane, Horse-riding, Other.		√	√
How do you usually travel to work (or school/ college/university)? Responses are as above.		√	√
Main mode of RA based on travel diary: Main mode of journey. Responses are as above.		√	√
Journey purposes place of work in course of work educational establishment shopping visit hospital or other health other personal business visiting friends or relatives eating/drinking alone or at work eating/drinking other occasions entertainment/other public activities participating in sport coming/going on holiday day trip other not coded escort (home, work, education, shops and personal) go home just go for a walk		√	√
Journey duration (in minutes)	√		√
Journey distance (in kms)	√		√

In most cases, this is due to the presence of one or more levels with low or zero frequencies. Re-coding such variables by omitting or combining some of their levels are the main statistical treatment employed in this chapter. For instance, the main transport mode variable in the travel diary part contains fifteen levels as responses (see Table 6-4). For the descriptive analysis, these levels have been reduced to eight. Similarly, the responses of the journey purpose indicator have been filtered down from twenty-three categories to eleven. On the other hand, some variables such as journey duration and journey distance have been transformed from continuous to categorical for descriptive analysis purposes.

6.3.3 Methodological SHS specific issues

As stated previously, out of 27,238 Scottish households that have been interviewed in the 2007/2008 SHS cycle only 288 households have been found located in the city centres. Of those 288 households, 166 random adults have completed the travel diary part. The discrepancy between the number of households and the number of completed travel diaries is because just over half of the random adults have made a trip on the previous day.

Given that the SHS defines a journey as a one-way course of travel having a single main purpose, the SHS recognises three main types of journeys: single stage journey, multi-stage journey and series of calls. A single stage journey is a journey that involves one mode of travel. A multi-stage journey is a journey that involves more than one form of transport. Series of calls is addressed when a journey involves several stops but for the same main purpose and using the same mode; shopping and travel in course of work are the typical examples. According to the SHS 07/08 Journey dataset file, people residing in the city centres have made 472 journeys; 469 (99.4%) of them are single stage journeys, three of them are multi-stage journeys (0.6%), and no series of calls journeys are observed. Therefore, the travel analyses in this chapter have based on the single-stage journey as the analytical unit. The definition of the main mode as the one used for the longest (in distance) part of the trip have been applied when analysing the multi-stage journeys.

There are two fundamental issues typically associated with major and large surveys such as the Scottish Household Survey; sampling method and response rate. The wide scope of the SHS makes the adoption of the stratified and clustered sampling methods such a reasonable choice. According to Hope (2010), the stratification has been adopted to ensure that each geographical area (such as the local authority) has an adequate number of interviews in each survey period. In contrast, to maximise the cost-effectiveness of survey fieldwork, an unclustered design has been used for urban areas and a clustered one for rural areas. On the other hand, the relatively long and comprehensive questionnaire (target of 45 minutes interview time using the CAPI technique) made the non-response rate a tangible issue. For these two fundamental issues, the weighting technique was appraised as a necessity.

The weighting technique has been employed and recommended in the SHS methodology. Two main types of weighting were found important according to the breadth and depth of the SHS. While the first is essential to consider the disproportion in the selection probabilities of the individuals and households, the second is aimed to tackle the inequality in response rate. Based on the methodological recommendation mentioned in Hope (2010, p.27) and SHS (2004, p.21), three weighting factors has been considered in the analysis conducted for this chapter. These are household weight (LA_WT), individual weight (IND_WT) and travel diary weight (TRAV_WT). Only one weighting factor should be used for each analysis. The household weighting factor is used when the analysis only contains household or householder variables whereas the individual weight factor is used when there is a combination of household and random adult variables. Finally, the travel diary weight utilised whenever there is a travel diary variable in the conducted analysis (Hope, 2010, p.31).

Finally, whereas journeys made by land, air or water transport within the United Kingdom are all included in the SHS survey, for the purpose and scope of the research conducted for the current study only land transport modes are considered.

6.4 Methodology

In order to address the pre-set objectives of this chapter and their corresponding research questions, a methodological framework have been developed. This framework consists of two essential stages. The first stage starts with identifying the conceptual framework appropriate for achieving the main objective. That is, to create travel models within the context of the general travel behaviour theory. In so doing, this implies specifying the best linear set of predictors that significantly associates with the specific mobility indicator (response variable). The second stage of the methodological framework comprises the statistical approach and techniques required to achieve the pre-set objectives within the defined conceptual framework.

6.4.1 Conceptual framework and model specification

Figure 6-1 schematically demonstrates the general conceptual model adopted for accomplishing the main objective of this chapter. The elliptical shapes in the left-hand side of the model represent the potential factors and variables that are collectively expected to form a combination of sets of predictors. The ellipses on the right-hand side represent the main travel behaviour indicators (outcome) included in the travel modelling analysis. Moreover, the headed arrows show the general hypothesised direction of influence in the relationship linking a specific travel measure as an outcome to a set of personal, spatial and attitudinal characteristics as predictors.

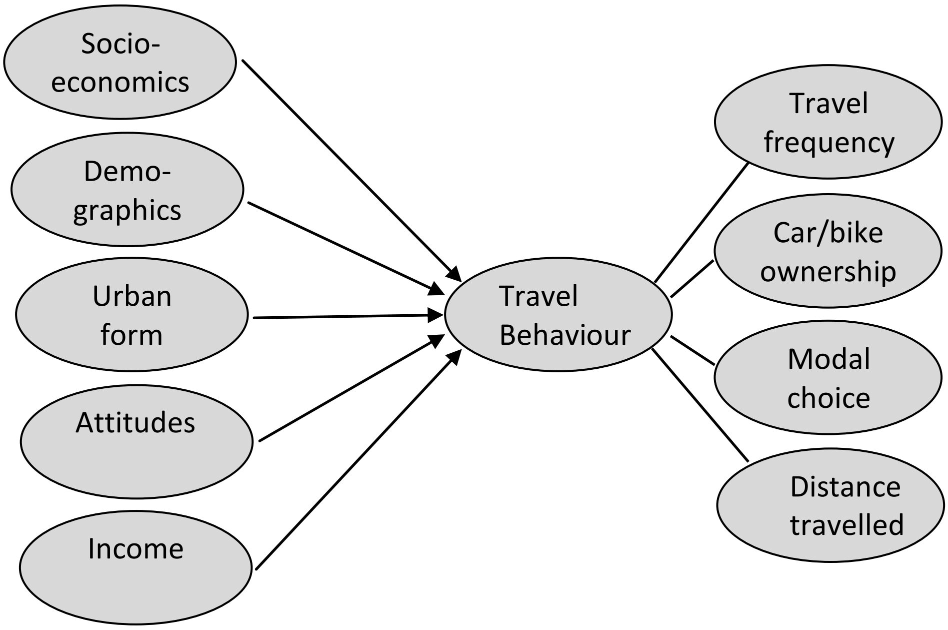

Figure 6-1: The conceptual framework of the travel analysis using the SHS dataset.

The predictors are in general selected based on practical and research grounds. The central practical issue is the availability and hence the eligibility of such a predictor for quantitative statistical analysis. In contrast, the research specific reason is twofold as highlighted in some detail in the methodology chapter under Section 4.2. The first is the availability of literature-based evidence regarding the potential influence of these factors and variables on people's personal mobility. In Section 2.4, substantiation-based findings have been presented with respect to the effects of several personal, spatial and attitudinal variables on an array of travel behaviour measures.

The second reason for considering these predictors is to cope with the overall context of the utility theory as a conceptual approach to travel behaviour modelling. As stated previously, this modelling philosophy of travelling has been publicised in the last quarter of the twentieth century by Domenich & McFadden (1975) and Ben Akiva & Lerman (1985). This behavioural theory is based on the assumption that the demand for travel is derived. Therefore, it implies that travellers maximise their utility by making a balance between their preferences and the associated cost within their resource restriction typically represented quantitatively by their income. In consequence, the inclusion of the personal traits of the traveller is presumed to simulate the preferences (tastes). The income is conceptually separated from others socioeconomics to exclusively reflect the traveller financial resource.

Finally, whereas price variables such as fuel prices and transit fares are not available in the SHS dataset, the urban form variables have been included as a general proxy for mobility restriction and travel cost. Such compensation has been theorised and utilised by several researchers as shown in Section 4.2; including Greenwald and Boarnet (2001), Snellen et al. (2002), Cao et al. (2009b) and Boarnet et al. (2011).

6.4.2 Statistical modelling strategy

6.4.2.1 Exploratory data analysis

Different exploratory data analysis techniques have been employed. Frequency tables, cross-tabulation, percentile analysis and chi-square test are the main methods utilised to explore and describe analysis variables and factors.

The exploration analyses have been conducted for two specific fundamental reasons. The first is statistics-specific, in order to know the available cell-frequencies in each level of the categorical variables. This paves the way towards recoding these variables by excluding/combining levels with no/low frequencies in order to create variables eligible for the subsequent modelling analysis. In contrast, the second reason for exploratory analysis is mainly to achieve the two secondary objectives of this chapter. That is, in the first place to inspect the distinctive city living characteristics in urban centres. Secondly, to aid in recognising the personal and spatial characteristics that are statistically eligible to work as predictors for the travel behaviour measures. In so doing, these characteristics have either to show an evident variation in their levels or to be associated with a wide range of values.

6.4.2.2 Confirmatory data analysis

Depending upon different inferential statistical techniques, confirmatory data analysis has been employed to build several travel models and to test the null hypotheses accompanied by specific research questions.

Overall, all the statistical models developed in this chapter belong directly or indirectly to the universal approach Generalised Lineal Model (GsLM). As stated in Chapter-4 (Section 4.4.3.2), the generalised linear model has an analytical structure capable of analyzing several regression models within a unified framework. This unified framework is achieved by using a link function that ensures the linearity between the response variable and the linear combination of the predictor variables. In this chapter, five statistical regression models that are components of the GsLM package have been employed to develop the required travel behaviour models. These are, ordinary-least-squares (OLS) linear regression, logistic multiple regression, multinomial logit regression, Poisson regression and negative binomial regression. IBM SPSS Statistics (20) has been utilised using the generalised linear model algorithm embedded in it.

Regarding sample size, two thresholds have been adopted. First, the overall sample size should be more than 100 regardless of the number of the estimated parameters and second, the sample should at least contain 10 cases for each estimated parameter (Orme, 2009, p. 20). Furthermore, with respect to the assumption checking and regression diagnostics, relevant details have been stated in Appendix-B. Independence of errors and absence of perfect multicollinearity are the most relevant effective assumptions in the GsLM. These assumptions have been checked and appropriate treatments have been conducted where necessary.

Whereas analysis, results and discussion are presented in Section 6.5, the following sub-sections briefly outline the developed travel behaviour models in line with the type of GsLM-based regression model used and the specific predictors included. Several points deserve to be initially underlined. First, unless otherwise stated, all the inferential analyses are with a 5% level of significance (α). Second, since the income is only available for the total household in an annual level, it has been divided by 6000 to make a one unit change in it (£6000 yearly which is equivalent to £500 monthly) more likely to be reasonably influential on the specific outcome. Investigating the potential impact of a change of £1 in the annual income on people's mobility is far beyond being realistic in addition to being statistically problematic. Third, specific and appropriate weighting factors have been used for each analysis in line with the SHS methodological recommendations.

(A) Travel frequency model

Two travel models have been developed in order to investigate the impact of several indicators on the total daily trips and total daily non-work trips conducted by the random adult. The actual number of trips has been computed based on the information available in the travel diary part for the random adult. Regarding the indicators, the total annual net household income has been included as a proxy to investigate the potential impact of financial status of the adult on the number of trips undertaken. The inclusion of the number of household cars is planned to work as an indicator to probe the impact of car availability/access for the adult on its travel frequency. Other included socioeconomic variables are the work status of the random adult, its highest educational qualification and its marital status. Finally, to know the possible consequences of the availability of the transit infrastructure on people's travel, the time required to walk to the nearest bus stop has been examined. The linear multiple regression technique has been utilised to develop these models with the ordinary least square (OLS) method to estimate the regression parameters. The bootstrap algorithm has been adopted to treat the violation of assumptions of normality and homogeneity in variance.

(B) Car and bike ownership models

The household propensities of possessing a car and a bike have been modelled in two separated travel behaviour models. The indicators are household size, number of children, householder economic status, household annual income and household internet access status. The householder economic status has been recoded into three groups (non-economically active, in education and in employment). The non-economically active group includes householders who are looking after home, retired, unemployed and seeking work, disabled, and unable to work. The in-employment group comprises the householders who are self-employed and those who are in full/part time employment. The internet access factor differentiates households with internet access from those without access. The outcome for both the car and bike ownership models is a binary (dichotomous) variable. That is, it contains only two responses; for example without car/with at least one car. In consequence, the generalised linear model algorithm has been specified by choosing the binomial as the probability distribution, logit as the link function and maximum likelihood as the parameter estimation method.

It is worthwhile recalling here what has been mentioned in Appendix-B regarding the interpretation of the analysis outputs of the logit regression. The linearity is only attained between the logit (ln(odds)) of the outcome variable and the predictors. No such linearity exists between the probability of occurrence of the outcome (for instance owning a car) and the linear predictor. Hence, it is a common practice to interpret the regression results in terms of the odds ratio (exp(b)). The value of the odds ratio of a specific predictor quantifies the change in the odds of owning a car/bike corresponding to a one-unit increase in that predictor. When the odds ratio of owning is positive for a certain predictor, this implies a one-unit rise in that predictor is associated with a rise in the probability of owning. The higher the odds-ratio, the higher is this probability. This association is, however, not linear.

Therefore, it has been a common practice in the travel studies that use discrete choice modelling with 'logit' link functions to interpret the modelling results specifically (with numbers) in terms of the odds ratios and/or generally in terms of the overall change in the probability. Both these approaches of interpreting the analysis results are adopted in the models developed in this work; (Böcker, Prillwitz, & Dijst, 2012; Buehler, 2011; Schwanen & Mokhtarian, 2005b; Vega & Reynolds-Feighan, 2008).

(C) Mode choice model

The propensity of the city centre individuals for choosing a specific means of road transport for working or education trips has been estimated. In the SHS, the random adults are asked to state how they usually travel to work/education. Whereas there are initially fourteen available modal responses, for the analysis purposes of this chapter they have been re-coded into only three essential categories. These new categories are travelling by a car, land public transport or active transport. Travelling by a car includes car/van driver, car/van passenger and taxi/minicab. Travelling by public transport includes school bus, work bus, ordinary (service) bus, rail and underground. Walking and bicycle comprises the active transport category. Other modes such as ferry, aeroplane and horse-riding have been excluded due to either zero or too low frequencies.

Four predictors have been selected to investigate their expected impact on the mode choice behaviour of the random adults in the city centre. These are annual household income, household car ownership, satisfaction level of the adult with the local transit services and finally the distance between adult's place of residence and its workplace (in km). The selection of predictors is generally based on the conceptual model of the utility theory in travel behaviour stated in Chapter 4. That is, it is assumed that people usually travel utilising the mode that maximizes utility and minimizes the disutility of travel. In addition, the availability of literature-based evidence has been the second criteria for choosing the predictors, specifically attitudinal ones.

The reasons for the inclusion of the income is twofold; first, to reflect the financial circumstance of the adult. The second is to be as a proxy for other income-related socioeconomics such as working status, occupational classification and post-school educational qualification. The reason behind not including such variables explicitly is the intention to meet the statistical requirement concerning cases-predictors ratio highlighted earlier in this section. The available non-weighted sample size for analysis is 119 city centre residents.

The inclusion of the household car ownership is to simulate the car mobility constraint of the random adult. Investigating the influence of the satisfaction with public transport could reflect the impact of the individual's attitude and perception on the propensity of choosing a mode. Furthermore, the travel distance has been incorporated in the model as a typical substitution to the missing travel cost indicator. The inclusion of travel distance in mode choice models is recognised in the literature; see for instance, Buehler (2011) and Czado and Prokopenko (2008). Statistically speaking, the outcome variable (modal choices) is discrete with three levels – car, transit and active transport. Hence, the generalised linear model has been employed to estimate the multinomial logit regression model. In so doing, the GsLM has been specified by choosing multinomial as the probability distribution, cumulative logit as the link function and maximum likelihood as the parameter estimation method.

As stated in Appendix-B, one of the unique and important assumptions that is specific to the multinomial logit model is the independence of irrelevant alternatives (IIA). Briefly and in the context of transport mode choice, the IIA assumption implies that adding a new choice (mode of transport) will not alter the proportions of the people's likelihoods of choosing the initial choices (Hausman & McFadden, 1984, p. 1220). For the current analysis, the adopted Small-Hsiao test is utilised to examine whether the multinomial logit model is appropriate and that the IIA assumption holds[12].

(D) Public transport use model

The frequencies of using local buses and local trains by the random adult within the last month have been estimated using two separate regression models. The potential impacts of nine personal, spatial and attitudinal predictors have been investigated. The personal predictors include one sociodemographic and four socioeconomic traits; these are random

[12] SPSS does not include this test; hence, the statistical package STATA (v.11) has been employed.

adult marital status, working status of the random adult, its highest educational qualification, number of cars owning by the household of the random adult and the annual net household income.

The two spatial environment factors included are specific to the transit provision and service. The first quantifies the headway of local bus services (in minutes) whereas the second quantifies public transport accessibility by classifying the walking time required to reach the nearest local bus stop into two groups. The first group comprises the bus stops that are within three minutes walking time from the random adult's residence while the second include bus stops with more than three minutes walking time. Furthermore, two attitudinal variables have been included in the model; the first is to scale the satisfaction of random adult with the public transport. The second is to scale its perception regarding the safety of travelling by bus in the evening.

With respect to the adopted statistical model, it is useful to recall that the outcome variable is a non-negative integer that represents the frequency of occurrence (incidence rate) of an event within a specific time. The event is the use of local bus or train and the specific time is within the previous month. Having mentioned that, the Poisson regression is the initial adequate choice. In so doing, the generalised linear model is specified by selecting Poisson as the probability distribution, log as the link function and maximum likelihood as the parameter estimation method.

It is imperative to mention that Poisson regression has a quite strict assumption in that the mean of the dependent variable should equal its variance. Based on the literature, the assumption is often not held. In consequence, the more general similar model, negative binomial regression, is typically utilised to solve this problem since it relaxes this assumption. Identifying the negative binomial model is quite similar to the Poisson model with except that the probability distribution is negative binomial instead of Poisson. For the current chapter analysis, the preliminary computations showed that the Poisson's model assumption is violated and there is trace of over-dispersion. Thus, the negative binomial model has been adopted.

(E) Vehicle kilometres travelled model

The vehicle kilometres travelled (VKT) is typically seen as a travel behaviour measure that quantifies the daily mobility of people. In the current analysis, the daily vehicle kilometres travelled by a random adult using motorised transport, specifically car, truck and public transport, has been computed. Using the travel diary information, the VKT for each individual is computed as the sum of products of number of daily trips taken by the individual using a specific motorised mode by the distance travelled using that mode.

The analysis carried out in this chapter shows that about 95% of journeys are less than 50 km in length (as will be shown in Table 6-22 later). Based on this and the statistical criteria for outliers, a threshold is set in that journeys with more than 50 km travel distance have been excluded from the analysis. It is worthwhile highlighting that in the 2011 GB National Travel Survey (Taylor., Humphrey., Pickering., & Tipping., 2012, p.46) long distance journey is define as a trip of 50 miles or more in one direction and with a single main purpose.

Seven explanatory variables have been incorporated in the model in order to examine their influence on the adult's vehicle kilometres travelled. Two of them are sociodemographic; these are gender and marital status. The marital status has been recoded into three levels; single, cohabiting and separated or divorced. In contrast, five of the explanatory variables are socioeconomic; these are number of household cars, household annual income, adult working status, whether the adult uses the internet for work or personal use and last but not least the highest educational qualification of the traveller.

Multiple linear regression has been employed to construct the vehicle kilometres travelled model. The SPSS bootstrap procedure has been used as a treatment for violation in the assumptions regarding residual normality and homogeneity in variances.

6.5 Analysis results and discussion

This section is devoted to displaying the main statistical analysis results in addition to providing a discussion on the interesting findings. The results and discussion of the exploratory analyses are listed under Section 6.5.1; the results and discussion of the confirmatory data analyses (travel models) are shown in Section 6.5.2.

6.5.1 Exploratory analysis

The descriptive analysis of the SHS dataset has been structured to cover three main aspects of the city centre living. These are; attributes of the city centre dwellers, city centre built environment and travel characteristics of city centre dwellers. The basic reasons are firstly to cope with the scope of the relevant research questions and secondly for the reader convenience.

6.5.1.1 Attributes of urban centre residents

(A) Socio-demographics

1) Household adult age

Figure 6-2 displays the proportional distribution of age bands for both the highest income householder (HIH) and the random adult (RA). Two main points could be highlighted; first, the percentage of individuals within a specific age band is quite similar for the householder and the random adult. Second, householders and individuals also have similar decreasing trend. Furthermore, they both show a significant drop in the percentage of people after age 34 years. About 70% of the city centre individuals in the SHS sample are young with combined age band of (16 – 34) years. It is worthwhile mentioning that, according to the Scotland's people report, the corresponding combined age band (16 – 34) in Scotland

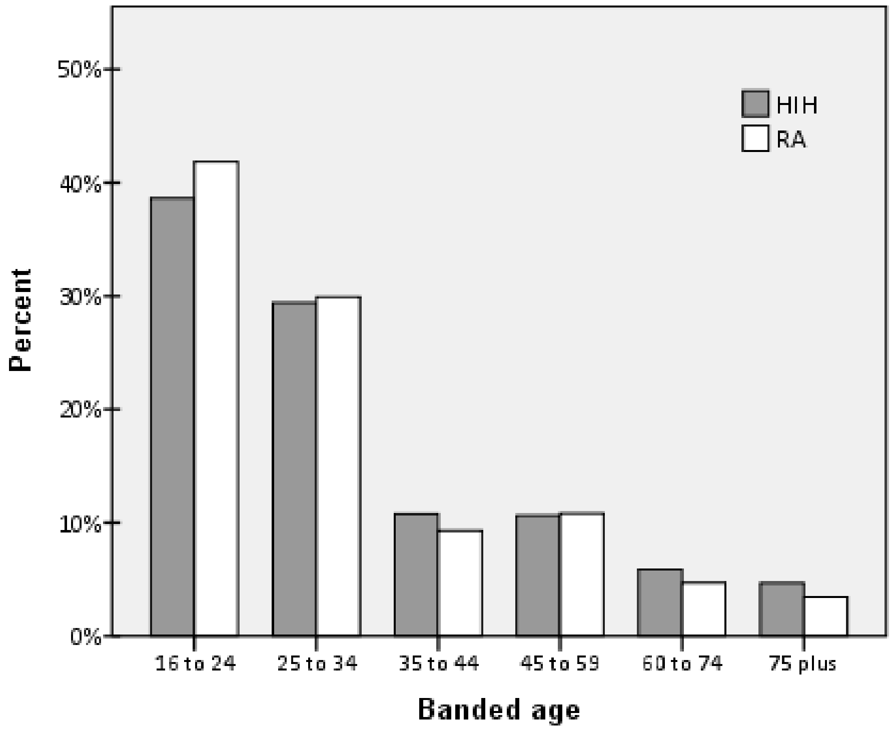

Figure 6-2: Banded age of the interviewed householder and random adult.

comprises only 31% of adults (Scottish Government, 2009a, p. 12). This supports the literature in that city living, specifically urban centres, are more attractive to young people.

2) Household size and composition

According to the SHS city centre sample, the average household size is 1.79 – the total number of residents (515) divided by the total number of households (288). According to the 2011 Census reference tables (Table KS403EW), this is evidently much lower than the England average of 2.4 (ONS, 2012a).

Concerning household structure, Table 6-5 presents the variation in the availability of the eight distinct household types in the city centre weighted sample. The figure states that just over half of households (50.5%) are in the single-person living alone category. This category incorporates both the single adult and single pensioner types. According to the 2011 Census Table KS105EW, this is obviously higher than the equivalent national average over England of 30.3% (ONS, 2012a). Likewise, households with two individuals (small adult and older smaller) form about 29.2% of the total households. Hence, almost 80% of city centre interviewed households are either one or two persons without children. In comparison, the corresponding national Scotland average is only 65% (Scottish Government, 2009a, p. 16). Hence, the evident finding is that urban centres are typically locations where the vast majority of the households are either single person or two people living together.

Table 6-5: Household types in the urban centres according to the SHS dataset.

Household type	Frequency	Percent
Single adult	141	39.6
Small adult	86	24.2
Single parent	5	1.4
Small family	25	6.9
Large family	5	1.3
Large adult	38	10.7
Older smaller	18	5.0
Single pensioner	39	11.0
Total	355	100.0

Moreover, Table 6-5 is agreed with the literature in that urban centres are not such attractive places for families with children; such families are found to form as little as 9.6% while the Scotland average is 24%. Finally, regarding elderly city centre residents, the SHS descriptive analysis shows that 11% are single pensioner households and 5% are two individual households with at least one of them is an elderly person. The corresponding Scotland average for these categories together is 31%.

(B) Socio-economics

1) Annual net household income

The variation in the annual net household income in the city centre sample of the SHS dataset is shown in Table 6-6. The table indicates that almost 80% of the households lie within the (£6001 - £40000). No evident pattern can be noticed. That is probably because the income is measured on the household level and hence household size plays an evident rule in the absence of such pattern. Another possible reason is that the presence of students as dwellers in urban centres might balance to some extent the presence of high-income professionals.

Table 6-6: Percentage variation in the annual net household income.

Annual income band	Frequency	Percent
£0 - £6000	29	8.8
£6001 - £10000	49	14.8
£10001 -£15000	69	20.7
£15001 - £20000	49	14.8
£20001 - £25000	49	14.8
£25001 - £30000	18	5.4
£30001 - £40000	28	8.5
£40001+	40	12.1
Total	331	

2) Household working status

In Figure 6-3, the bar charts represent the percentage of people in each of the five working status groups. It can be shown that households with at least one adult in paid employment represents nearly 65%. The rest are households where the members are either full-time students, retired or not in employment for whatever reason. According to the Scotland's people report, the percentages shown in the figure for the city centre are quite similar to the relevant averages across Scotland.

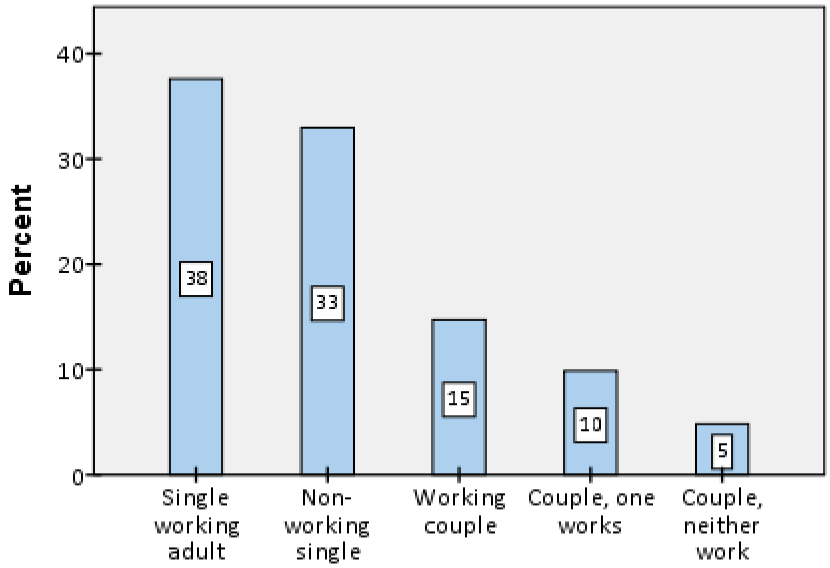

Figure 6-3: Working status of the city centre households.

3) Economic status

As an attempt to investigate the economic situation of the city centre dwellers, the highest income householders and random adults have been clustered according to their economic status (see Figure 6-4). Several findings can be obtained from the figure; first, there is no obvious discrepancy in the proportions between the householder and the adult. Second, for both of them, the vast majority (nearly 85%) are generally either in employment or in education while the rest are non-economically active (unavailable for work) due to different reasons including being retired, unemployed or disabled. In comparison, this is higher than the Scotland average which is 75% (Scottish Government, 2009a, p.44). Another interesting point is that whereas the students in higher/further education comprise about 30% of the adults of the city centre sample, the Scotland average of this group is as low as 7%.

4) Socioeconomic classification

The SHS 2007/2008 uses the national statistics socioeconomic classification (NS-SEC) as one of the approaches of coding occupational status for individuals. This classification discriminates individuals in employment according to their occupation into three essential groups; higher, intermediate and lower occupations. Figure 6-5 demonstrates the percentage distribution of the city centre householders and random adults according to their socioeconomic classification. It states that about 40% of adults and householders are in managerial and professional occupations. This is quite similar to the national average in Scotland. Nevertheless, based on the 2011 UK Census Table KS608EW it is much higher than the average over England of 28.2% (ONS, 2012a). Moreover, it is sensible to mention that the percentage of adults (HIH or RA) with higher occupations in the centre (around 14%) is a little higher than the average (11%) (Scottish Government, 2009a, p.46). This is in agreement with the literature that there is relatively high proportion of high occupational individuals living in urban centres.

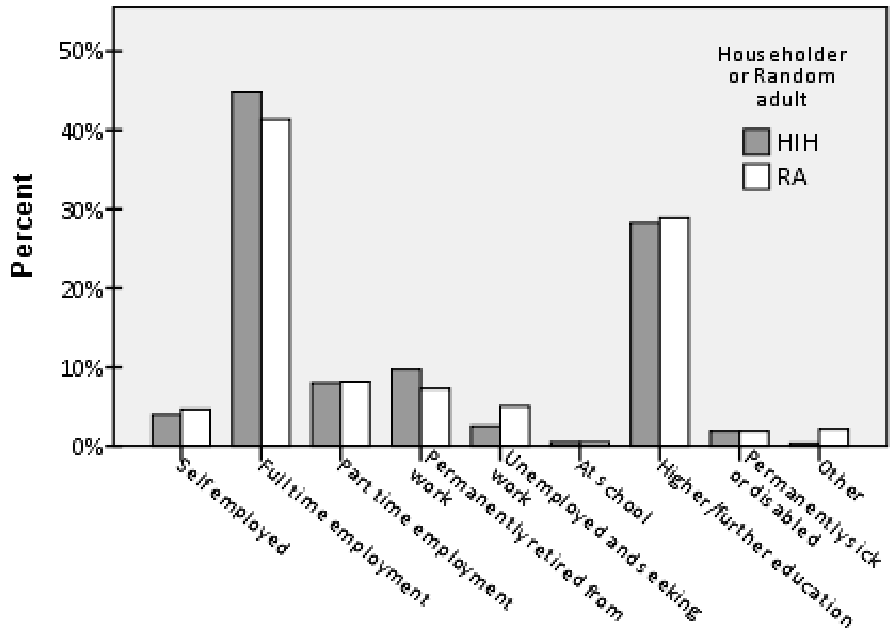

Figure 6-4: Economic status of the interviewed city centre residents.

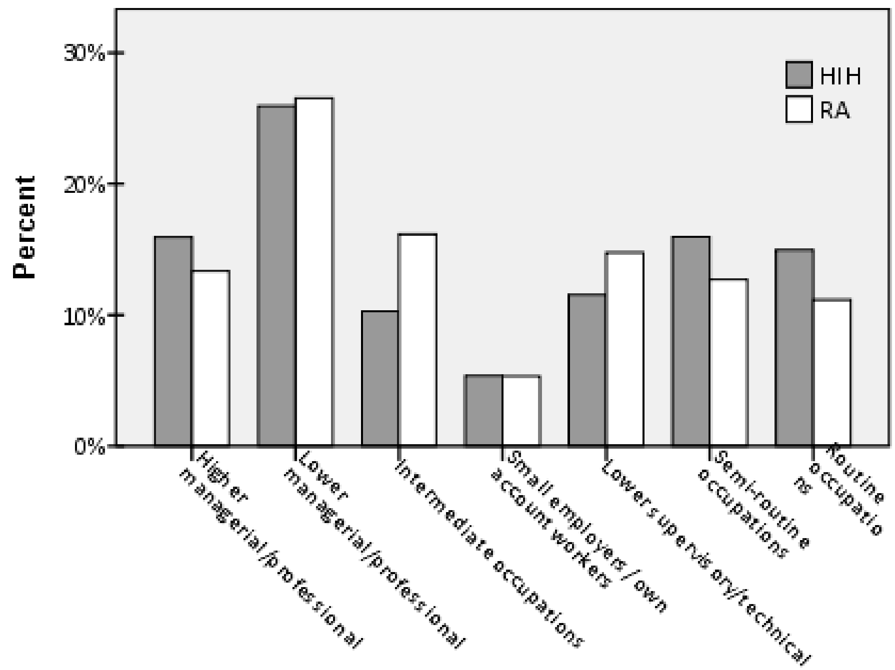

Figure 6-5: The NS-SEC analytic classes for HIH and RD.

5) Internet access and use

Quantifying Indications about the household internet access and about the internet access and use of the random adult are stated in Table 6-7. The overall point based on the tabulation data is that the internet plays an evident role in the city centre people's lives. Nearly two-thirds of the households have access to the worldwide web; this is higher than the Scotland average of 61% (Scottish Government, 2009a, p.97).

Table 6-7: Internet access and use.

Question	Response(s)	Frequency	Percent
Household has access to internet	No	104	34.7
	Yes	196	65.3
Random adult has access to internet at home	No	27	18.9
	Yes	115	81.1
Random adult uses internet for grocery shopping	No	50	57.8
	Yes	36	42.2
Random adult uses the internet these days	No, never use internet	23	11
	Yes, work only	10	5
	Yes, personal use only	57	27
	Yes, both work and personal use	119	57

More than 80% of the random adults can access the net at their place of residence. Furthermore, almost 89% of the city centre random adults have recently utilised the internet for work, personal or both use. Finally, the 11% of the adults who do not use the internet in the city centre sample is obviously low in comparison with the national percentage of Scotland 33.5% (Scottish Government, 2009a, p.93).

6) Educational qualification

Table 6-8 clusters the random adults in proportions according to their highest educational qualification. The highest proportion (41%) represents those individuals who gained a degree or professional qualification (above SVQ level). This percentage is far above the Scotland average 24% (Scottish Government, 2009a, p. 71) or the England one 27.4% (Based on the 2011 Census Table KS501EW (ONS, 2012a). Furthermore, while the national averages in Scotland and England of adults with no qualification are 23% and 22.5% respectively, Table 6-8 states that only 5.8% of such adults are present in the SHS city centre sample.

Table 6-8: Highest educational qualification of the random adult.

Highest educational qualification levels	Frequency	Percent
SVQ level 1 or 2 or equivalent	30	14.2
A-level or equivalent (SVQ Level 3)	40	19.3
SVQ Level 4 or 5 or equivalent	35	16.8
Degree, other above SVQ Level or equivalent	86	40.9
Other qualification	6	3.0
No qualifications	12	5.8
Total	209	100.0

(C) Attitude and preferences

1) Neighbourhood perception

As stated previously, the SHS defines the neighbourhood in urban locations as the street where an individual lives and the streets nearby. The random adults have been asked three attitudinal questions; one is regarding their neighbourhood as a living place and two are relating to the perceived safety when travelling by bus or on foot after dark. Table 6-9 confirms that the vast majority of random adults (97.5%) rate their city centre neighbourhoods as either very good or good places in which to live. This is higher than the Scotland average 92% (Scottish Government, 2009a, p.21). Around 80% have stated that the city centre is generally safe to walk alone or use buses in the evening.

Table 6-9: Perceptions of random adults towards their residential neighbourhoods.

Question	Response(s)	Frequency	Percent
Q1 - RA thinking now about the neighbourhood you live in, how would you rate it as a place to live?	very good	96	45.8
	fairly good	108	51.7
	fairly poor	5	2.2
	very poor	1	.3
Q2- RA To what extent would you say you are, or would be, safe from crime when traveling by bus in the evenings?	very safe	28	21.6
	fairly safe	75	57.2
	not particularly safe	9	6.6
	not safe at all	2	1.4
	don't know	17	13.1
Q3- RA How safe do you feel walking alone in your neighbourhood after dark?	very safe	23	17.8
	fairly safe	83	63.3
	a bit unsafe	21	16.2
	very unsafe	2	1.3
	don’t know	2	1.4

2) Travel attitude

The random adults who currently drive are also asked to state their opinion about several potential driver problems that they face these days. Five hypothetical problems are selected for their relevance to the general scope of the current study. These are, congestion, fuel cost, parking availability, lack of enough roads or narrow roads and negative consequences of speeding measures. Interestingly, overall, none of these aspects has been highlighted to be a problem by most of the respondents.

Table 6-10: Random adults' perceptions towards several hypothetical driver problems.

Driver problem	Response(s)	Frequency	Percent
Too many cars on the road / congestion	No	29	65.3
	Yes	15	34.7
Petrol prices / cost of fuel	No	39	88.2
	Yes	5	11.8
Lack of parking spaces	No	33	74.3
	Yes	11	25.7
Need more lanes/roads	No	44	98.1
	Yes	1	1.9
Traffic management / speeding measures	No	43	97.7
	Yes	1	2.3

Additionally, the random adults have been asked to express their satisfaction towards local public transport services. Table 6-11 shows that about three-quarters of the respondents are generally satisfied with transit services in their city centre areas.

Table 6-11: Random adults' satisfaction with local public transport services.

Question	Response(s)	Frequency	Percent
how satisfied or dissatisfied are you with the PT services?	Very satisfied	37	22.6
	Fairly satisfied	86	52.1
	Neither satisfied nor dissatisfied	18	10.6
	Fairly dissatisfied	13	7.6
	Very dissatisfied	3	1.8
	No opinion	9	5.2

6.5.1.2 City Centre Built environment

(A) Dwelling unit type and tenure

A hybrid factor has been created to reflect the housing unit's type and tenure of the households located in urban centres. Table 6-12 shows that flats comprise just over 87% of the housing units in urban centres. Moreover, the private housing market, i.e. units privately owned or rented, covers almost 78%. These findings are consistent with the results previously obtained using TRICS 2012 in Chapter 5.

Table 6-12: Housing unit type and tenure in the city centre sample.

Unit type	Frequency	Percent
Flats privately owned	243	68.3
Flats for rent	68	19.0
Houses privately owned	34	9.5
Houses for rent	2	.6
Others	9	2.6
Total	355	100.0

(B) Dwelling unit bedrooms

Table 6-13 categorises the dwelling units in the city centre according to their number of bedrooms. The table shows that 77% of units are with one or two bedrooms. In other words, the average number of bedrooms per household is 1.95 (total weighted bedrooms (696)/total weighted households (355)). This average is quite below the England and Wales average (2.7) (ONS, 2012b, p.24). This finding is directly supported in the literature and indirectly supported by the earlier analysis showing that the vast majority of city centre households are either single persons living alone or two cohabiting individuals.

Table 6-13: Percent distribution of dwelling units' bedrooms in the city centre sample.

	Frequency	Percent
1-bedroom	125	35.1
2-bedrooms	150	42.2
3-bedrooms	52	14.5
> 3-bedrooms	29	8.1
Total	355	100.0

(C) Bus stop accessibility

The bus stop accessibility has been quantified in the SHS dataset by asking the random adult to state the walking time to the nearest local bus stop. Table 6-14 lists the number and percentage of bus stops classified according to the walking time required to reach them.

Unsurprisingly, the table confirms that the vast majority (79%) of city centre respondents lives in units that are only within three minutes walking time to the nearest bus stop. In contrast, very few bus stops (1.5%) require a walking time of more than six minutes. This obviously highlights the adequate and dense distribution of bus stops in urban centres.

Table 6-14: Walking time to the nearest bus stop.

	Number	Percent
3 minutes or less	167	78.9
4 - 6 minutes	36	17.0
7 - 13 minutes	2	.9
14 - 26 minutes	1	.6
Don't know	5	2.6
Total	211	100.0

(D) Frequency of bus services

As an indication of the local public transport adequacy, the city centre respondents have been asked to state the frequency of local bus services (in minutes). The responses, as headways, have been extracted and tabulated (see Table 6-15). Approximately half of the respondents have recorded that the time headway between two consecutive buses is between 6 and 15 minutes.

Table 6-15: Percentage variation in the headway of bus services.

	Number	Percent
5 or less	29	14.0
6-10	64	30.6
11-15	42	20.4
16-20	17	8.2
21 or more	11	5.1
Don't know	45	21.8
Total	208	100

6.5.1.3 Travel patterns and characteristics

(A) Household car ownership

The descriptive analysis shows that for the city centre, nearly 55% of the households stated that they do not have a car; 39% are with one car and only 6% with two or more cars. According to the Scotland's people report, the corresponding national Scotland averages are 37%, 40% and 21% respectively (Scottish Government, 2009a, p.79). Similarly, according to the 2011 Census Table KS404EW, the corresponding England averages are 25.8%, 42.2% and 30.2% (ONS, 2012a). This generally highlights the low household car ownership in urban centres.

(B) Household bike ownership

Information about the availability of bicycles for use by adults in the household is also collected in the SHS. The descriptive analysis shows that almost one-third of the city centre interviewed households have highlighted the availability of bike.

(C) Driving licence status

The random adults have been also asked to state their current driving licence status. Figure 6-6 reveals that about 53% of the city centre respondents have a full licence, 8% have a provisional one and 37% have never held a UK driving licence. According to the Scotland's people report (Scottish Government, 2009a, p. 81), the Scotland average of adults with full driving licence is 67% which is clearly higher than the city centre parallel value.

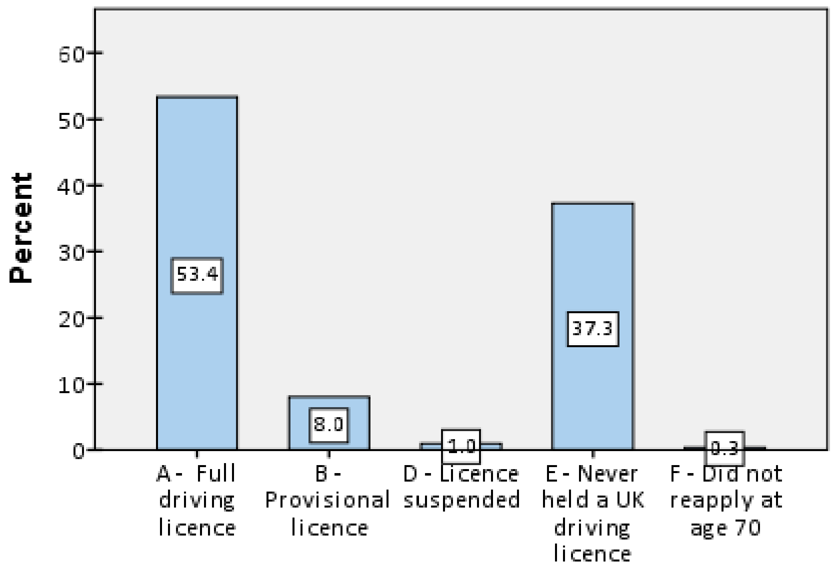

Figure 6-6: Percentage distribution of the current driving licence status.

(D) Travelling frequency

According to the SHS descriptive analysis and based on the travel diary, the mean individual total daily trip rate is 3.29; that is, the total weighted trips (688) divided by the total weighted number of individuals (209). Given that the average household size is 1.79, the mean household total daily trip rate would be 5.88 (3.29*1.79). The random adults also have been asked several questions that can indicate their travel frequency using several modes.

The bars in Figure 6-7 displays how often those random adults, who have a valid driving licence, currently drive a car/van for private purposes. According to the figure, almost 37% of the respondents have stated that their use of the car as driver ranges between three to seven days a week. In contrast, just under the fifth of the respondents have mentioned that nowadays driving a car is not one of their choice set options as a transport mode. It is worthwhile highlighting that while about 80% of the respondents in the city centre have generally stated that they drive a car nowadays, around 36% (28.6/80) of them confirm that they only use the car for a maximum three times a month.

One of the likely reasons is the intensification and walking accessibility in the city centre wards for most of the everyday activities such as shopping and entertaining. Furthermore, for instance, as will be shown later under point H, the analysis results state that about 40% of the workplaces are located within 1.5 km of the travellers' residences.

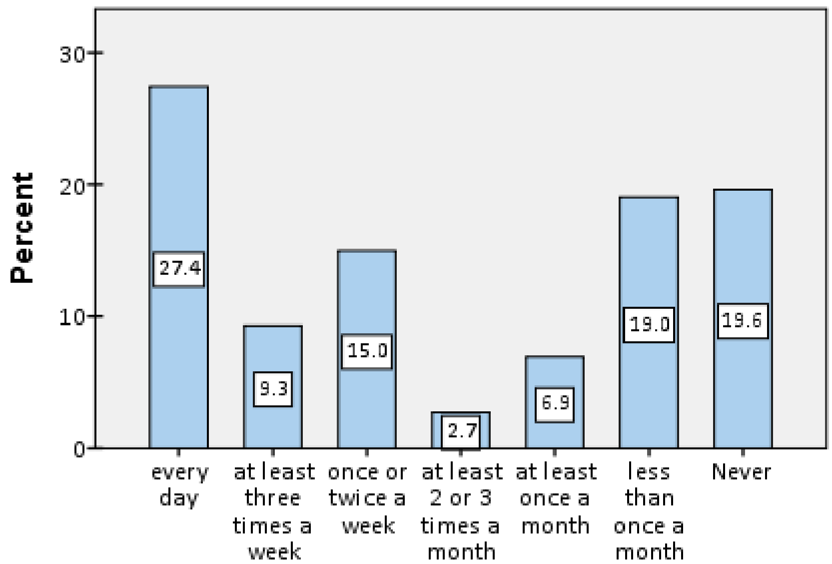

Figure 6-7: Driving frequency pattern of the interviewed city centre residents.

Table 6-16 displays the variation in the travel frequency behaviour for the random adults using public transport services. Several interesting points can be drawn based on the tabulated frequency analysis. First, regarding frequency of using local buses, 40% of adults have stated that they at least used the local bus service once a week in the previous month. Second, regarding the second part of the table which clusters the frequency of random adults using for the local train services[13], almost 75% of adults have stated that either they did not use the train in the previous month or they used it only once. In the third

[13] - According to the SHS questionnaire, this does not include the underground in Glasgow or London.

part of the table, the frequency that random adults travel by bus in the evenings is tabulated. Nearly 84% of random adults have stated that either they did not travel by bus in the evening nowadays or they did so only once during last month. The availability of several leisure and entertaining facilities within convenient walking distance such as cafes, bars and cinemas could be seen as an essential reason for the above high percentage. Furthermore, the travelling frequency of random adults using a local transit service is illustrated in the last part of Table 6-16. Just over half of the city centre respondents (51%) have stated that they use the local public transport at least once a week; in contrast, around 10% stated that they at best use it once a year.

Table 6-16: Travel frequency of the random adults using public transport services.

Question	Response(s)	Frequency	Percent
Q2- How often have you used your local bus service in the past month, if at all?	Every day	13	6.3
	Almost every day	23	11.1
	Two or three times per week	31	15.2
	About once a week	16	8.1
	About once a fortnight	26	12.7
	About once a month	19	9.3
	Not in the previous month	76	37.3
Q3 - How often have you used a train service in the past month?	Every day	1	.6
	Almost every day	3	1.5
	Two or three times per week	11	5.6
	About once a week	11	5.5
	About once a fortnight	25	12.1
	About once a month	33	16.2
	Not in the previous month	119	58.5
Q4 - How often, if ever, do you travel by bus in the evenings these days, say between 7pm and 10pm?	Most days	2	1.2
	At least once a week,	19	14.4
	At least once a month	14	10.6
	Less than once a month	16	11.8
	Never	81	61.3
	Don't know	1	.6
Q5- How often do you use Public transport?	More than once a week	50	36
	About once a week	22	15.5
	About once a fortnight	27	19.4
	About once a month	19	13.5
	About 2-3 times a year	7	4.8
	About once a year	1	0.6
	Less than once a year	13	9.5
	Don’t know	1	0.6

Table 6-17 categorises the random adults responses (yes, no) for the two questions concerning the propensity towards using active transport for at least 30 minutes in the last four weeks. The first question asks respondents to state whether they walked for recreational purposes in the last four weeks. Around 56% of the random adults claimed that they did that. The second question is quite similar to the first one except it is about cycling for recreational and health purposes.

The tabulated results show that almost 9% have recently biked for the above purposes whereas using a bike for such travel purposes does not sound an attractive option for the vast majority of the interviewed random adults.

Table 6-17: Active transport behaviour.

Qs- 6 7 8- In the last four weeks, have you done any of the following sporting activities?	Response(s)	Frequency	Percent
Walking (at least 30 minutes for recreational purposes).	No	61	43.8
	Yes	78	56.2
Cycling (at least 30 minutes for recreational, health purposes).	No	127	91.4
	Yes	12	8.6

Finally and in the same context of exploring the travel frequency of the random adults of the city centre sample in the SHS dataset, Table 6-18 exhibits how often the adult uses several specific city centre services. The table clearly highlights the activities which can be designated as essential for the city centre individuals since they are conducted several times a week. According to the tabulated descriptive analysis, examples of such activities are a small amount of grocery and food shopping, using a cash machine and utilising banking services. In contrast, activities related to the health sector such as visiting a health centre, hospital or pharmacy are not undertaken even on a weekly basis.

The findings presented above could be informative for the local planning policy makers. This is more evident in the context of evaluating the appropriate intervention for promoting sustainable transport options within the overall framework of the urban regeneration process in urban centres. To clarify, the effective policy intervention could be one of more investment in the land use sector in order to assure that high frequency activities are within walking distance from people’s housing units.

Table 6-18: Frequency of random adult to specific city centre services.

How often do you use the following services?		More than once a week	About once a week	About once a fortnight	About once a month	About 2-3 times a year	About once a year	Less than once a year	Don't know
Post office	Freq	4	14	28	47	26	1	16	2
	%	3.1	10.2	20.5	33.6	19	0.5	11.7	1.4
Cash machine	Freq	64	37	10	16	7	1	5	0
	%	46.2	26.6	6.9	11.3	4.7	1.0	3.3	0
Banking services	Freq	31	21	16	41	14	3	11	2
	%	22.1	14.9	11.5	29.4	10	2.5	7.9	1.6
Doctor's surgery	Freq	1	1	4	21	53	23	31	6
	%	0.6	0.6	2.8	15.0	38.2	16.6	22.3	4.1
Grocery/ food shops	Freq	99	30	9	1	0	0	0	0
	%	71.2	21.4	6.7	0.6	0	0	0	0
Chemist/ Pharmacist	Freq	1	8	28	48	25	7	19	2
	%	0.6	6.0	20.1	34.7	17.8	5.4	14	1.4
Hospital	Freq	0	1	2	1	16	10	100	8
	%	0	0.6	1.5	0.8	11.9	7.3	72	6
Petrol station	Freq	4	17	16	6	0	5	75	16
	%	2.8	12.3	11.5	4.2	0	3.7	54.3	11.3
Dentist	Freq	0	0	2	2	73	21	33	9
	%	0	0	1.5	1.1	52.3	14.8	23.9	6.3

(E) Transport mode

In the SHS 2007/2008 cycle dataset, data about the mode of travel adopted by the random adult is collected in three different ways. These ways are illustrated in the three parts of the Table 6-19. The first part generally demonstrates the mode shares usually adopted by the random adults for most of their trips. The analysis submits empirical-based evidence that walking is the prevailing mode of transport in the urban centres according to the SHS dataset. Over half of the respondents (53%) have stated that they usually travel by walking. This is followed by driving a car (20%) and then service bus (18%). For comparison, the corresponding averages over Scotland are 22% for walking, 50% for driving and 9% for service buses (Scottish Government, 2009b, p.22). The second part of Table 6-19 lists the exploratory analysis conducted using the travel diary data. Generally speaking, the results are similar to those in the first part. That is, half of the random adults' trips have been undertaken by walking. In addition, journeys conducted by driving a car are also slightly more than the journeys conducted using public transport (buses and trains). The percentages of journeys made using a bike or motorcycle are trivial; collectively, less than 1%. Furthermore, the table shows that just under one-third of the random adult journeys are by car (driver, passenger, or taxi).

Table 6-19: Mode of travel of the random adult .

Aspect	Response(s)	Frequency	Percent
What mode of transport do you normally use for most of the journeys you make?	Walking	41	52.9
	Driver car/van	16	20.1
	Service bus	14	18.1
	Others*	7	9.1
Modes used for the journeys undertaken by the random adult in the day preceding the interview day (figures extracted from the journey file based on the travel diary data).	Walking	344	50.0
	Driver Car/Van	134	19.5
	Passenger Car/Van	72	10.4
	Taxi/Minicab	13	1.9
	Bus	82	12.0
	Rail and UGround	37	5.4
	Motorcycle/ Moped	1	.2
	Bicycle	4	.6
How do you usually travel to work or education?	Walking	83	50.9
	Driver car/van	28	17.4
	Service bus	37	23
	Others*	14	8.8

* includes bicycle, taxi/minicab, aeroplane, train and underground.

Finally, the third part of Table 6-19 deals with the random adults who are employed, self-employed and in full-time education. It categorises them by their typical mode utilised to travel to work or education (school/ college/university). Likewise, just over half (51%) of the city centre respondents have stated that they commute to work/education by walking. Unlike the results above, public transport seems more attractive than driving a car. More people (23%) have used transit for travelling to their workplace or educational establishment than those who have travelled by driving a car/van (17.4%). The corresponding Scotland-wide percentages are 15% walking, 19% transit and 55% driving a car/van (Scottish Government, 2009a, p. 83). To sum up, the comparative exploratory analysis above obviously highlights the unique mode choice pattern in city centre areas and it generally matches the corresponding analysis previously conducted in Chapter 5 using the TRICS

2012a database (see Section 5.5.1.3(B)). That is walking is the most common mode of travel for the city centre respondents. Moreover, the use of public transport, specifically buses, could compete and be a strong alternative for driving a car.

(F) Journey purposes

As stated previously, the SHS defines the journey purpose as the activity in the place of the trip destination which the traveller is interested in. A specific section is available in the travel diary part of the SHS questionnaire asking people about the purposes of the trips they made on the previous day. Figure 6-8 displays in bar chart style the travel purposes and the percentage of people who have travelled for each purpose. It is worthwhile recalling that in the SHS 2007/2008 cycle dataset the 'go home' category is only used if this is not simply the return leg of a journey (Scottish Household Survey, 2011).

It is obvious from the figure that among travel purposes, work is the most stated travel purpose. Almost one-quarter of the trips carried out by the random adults in the city centre are commuting trips; this is followed by education trips (22%) and then shopping trips (20.4%). In comparison with the relevant averages across Scotland, proportions of commuting and shopping journeys are quite similar. However, the share of education journeys (3%) is considerably lower than its counterpart in the centre (Scottish Government, 2009b, p.11). In addition, Figure 6-8 shows that the social journeys (visiting friends or relatives) alone form 25% (8.3/33.1) of the remaining travel purposes.

With the intention of investigating the common travel mode usually adopted by the city centre respondents for their main daily activities, Table 6-20 crosstabulates the modal shares by several main activities (trip purposes). Travel diary data has been used and the chi-square statistical test has been employed. The modes included are walking, car driver, car passenger, bus, train and other modes. The main purposes included are work, education, shopping, social journeys and others. The Pearson Chi-square statistic is (509.4) and it is significant with p-value of 0.000 at 5% significance level. This indicates the existence of a significant difference between the numbers of trips conducted using different travel modes.The first obvious and interesting point is that among the incorporated travel modes walking includes the highest number of trips for each specific purpose (see the first data column). Secondly, the highest number of trips conducted by driving a car/van are actually working trips while the lowest number are education trips (the second data column). This could highlight the difference in economic status between students and individuals in employment. Another possible reason is the spatial dispersion of the corresponding destinations (more details regarding this point is stated by the percentile analysis carried out in the next subsection 6.5.1.3(G).

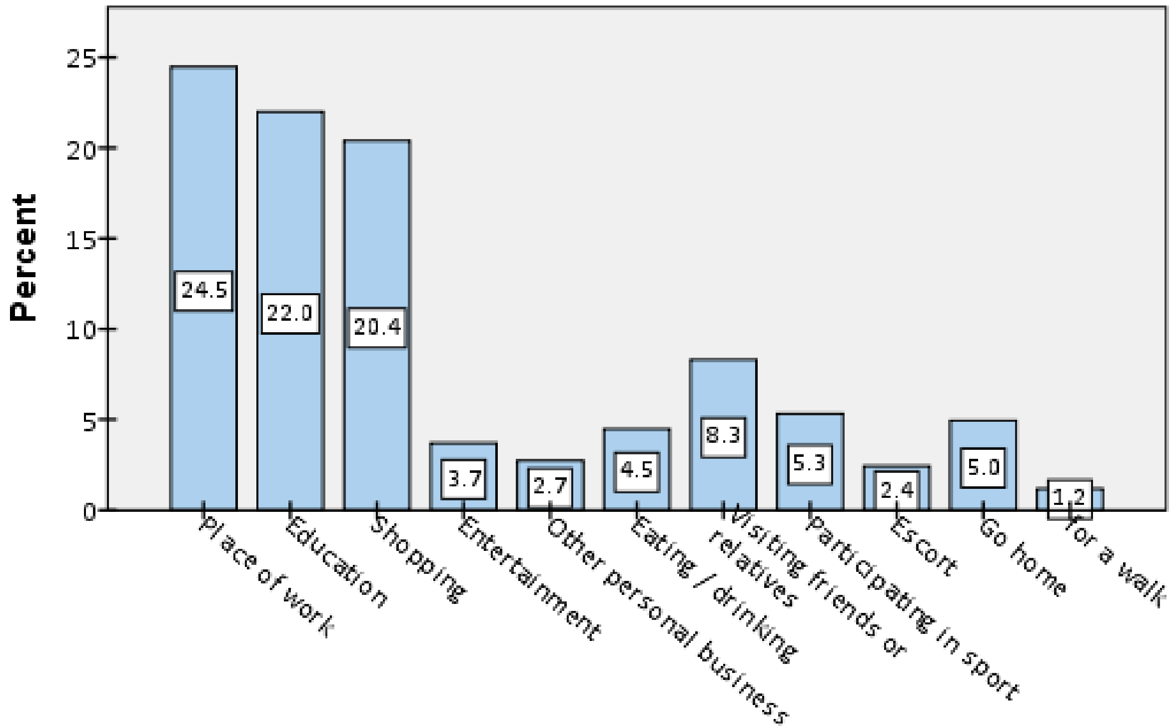

Figure 6-8: The main journey purposes of the interviewed adults.

Table 6-20: Number of journeys conducted by adults crosstabulated according to their mode and purpose.

Journey purpose	Travel mode						Total
	Walking	Driver car/van	Passenger car/van	Bus	Rail/under ground	Others[a]	
Work	59	53	8	25	14	9	168
Education	117	4	5	26	0	0	152
Shopping	87	17	27	10	0	0	141
Social visit	28	17	4	8	0	0	57
Others[b]	52	43	27	13	23	9	167
Total	343	134	71	82	37	18	685

Pearson Chi-square (509.4, 70) with p-value of 0.000 at 5% significance level; weighted N = 685.
[a] include motorcycle/moped, bicycle and taxi/minicab.
[b] include entertainment, eating/drinking, other personal business, escort, going for a walk and go home.

Furthermore, the proportions of commuting, education and shopping journeys undertaken by driving are compared with the corresponding Scotland averages (Scottish Government, 2009b, p. 11) in order to obtain a general understanding of car use behaviour in urban centres. In so doing, the table illustrates that only 31.5% (53/168) of the commuting journeys are undertaken by driving which is about half the Scotland average of around 62% . For education driving journey, while the city centre percentage is as small as 2.6%, the corresponding Scotland average is just under 20%. Finally, for shopping by driving, again the city centre figure (12%) is far below the average (45%). The opposite effect is observed for the same activities but by walking.

(G) Journey length - duration and distance

In order to investigate the variation in journeys according to their length, the journey duration and distance have been utilised from the travel diary data of the random adults. According to the travel diary user guide, the journey duration in minutes is derived from start time and end time of each trip, while the journey distance in km is computed based on the trip origin and destination data as the crow flies (Scottish Household survey, 2011). Table 6-21 displays the journeys conducted by the random adult categorised according to their durations. According to the table, 63.5% of the trips have less than 15 minutes travel time. In addition, almost 5% of the trips are for more than 90 minutes duration.

Table 6-21: The journey durations (in minutes) of city centre respondents

Duration category (in minutes)	Number of trips	Percent
5 or less	125	18.2
6 – 10	159	23.2
11 – 15	152	22.1
16 – 20	62	9.0
21 – 30	77	11.2
31 – 40	30	4.4
41 – 50	21	3.1
51 – 60	15	2.1
61 – 90	14	2.0
90 plus	34	4.9

Similarly, Table 6-22 sorts the random adults' trips by their distances. To examine the spatial distribution of the main activities of the city centre's respondents and hence knowing the geographical extension of their daily mobility, the Percentile statistical technique has been utilised. The percentile (or centile) allows us to calculate the percentage of trips which lie below a specific trip distance. Regardless of the purpose of the journey, the calculations state that while 50% of all journeys are with length of less than 1.5 km, 85% of the journeys have less than 6.25 km travelled distance. Consequently, it is reasonable to conclude that one-half of journeys taken by the respondents, for whatever purpose, are either inside the centre boundary or within the immediate surroundings. Furthermore, providing that 15% of the journeys have travel distances longer than 6.25 km, this indicates that these trips are highly likely to be with destinations located beyond the city of the traveller. As a comparison, while Table 6-22 emphasises that just over 73% of journeys in the city centre are within 3.0 km, the corresponding Scotland average percentage is only 50% (Scottish Government, 2009b, p.10).

Table 6-22: The variation in journey distances for the city centre respondents.

Trip distance category (in km)	Number of trips	Percent
up to 0.5 km	148	21.5
0.5 - 1.0	108	15.8
1.0 - 3.0	248	36.1
3.0 - 5.0	47	6.8
5.0 - 10.0	57	8.3
10.0 - 50.0	44	6.4
more than 50	35	5.1

Likewise, a percentile analysis has also been conducted to explore travel distances crosstabulated by five main travel purposes; work, education, shopping, entertainment and social visits. For work journeys, the analysis results state that about 40% of the workplaces are within 1.5 km of the travellers' residences. On the other hand, 75% of work journeys are less than 7.0 km. Regarding travel for educational establishments, just over 70% of these journeys are with destinations less than 1.5 Km from the traveller's residence. Furthermore, 85% of the education journeys are within 3.0 Km travel distance. This could reasonably justify the high percentage of education trips undertaken on foot as shown in Table 6-20.

With respect to shopping activity, 65% of all the types of shopping trips have been found within 1.5 km. This may reflect the influence of the typical vibrant retail sector in urban centres. Only less than 20% of shopping trips are with destinations located farther than about 2.0 km; beyond the central area.

For entertainment, public activities and day trip travel purposes, while only 30% of the trips are with travel distance up to 1.5 km from the traveller household, 90% of such trips are within 2.5 km. For travelling for social purposes such as visiting a friend or relative, the analysis results confirm that about half of such trips are shorter than 1.7 kms. However, 80% of all the trips for such activities have distance lengths less than 3.75 Km.

6.5.2 Inferential analysis – Travel behaviour analysis

The following sections include the statistical analyses required to build several travel behaviour models. As stated in the methodology section, the generalised linear model is the main statistical approach employed for model specification and estimation. Alternatively, the OLS linear regression analysis has been carried out using the regression procedure in the SPSS software. The reason is simply for convenience, i.e. some of the statistics regarding regression evaluation and diagnostics are not directly available in the GsLM procedure. The travel modelling generally covers five mobility measures. These are, trip frequency, public transport use, vehicle kilometres travelled, car and bike ownership and mode choice.

It is worthwhile indicating that since typically the output of a generalised linear model is comprehensive, only important output statistics have been selected and then presented in a condensed and informative tabulated form.

6.5.2.1 Trips frequency

Using the travel diary part (journey file) of the SHS dataset, the numbers of daily total and non-work trips conducted by the random adult have been computed. Hence, two new variables have been created and prepared as outcomes for the planned travel frequency modelling analyses. The first outcome variable is the total daily trips; the second is the total non-work trips.

(A) Total daily trips

Table 6-23 shows the statistical output for the employed linear regression analysis. The outcome (response) variable is the total daily trips conducted by the random adults in the city centre sample (n = 166 adults). Five predictors have been included in the model in order to examine their potential impact on the trip frequency behaviour. These are, number of household cars, annual household income, working status, educational qualification and the walking time required to reach the nearest bus stop. According to Table 6-23, among these explanatory variables only two are statistically significant – income and bus stop accessibility.

Table 6-23: The multiple linear regression results for the total trips model.

Parameter	B	SE	Sig.	VIF
(Constant)	2.718	.238	.001	
No. of household cars	-.022	.164	.858	1.266
Annual household income (in £6000s)	.049	.030	.034	1.258
RA in paid work? No	0[a]			
RA in paid work? Yes	-.230	.202	.264	1.098
RA education SVQ 1 and 2	0[a]			
RA education SVQ 3 and 4	.337	.227	.145	1.629
RA education above SVQ	.247	.195	.197	1.703
Time to nearest bus stop	-.303	.177	.090	1.014
R^2 / R^2 adjusted	0.054 / 0.018			
ANOVA	0.181			
Durbin-Watson	2.079			
Max. Std. Residuals	< 3.00			

[a] reference category.

While the income predictor is significant at the 5% significance level, the bus accessibility is only significant at 10%. Regarding their effect size (b-values), bus accessibility effect (-0.303) is more pronounced than income one (0.049). However, both of them are with a reasonable direction of influence. The increase in the income of the random adult's household is associated with the increase of total daily trips made by the random adult. As stated in the methodology subsection 6.4.2.2, the annual income has been divided by £6000 to make its variation more sensible. One of the explanations of the positive relationship is that being an adult member in a high-income family, this might enable you to conduct more journeys specifically discretionary ones. In contrast, the negative sign of the bus stop accessibility regression coefficient implies that an increase in the walking time to the bus stop would reduce the total daily trips. Statistically speaking, the coefficient of determination (R-square) is quite small and the ANOVA test implies that the model is not significant (p-value = 0.181). This could be considered as a statistical indication about the absence of other relevant predictors. This is not very surprising given that attempting to model the total daily trips for whatever purpose and using whatever mode is quite complicated. That is simply because of the wide array of potential variables and factors that might affect the outcome.

Finally, other fundamental assumptions of linear regression hold. There is no indication of the presence of a multicollinearity impact; the variance inflation factor (VIF) is within the recommended range (less than 10). In addition, the assumption of independence of errors is also met; the Durbin-Watson statistic is within the recommended range (1.0 – 3.0). Finally, the statistical criteria for outliers are also met and the maximum standardised residual is less than 3.29.

(B) Total daily non-work trips

The regression analysis output for the nonwork daily trips model is shown in Table 6-24. The examined predictors are number of household cars, annual household income, working and marital status of the random adult and bus stop accessibility. Among the predictors only the working status is statistically significant at 5% level of significance (p-value = 0.001) and with quite a strong impact (-1.290). The negative sign implies that random adults in paid work conduct fewer nonwok journeys than those not currently in paid work. One of the expected reasons is the typical lack of spare time for individuals in employment. With regard to the statistical evaluation, it is evident that the overall model is statistically significant (ANOVA p-value = 0.000). Regarding the goodness of fit of the model, the R-square is 0.17. Other statistical indicators are acceptable.

Table 6-24: The multiple linear regression results for the non-work trips model.

Parameter	B	SE	Sig.	VIF
(Constant)	2.817	0.260	0.001	
No of household cars	-0.142	0.213	0.465	1.312
Annual net hh income (in £6000s)	0.046	0.044	0.153	1.381
RA in paid work? Yes	-1.290	0.238	0.001	1.128
RA in paid work? No	0[a]			
RA marital status – cohabiting	0.264	0.295	0.383	1.220
RA marital status – divorced, separated ,....	-0.284	0.278	0.317	1.196
RA marital status – single	0[a]			
Time to nearest bus stop	-0.134	0.216	0.525	1.018
R^2 / R^2 adjusted	0.172 / 0.140			
ANOVA	0.000			
Durbin-Watson	2.291			
Max. Std. Residuals	< 3.00			

[a] reference category.

6.5.2.2 Public transport use

Two travel models have been developed in order to investigate the potential impact of several personal, spatial and attitudinal variables on the random adult's transit use behaviour. As stated in Section 6.4.2.2(D), both models have been modelled by using the negative binomial regression as a special case of the whole procedure of generalised linear model. Details of these models are stated in the following subsections.

(A) Frequency of using local buses

The statistical analysis results for the negative binomial regression are listed in Table 6-25. The response variable is the number of times the random adult used the local buses services during the previous month. Several predictors that quantify the characteristics of the random adult and the city centre neighbourhood have been found statistically significant.

With respect to the socioeconomic attributes of the traveller, the number of household cars and the educational qualification are significant. The table shows that the increase in the number of household cars is associated with the decrease in the monthly rate of using local buses. Specifically, one car increase in the household car ownership status would decrease the monthly rate of random adults of using local buses by a factor of (0.602); i.e. there would be a 40% [100(0.602-1)]. This could be justified as increasing the number of cars in a family would increase the opportunity that this car would be available to be used by the members. In contrast, for the highest educational qualification of the random adult, generally, the results confirm that there is an inverse relationship between the education and the local bus use. Individuals in SVQ level 3 or 4 and those with a degree or a professional qualification use buses less frequently per month than those in SVQ level 1 or 2.

Furthermore, the modelling analysis output also shows that the two included attitudinal variables, feeling safe to use buses in the evening and the satisfaction towards transit, are statistically significant. It is worthwhile recalling that the safety factor rating moves from ‘very safe’ to ‘not safe at all’ while the satisfaction factor rating moves from ‘very satisfied’ to ‘very dissatisfied’. However, while the safety factor is significant at 5% significance level, the satisfaction factor is only significant at 10% level. Both of them have been found to have an inverse influence on the bus use. Moving one level down in the safety factor would decrease the monthly rate of using buses by a factor of (0.476). This finding evidently emphasises that city centre safety is a central issue for its residents especially regarding choosing the mode of travel. Similarly, moving one level down towards transit dissatisfaction would decrease the monthly rate of using it by a factor of 0.826 (i.e. 17.5%). This finding may be an interesting one for the local planning stakeholders in the city centre. That is, investing in improving the reliability, frequency, punctuality and accessibility of public transport would increase the satisfaction and hence the use of local buses.

Table 6-25: The negative binomial regression results for the frequency of using local buses model.

Parameter	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B) Lower	Upper
(Intercept)	5.519	91.794	.000	249.28	80.613	770.881
No. of household cars	-.507	5.450	.020	.602	.393	.922
Annual net hh income (in £6000s)	-.028	.165	.685	.973	.852	1.111
RA in paid work? no	.285	1.756	.185	1.330	.872	2.026
RA in paid work? yes	0[a]	.	.	1	.	.
RA education above SVQ	-.539	3.244	.072	.584	.325	1.049
RA education SVQ 3 and 4	-.830	8.641	.003	.436	.251	.758
RA education SVQ 1 and 2	0[a]	.	.	1	.	.
Bus safety at evening	-.743	24.130	.000	.476	.354	.640
Satisfaction with PT	-.191	3.413	.065	.826	.675	1.012
Frequency of buses	-.073	11.209	.001	.930	.891	.970
Bus stop > 3 min	-.612	8.593	.003	.542	.360	.817
Bus stop <= 3 min	0[a]	.	.	1	.	.

Model likelihood ratio Chi-square (9) = 60.153 with p-value < 0.001.
McFadden’s pseudo R-squared = 0.127

[a] reference category.

Finally, the frequency of local bus services (in minutes) and walking time to the nearest bus stop have also been found with significant effect; both of them are with a p-value of less than 0.01. Increasing the time headway between two successive bus services by 1 minutes is found to reduce the monthly rate of using buses by 7%. In the same context, Table 6-25 also points out that individuals for whom the nearest bus stop is more than three minutes walking time from their homes conduct fewer monthly bus trips by a factor of 0.542 than those where the nearest bus stop is closer to their residences. The last two transit-related features explicitly support what has been highlighted in the previous paragraph regarding the frequency and accessibility of public transport in urban centres. Statistically, the whole model is significant; model likelihood ratio Chi-square is with p-value of less than 0.001. In addition, the McFadden’s pseudo R-squared is 0.127[14].

[14] SPSS does not provide explicit figure for the Pseudo R-squared in GsLM Negative Binomial regression procedure; therefore, Ii has been computed manually using the McFadden’s formula [1 – (log likelihood (model) / log likelihood (null))].

(B) Frequency of using local trains

A second negative binomial regression model has been developed to model the monthly train use of the SHS random adults living in city centres. Table 6-26 demonstrates the main analysis outputs.

Out of the six investigated explanatory variables, four of them are found to be statistically significant at 5% significance level. These are number of household cars, working status, educational qualification and marital status. Firstly, as expected, there is an inverse relationship between the number of vehicles that a household has and the monthly train use by a random adult in that household. One car increase is associated with 0.536 reduction factor in the monthly train use. As stated in the bus use model, the increase in the household car ownership would increase the random adult's access probability of using it.

Table 6-26: The negative binomial regression results for the frequency of using local trains model.

Parameter	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower	Upper
(Intercept)	.475	.787	.375	1.607	.563	4.587
No. of household cars	-.623	4.450	.035	.536	.300	.957
Annual net hh income (in £6000s)	.099	1.302	.254	1.104	.932	1.308
RA in paid work? no	-.891	7.511	.006	.410	.217	.776
RA in paid work? yes	0[a]	.	.	1	.	.
RA education above SVQ	.816	4.469	.035	2.261	1.061	4.817
RA education SVQ 3 and 4	.172	.167	.683	1.187	.521	2.704
RA education SVQ 1 and 2	0[a]	.	.	1	.	.
RA Marital status:						
Divorced, separated, ...	-1.141	4.143	.042	.319	.106	.959
Cohabited	-.180	.171	.679	.835	.355	1.962
Single	0[a]	.	.	1	.	.
Satisfaction with PT	-.084	.350	.554	.920	.697	1.214

Model likelihood ratio Chi-square (8) = 24.528 with p-value = 0.002.
McFadden's pseudo R-squared = 0.158

[a] reference category.

The second influential characteristic is the working status; individuals in employment use the train more than their unemployed counterparts. In numbers, being a random adult not in paid work, this would lead to a 59% decrease in the monthly rate of using local trains. This finding could highlight the working journeys conducted by the city centre residents using trains. Regarding educational qualification, the results emphasise that random adults with a degree or professional qualification travel by train 126% [100(2.261-1)] more than those less educationally qualified. This also could indicate that such individuals are more likely to be in employment and hence this increase in train use is partially due to commuting journeys. The fourth influential predictor is the marital status of the random adults. According to Table 6-26, people who are divorced, separated or widowed are conducting train journeys notably less than those who are singles. In particular, those individuals undertake 68% (exp(b) = 0.319) fewer train journeys than those taken by singles.

Statistically, the whole model is significant and the model likelihood ratio Chi-square is with p-value of 0.002. Additionally, the McFadden's pseudo R-squared is 0.158.

6.5.2.3 Vehicle kilometres travelled

Using the OLS linear regression method, a model has been developed to examine the potential influence of several socioeconomic and demographic variables on the daily vehicle kilometres travelled by the random adult. As stated previously, the total daily motorised mobility includes travelling by car, truck and public transport. Table 6-27 displays the main regression analysis results. Seven indicators have been included in the modelling. Two are regarding the random adult's household - household car ownership and household annual income; and five are regarding the random adult itself- working status, gender, education qualification, marital status and internet use. Of these predictors, car ownership and working status are found to be statistically significant at the 5% significance level (p-values are 0.001 and 0.003 respectively) whereas the Highest level of the educational qualification predictor is found only to be significant at 10% significance level (p-value = 0.069).

The table illustrates that the car ownership status of the adult's household has a considerable and positive impact on the vehicular mobility of random adult. A one unit change towards more household cars is associated with 12.64 increase in the daily vehicle kilometres travelled by the random adult of that household. This implies, generally speaking, increase car availability for city centre residents would increase the car use. For the working status, people in paid work conduct more motorised journeys than those who are not with jobs. This most probably speaks to the proportion of commuting trips undertaken by vehicular modes.

Table 6-27: The multiple linear regression results for the vehicle kilometres travelled model.

Parameter	B	SE	Sig.	VIF
(Constant)	2.544	3.785	.474	
No. of household cars	12.639	3.404	.001	1.335
Annual net hh income (in £6000s)	.100	.904	.883	1.427
RA in paid work? Yes	6.515	2.199	.003	1.130
RA in paid work? No	0[a]			
RA Gender – female	-4.653	2.908	.106	1.059
RA Gender – male	0[a]			
RA education above SVQ	6.448	3.351	.069	1.762
RA education SVQ 3 and 4	2.524	3.014	.401	1.813
RA education SVQ 1 and 2	0[a]			
RA marital status - cohabiting	2.097	4.278	.611	1.320
RA marital status- separated,...	-6.347	4.085	.135	1.290
RA marital status - single	0[a]			
RA uses net (work/personal)? – yes	-3.289	3.468	.314	1.345
RA uses net (work/personal) ?- No	0[a]			
R^2 / R^2 adjusted	0.224 / 0.190			
ANOVA	0.000			
Durbin-Watson	1.831			
Max. Std. Residuals	< 3.29			

[a] reference category.

The third predictor is the educational qualification. The results show that random adults with generally high educational qualification level conduct more vehicular journeys than those in lower or intermediate educational bands.

Statistically, according to the R-square statistic, the predictors have succeeded in explaining almost 22.5% of the variation in the vehicle kilometres travelled. The overall model is significant; that is the null hypothesis that all the regression coefficients (b-values) are zero is rejected at the 5% level of significance (p-value = 0.000). The other main regression assumption statistics are within the recommended limits.

6.5.2.4 Car ownership

Table 6-28 lists the key analysis outputs for the developed household car ownership model. The specific aim is to investigate the likely impacts of several personal characteristics of households (n = 288) on the propensity of owning a car. The attributes included comprise annual household income, householder economic status, household internet access status, household size and number of children. The generalised linear model procedure has been utilised and specified to develop the binary logistic model. Of the potential predictors, only two are statistically significant. Whereas the income variable is significant at the 5% significance level (p-value = 0.000), the internet access status is only significant at the 10% level (p-value = 0.062).

According to Table 6-28, household income is positively associated with the tendency of owning a car. Given that the annual income variable has been divided by £6000, a more specific explanation is that a one-unit increase (i.e. £6000) in the annual income of a household increases the odds of owning a car by a factor of 1.797. In other words, the odds of owning a car are about 80% [(1.797 – 1)*100] higher for a family with a specific income compared to a one with £6000 lower income. This finding evidently indicates the impacts of the household financial status of the tendency of owning a car.

Table 6-28: The binomial logistic regression results for the household car ownership model.

Parameter	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower	Upper
(Intercept)	-2.649	35.575	.000	.071	.030	.169
Annual net hh income (in £6000s)	.586	34.564	.000	1.797	1.478	2.185
HIH econ. status - in emp.	.337	.775	.379	1.401	.661	2.970
HIH econ. status - in edu.	-.577	1.030	.310	.562	.185	1.710
HIH econ. Status- not active	0[a]	.	.	1	.	.
HH net access?-yes	.663	3.475	.062	1.941	.967	3.898
HH net access?-no	0[a]	.	.	1	.	.
Household size	-.016	.008	.930	.984	.691	1.402
Number of children	.514	1.446	.229	1.673	.723	3.868

Model likelihood ratio Chi-square (7) = 127.144 with p-value < 0.001.
R-square: Cox and Snell (0.322) and Nagelkerke (0.430).
Model log likelihood = - 159.52.

Regarding the internet access condition, the statistical analysis confirms that the likelihoods of owning a car are higher for households with access to the internet compared to those who have no such access. That is a difference in the household status from with no internet access to with internet access increases the odds of owning a car by 94%. The economic status of the householder has shown no significant impact of the inclination of possessing a vehicle. That is whether householder is in employment, in education or not economically active due to being for instance retired or disabled does not influence the tendency towards possessing a car. Furthermore, the household size and number of children have also exhibited no notable impact in spite of existing literature-based evidence that indicates such an effect. One of the most likely reasons is the lack of adequate variation in these variables in the city centre neighbourhood. For example, the exploratory analysis has emphasised that almost 80% of city centre interviewed households are either one or two persons without children (see Table 6-5).

Finally, the model evaluation statistics state that the overall model is significant (p-value < 0.001) at the 5% significance level according to the likelihood ratio Chi-square test. Additionally, the model is with R-square of 0.322 according to Cox and Snell and 0.430 according to Nagelkerke.

6.5.2.5 Bike ownership

A statistical model similar to the car ownership one has been developed to model the city centre household owning of a bike. As shown in Table 6-29, similar predictors have been examined. Three socioeconomic variables have been found significant. While household annual income and internet access status are at a 5% significance (p-values are 0.045 and 0.013 respectively), the random adult economic status is only almost significant at 10% (p-value = 0.102).

The income influence is positive; that is a one-unit increase (i.e. £6000) in the annual income of a household increases the probability of owning a bike. In other words, the odds that a household may own a bike are 10.4% higher for a family with a specific yearly income compared to a one with £6000 lower income. This seems to imply that household financial status influences the propensity of possessing a bike. Examining the impact of the householder economic status reveals that households with the householder in employment are associated with the odds of owning a bike that is about 88% [100(1.882-1)] higher than those where householders are not in employment or generally not economically active. Probably this also highlights the influence of the financial status of the city centres households on the likelihood of possessing a bike. The tabulated results also confirm that one level change in the household status from with no internet access to with internet access increases the odds of owning a bike by factor of 2.365.

The statistical typical indicators show that the overall model is significant (p-value < 0.001) at the 5% significance level according to the likelihood ratio Chi-square test. Additionally, the model is with an R-square of 0.100 according to Cox and Snell and 0.139 according to Nagelkerke.

Table 6-29: The binomial logistic regression results for the household bike ownership model.

Parameter	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower	Upper
(Intercept)	-1.96 1	23.247	.000	.141	.063	.312
Annual net hh income (in £6000s)	.099	4.029	.045	1.104	1.002	1.216
HIH econ. status - in emp.	.632	2.673	.102	1.882	.882	4.015
HIH econ. status - in edu.	.190	.149	.699	1.209	.462	3.164
HIH econ. Status- not active	0[a]	.	.	1	.	.
HH net access?-yes	.861	6.231	.013	2.365	1.203	4.648
HH net access?-no	0[a]	.	.	1	.	.
Household size	-.082	.243	.622	.922	.666	1.275
No. of children	.257	.567	.451	1.294	.662	2.528

Model likelihood ratio Chi-square (7) = 33.960 with p-value < 0.001.
R-square: Cox and Snell (0.100) and Nagelkerke (0.139).
Model log likelihood = - 184.99

6.5.2.6 Mode choice

The last developed travel model for the city centre residents in the SHS dataset is the mode choice behaviour logit model. In this model, the choice behaviour of the random adult in selecting the mode for journeys undertaken to work or education is jointly examined. The choice set comprises three modes of transport; active transport (walking and biking), public transport and travelling by car. The potential influence of four predictors has been examined. These are household car ownership, household annual income, satisfaction of random adults towards local public transport, and the distance from the traveller’s place of residence to the place of work/education (in km).

The conceptual choice model has been statistically specified and modelled using the multinomial logit model embedded in the generalised linear model procedure. Table 6-30 displays the main analysis results. In order to assure clarity regarding interpretation and for the convenience of the reader, the analysis results of all the choices have been listed. The upper part of the table shows the results where the reference category is the active transport, while the lower part shows the results where the reference category is travelling by car. According to the table, two predictors are found to be influential in the mode choice behaviour of the random adults – car ownership and travel distance. Two points can be seen in the upper part of Table 6-30; the first is the obvious appearance of the expected alteration in choice behaviour due to the travel distance effect. This effect is statistically significant with p-value of 0.000. That is, when the travel distance to the destination (work/education) increases, the tendency of travellers towards adopting motorised transport rather than active transport notably increases. In particular, one kilometre increase in the travel distance would lead to an increase in the odds of choosing transit compared to active transport by a factor of 2.504.

Table 6-30: The multinomial logit regression results for the mode choice model.

Reference category = Active transport (walking/biking)		B	Wald Chi-square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
						Lower Bound	Upper Bound
By transit	Intercept	-1.901	5.849	.016			
	No. of hh cars	-.726	1.891	.169	.484	.172	1.362
	Annual hh income (in 6000s)	-.126	.811	.368	.882	.670	1.160
	Satisfaction with PT	-.110	.218	.641	.896	.564	1.423
	Distance to work/edu.	.918	29.994	.000	2.504	1.803	3.478
By car	Intercept	-5.630	30.045	.000			
	No. of hh cars	2.557	17.082	.000	12.891	3.835	43.333
	Annual hh income (in 6000s)	-.002	.001	.979	.998	.847	1.175
	Satisfaction with PT	.157	.332	.565	1.170	.685	1.998
	Distance to work/edu.	.909	39.375	.000	2.482	1.787	3.449
Reference category = by car		B	Wald Chi-square	Sig.	Exp(B)	95% CI for Exp(B)	
						Lower Bound	Upper Bound
By transit	Intercept	3.729	15.754	.000			
	No. of hh cars	-3.282	20.798	.000	.038	.009	.154
	Annual hh income (in 6000s)	-.124	.787	.375	.884	.672	1.162
	Satisfaction with PT	-.268	.915	.339	.765	.442	1.324
	Distance to work/edu.	.009	.654	.453	1.009	.986	1.032

Pseudo R-square: Cox and Snell (0.561), Nagelkerke (0.646), McFadden (0.406)
Likelihood ratio Chi-square test (8) = 139.812 with p-value < 0.001.

A very similar effect is also found regarding the relative propensity between travelling by car or walking/biking. The second point covers the impact of the household car ownership status. No significant impact has been found of the number of household cars on the relative tendencies of choosing between public and active transport. In comparison, the analysis results confirm the existence of such significant impact of the selection probabilities between travelling by car and walking/biking. This finding sounds self-evident, in that holding everything else constant, the presence of car boosts the probability of its use.

With respect to the lower part of the table, the same interesting two points highlighted above are revisited. The first is that increasing the number of household cars reduces the likelihood of using transit in favour of travelling by car. This effect is statistically significant with p-value of 0.000. In particular, one car increase in the car ownership status of the random adult's household considerably reduces its odds to use transit instead of travelling by car by 96% [100(1-0.038)]. As stated before, this finding could highlight the strong association between car availability for a random adult and its use.

For the impact of distance, the table shows that there is no significant impact of the distance to work/education on the random adult's selection likelihoods of travelling by car or public transport. This finding sounds reasonable providing that overseas journeys are excluded. It is worthwhile pointing out that one might argue that breaking down the above model to examine the effect of predictors in short, intermediate and long distance journeys would be more appropriate. While the researcher is aware about this point and it was already planned to do that, the relatively small number of observations available made it statistically problematic to take such action. The number of random adults included is 119.

Finally, the statistical typical indicators emphasise the overall model is significant (Chi-square test p-value is less than 0.001) at the 5% significance level. In addition, the model is with pseudo R-squares of 0.561 (Cox and Snell), 0.646 (Nagelkerke) and 0.406 (McFadden).

6.6 Summary of main findings and policy implications

The city centre sample extracted from the Scottish Household Survey (2007/2008 cycle) is the employed dataset for the statistical analyses carried out in this chapter. To gain a better understanding and more objective interpretation, the analysis results for city centres have been compared with the corresponding averages for Scotland where appropriate and where such statistics are available. Having said that, this section highlights the main findings of the exploratory and inferential statistical analyses carried out in order to address the objectives and research questions already set for this chapter.

6.6.1 Exploratory analysis

6.6.1.1 Personal characteristics of residents

The demographics of the city centre residents have been explored. The analysis shows that the majority of city centre adults are young people within the age band of (16-34) years. Moreover, the analysis emphasises that while urban centres are more attractive for households with single persons or childless couples, it is not so for families with children or elderly people. Similarly, the socioeconomic attributes have also been investigated. Based on the analysis outputs, there is a significant proportion of the city centre adult population (about 40%) who are in managerial or professional occupations. Moreover, the percentage of adults with higher occupations is even higher than the average of Scotland. Regarding internet use and access, results indicate that the internet has an obvious role in city living. The proportion of city centre households which have access and use the internet is comparatively higher than the Scotland average. Furthermore, the analysis also demonstrated that individuals with high educational qualifications, such as with a degree or professional qualification, form a recognised segment of residents. In contrast, the percentage of adults with no qualification is relatively small.

6.6.1.2 Travel characteristics of residents

(A) Car ownership

The analysis results confirm that there is a unique pattern regarding car ownership in urban centres. City centre's households have less propensity to have a car. The fraction of city centre households with no car (55%) is considerably higher than the Scotland average (39%). In contrast, the fraction of city centre households with two or more cars (6%) is much lower the average for Scotland 21%). In the same context, the percentage of adults with full driving licence status is smaller than the average.

(B) Travelling frequency

The relevant analysis has revealed two points. First, city centre residents' use of local transit services is considerable. Just over half of the city centre respondents (51%) have stated that they use the local public transport at least once a week; in contrast, around 10% stated that they at best use it once a year.

Second, there are activities that are found to be essential for the city centre individuals in that they are undertaken several times a week. Examples of such activities are a small amount of grocery and food shopping, using a cash machine and utilising banking services. This finding could be interesting in the context of evaluating the appropriate intervention for promoting eco-friendly transport options to cope with the planning policy prospects for sustainable urban regeneration in city centres. To clarify, the effective policy intervention could be more investment in the land use sector in order to assure that high frequency activities are within walking distance from people's housing units.

(C) Mode of travel

The comparative exploratory analysis between city centre percentages of mode shares and the averages in Scotland has revealed three important points. First, the residents of a city centre are typically walking much more and driving much less than their counterparts who living in out of centre locations. Second, walking is the prevailing mode of transport in urban centres regardless of the purpose of travel. Third, the use of public transport in city centres, specifically buses, could compete and be a strong alternative for driving a car. More people have used transit for travelling to their workplace or educational establishment than those who have travelled by driving a car/van.

(D) Travel purpose

The preliminary analysis states that among travel purposes, work is the most stated travel purpose, followed by education and then shopping trips. In comparison with the relevant averages across Scotland, the proportion of education journeys in city centres is found to be notably higher than the average for Scotland.

The empirical results also confirm that the highest number of trips conducted by driving in urban centres is actually for working trips while the lowest number is for education trips. Regarding car use behaviour by different travel activities, the commuting journeys in urban centres undertaken by driving are around half the Scotland average. Similarly, for the education and shopping driving journey, the city centre percentage is much lower than the corresponding Scotland average. This could highlight the difference in economic status between students and other individuals in employment. Another possible reason is the spatial dispersion of the corresponding destinations as shown below in point (E).

(E) Journey length

One of the interesting general findings regarding the spatial distribution of people's activities is that around half of journeys taken by the respondents in urban centres, for whatever purpose, are either inside the centre boundary or within the immediate surroundings. For a comparison, while approximately 73% of journeys in the city centre are within 3.0 km, the corresponding Scotland average percentage is only 50%. To sum up, empirical evidence has been found that promoting the land use diversity could considerably reduce the travelled distances for all the main travel purposes such as commuting, shopping, education and leisure trips.

6.6.2 Inferential analysis

6.6.2.1 Journey frequency

With respect to the total daily journeys conducted by the city centre's adults, the analysis shows that among the potential predictors only two are statistically significant – income and bus stop accessibility. An increase in the income of a random adult's households is associated with an increase in its daily journeys. That is, being an adult member in a high-income family might enable you to conduct more journeys. In contrast, the negative sign of the bus stop accessibility regression coefficient implies that an increase in the walking time to the bus stop would reduce the total daily trips. For the non-work daily journeys, the results imply that adults in paid work conduct fewer non-work journeys than those not currently in paid work. One of the expected reasons is the typical lack of spare time for individuals in employment.

6.6.2.2 Public transport use

Several personal and spatial characteristics have been found influential in modelling the frequency of adults of using local buses and trains in urban centres.

Empirical findings show that the increase in the number of household cars is associated with a decrease in the monthly rate of using local buses and trains alike. This might be because of the fact that the increase in the household car ownership would increase the car access likelihood for the adult. On the topic of educational qualification, the results confirm that adults with a degree or professional qualification use buses less frequently than their counterparts with less educational levels. In contrast, the results also confirm that adults with high educational levels do use local trains more than those in lower levels. One explanation is that individuals with high academic/professional qualifications might consider the symbolic value of trains or simply they may appraise travelling by a train to be more convenient than by bus.

Relating to feeling safe to use buses in the evening is found to have a positive impact on the bus use monthly rate. This finding reveals the importance of the safety issue for a city centre's dwellers and how it could alter their likelihoods of choosing the mode of travel. Likewise, moving one level down towards public transport dissatisfaction would also notably reduce the monthly frequency of use. This finding may be interesting for the local planning stakeholders in the city centre. That is, investing in improving the reliability, frequency, punctuality and accessibility of public transport would increase the satisfaction and hence the use of local buses.

Furthermore, two findings are found clearly to show the importance of the frequency and accessibility of public transport in urban centres on their resident's bus use behaviour. First, increasing the time headway between two successive buses is found to reduce the monthly rate of using buses. Second, equally, individuals for whom the nearest bus stop is more than three minutes walking time from their homes have been found to conduct fewer monthly bus journeys than those where their nearest bus stop is closer.

For local rail use specifically, two traveller traits have been found vital; working status and marital status. Individuals in employment use the train much more than their unemployed counterparts. This finding could indicate the working journeys conducted by the city centre residents using trains. For the marital status of the urban centre's adults, divorced, separated or widowed adults are conducting notably fewer train journeys than those who are single.

6.6.2.3 Vehicle kilometres travelled

Three socioeconomic attributes have shown a tangible affect on vehicle kilometres travelled by the city centre's adults; these are car ownership, working status and educational qualification. The analysis pointed out that the car ownership status of the adults' household positively affects its motorised travelled distance. That is, boosting car access for city centre residents would increase its use of it. In addition, the analysis revealed that employed individuals accomplish more motorised journeys than those who are not in paid jobs. This most probably speaks to the proportion of commuting trips undertaken by vehicular modes. Finally, adults with a generally higher educational qualification level carry out more vehicular journeys than those with intermediate or lower educational levels.

6.6.2.4 Car ownership

According to the SHS dataset, only household income and the internet access status exert significant impact on households' car ownership status. An increase in the annual income of a household is found to be linked to an increase in the likelihood of having a car. This finding plainly reflects the influence of the household financial status on the propensity of owning a car. In contrast, the analysis also confirms that getting a car (or a second one) is much higher for households with an access to the internet compared to those who have no such access.

6.6.2.5 Bike ownership

The estimated logit model implies that income, economic status and internet access status are all found to be positively related with the probability of a household owning a bike. That is, the likelihood that a household may have a bike is higher for a family with a specific yearly income compared to one with a lower one. Additionally, households with a householder in employment are more probable to have a bike. Finally, a change in the household status from with no internet access to with access would increase the likelihoods of owning a bike.

6.6.2.6 Mode choice behaviour

The developed choice model indicates two features that have a tangible influence on the mode choice behaviour of the adults for work/education journeys; these are car ownership and travel distance.

Regarding household car ownership, the quantitative analysis demonstrates that when the number of cars in a city centre household increases, the likelihood of an adult choosing active travel or transit rather than driving decreases. This finding sounds self-evident, in that holding everything else constant, the presence of a car boosts the probability of its use.

Moreover, with regard to the travel distance to work/destination, analysis reveals that when the travel distance to the destination becomes longer, the inclination of adults towards adopting motorised transport rather than active transport notably increases. No analogous influence has been noticed between travelling by car and public transport; this sounds reasonable providing that overseas journeys have been excluded.

6.7 Summary

The central target of this chapter is to investigate the potential determinants that might influence the personal mobility of urban centre's dwellers. Consequently, this would inform planning policy makers regarding the possible effective interventions required to plan and implement a city centre urban renaissance with sustainable transport options.

The Scottish Household Survey (07/08 cycle) dataset has been used and a city centre sample has been extracted. Both descriptive and predictive statistical techniques have been utilised. In particular, the Generalised Linear Model procedure has been mainly employed to develop the required travel behaviour models.

The analysis results indicate the presence of several personal and urban form characteristics that are shaping the panorama of city living. Additionally, the statistical modelling also emphases that there is empirical-based evidence about the link between the travel behaviour of city centre's people and several personal, attitudinal and spatial features.

In the next chapter, Chapter seven, an investigation of the main themes of city living with particular focus on travel behaviour is carried out for the residents of Manchester city centre. Generally, the purpose is twofold; first, while Chapter five includes centres at both the town and city level and Chapter six includes centres solely at the city level, the next chapter is focused on examining a mature and recognised urban city centre. Second, it is a prompt response to the overarching target set by the local planning scheme in the city of Manchester about implementing a sustainable urban regeneration in the city centre. Therefore, the importance of understanding personal mobility of the city centre's residents is central and recognised.

CHAPTER 7: TRAVEL BEHAVIOUR ANALYSIS USING MANCHESTER CITY CENTRE HOUSEHOLD TRAVEL SURVEY DATA

7.1 General

This chapter is comparable to Chapter 6 in terms of objectives, conceptual model and modelling strategy. Nonetheless, it has three distinguishing aspects. First, it exclusively speaks to one of the most recognised urban centres in the United Kingdom; Manchester city centre. Second, the dataset has been obtained by conducting an original household travel survey. Third, the chapter comparatively pays more attention to the impact of people's attitude and preferences.

The chapter starts, after the general introduction, with highlighting the objectives and related research questions (Section 7.2). Thereafter, the importance of researching Manchester city centre and the expected contribution is highlighted in Section 7.3 before a quick review about the urban regeneration of the Manchester city centre is shown in Section 7.4. In section 7.5, the existing knowledge about several features of Manchester city centre living is briefly reviewed. The research methodology is detailed in Section 7.6 in which three major aspects have been thoroughly addressed. These involve the conceptual framework, survey design and methodology and the statistical modelling strategy. The results of the descriptive and inferential statistical analysis have been displayed and discussed in Section 7.7. Thereafter, Section 7.8 has been devoted to cover the summary of the main findings and their expected planning policy implications. Finally, the concluding summary of the chapter has been shown in Section 7.9.

7.2 Objectives and research questions

The ultimate target of local planners and policy makers in Manchester towards its city centre is to deliver and run sustainable regeneration programmes that include the strategic transport aim of creating a minimal ecological footprint. Hence, as an attempt to assist in achieving this target, the overall aim of this chapter is to investigate the living characteristics of Manchester city centre within a travel behaviour perspective. In contrast, a more specific aim is to reach a better understanding of the potential impacts of the personal and spatial living characteristics on the mobility performance of the Manchester city centre residents. In doing so, three relevant objectives similar to those in Chapter 6 can be identified:

a- To develop several travel behaviour models that collectively aid in realizing the mobility patterns of Manchester city centre's residents. Household vehicle ownership, daily and weekly journey frequency for specific activities and mode choice are examples of these models. The typical associated research questions are two; first, how much variation in a specific mobility measure can be accounted for by the urban form characteristics of the Manchester city centre and/or the personal traits of its residents? The second question is, where viable and sensible, what is the relative contribution of spatial, socioeconomics/demographics and attitudinal characteristics per se? The latter research question would help in examining the impacts of people's attitude and preferences on their personal travel options and decisions after controlling for socio-spatial features. However, two related secondary objectives are imperative to be initially addressed in order to manage this primary objective:

b- Examining the personal traits and spatial features of Manchester city centres' residents and its built environment respectively and, where appropriate, evaluating these traits and features with their equivalent rates in Manchester or nationally using the 2011 National Travel Survey results and the 2011 Census findings. Having done this, two research questions could be now tackled. First, what are the main distinctive socioeconomic, demographic and attitudinal traits of people residing in Manchester city centre? Second, and to a lesser extent, what spatial features are notable in Manchester city centre?

c- Determining the Manchester city centre living characteristics, personal or spatial, that are statistically eligible to be utilised as model indicators. In other words, identifying the categorical variables that are with adequate levels and frequencies; similarly, identifying the quantitative variables that are with adequate ranges (variation). This objective could contribute in dealing with the research question concerning specifying the personal and spatial characteristics that are statistically eligible to be designated as the linear predictor in the travel behaviour model.

7.3 Importance of the research and contribution

As stated previously in Chapter 3 (Section 3.6), the focal national planning policy perspective regarding city centres is to activate their urban role by endorsing their viability and vitality. The planning policy has called for city centre regeneration schemes that could satisfy its aspirations and within an adequate sustainability agenda. Manchester City Council has clearly adopted and stated this vision in its 2009-2012 strategic plan for Manchester city centre (Manchester City Council, 2009). The local planning authority has also adequately and evidently addressed these policy issues in the renewal and transport vision for its city centre. In particular, the City Council set their transport strategy in the city centre to support a 'Smarter Choices' agenda to encourage people to change their travel habits to more eco-friendly ones, for instance, the use of travel plans that set targets on travel behaviour (Manchester City Council, 2010a).

Thus, in so doing, the logical first step that should be rigorously tackled is to explore the travel behaviour of Manchester city centre residents and to investigate the potential variables and factors that might trigger the change in that behaviour. Generally, this thesis and, in particular, the survey findings of this chapter could effectively help to inform housing and transport planning policy in addition to the sustainability agenda.

7.4 Manchester city centre regeneration

The reasons and evolution of urban sprawl and urban regeneration in Manchester city centre are not different from those experienced in most of the major city centres in the UK, Europe and to less extent in the rest of industrialised nations. Relevant articles in Chapter 3 are reasonably applicable for the Manchester city centre case. Nevertheless, two points could be worthwhile to be mentioned. The first is that Manchester city is one of the pioneering UK cities in adopting a clear and efficient urban renaissance policy in its centre since the early 1990s (Manchester City Council, 2009). Second, in addition to the conventional strategies in urban centres renewal programmes aiming to attract people to the centre, the officials in Manchester have paid significant effort to the cultural and leisure dimensions in promoting night-time activities. Many concert halls, theatres and restaurants have been produced in addition to a colourful diversity of bars and pubs with a liberal approach to regulations (Allen & Blandy, 2004).

The increase of the city centre population from as low as 250 dwellers in 1988 to about 10,000 in 2002 (Williams, 2003) and to an estimation of nearly 19,000 recently (Manchester City Council, 2009) is a clear evidence of the regeneration policy achievement. According to the 2011 UK Census results, the population of the Manchester city centre ward is 17,861 (Manchester City Council, 2012a), a tangible increase from only 5012 residents in the 2001 Census (Manchester City Council, 2011a).

7.5 Manchester city centre socio-spatial features

The 2011 UK Census provides the best resource for commenting on the current socio-demographic profile for Manchester city centre residents. However, the outputs from the census were not available in time to be included in this thesis. For this reason, information from the 2001 Census is presented, but the reader should treat these with caution as there have been substantial changes in the intervening period. More recent estimates from other authoritative sources have been presented where possible.

7.5.1 Socioeconomics and demographics of city centre residents

7.5.1.1 Age and gender

According to the 2001 UK Census data, the pensionable age proportion of people living in the Manchester city centre is 5.3% (Manchester City Council, 2003b). Likewise, the 2009 mid-year estimation (2009 MYE) of the office of national statistics (ONS, 2011b) stated that the proportion of the more than 65 years people is 4.15%, while the working age and less than 15 years people are about 91% and 4.6% respectively. That is, about 90% are economically active (16 – 59F/64M). With respect to gender, according to the 2001 Census, the male and female percentages at Manchester city centre are 57% and 43% respectively. Likewise, according to the 2009 MYE of the ONS these percentages are 53.5% and 46.5% respectively (ONS, 2011).

7.5.1.2 Household size and structure

According to the 2001 Census statistics for Manchester city centre, single-person households comprise about 73% while two people households are 23%. Furthermore, according to the 2007 Council Tax Data and Housing Information Unit, the average household size is 1.37 (Manchester City Council, 2010c). In addition, the 2001 Census statistics for Manchester city centre states that the household composition is as follows: 5.6% lone pensioner, 68% one adult, 24% two or more adults, 1.6% couples with dependent children, and 0.9% lone parent with dependent children (Manchester City Council, 2003a).

7.5.1.3 Employment status

The 2001 Census figures show that about 59% of economically active residents in Manchester city centre are employed, almost 10% are self-employed and 25% are full-time students in employments while just about 6.5% are unemployed (Manchester City Council, 2010c, p13).

7.5.1.4 Income

The 2009 CACI Paycheck data points out that the median annual household income in Manchester city centre is £ (30683 – 57977) which is relatively high comparing with the other Manchester city wards (Manchester city centre, 2010c). Manchester Locality Joint Strategic Needs Assessment (Manchester city centre, 2010d) shows that according to the ONS 2009 statistics the mean annual income in the city centre is about £47,500 which is notably higher than other north Manchester wards.

7.5.2 City centre built-environment

Urban city centre areas are often mixed-use and high-density developments. According to two of Manchester city council's publications; A Strategic Plan for Manchester City Centre 2009-2012 (Man. City Council, 2009) and Transport Strategy for Manchester City Centre (Man. City Council, 2010a), the Manchester City Centre sits at the heart of the most important economic area in the North of England. It is a recognised centre for financial and professional services and creative industries. Since the late 1990s, Manchester City Centre has attracted massive investment and seen the creation of over 40,000 new jobs. It is also a national centre for cultural events in addition to being a major retail attraction. Finally, Manchester city centre contains residential areas with various types and tenures.

Equally, according to the Manchester city centre boundary map (Manchester City Council, 2010c), the city centre contains the following key surface transport infrastructure:

- Two bus stations (Piccadilly gardens and Shudehill)
- Eight metrolink stations (Victoria, Shudehill, Market Street, St. Peter's Square, GMEX, Piccadilly Gardens, Mosely Street, Piccadilly), and

- Four train stations (Deansgate, Oxford Road, Piccadilly, Manchester Victoria).

7.6 Research methodology

The research methodology is quite similar to the one described in Chapter 6 (Section 6.4). Nevertheless, it consists of three main stages. The first stage is the conceptual framework, where a schematic roadmap is proposed to show the theoretical and empirical bases of the quantitative statistical analysis needed to achieve the objectives of this chapter. Considering this, the second stage addresses the design and methodology used in conducting an original household travel survey in order to obtain the data required to operate the conceptual framework. The third stage is the statistical modelling strategy; it involves adopting an effective and adequate statistical approach and techniques necessary to accomplish the specific objectives within the defined conceptual framework.

7.6.1 Conceptual framework

Figure 7-1 shows the overall conceptual model adopted for achieving the research questions associated with the major objective of this chapter. As for the conceptual model adopted for the analysis in Chapter 6, the travel behavioural schema displays the hypothetical linkage between the proposed set of predictors and the selected measures of people's personal mobility. Hence, it allows to address the first main research question about examining the impact of these predictors on the personal travel of Manchester city centre's residents. The predictors are an array of personal, spatial and attitudinal attributes that have been chosen depending on sensible practical and research grounds. The essential practical reason is the availability and adequacy of these predictors for the quantitative statistical analysis. Furthermore, there are two basic research-related reasons; the first is the availability of empirical support about the potential impact of these factors and variables on people's travel patterns (see Section 2.4). The second reason for choosing these attributes as explanatory variables is to cope with the overall context of the utility theory as a recent method in travel behaviour modelling (see Section 4.2).

On the other hand, the conceptual model is also capable of achieving the second main research question. That is to examine the relative contribution of these predictors in order to reveal the impacts of people's attitude and preferences on their personal travel behaviour after controlling for the socio-spatial variables. That is, the basic model (reduced model) will often only include the urban form characteristics of the Manchester city centre in order to initially control for their effect, if any. The proposition is that there is little intuitive and substantive indication regarding the presence of significant variation in the spatial characteristics of the local neighbourhoods of the individuals' residences. To clarify, for example issues such as density, land use mixing, and road network design and transit provision are not expected to vary considerably over the limited area of the Manchester city centre. Therefore, the most attention has been, instead, paid to examine the potential influence of the socioeconomic and sociodemographic traits and thereafter, eventually, to examine the influence of attitudinal characteristics. As will be shown later (Section 7.6.3.3), the hierarchical regression technique has been employed to achieve this objective.

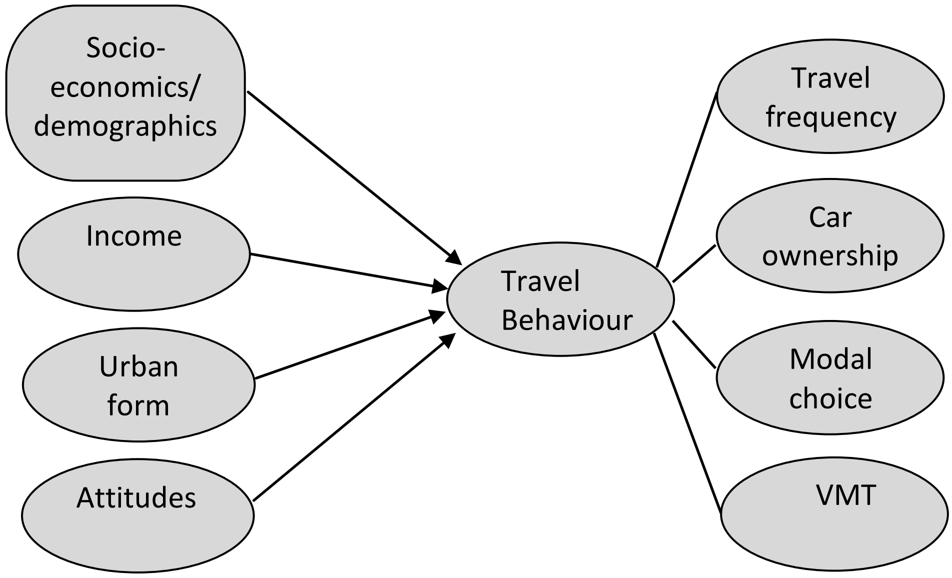

Figure 7-1: The conceptual framework of the travel analysis using the Manchester city centre household travel survey dataset.

7.6.2 Survey design and methodology

A household travel survey has been conducted in the Manchester city area with cross sectional data having been collected. A sample of the residents in Manchester city centre was selected.

The survey was designed to gather information on three major aspects; personal characteristics, travel behaviour, and attitude and preferences. Respondents were offered three techniques of completing the survey; self-administered hard copy questionnaire, self-administered on-line questionnaire and in-person interview. Standard recommendations were followed so as not to jeopardise the requirement for the sample to be representative of the target population.

7.6.2.1 Sample design and selection

The survey area is Manchester city centre (280 hectares) as defined by the boundary map prepared by the city centre regeneration team in Manchester City Council. Figure 7-1 shows the boundary map of the Manchester city centre (the study area) in addition to the locations of the 67 residential blocks from which the sample was taken. Accordingly, the initial target population for the household travel survey is all the occupied households located within the survey area, 8979 in total according to the statistics of Revenues and Benefits Unit in Manchester City Council (Man. City Council, 2010). According to Census 2001 statistics, more than 96% of the properties in Manchester city centre are flats (Manchester City Council, 2003a). Having said that and due to the concern that people living in houses could have different travel actions (as proven in Chapter-5), the survey has only considered those people who live in flats/apartments. For the same reasons, people who living in social housing are excluded in this survey. According to Council Tax/HNA and the Greater Manchester Forecasting Model, social housing in 2009 represented just 5% of the residential properties in Manchester city centre (Manchester City Council, 2010d). Hence, the final target population in this survey is only those city centre residents who live in flats/apartments privately owned or rented.

A probability sampling design process has been adopted to create the survey sample in order to select a sample that as far as possible truly represents the final target population. The probability design ensures that each household living in privately owned/rented apartment will have an equal chance of selection. The simple random sampling method was adopted rather than the other two common sampling methods: stratified and clustered. The availability of an updated and reliable sampling frame is the rationale behind adopting the simple random sampling method (Sapsford & Jupp, 1996). The adopted sampling frame was the most up to date Electoral Register of Manchester city centre residents. The electoral register is the preferred and typical sampling frame for household and individual surveys (Lohr, 2010). The edited version of the register was formally bought from the Electoral Service Unit in the Manchester City Council in July 2011. People living in residential units other than privately owned or rented flats such as student courts, social housing and sheltered accommodations were first removed from the electoral roll. Thereafter, following the random sampling procedure, a subset of respondents has been randomly selected

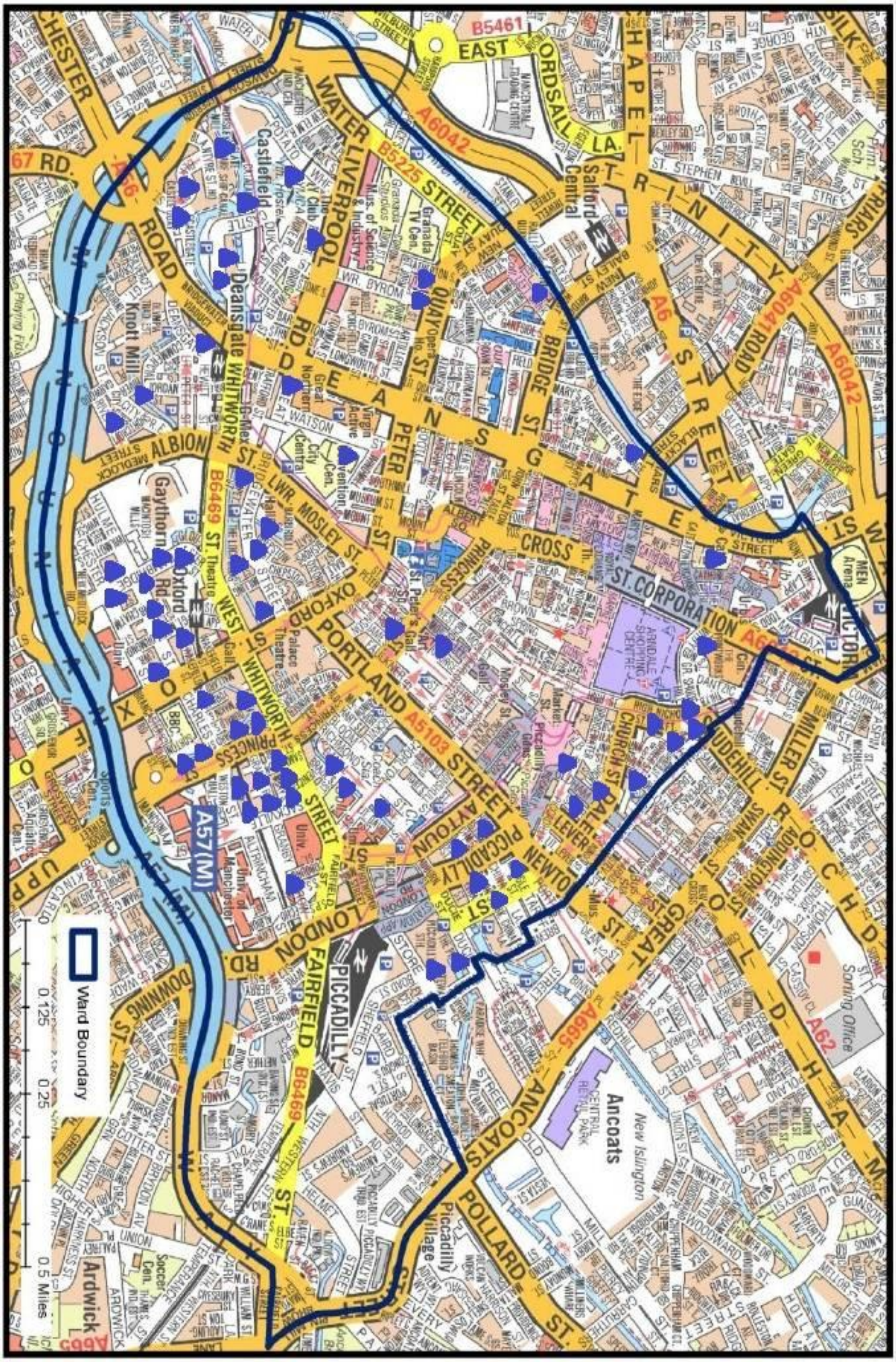

Figure 7-2: Manchester city centre (study area) boundary map with triangular shape dots representing the locations of the approached 67 buildings. (Source: Manchester City Centre (2010c))

(A) Sample size

The adequate number of subjects (here households) recommended to be recruited, i.e. the sample size, almost always depends on issues such as the funding available, scope of the study, statistical techniques planned to be applied, and the experience gained from previous relevant research surveys.

Well-funded city centre living surveys like those conducted by city councils usually distribute about 3000 postal questionnaires. For example in the Nottingham City Centre Living Survey 3,028 questionnaires were posted (Nottingham City Council, 2007a) and in the City Centre Living survey in Coventry a total of 3,142 questionnaire forms were sent out. In recent related research, Beaney (2009, p.88) in his PhD work on the perceptions and experiences of Sheffield city centre residents, sent out about 1940 mail questionnaires as measurement instruments for the thesis research analysis. It is worthwhile mentioning that the data collected using these questionnaires were the main dataset for his PhD research. Having said that, taking into account the limited funding for my survey on one side and noting that it is not the only source of data used in my PhD research on the other, 2000 letters inviting people to participate in this survey were mailed.

(B) Response rate

Overall, it has been frequently reported recently that there has been a continuous decline in the response rate for household surveys in general and travel household surveys in particular (Stopher & Greaves, 2007; Zimowski, Tourangeau, Ghadialy, & Pedlow, 1997). Furthermore, issues such as limitations of sampling frame, privacy concerns and increases the breadth and depth of the data needed have been also considered as strong barriers to conducting adequate travel surveys nowadays (Bonnel, Lee-Gosselin, Madre, & Zmud, 2009, p10; Bro¨g & Ker, 2009, p140). One of the recognised reasons for the decrease in the response rate in household travel surveys lately, regardless of the method adopted, is the growing reluctance of the public to participate in surveys in general (Stopher, 2009, p19). While a typical response rate is reported to range from 20 to 40 percent (Nachmias & Nachmias, 1981; Zimowski, et al., 1997, p.i), household surveys with a response rate as low as 5% have also been pointed out (Zimowski, et al., 1997, p.i) or even 3.3% (Lohr, 2010).

Regarding the Manchester city centre survey conducted for this study research, as mentioned above, 2000 recruitment letters were posted. Only 172 households have sent their consent forms showing their agreement for participation in the survey. Thus, the gross initial response rate for participation in the survey is just over 8.6% (172/2000) which is often appraised as low response rate. For objective assessment, however, while some researchers exclude the number of vacant dwelling units which will apparently increase the response rate, here the figure 2000 includes both occupied and non-occupied dwelling units. Nevertheless, of the 172 households only 109 returned their completed questionnaires (hard copy and online) or have been interviewed. Obviously, some of the respondents have changed their mind or forgotten to fill it in. Conducting a follow-up contact to gently remind those who did not respond increased the total participating household to 125. This resulted in a final response rate of about 6.3% (125/2000).

Two main reasons are most likely to be attributed to this low response: first, the dynamic nature of the city centre living in general and in the mature Manchester city centre in particular. An active housing sale/rental market on one side and the prevailing short-term living on the other side have both reduced directly and indirectly the probability of gaining a high response rate. The vigorous housing market speaks to the high possibility of the approached household being vacant, while short-term living could reflect a high proportion of people that are not keen to spend time filling in questionnaire forms. Adding more to these points, for example, the housing market research study carried out in Liverpool city centre showed evidently the unique transient feature of people living in the city centre. Renters in the city centre residential sector typically tend to only stay for a short duration with almost 75% of residents stating that they would move within less than one year (Liverpool City Council, 2008, p4). Similarly, in the Nottingham city centre living survey, only 40% of respondents have reported that they have been living in the centre for more than 18 months (Nottingham City Council, 2007).

The second reason is the limited funding implications. For example, in essence, this was one of the key reasons behind planning to distribute only 2000 invitation letters. Furthermore, nearly 50% of these letters have been delivered by hand in the respondents letter boxes rather than posting for the same reason. Hand-delivered letters are less likely to be opened than ones with formal stamps for obvious reasons. In addition, given the limited finance, it was not practical to send a reminder to those who did not reply about their agreement to participate.

An additional potential factor is the very limited number of similar travel surveys in city centre developments, especially those with a travel diary part in the questionnaire form. This has made learning from previous knowledge unduly narrow. On the other hand, the available household surveys in city centre areas have mostly dealt with issues such as living characteristics and resident's perception without a detailed travel diary section or retrospective questions as in the questionnaire form used in this research. This could explain the relatively acceptable response rates (10-30)% in these surveys which initially gave a spurious optimistic impression that ending up with such rates was feasible. For example, the response rate in the Nottingham city centre living survey was 27.7% (Nottingham City Council, 2007a), 14.5% in the city centre living survey in Coventry (Chester, 2006) and 11% in the Liverpool city centre perceptions survey (Palfrey, 2006). It is worthwhile mentioning that all the three previous surveys used a postal self-administered questionnaire technique.

Whereas the response rate gained for the Manchester city centre household mobility survey conducted for the current study is quite low (6.3%), four points are worthy to be noted. First, this survey dataset is only one of three datasets employed in the whole thesis; the other two datasets are TRICS and the Scottish Household Survey. Second, there is no concern of bias that might jeopardise the representativeness of the sample because of the adequate random sampling method employed. Third, there is no anticipated loss in reliability especially when results will not be generalised to the whole population of the city centre. However, the findings definitely still speak to the personal and travel characteristics of 125 households living in the centre with 203 residents and 685 main journeys. Finally yet importantly, the observable shortage in household travel surveys in UK city centres and the urgent need for such data makes any relevant effort beneficial.

A final issue that is worth noting is the item response rate. While the overall response rate is quite low, the item response rate is interestingly high. Moreover, the response rate for the income question was 99.2% (1 missing value). Allowing for the sensitive nature and the typical people's reluctance for answering such questions, this rate was not expected. Having reported that, this may suggest an obvious clustering in the target population of the city centre regarding their willingness to participate in research surveys. The first group, which apparently forms a very low proportion, has high propensity to participate. The second group, in contrast, which forms the majority, is not keen to take part in household travel surveys.

7.6.2.2 Data collection procedure and survey administration

The required data has been gathered using the three steps in the systematic data collection process: recruitment, mailing and retrieval.

(A) Recruitment process

Although the Research Ethics Panel in the University of Salford granted the Ethical Approval permission of the survey in early July/2011, the actual invitation process did not start until late August/2011. The intention was to avoid the major holiday month of July and the corresponding possibility of low response rate (Naess, 2011).

At least two apartment blocks were randomly chosen in each of the six polling districts lying inside Manchester city centre. Households within each building were also randomly chosen from the edited electoral roll. The rationale behind that was to ensure a representative sample which will according to the sampling theory lead to minimal sampling error; i.e. leads to sample statistics that are fairly close to the population parameters. Having mentioned that, these six polling districts comprise the sampling units of the survey target population.

At this stage, the recruitment stage, the invitation package had been distributed to about 2000 households residing within the boundary of Manchester city centre. The package included the survey information sheet, informed consent form and a Business-reply prepaid envelope (See Appendix-D).

The participant info sheet includes a brief description to the survey, the aims and the importance of participation. Details about an incentive for those who sign the consent form and return properly completed questionnaires have been mentioned. The incentive is usually offered as an appreciation for the respondent's time and as a motivation for respondents who are not interested in the field of survey. Utilising the incentive in surveys as a way of maximising response rate is very common in household surveys; for instance, one of the recognised household travel surveys that uses this technique is the GB National Travel Survey (Taylor et al., 2012). In this survey, the incentive is a prize draw of 5 lots of

£50. Finally, an outline of what will happen later has been given. For the purpose of increasing the response rate by stimulating the desire of some people who find using the internet is an effective tool for saving time and effort, the respondents have also been offered the option to fill in an online copy of the consent form. A website-link was listed in the information sheet. A webpage was already created using the UK Smart Survey website – an internet-based survey software specialising in creating, publishing and managing online surveys (http://www.smart-survey.co.uk). To benefit from the full capacity of required features, membership of this site was upgraded to the professional version of the software (Screenshots of the created online copy of the consent form are attached in Appendix-D).

In contrast, in the consent form, the householders were asked to read it and sign if they were happy to take part in the survey. The form was then to be returned using the provided prepaid envelope. By signing the form, the householders agreed that they had been told that they had the right of withdrawing whenever, asking questions, and keeping their personal information unrevealed. In addition, they were informed that their participation was voluntary and highly appreciated. Furthermore, the householder had been asked to tick a checkbox if its household had moved to the centre within the last year. The justification was twofold; the first was to discriminate between movers and non-movers so that the corresponding questionnaire could be sent while the second was to gain an early feedback of the suitability of movers/non-movers response rates and the adequacy of the movers sample size. Since few households were found to have moved within the last year, no great attention will be given to their relocation process.

Finally, in the end of the consent form page, city centre residents were offered three different ways for filling in the survey questionnaire form. First, by sending them a hard copy (HC) of the form; second, e-mailing them a web-link to fill in the electronic copy (e-copy) of the questionnaire online; third, by conducting an interview. The overall purpose was obviously to use any attempt to maximise the response rate. Seventy-nine questionnaires were completed online, 25 by using the hard copy version while 21 participants have been interviewed.

(B) Survey material mailing

A self-completion questionnaire is the main measurement instrument in the Manchester city centre survey. The questionnaires of the twenty-one interviewees were completed by the researcher. The mail questionnaire method of executing household surveys is typical and common to some extent due to being relatively cheap and quick; however, the highly expected non-response rate has been considered as its major flaw (Sharp & Murakami, 2004; United Nations Statistical Division, 2008, p.16).

Great effort has been devoted to produce a well-designed and neatly structured layout. Items (questions) have been carefully worded to make them understandable and to attain validity without compromising the research objective behind each of them (A copy of the hard-copy survey questionnaire form is attached in Appendix-C, while screen shots for the e-copy form is shown in Appendix-E). To comply with the ethical requirements, participants have been interviewed, sent a hard copy questionnaire or the web link of the online copy only after obtaining their completed and signed consent forms**.**

Almost one-half (1000) of the hard-copy questionnaire forms have been administered using a mail-out- mail-back approach. The second half has been posted directly through the letterboxes of the respondents whilst a few (around 50) were physically handed to the respondents. Although letters manually delivered (not by postage carrier) are as stated previously less likely to even be opened, there are some surveys where such an approach is adopted including (Ryley, 2008)**.** A C5 prepaid envelope has been attached with each HC questionnaire. The survey forms have been mailed to randomly selected apartment blocks and households within each block.

The survey questionnaire consists of three major parts: (1) Household and individual socioeconomic information, (2) personal travel diary, and (3) travel attitude and residential preference attributes. Most of the survey questions have been developed (with customisation where needed) from surveys used in previous relevant research household travel surveys. In the first part, the socioeconomic characteristics have been collected from the households including income, employment status, occupation, academic qualification, driving licence status, and car ownership and use. In addition, demographic characteristics are obtained by asking households several questions regarding their age, gender, household size and household structure.

In the second part, the travel diary part, the householder and the second adult were asked to list full information about the trips they have made on the travel day. The travel day has been defined for the respondents as any typical weekday with preference given to the day immediately before the day of filling in the travel diary. The information includes origin and destination of each single trip, purpose, time of travel, travel mode, travel distance, and number of occupants. Two travel diaries were enclosed; one to be filled in by the householder while the second by any adult household member who shared in the decision making for the household and/or who participated in selecting the current residence. There are two reasons for selecting only two household members to fill in the travel diary; the first is to reduce the burden on the respondent. The second one is statistical; according to the 2001 Census data, only 3.7% of the total households in Manchester city centre are with three or more residents (Manchester City Council, 2011b). Moreover, according to the council tax data and housing information unit, in 2007 the average household's size is 1.37 (Manchester City Council, 2010c).

In the third part of the questionnaire, the householders were asked about their perceptions towards many travel and housing aspects. Several revealed and stated preference questions have been employed. With respect to their current neighbourhood (city centre), householders have been asked 16 attitudinal questions regarding their perception towards several aspects of city centre living. Thereafter, they have been asked 17 questions about how important each of the listed residential preference questions was for them when reaching their decision to relocate in the Manchester city centre. Finally, 16 extra attitudinal questions were asked about respondents' perceptions towards many travel-related topics (see Appendix-C). All the above attitude and preference questions have been scaled using a 5-step Likert scale.

(C) Retrieval process

City centre respondents who opted to fill in a hard copy version of the survey questionnaire were asked to post questionnaires back to the University of Salford using the provided prepaid-reply envelopes. For those who chose to complete the form online, their responses have been collected using the Smart-Survey online software. Finally, the questionnaires of the interviewees have been collected in-site after finishing the interview.

Two more issues regarding the survey administration are the reminder e-mails and the pilot survey. Four weeks after sending the questionnaires, a follow-up reminder e-mail was sent to those who had not yet responded. Regarding the pilot survey, a small group of the PG researchers in the University of Salford were asked to fill in the first draft of the survey instrument and to list their notes and any issue towards the design, structure, wording and the length of the questionnaire. Some of these notes, especially common ones, were beneficial and accordingly have been considered.

7.6.2.3 Methodological issues

In addition to what have been mentioned in the previous sections, there are several survey methodological points which it is worthwhile highlighting.

First, in general the overall purpose of the journey is typically taken as the activity at the destination. However, there is one exception; this is when the destination is "home" and the trip is the direct return part of a simple two parts journey. In such situations, the purpose of the return part is considered as the same as the purpose of the outward (origin) part. This approach of purpose coding is common in several national surveys including the Scottish Household Survey (Hope, 2010, p.117; Scottish Household Survey, 2011) and the GB National Travel Survey (Taylor., et al., 2012)**.** In the same context, in the Manchester city centre travel survey the leisure activity includes entertainment, social, eating-drinking, sport, holidays and walking out. This definition of leisure trips is akin to that adopted in the NTS (DfT, 2012, p.7). A quite similar way is adopted in the SHS but without the social journeys of visiting a friend (Scottish Government, 2009b)**.**

Second, when a journey contains more than one transport mode, then the considered mode is the main mode of travel. The main travel mode is defined as that mode which has been chosen for the longest (in distance) part of the journey. This approach of travel mode coding and identifying is used in several surveys; for instance, the SHS and GB NTS (Scottish Household Survey, 2011).

7.6.2.4 Data processing and data anonymity

(A) Data processing

The data gathered from the questionnaires have been entered into an MS-Excel file to create the database master file of the Manchester city centre household travel survey. At this stage and according to the recommendations of statisticians, the tabulated raw data have been carefully scanned before performing the main statistical analysis (for example, see Landau and Everitt, 2004; Thompson, 2006; Tabachnick and Fidell, 2007). This is because problems such as data inaccuracy, missing data and outliers could directly affect the average value statistic (especially the mean) and hence indirectly all other descriptive and inferential statistics later. Finally, using the Statistical Package for Social Science software (SPSS Statistics v.20), the MS-Excel survey database has been imported and several SPSS files have been formed and prepared for the required travel analysis and modelling.

(B) Data anonymity

In compliance with the University of Salford Research Ethics Panel requirements, several mechanisms have been adopted to ensure the security of participants' personal information.

First, all participants have been ensured that their personal information will not be revealed outside the research staff (the researcher and his supervisor). Second, the hard copy questionnaire, originally, does not contain a field for the name or contact address of the participant. Instead, each questionnaire has been marked with a unique household identification number (reference number). Third, the prize slip details (name and contact no. /email) are securely stored in a lockable cupboard before destroying immediately after the prize draw has been completed. In addition, all the questionnaires and other related survey materials are stored securely in a lockable cupboard in the University. Finally, the created survey master file and other relevant data files are properly coded and protected by a password.

In the case of the online questionnaire, subscription to the professional version of the online survey software (Smart-Survey) was upgraded to benefit from the high security option (SSL Encryption). SSL stands for Secure Sockets Layer protocol which is an e-technique of passing sensitive information, such as credit card details, over the Internet. By this technique, the entire communication is encrypted to prevent eavesdropping. An SSL URL is preceded by https:// instead of http://.

7.6.3 Statistical modelling strategy

7.6.3.1 Analysis variables

The variables that have been measured using the questionnaire of the Manchester city centre household travel survey can be classified into four groups: socioeconomics and demographics, built environment, attitudes and preferences and finally travel behaviour indicators. Firstly, the socioeconomics and demographics variables include an array of personal attributes. For instance, gender, age, employment status, household income, household size and residential tenure. These personal variables could assist in reflecting several aspects of city centre living in addition to being adequate explanatory variables in most of the travel analysis models. A list of these personal attributes in and with a brief description regarding their measurement and disaggregation level is shown in Table 7-1.

Table 7-1: List of the Manchester city centre household survey socioeconomic and demographic variables used in the analysis.

Variable name	Measurement level		Disaggregation level	
	Num.	Cat.	HH	Adult
Age (in years) 16 – 24, 25 – 34, 35 – 44, 45 – 54, 55 – 64 and 65- plus		√		√
Household size In terms of adults and children	√		√	
Employment status Employment (full time/part time); self-employed; student, unemployment; retired; others.		√		√
Annual total household income (£) Less than 10000; 10000 – 19000; 20000 – 29.000; 30000 – 39000; 40000 – 49000; 50000-plus		√	√	
Occupational status Professional; senior managerial; middle managerial; clerical; administrative; skilled manual; and other manual.		√		√
Highest educational qualification GCSE; A level or equivalent; U.G degree of equiv.; P.G degree or equiv.; Other qualifications.		√		√

Secondly, the survey questionnaire contains a few questions about different aspects of the spatial environment of Manchester city centre. These variables includes; dwelling unit tenure, availability of parking and number of bedrooms. In addition, information regarding the accessibility to the nearest train station and tram stop has been collected separately.

With respect to the third set of the analysis variables, the Likert-scale has been utilised to quantify the city centre residents' attitudes and preferences towards an assorted set of housing and travel aspects. Individuals have been invited to show to what extent they agree with a set of revealed and stated preference questions regarding their perception of current residence characteristics. The original scale band is from 1 ("strongly agree") to 5 ("strongly disagree"). This scale has been reversed later when running the principal components analysis for compatibility and ease of interpretation reasons. Moreover, the respondents were also requested to show the importance of a set of housing aspects to their relocation decision retrospectively; i.e., just before relocating into Manchester city centre. The five step Likert scale has been coded as 1 (“Not at all important”) to 5 (“Very important”). Finally, a third Likert scale has been set to measure individual’s attitudes towards a variety of travel aspects. The scale band is from 1 (“strongly agree”) to 5 (“strongly disagree”). Similarly, the code has later been reversed for the same reasons mentioned above.

Finally, yet importantly, the fourth group of variables is the set of travel behaviour indicators. The questionnaire also consists of several personal mobility measures that quantify people’s travel behaviour. In general, the measures are supposed to cover some characteristics of daily and weekly personal travel, including frequency of trips, travelled miles, journey time, and mode share. Table 7-2 displays a full list of these mobility measures.

Table 7-2: List of the Travel Behaviour indicators used in the quantitative analysis.

Variable name	**Measurement level**		**Disaggregation level**	
	Num.	**Cat.**	**HH**	**Adult**
Number of household bikes	√		√	√
Household car use status Full use; Partial use; None; Have no car		√		√
Driving licence status Full; Provisional; Never held a UK DL; Given up driving		√		√
Driving licence holders	√		√	
Number of household cars	√		√	
Mode of transport (travel diary) Walking, Driver Car, Passenger Car, Bicycle, Bus, Taxi, Rail, Underground, Other.		√		√
Journey purposes (travel diary) work-related; for educational; shopping; leisure; others.		√		√
Journey duration (in minutes)	√			√
Journey distance (in miles)	√			√
Number of daily trips	√		√	√
Number of commuting and education weekly trips	√		√	√
Number of shopping and leisure weekly trips	√		√	
Typical mode of weekly commuting, education, shopping and leisure trips		√		√

It is worthwhile mentioning that the survey questionnaire also initially has contained several quasi-experimental indicators to attempt to quantify the change in travel behaviour and some socio-economic data before and after moving to Manchester city centre. However, these variables have been dropped from any further analysis due to a severe lack of response. It is also sensible here to point out that some of the categorical variables have been transformed to new ones with fewer levels, especially in the inferential analysis. This re-categorisation was done by either deleting or combining some groups. Examples of these are; employment status, highest education level, occupation and household income. As stated in chapter six, this combining is justified on two bases; the first is the very low frequencies of some original categories while the second is that some of the groups have no tangible contribution to the major aim and objectives of the current study.

After collecting, inputting, cleaning and coding the dataset, it was ready to be analysed.

7.6.3.2 Exploratory data analysis

A variety of descriptive analysis techniques has been employed. These include the typical methods including cross-tabulation, percentile analysis and chi-square test in addition to the sophisticated multivariate Principal Components Analysis (PCA) technique.

(A) Typical descriptive analysis

The merit of using the typical descriptive analysis techniques is twofold and it is similar to that mentioned in Chapter 6. That is, firstly it helps in achieving the secondary objective (C) by exploring the variables and hence aids in assessing their suitability to be included in the statistical analysis or in finding the suitable treatment for improper ones. Obvious examples of these are exploring normalities of continuous variables and exploring the available cell-frequencies in each level of the categorical variables. In contrast, the second advantage of descriptive analysis is simply to address the secondary objective (B) of this chapter. In other words, to look over the distinguishing themes of Manchester city centre. This is by exploring the survey personal, attitudinal and spatial attributes of city centre living and where possible comparing them with their corresponding local and national averages.

(B) Principal components analysis

As stated previously, the third part of the questionnaire involves the attitudinal questions and it consists of three main experiments. The first experiment contains 16 items and it involves analysing the respondent's perception towards their current neighbourhood as the residents of Manchester city centre. In the second part, the residential preferences of the respondents have been revealed using 17 questions. Finally, an extra 16 Likert-scaled items have been employed to measure the travel attitude of the city centre respondents in the third part.

Accordingly, the embedded mathematical abilities of the principal components analysis technique have been employed in this chapter analysis in order to achieve two goals. The first is to reduce the previous 49 items to a smaller number of components by attempting to combine items that are found to measure similar underlying attitudinal constructs. It is sensible here to highlight that an item with low conceptual interpretability or not reasonably correlated with any other items has been dropped from the analysis. The second goal of using the components analysis technique is to compute the scores of the extracted components (attitudinal factors). Subsequently, these factor scores have been used later as explanatory variables (predictors) in the developed travel regression models

7.6.3.3 Confirmatory data analysis

It is useful to recall that confirmatory data analysis is the statistical inferential analysis that involves testing hypotheses typically associated with research questions. In addition, it usually involves computing specific statistics of the sample in order to infer their corresponding population parameters. In this chapter, all the conducted regression analyses, as in the previous chapter, are listed under the overall unified framework of the sophisticated statistical approach known as Generalised Linear Models (GsLMs). An array of regression models has been developed; these include Multiple linear, Poisson, Negative binomial and binary logistic regressions. Nevertheless, the standard OLS linear regression analysis has been carried out using the regression procedure in the SPSS software. The reason is simply for convenience in that some of the output statistics are not directly available in the GsLM procedure.

Standard multiple linear regression has been used to develop the vehicle miles travelled models of the household and individual. Poisson and negative binomial regression models have been used to develop the five trip frequency models. Finally, four binary logistic regressions have been specified; one for the car ownership model and three for the mode choice models.

It is worthwhile briefly stating that for all the models with count outcome (dependent) variables, as expected, the Poisson regression's assumption of equality of the mean and variance of the count variable is not held. Lagrange's Multiplier statistic has been utilised to test this assumption following the recommended typical steps (IBM Corp., 2011b, pp.48-49; Orme & Combs-Orme, 2009, p.186). In consequence, the negative binomial model has been adopted.

Regarding the mode choice analysis, initially four modes were planned to be included as the set of alternatives (choices) in the discrete choice model. These are, private car, public transport, bike and on foot. In order to ensure that the sample size is statistically eligible, the recommended cross-tabulation analysis has been run. The discrete outcome variable was cross-tabulated with each level of the categorical predictors at the beginning (2009, Orme, p32). The analysis results have indicated the existence of several cells with very low or even zero frequencies. Accordingly, in order to overtake this problem the choice set has been reduced to only two categories (active transport vs. motorised transport).

It is also useful to state that in order to cope with the objectives within the set conceptual model, specifically the second research question of the main objective, the sequential regression principles have been utilised. The purpose is to examine the relative influence of the personal, spatial and attitudinal characteristics. In so doing, in the first block (first model) only spatial data has been entered; spatial and personal in the second, and finally the perception data will be added. The analytic strategy is to include predictors hierarchically from less important to more important predictors; that is, to control for their influence at first. Statistically speaking, this is a legitimate analysis approach (Ho, 2006, p.246). It is worthwhile mentioning that the sequential examining of variables is only adopted where viable and sensible; i.e., where sample size is statistically eligible and where there is a conceptual justification.

Table 7-3 displays the variables (predictors and responses) included in the inferential analysis. Basic information about each variable such as symbol, frequency, measurement level, mean, median and standard deviation are also listed where available. It is evident in the table that, as explained previously, some of the categorical variables have been re-grouped to ensure their statistical eligibility and analytical reliability. The 95 percent confidence level is chosen since, as stated previously, it is typically taken as the standard in household surveys.

Table 7-3: The key statistics of the variables and factors used in the inferential analysis.

Analysis variable	Symbol	Level (HH / Indv.)	N	Mean	Std. Deviation
Personal attributes					
No. of household cars	HH cars	HH	125	0.62	0.657
No. of 16+ adults	HH size	HH	125	1.63	0.547
No of employees (FT, PT and self-employed)	Employees	HH	125	1.19	0.769
No of driving licence holders	DL holders	HH	125	1.29	0.670
Household annual income (£)		HH	125		
Low (< 30,000)	Low HHincom		46		
Middle (30,000 – 50,000)	Mid HHincom		38		
High (> 50,000)	High HHincom		41		
Highest education level		Indv.	200		
PG or equivalent	Edu_PG		67		
UG or equivalent	Edu_UG		95		
Less than UG	Edu_Less		38		
Driving licence status	DLstatus	Indv.	200		
Full licence	DL-full		140		
Others (provisional, none,..)	DL-others		60		
Employment status		Indv.	200		
In employment	In employ.		148		
Not in employment	Not in employ.		52		
Built environment					
Nearest train sta. (in metres)	Distrain	HH	125	281	128
Nearest tram stop (in metres)	Distram	HH	125	329	153
Distance to work (in miles)	Diswork	Indv.	138	7.25	13.7
Car park space		HH	125		
Building without park	Park_no		68		
Building with park	Park_yes		57		
Attitudinal factors					
Attitude pro- driving	F1 pro-driving	Indv.	149	-0.0006	1.000

Attitude pro- sustainability	F2 pro-sustain	Indv.	149	-0.0001	0.999
Attitude pro- virtual mobility	F3 pro-vmob	Indv.	149	-0.0002	1.000
Attitude pro- active transport	F4 pro-active	Indv.	149	0.0003	1.000
Perception accessibility	F5 access	Indv.	149	0.0000	0.999
Mobility measures					
Daily household total trips		HH	125	5.26	2.355
Daily individual total trips		Indv.	200	3.32	1.424
Daily household shop. trips		HH	125	0.87	1.101
Daily household leisure trips		HH	125	1.30	1.561
Weekly household shop. trips		HH	125	3.17	3.28
Weekly household leisu. trips		HH	125	2.147	1.517
Total household daily VMT		HH	125	17.8	31.0
Total individual daily VMT		Indv.	200	11.5	22.8

HH: household; Indv.: individual; VMT: vehicle miles travelled.

7.7 Analysis results and discussion

7.7.1 Exploratory analysis

This section presents the results of the descriptive analysis utilising the data of the Manchester city centre household travel survey. The results include findings about three major features of city centre living; personal traits of city centres' respondents, urban form and travel characteristics and patterns. Two disaggregation levels of analysis are included; household-level and individual-level.

7.7.1.1 Attributes of Manchester city centre's residents

(A) Socio-demographics

1) Age

In Table 7-4 the city centre respondents have been classified according to seven age bands. One of the most notable points is that over 82% of city centre respondents are young people with age category of (16-44) years. According to the 2011 UK Census concerning ward population of Manchester (Manchester City Council, 2012a), this is clearly high in comparison with the corresponding proportions in Manchester city (54.3%) and England (40.6%). Furthermore, Table 7-4 also indicates that the Manchester city centre sample contains notably small proportions of households with children of less than 16 years old (0.5%) or for elderly people of more than 55 years old (7.8%). The implication of this finding appears evident when exploring the corresponding proportions in Manchester or over England.

Overall, the above findings are in agreement with the relevant literature in that Manchester city centre in particular and urban centres in general are not attractive living places for households with dependent children or for elderly people; instead, they are attractive for young people.

Table 7-4: Residents' age bands.

Age bands	Frequency - city centre	Percent- city centre	Cumulative Percent-CC	% 2011 census Man. city[a]	% 2011 census England[a]
< 16	1	0.50	0.50	18.2	17.7
16-24	51	25.1	25.6	20.9	13.1
25-34	86	42.4	68.0	20.2	13.5
35-44	30	14.8	82.8	13.2	14.0
45-54	19	9.4	92.2	10.4	13.7
55-64	7	3.5	95.7	7.5	11.6
>= 65	9	4.3	100.0	9.5	16.3
Total	203	100.0		503,127	53,012,456

[a] These figures are extracted from Table Q_01 (Manchester city council, 2012a).

2) Household structure

Table 7-5 demonstrates that about 40% of the households participating in the city centre survey are single-person households. This is higher than the averages in Manchester and England; 35% and 30% respectively. Additionally, the results show that about 57% of the households are two- people households. Specifically, childless couple's households comprise about 37.6%, which is much higher the equivalent averages in Manchester (16.3%) and over England (25.7%). Overall, the tabulated analysis results point out that almost 97% of the participant households are either one or two people households.

Table 7-5: Household structure.

<table>
<tr><th>Composition</th><th>Frequency</th><th>Percent</th><th>Cumulative Percent</th><th>% Man city [a]</th><th>% England [a]</th></tr>
<tr><td>Single person HH</td><td>50</td><td>40.0</td><td>40.0</td><td>35.2</td><td>30.3</td></tr>
<tr><td>Childless couples HH</td><td>47</td><td>37.6</td><td>77.6</td><td>16.3</td><td>25.7</td></tr>
<tr><td>Others two people HH</td><td>24</td><td>19.2</td><td>96.8</td><td rowspan="2">48.5</td><td rowspan="2">44.0</td></tr>
<tr><td>3 or more people HH</td><td>4</td><td>3.2</td><td>100.0</td></tr>
<tr><td>Total</td><td>125</td><td>100.0</td><td></td><td>100.0</td><td>100.0</td></tr>
</table>

[a] Computed based on the 2011 Census Table KS105EW (ONS, 2012b, p.29). HH: household.

Moreover, the average household size in Manchester city centre based on the survey is 1.6 – the total number of respondents household members (203) divided by the total number of participated households (125). According to the 2011 Census reference tables (Table KS403EW), this average is much lower than the Manchester average (2.3) or the England average (2.4) (ONS, 2012a).

(B) Socio-economics

1) Household total annual income

A tabulated distribution of the total yearly households' income can be shown in Table 7-6. Taking into account the sensitive nature of this variable, respondents were asked to select one of six income groups that best suit their total household income instead of asking them to report the exact value of each individual. This technique has shown signs of success in that the item-response rate for this question is 99.2%. One of the interesting points that could be noted in the table is that one-third of the households have an income more than £50,000. According to the literature (Section 7.5.1.4), the median annual household income in Manchester's centre is £ (30683 – 57977) (Manchester city centre, 2010c, p.15). In addition, according to the ONS 2009 statistics, the mean annual income is about £47,500 (Manchester city centre, 2010d). Both of these statistics are relatively high in comparison with other areas within Manchester. In addition, these statistics are reasonably similar to the survey data shown in Table 7-6.

Table 7-6: Household total annual income.

Income bands	Frequency	Percent	Cumulative Percent
Less than £ 10,000	12	9.7	9.7
£ 10,000 - 19,999	15	12.1	21.8
£ 20,000 - 29,999	18	14.5	36.3
£ 30,000 - 39,999	19	15.3	51.6
£ 40,000 - 49,999	19	15.3	66.9
More than £ 50,000	41	33.1	100.0
Total	124	100.0	

2) Economic Status

The economic activity status for city centre respondents and their adult household members (16 years old or more) is shown in Table 7-7. Seven groups have been listed in the questionnaire (Employed full/part time, self-employed, student, retired, unemployed, and others). The exploratory data analysis points out that almost three-quarters of the respondents are either in employment or self-employed. This is much higher than the averages in Manchester and over England; 50.7% and 61.9% respectively (ONS, 2012a). The second interesting point is that economically inactive people due to being retired (5.0%) or those who are currently unemployed (4%) are also lower than the local and national averages (see Table 7-7). Finally, the analysis also shows that just over 18% of the total respondents have reported that they are in education. While this proportion is double the England average (9.2%), it is slightly less than the Manchester average (21.3%). Being higher than the national average would probably reflect the thriving educational sector in the region of Greater Manchester and specifically in the city of Manchester. In contrast, being less than the Manchester's average is probably because students' accommodation halls have not been included in the survey target population due to financial limitation issues.

Overall, the findings support the literature in that the vast majority of the people living in the city centre are economically active.

Table 7-7: Employment status of residents.

Category	Frequency	Percent	Cumulative Percent	% Manchester city [a]	% England [a]
Full-time	134	66.3	66.3	44.5	52.2
Part-time	10	5.0	71.3		
Self-employed	6	3.0	74.3	6.2	9.7
Student	37	18.3	92.6	21.3	9.2
Retired	10	5.0	97.6	7.7	13.8
Unemployed	4	2.0	99.6	5.7	4.4
Others	1	0.4	100.0	14.6	10.7
Total	202	100.0			

[a] Computed based on the 2011 Census Table KS601EW (ONS, 2012a).

3) Occupational status

Furthermore, the percentage distribution of the respondents' occupational status can be shown in Table 7-8. For obvious reasons, individuals who are not in the economic activity age (16-74) or adults who are students, retired or unemployed are excluded. The occupational categories reveal that adults in the high occupational rank (such as professionals, seniors, managers and directors) represent a major proportion; approximately two-thirds of the whole participants. Based on the data extracted from the 2011 Census Table KS608EW, the corresponding averages in Manchester is (27.5%) and over England is (28.4%) (ONS, 2012a). These averages and the survey data results evidently reveal that

Manchester city centre is a strong attractive place for people with high occupations. In addition, Table 7-8 also reveals that 28% of respondents are in middle occupations, while only just over 5% of them are with manual occupations.

Table 7-8: Occupational status of residents.

Category	Frequency	Percent	Cumulative Percent
Professional/Senior/Manager/Director	102	66.7	66.7
Middle manager/Clerical/Admin.	43	28.1	94.8
Skilled manual	6	3.9	98.7
Other manual	2	1.3	100.0
Total	153	100.0	

4) Educational qualification

Table 7-9 categorises the highest level of academic qualification for the city centre residents who participated in the survey. One of the key points is that one-third of the respondents have reported that they are post grads (PG) or with an equivalent degree. Moreover, 80% of them have claimed that they are at least at under-graduate level (UG) or equivalent degree. This proportion is much higher than the local average in Manchester (29%) or the national one over England (27.4%) (Based on the 2011 Census Table KS501EW (ONS, 2012a) for 16+ individuals).

Another notable point is that while the proportion of people without qualification in Manchester or England is about 23%, the corresponding percentage in the city centre survey is as low as 1.0%. Overall, the above results are in agreement with the equivalent Scottish Household Survey analysis carried out previously (Table 6-8). Additionally, the analysis results are also supported by the literature.

Table 7-9: Education level of residents.

Highest level	Frequency	Percent	Cumulative Percent
PG Degree or Eqv.	67	33.3	33.3
UG Degree or Eqv.	95	47.3	80.6
A-level or Eqv.	31	15.4	96.0
GCSE	6	3.0	99.0
Others	2	1.0	100.0
Total	201	100.0	

(C) Attitude and preferences

This section displays the analysis results based on the attitudinal questions part of the survey questionnaire. As stated previously, this section comprises three parts; perception towards Manchester city centre, residential preferences and travel attitude. For each part, two statistical techniques have been employed. The frequency analysis has been used to tabulate the percentage proportion of the Likert-scaled responses. In contrast, the principal components analysis has been run to investigate the potential underlying constructs in order to be used later in the travel modelling analysis as attitudinal predictors.

1) Perception

In Table 7-10, the perception of the respondents towards 16 aspects of the city centre living is listed. The two first attitudinal questions (Q1 and Q2) speak to the proximity and adequacy of the public transport in the city centre. Regarding the proximity, almost all the respondents (73% + 25%) strongly agree or just agree respectively that buses, trams and trains are nearby. The vast majority (84%) also in general have agreed that the transit system in the city centre is adequate, although 4% have disagreed.

Questions 3 to 7 deal with the accessibility issue to a variety of activities. For Q3, 93% (67% + 26%) agree that city centre living makes the approachability to several public amenities, offices and colleges by walking feasible. With regard to Q4, almost all the respondents (97%) have stated there is an array of retailers within walking distance from their residence. In the fifth question, the vast majority (95%) of the respondents have also confirmed that leisure and entertainment facilities are nearby. Asking about the proximity to work or study places in Q6, 68% of the respondents showed their agreement about the proximity of these places; however, 14% have either disagreed or strongly disagreed. Question 7 is the last accessibility perception question. The respondents have been asked to express their agreement about the ease of motorway accessibility. Seventy two percent of them have agreed about that. To sum up, there is a general perception that living in the core of the city considerably aids the access to multiple facilities such as public amenities, retailers and leisure places. This is also, to a lesser extent, true with respect to the accessibility to the employment and educational places and to the motorway. The eighth question attempts to probe how residents appraise the buzz of city living, 92% of the respondents agree that the city centre is such a vibrant place.

Table 7-10: Perception of respondents towards city centre living (%).

	Attitudinal question	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
1	Public transport (bus, tram, train) stations are nearby	0	1	1	25	73
2	Adequate public transport services	0	4	12	34	50
3	Colleges, offices and public amenities all within walking distance	1	2	6	35	56
4	Variety of retailers is within walking distance	0	1	2	28	69
5	Entertainment and leisure facilities are nearby	0	2	3	27	68
6	Close to where I work/Study	7	11	16	26	40
7	Easy access to the motorway	0	5	23	40	32
8	Buzz of city living	0	1	7	29	63
9	External network of cycle routes provides adequate access to the area surrounding my neighbourhood	5	19	44	19	13
10	The design of the neighbourhood encourages my preferred mode of travel	2	7	21	30	40
11	Suitable pavements (footways) for pedestrians throughout the neighbourhood	1	5	4	47	43
12	There are plenty of off–street parking options available	14	27	29	21	9
13	Off – street parking charges are affordable	26	28	37	5	4
14	Crime rate is minimal within the neighbourhood	3	15	29	40	13
15	I feel safe to walk within the neighbourhood	0	3	20	48	29
16	Good street lighting	1	5	8	49	37

Number of individuals = 149.

According to Table 7-10, questions 9, 10 and 11 attempt to scale the attitude of the respondents towards three travel-related spatial characteristics. Regarding Q9, while 32% of the respondents agree that the external network of cycle routes provides adequate access to the area surrounding the centre, 24% have disagreed. About whether the city centre urban form encourages some people's modes of travel (Q10), 70% of the participants approved this while only 7% have disagreed. Finally, with regard to the eleventh question, 90% of the respondents think that there are adequate footways for pedestrians throughout Manchester city centre.

On the topic of car parking adequacy in terms of their availability and affordability in the Manchester centre, Q12 and Q13 have been developed respectively. Less than a third of the respondents has agreed that there is plenty of off-street parking. In contrast, 41% of respondents have perceived Manchester city centre as a neighbourhood with a lack of off-street parking. About the parking cost, 54% of the survey participants has explicitly expressed that the off-street parking charges in Manchester city centre are not affordable. These two aspects may be interesting for parking policy makers who utilise car parking as an effective tool in travel supply management.

Table 7-10 also shows that for the final three questions, Q14, Q15 and Q16, the individuals have been asked about three safety aspects of living in the city centre; crime, pedestrian safety and street lighting. Regarding whether the crime rate in the city centre is minimal, just over half of participants have agreed. With respect to the safety of walking in Manchester centre, 77% reported that it is safe to walk around. Finally, 86% of the respondents have shown their agreement that the street lighting is sufficient in the centre.

Table 7-11 displays the principal components analysis results. Four attitudinal factors (components) have been extracted. Each one of these factors has been accounted for (loaded) by a couple of items (questions) which are aimed at highlighting a common construct. The first factor has been named 'Vibrancy' since it combines three questions that generally highlight the perception of the participants towards the liveliness of Manchester city centre. The second factor, 'Accessibility', reflects the attitude of the residents towards the accessibility of the city centre relative to their work, university and other public amenities. Table 7-11 also shows that the two questions regarding the availability and affordability of off-street parking in Manchester city centre can be combined in one factor which has been named as 'Parking adequacy'. Last but not least, the perception of the people towards issues such as walking safety, crime rate and street lighting have all been found to highlight one common construct. For obvious reasons, this latent construct has been referred as 'Safety'. It is worthwhile noting that according to the footnotes of Table

7-11, the diagnostic statistics of factor analysis are all acceptable and accordingly they confirm the reliability of the results.

Table 7-11: Pattern matrix for perceived neighbourhood characteristic factors.

Factor[a,b]	Statement	Loading[c,d]
Vibrancy	Buzz of city living	0.840
	Variety of retailers is within walking distance	0.790
	Entertainment and leisure facilities are nearby	0.865
Accessibility	Close to where I work/Study	0.714
	Colleges, offices and public amenities all within walking distance	0.864
Parking adequacy	There are plenty of off–street parking options available	0.870
	Off – street parking charges are affordable	0.725
Safety	Crime rate is minimal within the neighbourhood	0.738
	I feel safe to walk within the neighbourhood	0.827
	Good street lighting	0.698

a. Extraction technique: principal components analysis; Rotation method: Oblimin with Kaiser Normalization.
b. KMO statistic is 0.664; Bartlett's test is significant (p-value = 0.000); Correlation matrix determinant = 0.127.
c. Extracted from the factor pattern matrix in which loadings represent the regression coefficient of each variable (statement) on the specific factor.
d. Factor loadings lower in magnitude than 0.45 are suppressed.

2) Neighbourhood preferences

Table 7-12 displays the results of the frequency analysis conducted on the five point Likert-scaled answers of the respondents. They were asked about the importance of several city centre living's aspects just before they decided to move to Manchester city centre. It is useful to mention that the questions are similar to those used in Table 7-10 but with one new question (Q8: Easy access to the city centre). This question highlights the overall importance for the respondents of living near Manchester city centre. The answers show that 94% (60% very important + 34% important) of them have addressed the importance of this aspect. In consequence, it is sensible to conclude that residential preferences play a main role when people are deciding to relocate. With regard to how important the proximity and adequacy of transit are (Q1 and Q2), Table 7-12 reveals that about three quarters of the respondents have agreed the importance of them per se during the relocation-process decisions. This empirical finding evidently expresses the central role of transit on people's major decisions and hence it has a likely role as an effective urban planning policy tool. The proximity to the public amenities (Q3), retailers (Q4) and leisure facilities (Q5) have been assessed as either important or very important by about (70 – 85)% of the respondents. This obviously addresses the issue that one of the reasons for Manchester city centre being such an attractive place is its recognised diversity.

Table 7-12: Residential preferences of respondents before moving to Manchester city centre (%).

	Preference question	Not at all Important	Not Important	Neutral	Important	Very Important
1	Public transport (bus, tram, train) stations are nearby	7	5	11	37	40
2	Adequate public transport services	1	4	16	44	35
3	Colleges, offices and public amenities all within walking distance	3	7	21	37	32
4	Variety of retailers is within walking distance	1	2	12	47	38
5	Entertainment and leisure facilities are nearby	1	4	10	45	40
6	Close to where I work/Study	7	12	18	29	34
7	Easy access to the motorway	21	29	25	13	12
8	Easy access to the city centre	1	1	4	34	60
9	Buzz of city living	0	4	19	39	38
10	External network of cycle routes provides adequate access to the area surrounding my neighbourhood	33	27	23	13	4
11	The design of the neighbourhood encourages my preferred mode of travel	2	6	36	37	19
12	Suitable pavements (footways) for pedestrians throughout the neighbourhood	5	8	28	48	11
13	There are plenty of off–street parking options available	23	24	25	21	7
14	Off – street parking charges are affordable	24	16	25	24	11
15	Crime rate is minimal within the neighbourhood	0	7	17	51	25
16	I feel safe to walk within the neighbourhood	1	2	8	41	48
17	Good street lighting	2	6	30	49	13

Number of individuals = 136.

Table 7-12 also reveals that closeness to the work or study place (Q6) was vital for 63% of the respondents, while accessibility to the motorway (Q7) was a key factor during moving for only 25% of the participants. Furthermore, the typical liveliness of the city centre (Q9) has participated in motivating 70% of respondents. Additionally, the table states that the status of the cycle network (Q10) was only important to 17% of the respondents. In contrast, other spatial urban features including these stated in Q11 (how encouraging is Manchester city centre to the respondent's preferred mode of travel?) or in Q12 (the availability of adequate footways) have been found to be influential factors for 56% and 59% of the respondents respectively during relocation. This finding highlights the existence of the self-selection effect. That is, for more than half of the respondents, the matching of the built environment of Manchester city centre to their travel preferences is one of the important factors that have essentially been taken into account before relocating.

Furthermore, while the availability of parking (Q13) is found to be central for only 28%, over a third of the respondents has appraised the affordability of parking charges as a key issue (Q14). These figures are quite considerable especially when bearing in mind that about half of the households now have actually no car (as will be seen later in Table 7-20). As a result, the previous two percentages highly likely reflect the other half – those who are with at least one household car. Hence, adequacy of parking is thought to be quite an important issue for people who drive.

Finally, with respect to the three safety questions, Table 7-12 reveals that to move to a place with a minimal crime rate (Q15) has been central for almost three-quarters of the respondents. Similarly, feeling safe to stroll (walking for leisure) in the city centre (Q16) has been essential for a large proportion of the respondents (89%). This finding clearly indicates the possible impact of feeling safe on walking behaviour. Last but not least, about 62% of the participants have approved the importance of the city centre's street lighting (Q17).

Table 7-13 lists the result of principal components analysis based on thirteen residential preference questions. These questions highlight a range of aspects that were important to the individuals to be considered before moving to Manchester city centre. It has been found statistically possible to categorise these thirteen different aspects into five categories according to the essential factors they contribute to. Each category (factor) represents a group of people who have quite similar prioritisation for the factors that might be governing during relocation. These five factors, according to Table 7-13, are transit adequacy, vibrancy, accessibility, parking adequacy and safety. The transit adequacy factor consists of two logical items, the accessibility to transit stations and adequacy of the transit services per se. Other factors are generally similar to those listed in Table 7-11. The principal components analysis statistics listed in the end of the table assure the statistical legitimacy of the analysis.

Table 7-13: Pattern matrix for preferred neighbourhood characteristic factors.

Factor[a,b]	Statement	Loading[c,d]
Transit adequacy	Public transport (bus, tram, train) stations are nearby	0.841
	Adequate public transport services	0.769
Vibrancy	Easy access to the city centre	0.458
	Buzz of city living	0.874
	Entertainment and leisure facilities are nearby	0.818
	Variety of retailers is within walking distance	0.544
Accessibility	Close to where I work/Study	-0.848
	Colleges, offices and public amenities all within walking distance	-0.782
Parking adequacy	There are plenty of off–street parking options available	0.952
	Off – street parking charges are affordable	0.936
Safety	Crime rate is minimal within the neighbourhood	-0.934
	Good street lighting	-0.766
	I feel safe to walk within the neighbourhood	-0.692

a. Extraction technique: principal components analysis; Rotation method: Oblimin with Kaiser Normalization.
b. KMO statistic is 0.71; Bartlett's test is significant (p-value = 0.000); Correlation matrix determinant = 0.004.
c. Extracted from the factor pattern matrix in which loadings represent the regression coefficient of each variable (statement) on the specific factor.
d. Factor loadings lower in magnitude than 0.45 are suppressed.

3) Travel attitude

In the last part of the attitudinal questions, the respondents have been asked to state the degree of their agreements towards 16 attitudinal revealed and stated-preference hypothetical questions. The questions attempt to reflect their preferences towards several aspects of their daily travel patterns as residents in Manchester city centre. Table 7-14 shows the distributions of Likert-scaled answers of the respondents.

The three first travel-attitude questions speak to the preferences of the respondents towards active transport (walking and biking) issues. In the first question (Q1), 90% of the adults have stated their overall agreement that they are fond of walking for pursuing activities within 2 miles distance. However, regarding liking cycling (Q2), only 46% have confirmed that, while 30% either disagree or strongly disagree. In appraising walking and biking as healthy travel modes (Q3), a great proportion of the respondents (95%) has shown their agreement.

Table 7-14: Current travel attitude of city centre respondents.

	Attitudinal question	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
1	I like walking for pursuing activities less than 2 miles	0	1	9	34	56
2	I like cycling.	13	17	24	27	19
3	Walking and cycling are healthy modes to travel.	0	1	4	29	66
4	I like driving.	4	8	30	34	24
5	Driving is safer than walking, biking, and public transport.	7	36	34	15	8
6	Commuting without a car is a hassle.	15	34	15	23	13
7	I would move out of Manchester city centre if it were to become a car-free (no car) development.	35	24	17	13	11
8	I consider public transport as an efficient choice for travel.	3	15	16	41	25
9	The availability of good and affordable public transport service could lead me to give up driving.	10	20	22	25	23
10	Proximity and pricing of parking do affect my decision of owning/giving up a car.	5	11	28	35	21
11	Where possible, occasionally I use phone and/or internet instead of travelling.	3	9	27	40	21
12	Where possible, I prefer to telework/telecommute rather than travelling.	7	22	37	24	10
13	Car sharing is an efficient means to reduce congestion.	2	8	16	42	32
14	I prefer to manage my travel by driving to more than one location in a single journey.	7	9	43	30	11
15	I usually consider fuel consumption when deciding to buy a car.	7	12	33	30	18
16	I make an effort to minimise my car-trips to help reducing emissions.	4	13	53	17	13

Number of individuals = 149.

According to Table 7-14, thereafter, four driving and car-related questions have been asked. The direct stated-preference question, “I like driving” (Q4), has gained a sum of strongly agrees and agrees of only 58% of the respondents; conversely, 12% of them have stated their disagreement to this statement. In the fifth question, only 23% of the respondents have a perception that driving is safer than cycling and biking, while the opponents comprised 43%. Moreover, in an attempt to probe how easy it may be to get people out of their cars, the opinion of respondents has been requested to assess the sixth question’s statement - “Commuting without a car is a hassle”. The tabulated results reveal that almost half of the respondents have expressed their disagreement while 36% have generally agreed. For the same purpose as the last question, the seventh question asks the participants to state their attitude towards the stated-preference statement that “I would move out of Manchester city centre if it were to become a car-free development”. Whereas 24% of the respondents have generally agreed, 59% of them stated that they would not.

Table 7-14 also demonstrates that with respect to the eighth question about considering public transport as an efficient option for travel, around two-thirds of the respondents have shown their agreement, while only 18% of them are opposed. In the same context, the respondents have been placed in a trade off between adequate transit service and giving up driving (Q9). The frequency analysis results show that while nearly half of them have declared their readiness to get off their vehicles, 30% have refused indicating that it is not about the sufficiency of public transport. To sum up, the responses of the last two stated preference questions could be quite informative as they confirm the potential role of transit as a policy tool in reducing car dependency. Nevertheless, it is worthwhile mentioning that results based on stated-preference experiments usually leads to over-estimate of forecasts. That is probably due to the typical discrepancy between what people state in an experiment and how they actually behave in real-life (Ryley, 2008).

The tenth question in Table 7-14 aims to predict the potential effectiveness of travel supply and travel demand management strategies such as the availability (supply) and affordability (demand) of car parking. In so doing, the respondents have been asked about the strength of the impact of the proximity and cost of parking on owning or giving up a car. Only 16% have indicated that these two issues are not influential, while 56% have underlined the importance of these aspects. Again, this might be quite interesting to the planning policy people in Manchester city council. That is because this offers evidence about the potential flexibility between parking policy in Manchester city centre and car ownership changes of its residents.

In questions (11) and (12), the effects of the telecommunication technology on the amount of travel have been investigated. Table 7-14 shows that 61% of respondents have stated that they occasionally use the phone and/or internet instead of travelling while only 12% have indicated that these tools have no impact on their travel patterns. In contrast, in Q12, while 34% of the respondents claimed that where possible they would telecommute rather than travel, 29% of them have reported the opposite.

In questions 13 and 14, the perception has been measured towards two techniques of minimising car-dependence; these are car sharing and tour trips. In Q13, about three-quarters of the respondents have stated that car sharing is an efficient way to mitigate traffic congestion. In Q14, 41% of the participants have claimed that they have a preference to manage their travel by driving to more than one location in a single journey (conduct a tour journey). In contrast, 16% of the city centre residents included in the survey sample have shown no interest concerning touring behaviour.

In the last two questions of Table 7-14, Q15 and Q16, the aim was to probe the participants' stated response towards two of the global transport-related concerns; energy use and transport-related emissions. In Q15, 48% of the city centre sample has confirmed the considering of fuel consumption when buying a car while 19% of the respondents represented the opposite side. This question also speaks to the impact of fuel pricing on car ownership, model and size. In the last question Q16, 30% of the respondents emphasised that they usually make an effort to minimise their vehicular journeys to assist reducing emissions. However, 17% of them declared their disagreement indicating that such an issue is not interesting for them.

As in Table 7-11 and Table 7-13, Table 7-15 displays the results of the third principal components analysis. The table reveals that the participating city centre residents can be grouped according to their travel attitude into four different principal groups. These are pro-active transport, pro- driving, pro- virtual mobility and pro- sustainability. The names of these components (groups) are self-evident. The pro- active transport component refers to two items (questions); the propensity of walking and the healthy assessing of active transport in general. The second factor, pro- driving, covers four items regarding how people appraise car and driving. Pro- virtual mobility, the third factor, comprises issues about how to do activities that are spatially far without being physically over there. This is done by using means such as telecommuting, phones and internet (Kenyon, Lyons, & Rafferty, 2002). Finally, the pro- sustainability factor comprises the attitude of individuals about three themes; these are car sharing, traffic congestion and travel emissions. Based on the diagnostic statistics listed, no assumption violations have been noticed.

Table 7-15: Pattern Matrix for Perceived travel Characteristic Factors.

Factor[a,b]	Item (question)	Loading[c,d]
Pro- active transport	I like walking for pursuing activities less than 2 miles	0.869
	Walking and cycling are healthy modes to travel.	0.691
Pro- driving	Commuting without a car is a hassle.	0.809
	I would move out of Manchester city centre if it were to become a car-free development.	0.727
	Driving is safer than walking, biking, and public transport.	0.675
	I like driving.	0.639
Pro- virtual mobility	Where possible, I prefer to telework/telecommute rather than travelling.	0.795
	Where possible, occasionally I use phone and/or internet instead of travelling.	0.781
Pro- sustainability	I make an effort to minimise my car-trips to help reducing emissions.	0.705
	I usually consider fuel consumption when deciding to buy a car.	0.695
	Car sharing is an efficient means to reduce congestion.	0.687

a. Extraction technique: principal components analysis; Rotation method: Oblimin with Kaiser Normalization.
b. KMO statistic is 0.61; Bartlett's test is significant (p-value = 0.000); Correlation matrix determinant = 0.163.
c. Extracted from the factor pattern matrix in which loadings represent the regression coefficient of each variable (statement) on the specific factor.
d. Factor loadings lower in magnitude than 0.45 are suppressed.

7.7.1.2 City centre built environment

(A) Dwelling unit tenure

Table 7-16 categorises the 125 approached dwelling units according to their tenure type. According to the table, there appears to be no significant difference in percentages between the units privately owned and those which are privately rented. However, in comparison with the average for England regarding the proportion of private renting (18%), it can be argued that the renting sector is thriving in Manchester city centre.

Table 7-16: Dwelling unit tenure.

Tenure	Frequency	Percent	Cumulative Percent	% in Manchester city [a]	% in England [a]
Privately owned	56	44.8	44.8	38.5	64.2
Privately Rented	67	53.6	98.4	30.0	18.1
Social housing	1	.8	99.2	31.6	17.7
Others	1	.8	100.0	0.0	0.0
Total	125	100.0		100	100

[a] According to the 2011 Census key statistics for England and Wales (ONS, 2012b, p23).

(B) Dwelling unit bedrooms

Table 7-17 shows that 94.4% of dwellings in the city centre sample are with one or two bedrooms. In other words, the average number of bedrooms per household is 1.71 (total bedrooms (214)/total households(125)). This average is much below the Manchester average (2.5) or the England average (2.7) (ONS, 2012a). This finding matches with the average household size (1.6) previously computed using the Manchester city centre survey data (Section 7.7.1.1(A)2).

Table 7-17: Number of dwelling unit bedrooms.

Bedrooms	Frequency	Percent	Cumulative Percent
1	44	35.2	35.2
2	74	59.2	94.4
3	6	4.8	99.2
4	1	.8	100.0
Total	125	100.0	

(C) Availability of communal parking

Table 7-18 classifies the dwelling units in the city centre sample according to the availability of communal parking in the apartment buildings. According to the analysis results, the apartment buildings with car parking are a little less than those without parking.

Table 7-18: Communal parking availability.

Status	Frequency	Percent	Cumulative Percent
Yes	57	45.6	45.6
No	68	54.4	100.0
Total	125	100.0	

(D) Accessibility to train stations and tram stops

As stated earlier, according to the boundary map of Manchester city centre, there are four over ground train stations and eight tram stops (see Figure 7-2). However, based on the public transport map of Manchester city centre, the Salford Central station is included in addition to the four mentioned above. It is useful to mention that according to this map the Salford Central station is only 200 m away from the official city centre's boundary. Hence, it has been included in the percentile analysis shown in Table 7-19

One of the most important points in the table is that the train stations are much more sufficiently scattered over the city centre than the tram stops. For instance, 15% of the dwellings in the city centre sample are in locations where the nearest train station is within only 100 metres. In contrast, the corresponding percent for tram stops is almost half (8%).

Table 7-19: Accessibility to train stations and tram stops.

Distance	Train stations (Cumulative %)	Tram stops (Cumulative %)
100	15	8
200	36	23
300	53	47
400	88	70
500	97	88
600	99	92
700	100	100

Number of included dwelling units = 116.

7.7.1.3 Travel patterns and characteristics

This section sheds light on some mobility-related features of the respondents.

(A) Household car ownership

Table 7-20 explores the household car ownership status due to its expected influence on mode choice and travel patterns. One of the most notable points is that just under half (48%) of the total contacted households has no access to a household car. This is somewhat more than the average over England (25.8%) (ONS, 2012a). The table also states that one-car city centre households encompass about (42.4%); this is quite similar to the local and national averages in Manchester and England. Moreover, while city centre households with two or more vehicles comprise as low as (9.6%), the 2011 Census figures shows that the corresponding average in Manchester city is (14.8%) and interestingly almost one-third of

English people are in a one household with more than one car (ONS, 2012a). Finally, according to Table 7-20, the household car availability is 0.61; mathematically, this is the total number of household cars (77) divided by the total participated households (125). According to the 2011 National Travel Survey (Table NTS0205), the corresponding rate in Great Britain is 1.14(Inside Government, 2012). To sum up, Table 7-20 suggests a specific relative car ownership status in Manchester city centre in which there is a notable proportion of households with no vehicle and, in contrast, a notable proportion with more than one vehicle. In addition, household car availability in city centres is much lower than the national rate.

Table 7-20: Number of vehicles per households.

No. of cars	Frequency - city centre	Percent-city centre	Cumulative Percent-CC	% Car Own. – Man. city[a]	% Car Own. – England[a]
0	60	48.0	48.0	44.5	25.8
1	53	42.4	90.4	40.6	42.2
2	12	9.6	100.0	12.5	24.7
>= 3	0	0	100.0	2.3	7.4
Total	125	100.0		100.0	100.0

[a] According to 2011 Census Table KS404EW (ONS, 2012a).

Table 7-21 summarises the number of car users in the city centre households in the sample. In general, one-half of the households are with no car user while the other half are with one or two users. Moreover, Table 7-22 classifies the city centre respondents whose households have a car according to their household car use status.

Table 7-21: Number of car users in households.

No. of car users	Frequency	Percent	Cumulative Percent
0	61	48.8	48.8
1	38	30.4	79.2
2	26	20.8	100.0
Total	125	100.0	

Table 7-22: Car use status of respondents.

Car use status	Frequency	Percent	Cumulative Percent
Full use	66	62.9	62.9
Partial use	24	22.8	85.7
None	15	14.3	100.0
Total	105	100.0	

The tabulated analysis results reveal that 63% of those individuals have stated that they fully use the household vehicle. In contrast, almost 23% of the individuals have reported that they partially use the household vehicle; while the rest (14.3%) reported that they usually do not use it.

(B) Household bicycle ownership

In an attempt to shed light on the propensity of city centre residents towards cycling, respondents were asked about their bike ownership. Table 7-23 shows that just over two-thirds of households have no bike. In contrast, 21.6% of the households have only one bike and 11.2% have two or more.

Table 7-23: Number of bikes in a household.

No. of bikes	Frequency	Percent	Cumulative Percent
0	84	67.2	67.2
1	27	21.6	88.8
2	13	10.4	99.2
More than 2	1	0.8	100.0
Total	125	100.0	

Moreover, Table 7-24 reveals that nearly 75% of the city centre respondents have no bike. This is a little higher than the British average for adults (16+) of 71% (calculated based on 2011 NTS Table 0608 - (Inside Government, 2012)). The remaining quarter of the respondents reported that they have at least one bike.

Table 7-24: Number of bikes per individual.

No. of bikes	Frequency	Percent	Cumulative Percent
0	150	74.3	74.3
1	48	23.8	98.0
2	4	2.0	100.0
Total	202	100.0	

(C) Car driving licence status

Table 7-25 demonstrates the variation in the households regarding the number of their members who holds a UK driving licence. The descriptive analysis results disclose that almost 90% of the city centre households are with members who have at least one UK driving licence. In order to gain a better understanding about mobility restriction and vehicle access issues, participants have been asked to state the status of their UK valid driving licence.

Table 7-26 states that nearly 70% of the city centre respondents have a full driving licence. This is slightly less than the British national average; according to the 2011 NTS Table 0201, adults of (17+) years old with a full car driving licence comprise about 72% of the total participants (Inside Government, 2012). The table also reveals that 8.4% have a provisional driving licence while the rest 21.6% either have never held a UK driving licence or have given up driving. In other words, of the 161 driving licence holders, 87.6% have a full licence and 10.6% have provisional one. It is worthwhile noting that whilst approximately 90% of the households have at least one driving licence (see Table 7-25), only just over half (52%) of them actually have at least one car (see Table 7-20).

Table 7-25: Number of driving licence holders in households.

Licence holders	Frequency	Percent	Cumulative Percent
0	13	10.4	10.4
1	65	52.0	62.4
2	45	36.0	98.4
3	2	1.6	100.0
Total	125	100.0	

Table 7-26: Driving licence type of respondents.

Licence type	Frequency	Percent	Cumulative Percent
Full licence	141	69.8	69.8
Provisional	17	8.4	78.2
Never held UK DL	41	20.3	98.5
Giving up driving	3	1.5	100.0
Total	202	100.0	

(D) Travelling frequency

As an attempt to explore the variation in the number of total daily trips usually undertaken by city centre's respondents in their typical travel weekday, Table 7-27 shows the relevant frequency analysis. According to this table, there are 4 respondents who stated that they generally do not conduct any trips in their typical travel day either because they work from home or for other personal reasons. The table also reveals that 40% of the total respondents (202) usually conduct only 2 trips daily; 12% conduct 3 trips; 27.7% conduct 4 trips; 11% conduct 5 trips and 8.4% conduct six or more daily trips.

Table 7-27: The frequency analysis of the Individual total daily trips.

No. of trips	Frequency	Percent	Cumulative Percent
0	4	2.0	2.0
2	79	39.1	41.1
3	24	11.9	53.0
4	56	27.7	80.7
5	22	10.9	91.6
6	15	7.4	99.0
7	2	1.0	100.0
Total	202	100.0	

Utilising the information included in the travel diary part of the household travel survey questionnaire, Table 7-28 lists the household and individual daily trip rates for several different reasons of travel (activities). In addition, the table also shows the total trip rates and the home-based trip rates. The equivalent Great Britain rates computed using the 2011 National Travel Survey (Table NTS0403) have been listed in the table for comparison purposes. Generally, the trip rate for a particular activity has been calculated as the total number of daily trips undertaken by a household (or individual) divided by the total number of households (125) (or individuals (202)).

The statistical descriptive analyses state that the mean total daily trip rate of the city centre's participating households is 5.26 (657/125) whereas the corresponding trip rate for individuals is 3.25. Furthermore, 87.6% [(576/657)*100] of these trips are home-based trips; that is, trips where either the origin or the destination is the home. This is quite consistent with the range reported by Ortuzar and Willumsen (2011, p.141) that non-home-based (NHB) trips are typically about (15-20) % of all journeys.

Table 7-28: Household and individual daily trip rates by activity.

Purpose	No. of daily trips	Household daily trip rate	Individual daily trip rate	2011 NTS Table 0403 Indv. daily trip rate GB
Work	253	2.02	1.25	0.40
Education	68	0.54	0.33	0.16
Shopping	109	0.87	0.54	0.53
Leisure	162	1.30	0.80	0.70
Others	11	0.09	0.05	0.84
Home	55	0.44	0.27	
Home-based	576	4.61	2.85	
Total daily	657	**5.26**	**3.25**	

Additionally, given that about 75% of the city centre respondents are in employment and that 47% of the households are occupied by only one person, it sounds logical that work trips are the highest trip rate of all the activities. The household work daily trip rate is about 2.0. In addition, the individual work trip rate is 1.25 and is notably higher than the British average of 0.40. The comparatively low figure of the education trips is probably because student's accommodations have not been approached. However, students living in apartment buildings within the city centre have not been excluded. Even so, the individual education trip rate (0.33) is twice than the national average. This is very likely because most of the buildings belonging to the three well-known Greater Manchester universities are within about only one mile from the city centre boundary. These universities are; Manchester, Manchester Metropolitan and Salford.

The table also highlights that leisure trips are the second highest trip rate (1.3 for households and 0.8 for individuals). It is slightly higher than British national average. It is worthwhile recalling here that leisure activities include entertainment, social, eating-drinking, sport, holidays and walking out journeys. Unsurprisingly, shopping daily trip rates have come in the third place with 0.87 for households and 0.54 for individuals. This individual trip rate for Manchester city centre is similar to the equivalent national average of 0.53. Trips listed under "Others" and "Home" categories encompass all other personal and escort trips. Table 7-28 reveals that the British average of these two categories (0.84) is much higher than the Manchester centre figure of 0.32 (0.27+0.05). Exploring the reason of these differences leads to the realisation that out-of-centre residents do indeed make more escort trips than the city centre dwellers. This is especially true for education-related escort trips regarding school-pupils (less than 17 years old).

Table 7-29 cross tabulates the household and individual weekly trip rates by the three main travel purposes; work, shopping and leisure. The results are quite similar to those listed in Table 7-28 in that work activity is the most frequent travel activity. This is followed by leisure and then shopping activities.

(E) Transport mode

The proportions of respondents using different travel modes for their daily personal travel are illustrated in Table 7-30 based on the travel diary data. The corresponding British averages figures computed using the 2011 National Travel Survey (Table NTS0301) are also

Table 7-29: Household and individual weekly trip rates to specific activities.

Purpose	No. of Weekly trips	Household weekly trip rate	Individual weekly trip rate
To Work	734	7.41	4.86[a]
To Shopping	446	3.57	2.21[b]
To Leisure	495	3.96	2.45 [b]

[a] total number of *to* work trips divided by the number of individuals who conducted these trips.

[b] total number of *to* shopping trips divided by the total number of individuals.

listed in the table (Inside Government, 2012). Seven travel modes has been explored; car driver, car passenger, walk, bike, bus, tram and train. The results confirm the perceived knowledge regarding the travel behaviour of the city centre residents already obtained from the previous analysis of this study and from the literature. According to the table, just over 60% of the respondents' daily trips are on foot. This is much higher than the national percentage (23%). Travelling by car has been found to comprise 20% of the total journeys which is considerably less than the British national average (64%). In contrast, travelling by public transport (specifically, buses, trams and trains) comprises 16.6% of the total daily journeys. Only 2.8% of journeys have been undertaken by cycling. Furthermore, Table 7-30 also shows that the use of bike, bus and train in Manchester city centre is quite higher than the corresponding national averages.

Table 7-30: Journey mode shares.

Mode	Frequency	Percent %	Cumulative Percent %	2011 GB NTS mode shares %
Car driver	127	18.5	18.5	42.0
Car passenger	10	1.5	20.0	22.0
Walk	415	60.6	80.6	23.0
Bike	19	2.8	83.4	2.0
Bus	57	8.3	91.7	7.0
Tram	25	3.6	95.3	-
Train	32	4.7	100.0	3.0
Total	685	100.0		

Additionally, the individual and household daily trip rates for each of the seven mentioned travel modes as well as to the individual equivalent national averages have been presented in Table 7-31. Generally, the tabulated results, as in Table 7-30, suggest that the respondents of Manchester city centre conduct more walking trips and fewer car trips than the GB national average (NTS Table 0303 – Inside Government (2012)). The comparatively high use of train is also evident.

Table 7-31: Household and individual daily trip rates crosstabulated by travel modes.

Mode	HH trip rate[a]	Ind. trip rate[b]	2011 GB NTS - Individual trip rates by mode %
Car driver	1.01	0.63	1.10
Car passenger	0.08	0.05	0.58
Walk	3.32	2.05	0.61
Bike	0.15	0.09	0.04
Bus	0.45	0.28	0.18
Tram	0.2	0.12	-
Train	0.25	0.16	0.05

[a] number of trips (specific mode) divided by the total households (125).
[b] number of trips (specific mode) divided by the total individuals (202).

(F) Journey purposes

In order to explore the common reasons for travel of the city centre residents based on the travel diary data, Table 7-32 exhibits the percentages of the essential daily activities that city centre respondents normally travel to carry out. According to the statistical analysis, travel to workplace comes in the first place. About 40% of the conducted daily trips are work-related trips. This is much higher than the national average of (15%) according to the 2011 NTS tables.

Leisure activities are found in the second place; 25% of respondents' journeys were for leisure purposes. This is quite lower than the national average of (31%). Two expected reasons could be proposed. The first is that while the city centre's respondents in the Manchester survey are asked to record trips of a single normal weekday, the NTS respondents were asked to fill in a 7-days travel diary. Hence, bearing in mind that leisure trips are typically more common during weekends, then it is understood to see this discrepancy in leisure trips. The second expected reason is trip chain behaviour in the personal mobility of city centre residents.

With respect to the shopping activity, while it comprises 16% of the journeys of the city centre respondents, it comprised 20% of the trips in the NTS. Both the suggested reasons regarding leisure activity could be adopted here too. Concerning educational establishments, the results reveal that they comprise only 10% of the total trips of the city centre residents. This share is obviously higher than the British national average (for all ages) of 6.0% rather than the specific corresponding average (older than 16 years adults) of 1.3%. The discrepancy in averages clearly arises from school trips. Table 7-32 also proposes that

"Others" and "Home" cover only (9.6%) of total trips and they are much lower than the Great Britain proportion of 27.8%. As stated previously, the reason is the difference in the escort trips.

Table 7-32: Proportions of journeys by purpose shares.

Purpose	Percent(%)[a]	2011 GB NTS purpose shares %[b]
Work	39.6	15.0
Education	9.8	6.0 (1.3[c])
Shopping	16.2	20.0
Leisure	24.8	31.0
Others	1.6	27.8
Home	8.0	
Total	100	

[a] N (total number of trips = 685.
b Based on the 2011 NTS Tables 0401 and 0403 (Inside Government, 2012).
c Calculated based on the 2011 NTS Table 0611 using the weighted average method after excluding persons less than 17 years old (Inside Government, 2012).

In an attempt to explore the variation in mode use for the main daily activities of city centre residents, Table 7-33 has been created. In this table, the statistics for total daily person trips broken down by activity and by travel mode are listed. Statistically speaking, the cross tabulation analysis shows that Pearson's Chi-square test of independence is significant (p-value = 0.000) at the 5% significance level. That is, there is a notable influence of the travel purpose on the proportions of journeys conducted by travel modes.

Furthermore, figures in parentheses shown in the table represent the percentage shares of journeys categorised by travel modes for each specific travel purpose. These figures have been listed to ease the comparison with the British national averages. The corresponding averages have been computed manually based on the GB NTS Table 0409 (Inside Government, 2012). Several interesting points can be drawn from the comparison.

Regarding travel to workplaces, the city centre analysis suggests that nearly half (48%) of the trips to workplaces are on foot and third of them by car. This is obviously in contrast with the equivalent national averages for walk 10% and by car 67% (see Table 7-33). The national averages speaks clearly to the spatial separation between housing developments and workplaces

For education, the Manchester survey sample suggests that the majority of trips (63%) to the educational destinations are by public transport while 28% of them are by walking. Nationally, the picture is different; travel by car (driver or passenger) and on foot are the two major modes of travelling for education reasons. Travel by transit is only responsible for 13% of trips. It is worthwhile highlighting here that the NTS averages here include all ages; i.e., trips and escort trips for primary and secondary schools are included (see Table 7-33).

In the case of the shopping behaviour of the city centre's residents, the analysis reveals that the vast majority (83%) of shopping journeys have been conducted by walking. This is followed by transit (11.7%) and then by car (5.4%). Over Britain, the corresponding averages for walking, transit and car are 23%, 11% and 64% respectively. Comparatively, the share of car over Britain is very high and its role is quite evident.

Finally yet importantly, based on this survey nearly three-quarters of leisure trips have been travelled on foot. The car was the mode for only 17% of them. The British averages suggest a different picture in which the car plays a vital role; based on the NTS, 70% of leisure trips are conducted by cars. This is followed by walk (16%) and then by public transport (11%).

Table 7-33: Number of adults daily journeys crosstabulated by mode and purpose.

Journey purpose	Number of total daily trips (%)				
	Walk	Bike	PT	By car	Total
Work	130 (48)	8 (3)	42 (15.5)	91 (33.5)	271 (100)
Education	19 (28.3)	4 (6)	42 (62.7)	2 (3)	67 (100)
Shopping	92 (82.9)	0 (0)	13 (11.7)	6 (5.4)	111 (100)
Leisure	125 (73.5)	6 (3.5)	9 (5.3)	30 (17.7)	170 (100)
Others[a]	7 (63.6)	0 (0.0)	4 (36.4)	0 (0.0)	11 (100)
Home	42 (76.4)	1 (1.7)	4 (7.3)	8 (14.6)	55 (100)
Total	415 (60.6)	19 (2.8)	114 (16.6)	137 (20)	685 (100)

Pearson Chi-square (196.9, 15) with p-value of 0.000 at 5% significance level; N = 685.
[a] include other personal business trips and escort trips.

As, highlighted previously, the travel diary part of the questionnaire only includes travel information about one day for which the respondents were asked to choose a normal weekday of travel. Therefore and for the purpose of obtaining a better understanding of people's travel behaviour, the respondents were asked also to record several responses regarding their weekly personal mobility. Table 7-34 and Table 7-35 display the results based on the descriptive analysis for weekly trips data. Table 7-34 shows the average numbers of weekly trips conducted to work, shopping and leisure activities separately and using four different modes. These modes are walking, cycling, public transport and by car. The first important point in the table is that going to a workplace is the most frequent weekly reason for travel among city centre respondents. This is in spite of the point that work trip rates are at the individual level while shopping and leisure rates are at the household level.

This supports the previous finding that the vast majority of respondents are in employment or self-employed. Leisure and shopping activities come in second and third places respectively. The second key point is that for all activities the highest weekly trip rates have been found in the walk category (first row). That is, walk is the most popular mode of travel. This is followed by the household car, transit and finally the bicycle.

Table 7-34: The average number of weekly trips to several activities by different modes.

Mode	To work (per person)	To shopping (per household)	To leisure (per household)
Walk	4.48	3.51	3.26
Bike	3.20	1.67	2.00
Transit	3.67	1.73	2.06
Car	3.93	1.75	2.42

In contrast, Table 7-35 is like the preceding table but the numbers represent the percentages of individuals or households in each specific category. For instance, it suggests that walking is the weekly typical mode for commuting for 45% of individuals. Similar to Table 7-34, the table indicates two key issues; first, it indicates that walking is the preferred mode for Manchester city centre residents and households for commuting, shopping and leisure. Moreover, walking is the choice for the vast majority of households (73% and 70%) as the typical mode for shopping and leisure respectively. Second, the highest uses for car and transit are for commuting.

Table 7-35: HH and individual typical mode use variation for weekly work, shopping and leisure trips.

Mode	% To work[a]	% To shopping[b]	% To leisure[c]
Walk	45.1	73.3	70.0
Bike	3.9	1.7	3.0
Transit	20.3	8.5	7.5
By car	30.7	16.1	19.5

[a] individual- level analysis N=202 [b] Household-level analysis N=125

[c] Household-level analysis N=125

(G) Journey length – distance and duration

This section covers the last exploratory analysis that deals with the travel behaviour of the Manchester city centre respondents. This travel analysis sheds light on the daily spatial dispersion of the personal mobility of the city centre respondents. The objective is to examine to what extent the built environment of the city centre as a high density and mixed use neighbourhood could help in reducing the journey distance or duration and hence the corresponding negative impacts.

The results of the percentile analysis regarding percentages of trips within a specific length and categorised according to activity or mode are shown in Table 7-36 and Table 7-37 respectively. The analysis is based on the travel diary data. Four key distances have been chosen as thresholds. These distances are 0.75, 2.0, 5.0 and 12.5 miles. Different reasons are behind choosing these specific cut points. According to the factsheet tables included in the Manchester City Council website, the 2011 Census states that the Greater Manchester area is 127,603 hectares and Manchester city centre area is about 306 hectares (Manchester City Council, 2012b). Accordingly, the equivalent radii of these areas are approximately 12.5 mi and 0.61 mi respectively. The 0.61 mile distance has been slightly increased to 0.75 mile to include areas that have a similar nature to the city centre although some of them might administratively be on the edge of city centre.

Furthermore, the 5 mile cut-off has been chosen as according to the Google Maps website (http://maps.google.co.uk) it simulates the radius to the Manchester outer ring road (M60 Motorway). Finally, the 2-mile cut-off is usually the limit which is almost always applied to walking trips. Having stated that, the four cut points adopted to shape the percentile analysis are the three radii in addition to the 2-mile distance.

Table 7-36 shows the cumulative percent of trips as a total and broken down by activities at the four cut points. Three interesting points can be seen. First and foremost, about 70% of the whole daily mobility happens within two miles from the respondent's residence. In comparison, the corresponding national British average is only 39% (Table NTS0308; Inside Government, 2012). This finding could add to the compact city concepts in that promoting the intensification of a neighbourhood to be akin to the Manchester city centre one could assist in reducing the miles travelled. Second, trips to workplaces are the most scattered ones in comparison with the shopping and leisure trips. That is, while only half of the journeys to jobs are within 2 miles from the residences, the parallel percentages for shopping and leisure trips are 88% and 84% respectively. Nevertheless, trips of the Manchester centre residents to their workplaces are still considered notably shorter in comparison with the national GB average. In numbers, according to Table 7-36, the median of commuting distances is about 2 miles while the national average is nearly 9 miles (Table NTS0405; Inside Government, 2012). Third, shopping and leisure trips have quite a similar spatial dispersion. Based on the second and third points above, it is quite reasonable to underline the strength of the retail and entertainment sectors in the Manchester central area.

For comparison purposes, the total journeys corresponding for 1mile distance is also calculated. The calculations show that 57% of the total journeys are within only 1mile from the residences. The equivalent percentage in the SHS urban centres sample is 53%. This might be due to the recognised compact nature of the Manchester city centre.

Table 7-36: Journey distance frequency by activity.

Distance (mi)	Accumulative percent of trips %			
	All activities %	Work %	Shopping %	Leisure %
0.75	42	27	58	58
2.0	70	51	88	84
5.0	83	68	94	94
12.5	93	87	98	98

Table 7-37 is generally similar to Table 7-36 but it breaks down the trips by the mode of travel. The first worthwhile point to note is that over two-thirds of the walking trips of the Manchester centre respondents are within 0.75 mile; i.e., within the boundary of the city centre. According to the 2011 GB NTS findings (Table NTS0308; Inside Government, (2012)), this is higher than the national equivalent average of 52%. Moreover, it is obvious that almost all the walking travel is within 2 miles from the residents’ homes. Regarding the spatial dispersion of travel by public transport, the tabulated results suggest that two-thirds of journeys can be considered as urban and within the M60 Manchester ring road. Moreover, only 3% of journeys are longer than 12.5 miles; i.e., most probably beyond the boundary of Greater Manchester. The final key point in Table 7-37 is that travelling by car for the centre’s residents is well below the British average based on the 2011 National Travel Survey, especially for short distances. For instance, up to two miles the included car trips for the centre residents is only 13% which is almost half the corresponding national British average of 24% (TableNTS0308; Inside Government, (2012)). These percentages become quite similar at 31-mile distance; 90% and 94% respectively. One of the probable reasons is the absence of school escort trips (typically short) in the centre whereby the travel by car comprises about 43% of them (Table NTS0409; Inside Government, 2012).

Table 7-37: Journey distance frequency by travel mode.

Distance (mi)	Cumulative Percent of trips %		
	Walking	Transit	By Car
0.75	68	5	2
2.0	99	33	13
5.0	100	66	46
12.5	100	97	70
31.0	100	99	90

In contrast, a percentile analysis has been run on the journey duration data in an analogous way to the analysis of journey distances. The percentile analyses concerning proportions of journeys which are within a specific time and categorised according to activity or mode are shown in Table 7-38 and Table 7-39 respectively.

Table 7-38 reveals that one-third of the trips of the Manchester city centre respondents are within 10 minutes from their homes regardless of the reason for travel. The table also highlights that employment places are more scattered than shopping and leisure centres. This confirms the relevant argument mentioned above based on Table 7-36. Finally, while the city centre sample shows that the average journey duration is 15 minutes, the parallel British average is 22.8 minutes (Table NTS0406; Inside Government, 2012).

Table 7-38: Journey time frequency by activity.

Time (min.)	Cumulative Percent of trips			
	All trips	Work	Shopping	Leisure
10	33	21	46	52
15	58	38	68	83
30	86	75	95	93
45	95	92	97	99
60	99	98	100	100

Regarding exploring journey travel time by modes, the analysis of the travel diary part of the Manchester household survey discloses that the median trip duration on foot is 15 minutes, by transit is 25 minutes and by car is 30 minutes (see Table 7-39). The corresponding 2011 NTS averages are 17 minutes by walking and 21 minutes by car (Table NTS0311; Inside Government, 2012). While there is no notable discrepancy regarding walking trips, it seems that the city centre dwellers travel by car for relatively long journeys. It is worthwhile recalling here the absence of the escort school trips by car as one of the likely reasons for this behaviour.

Table 7-39: Journey time frequency by travel mode.

Time (min.)	Cumulative Percent of trips		
	Walking	Transit	By Car
10	48	6	3
15	75	27	12
30	98	64	66
45	99	85	91
60	100	100	96

7.7.2 Inferential Analysis

The subsequent sections display the results of the statistical analyses performed to develop the necessary travel behaviour models.

7.7.2.1 Journey frequency

Using the trip frequency information embedded in the survey questionnaire, especially the travel diary part, six travel behaviour models have been developed to examine various measures of travel frequency (trip incidence). Given that the outcome (dependent variable) is a count variable, the GsLM procedure has been employed to run the six Negative Binomial regression models. The models have been specified by choosing the negative binomial as the probability distribution, log as the link function and maximum likelihood as the parameter estimation method. Five of the developed models are at household level (N=125 households) and one at the individual level (N= 149 residents).

(A) Daily household total trips

Table 7-40 shows the analysis results for the developed negative binomial regression model. The outcome (response) variable represents the total daily trips conducted by the households in the city centre sample. Seven personal and spatial features have been chosen to comprise the model predictors in order to inspect their potential effect on the daily household journey frequency. These predictors are, household income level, availability of communal parking, household size, number of household cars, number of household members in employment, distance to the nearest train station and lastly distance to the nearest bus stop.

According to the model statistics listed in Table 7-40, two main points may be underlined. First, with the exception of household size, all other included characteristics (IVs) are not significant at the 5% level. The number of household adults is found to have quite a tangible and logical effect on the household total daily trips. The value and sign of the incident rate ratio (Exp(B)) corresponding to the household size predictor is 1.701. This implies that one adult increase in the number of household members would lead to 70% increase in the number of daily trips. However, the second important point to report is that the whole model is not statistically significant. The Model likelihood ratio's Chi-square has a p-value of 0.470, which is larger than the significance level of 0.05.

Table 7-40: The GsLM negative binomial regression results for the total daily household trips model.

Parameter	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower	Upper
(Intercept)	.714	2.500	.114	2.042	.843	4.950
High HHincom	.089	.070	.791	1.093	.566	2.111
Mid HHincom	.075	.073	.788	1.078	.623	1.865
Low HHincom	0[a]	.	.	1	.	.
Park_yes	.104	.161	.688	1.109	.668	1.843
Park_no	0[a]	.	.	1	.	.
HHSize	.531	6.855	.009	1.701	1.143	2.532
HHcars	-.065	.108	.742	.937	.634	1.384
Employees	-.067	.155	.694	.935	.668	1.307
Distrain	<.001	.242	.623	1.000	.999	1.002
Distram	<.001	.040	.842	1.000	.999	1.001

Model likelihood ratio Chi-square (8) = 7.637 with p-value of 0.470.
McFadden's pseudo R-squared = 0.01

[a] reference category.

On the other hand, different possible reasons can be outlined to explain this lack of statistical significance. For example, the absence of an income effect could be justified as that how affluent a household is could only notably affect the quality of the journey in terms of for instance the mode and the properties of the activity location. No such effect is expected on the quantity of travel. In other words, people may take the same number of shopping or entertainment journeys but spend money differently. Regarding the availability of the household car, being not significant factor is possibly because car availability would affect accessibility (trip length) more than the frequency. Finally, taking the accessibility to train stations and tram stops as our final example , two possible reasons could be behind the not a significant impact of them. First, as shown in Table 7-36, 70% of the journeys of the city centre's sample are actually within only 2 miles from traveller's residences. Second, as with the car the closeness of these stops and stations might affect the length of the trip rather than its incidence rate. The third reason is statistical, that is these transit infrastructures, especially train stations, are quite evenly distributed over the city centre catchment area and they are all within reasonable walking distances from the households. Hence, this reduces the possibility of there being a significant difference among households.

(B) Daily household shopping and leisure trips

Table 7-41 and Table 7-42 display the statistical outputs for the daily household shopping and leisure trips models respectively. In both models, the six included explanatory variables are, household income level, household size, number of household cars, number of household members in employment and the distances to the nearest train station and bus stop. According to Table 7-41, the analysis output reveals that all the predictors are not significant at 5%; nevertheless, the number of vehicles is only significant at 10% significance. Furthermore, the results suggests that increasing the household car ownership by one car would lead to a decrease in the daily shopping journeys by a factor of 0.654 (Exp(B)). That is, households with a car are expected to conduct 34.6% fewer shopping journeys than households without car. The apparent explanation is that the presence of household vehicle would increase the propensity of doing say two weekly main shopping journeys rather than three minor ones. Statistically speaking, the overall model is not significant. The Model likelihood ratio's Chi-square is with p-value of 0.427; again reasonably larger than the adopted significance level of 0.05.

Likewise, according to Table 7-42 only two variables are significant; these are household size (p-value = 0.019) and number of household members in employment (p-value = 0.057). Regarding household size, the results suggest that the presence of one additional household member would increase the daily leisure trip frequency by a factor of 1.767. That is, there is about 77% rise in the leisure trip rate when the number of the 16+ adults increased by one.

Table 7-41: The negative binomial regression results for the daily household shopping trips model.

Parameter	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower	Upper
(Intercept)	-.859	2.041	.153	.424	.130	1.377
High HHincom	.212	.221	.638	1.236	.512	2.985
Mid HHincom	.175	.242	.623	1.191	.594	2.389
Low HHincom	0[a]	.	.	1	.	.
HHSize	.293	1.266	.260	1.340	.805	2.231
HHcars	-.425	3.109	.078	.654	.408	1.049
Employees	-.215	.987	.321	.806	.527	1.233
Distrain	<.001	1.847	.174	1.001	.999	1.003
Distram	<.001	.432	.511	1.001	.999	1.002

Model likelihood ratio Chi-square (8) = 7.015 with p-value of 0.427.
McFadden's pseudo R-squared = 0.022

[a] reference category.

Table 7-42: The negative binomial regression results for the daily household leisure trips model.

Parameter	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower	Upper
(Intercept)	-.527	.879	.348	.591	.196	1.776
High HHincom	.492	1.333	.248	1.635	.710	3.769
Mid HHincom	.435	1.519	.218	1.544	.774	3.082
Low HHincom	0[a]	.	.	1	.	.
HHSize	.569	5.487	.019	1.767	1.097	2.846
HHcars	.153	.512	.474	1.166	.766	1.774
Employees	-.398	3.634	.057	.672	.447	1.011
Distrain	<.001	.018	.893	1.000	.998	1.002
Distram	<.001	.346	.556	1.000	.998	1.001

Model likelihood ratio Chi-square (7) = 8.863 with p-value of 0.263.
McFadden's pseudo R-squared = 0.023

[a] reference category.

On the other hand, the table also reveals that the presence of employed people in a household would in general reduce its outdoor leisure activities. Speaking in numbers, for example a two-employed family would make fewer leisure trips than a one-employed family by a factor of 0.672. In other words, the two-employed family would conduct about 33% fewer leisure trips than the one-employed one. This probably reflects the relative lack of spare time for people in employment. Finally, the overall model is not statistically significant (p-value = 0.263).

(C) Weekly household shopping and leisure trips

Table 7-43 and Table 7-44 show the statistical output of the weekly household shopping and leisure models respectively.

Table 7-43: The negative binomial regression results for the weekly household shopping trips model.

Parameter	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower	Upper
(Intercept)	.943	4.211	.040	2.568	1.043	6.323
High HHincom	.237	.478	.490	1.268	.647	2.484
Mid HHincom	.219	.592	.442	1.245	.713	2.173
Low HHincom	0[a]	.	.	1	.	.
HHSize	-.016	.006	.936	.984	.665	1.457
HHcars	-.189	.965	.326	.828	.568	1.207
Employees	.007	.002	.966	1.007	.721	1.408
Distrain	<.001	.708	.400	1.001	.999	1.002
Distram	<.001	.001	.990	1.000	.999	1.001

Model likelihood ratio Chi-square (7) = 2.421 with p-value of 0.933.
McFadden's pseudo R-squared = 0.005

[a] reference category.

Table 7-44: The negative binomial regression results for the weekly household leisure trips model.

Parameter	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower	Upper
(Intercept)	1.244	7.191	.007	3.471	1.398	8.618
High HHincom	.305	.798	.372	1.357	.695	2.651
Mid HHincom	.345	1.497	.221	1.412	.812	2.454
Low HHincom	0[a]	.	.	1	.	.
HHSize	.028	.020	.888	1.029	.691	1.532
HHCars	-.074	.149	.700	.929	.639	1.350
Employees	-.062	.125	.724	.940	.665	1.327
Distrain	<.001	.088	.767	1.000	.998	1.001
Distram	<.001	.324	.569	1.000	.998	1.001

Model likelihood ratio Chi-square (7) = 2.072 with p-value of 0.956.
McFadden's pseudo R-squared = 0.004

[a] reference category.

The same predictors have been utilised in both negative binomial regression models; these are income level, household size, household cars, people in employment and accessibility to train stations and tram stops. None of these personal and spatial characteristics is statistically influential. Furthermore, the statistics of the Chi-square tests reveal that the overall models are also not significant at 5% level. The tabulated analysis results generally indicate that households living in Manchester city centre have a shopping and leisure weekly trip frequency behaviour that is not obviously affected by personal attributes or by the closeness to train stations and tram stops.

(D) Daily individual total trips

A travel behavioural model has also been developed for the total daily individual trips. Several personal, spatial and attitudinal attributes have been utilised as indicators. According to Table 7-45, these indicators are highest individual education level, driving licence status, total annual household's income class, number of household cars, distances from individual's residence to the closest train station and tram stop, pro-driving factor and lastly pro-active factor. The table also lists the negative binomial regression analysis results.

Table 7-45: The analysis results of the GsLM negative binomial regression model of the individual daily total trips.

Parameter	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower	Upper
(Intercept)	1.236	9.464	.002	3.442	1.566	7.566
Edu_Less	-.172	.350	.554	.842	.477	1.488
Edu_UG	.037	.030	.861	1.038	.684	1.575
Edu_PG	0[a]	.	.	1	.	.
DL-others	.081	.091	.763	1.084	.642	1.829
DL-full	0[a]	.	.	1	.	.
High HHincom	-.064	.051	.821	.938	.541	1.628
Mid HHincom	-.025	.009	.924	.976	.588	1.619
Low HHincom	0[a]	.	.	1	.	.
HHCars	-.051	.073	.788	.951	.658	1.374
Distrain	<.001	.090	.765	1.000	.999	1.002
Distram	-0.001	.006	.938	1.000	.999	1.001
F1 pro-driving	.038	.104	.747	1.038	.826	1.306
F4 pro-active	.105	1.161	.281	1.111	.918	1.344

Model likelihood ratio Chi-square (10) = 2.225 with p-value of 0.994.
McFadden's pseudo R-squared = 0.004

[a] reference category.

According to these results, all the mentioned variables and factors have shown no considerable impact on the individual's daily trip incidence rate. In addition, the overall model is not statistically significant (p-value = 0.994). That is to say, the analysis implies that how many journeys the respondents of Manchester city centre perform is not notably influenced by the examined characteristics. This is generally comparable with the previous corresponding model using the SHS dataset (see Table 6-23). That is, with the exception of 'time to nearest bus stop', all the examined variables have no tangible influence on the individual's trip frequency. This variable was initially excluded from the Manchester model due to the specific nature of Manchester city centre where bus stops are well distributed and hence there was no indication about the benefit of including this transport infrastructure variable.

7.7.2.2 Vehicle miles travelled (VMT)

Two travel models have been developed to examine the characteristics that might affect the vehicle miles travelled (VMT) of the Manchester city centre's residents. Extracting data from the travel diary part of the survey questionnaire, the first model is devoted to investigating the motorised travel distance of 124 households whereas the second one is to examine the VMT of 149 individuals. In both models, the sequential multiple linear regression has been employed for the statistical analysis.

It is useful at the outset to highlight that all the major assumptions of linear regression are met. Multicollinearity is not present; the variance inflation factor (VIF) is within the recommended range (less than 10). Furthermore, the assumption of independence of errors holds; the Durbin-Watson statistic is within the recommended range (1.0 – 3.0). Finally, the statistical criterion for identifying outliers is also met; maximum standardised residuals are less than 3.29.

(A) Total daily household VMT

Table 7-46 displays the sequential regression analysis results for both the reduced (Model No. 1) and full (Model No.2) models. The outcome variable is the household vehicle miles travelled. As mentioned previously, the first model only contains the spatial characteristics. The table states that three transport-related features are included; these are availability of communal parking, distance to train station and distance to tram stop. Among these three, only car parking availability is found to be statistically significant (p-value = 0.006). The analysis results suggest households with a car parking space provided with their apartments conduct more than 13 miles motorised travel than those without parking provision. The apparent explanation is that households who choose an apartment provided with a car parking space usually have a car.

The results of Model No.2, where socioeconomic data are added, support this proposed explanation. Five variables that attempt to describe the household socioeconomic circumstances have been added to the already existing ones to formulate altogether the predictors of the second model. Table 7-46 shows that these five are household size, number of household members with a driving licence, number of employees, number of cars and household income. Overall, among these personal and spatial indicators, only the number of household cars has been found to have a significant impact (p-value = 0.002), logical sign (positive) and considerable value (14.42). One car increase in the vehicle ownership status is found to be associated with more than fourteen miles rise in the household motorised distance.

Table 7-46: The OLS linear regression results for the hh daily total VMT model.

Parameter	Model No. 1			Model No. 2		
	B	SE	Sig.	B	SE	Sig.
Constant	-2.936	7.117	.682	-11.535	8.727	.203
Park_yes	13.268	4.428	.006	2.950	4.727	.554
Park_no	0[a]					
Distrain	.022	.014	.118	.012	.014	.379
Distram	.021	.016	.198	.017	.018	.345
HHsize				5.120	3.670	.160
DLholders				-2.063	3.672	.589
Employees				3.172	2.974	.306
HHcars				14.419	4.487	.002
Low HHincom				0[a]		
Mid HHincom				-.026	5.135	.995
High HHincom				-2.359	7.412	.774
R^2 adjusted		0.094			0.176	
ANOVA – p-value		0.002			0.000	
Durbin-Watson			1.826			
Max. Std. Residuals			< 3.29			
Max VIF		1.104			2.547	

[a] Reference category.

In brief, this implies that household personal characteristics in general and household vehicles in particular still affect the travelled miles distance of a household even after controlling the effects of spatial features. While the first model was capable of explaining only 9% of the total variation in the outcome, the total model is capable of explaining more than 17.5%. According to the ANOVA F-statistic, both of the models are statistically significant.

(B) Total daily individual vehicle miles travelled

Similarly, Table 7-47 lists the statistical results for the individual total daily VMT. In the first model, the analysis results reveal that distance from the household residence to the nearest tram stop is the only influential variable. However, it is only significant at the 10% significance level and with a small magnitude. Moving to the second model where several socioeconomics have been included, interestingly only the number of household vehicles is statistically significant at 5% and with quite a tangible effect. The presence of a car has been found to be linked with almost a ten miles rise in the individual vehicular distance. The proportion is also true regarding for instance two households one with two cars and the other with only one. No empirical evidence has been found about a notable impact of other variables such as education level, employment status, driving licence status and household income. Both models are statistically significant and the second model has raised the amount of variance explained by the predictors by more than 4% (difference in R-squares).

In the third model, four perception factors have been added to the variables already present. The purpose is to help in answering the essential question as to the extent the perception of Manchester city centre's dwellers towards several housing and travel aspects could affect their motorised travel behaviour. The attitudinal factors are perceived accessibility and individuals with pro-active transport, pro-virtual mobility and pro- driving travel attitude. Table 7-47 shows that among these factors only the perceived accessibility factor has a noteworthy impact at the 5% significance level. The sign of the specific regression parameter is logically negative and its value is quite large (6.664). This implies that there is a connection between the individuals, who perceive Manchester city centre as a place where all the public amenities and work/study places are within reasonable walking distances, and their daily vehicular travel. In particular, a one unit rise of such perception is found notably correlated with 6.664 miles reduction in the individual vehicle miles travelled.

This is quite self-evident, in that when most of the everyday-life destinations are within walking distances, this would highly probably reduce the propensity of using vehicular modes of travel. It is sensible to finally point out that the third model is statistically significant (p-value = 0.001) and it added more than 5% to the amount of the explained variation in the response variable.

Table 7-47: The OLS linear regression results for the indv daily total VMT model.

Parameter	Model No. 1		Model No. 2		Model No. 3	
	B	SE	B	SE	B	SE
(Constant)	-5.337	7.722	-7.225	7.037	-2.375	7.303
Distrain	0.016	0.011	0.005	0.011	0.004	0.011
Distram	0.039*	0.021	0.028	0.020	0.025	0.019
In employ.			3.836	3.818	4.079	3.637
Not in employ.	0[a]					
Edu_PG			-1.655	4.023	0.443	4.082
Edu_Less			1.290	4.748	0.049	4.342
Edu_UG [a]						
DL-full			-0.356	4.171	-2.745	4.275
DL-others			0[a]			
Low HHincom			0[a]			
Mid HHincom			0.162	4.052	-1.129	3.813
High HHincom			1.285	6.083	-0.243	5.124
HHcars			9.804**	3.847	6.884	4.474
F5 access					-6.664**	2.137
F4 pro active					0.404	2.441
F3 pro vmob					-0.981	2.639
F1 pro driving					1.617	1.574
R^2 adjusted	0.052		0.095		0.148	
ANOVA – p-value	0.007		0.006		0.001	
Durbin-Watson			2.189			
Max. Std. Residuals			< 3.29			
Max VIF	1.008		2.319		2.365	

[a] Reference category.
* Significant at 10% level of significance.
** Significant at 5% level of significance.

7.7.2.3 Car ownership

Table 7-48 displays the binary logistic regression analysis output for the household vehicle ownership model. The outcome (dependent variable) is a dichotomous variable (without car/with at least one car). The first category (without car) has been chosen to be the reference category. The conceptual reason for that is the specific interest of the current analysis in examining what makes households acquire a car. In consequence, the generalised linear model algorithm has been specified by choosing binomial as the probability distribution, logit as the link function and maximum likelihood as the parameter estimation method. The data of the 125 city centre sample's households was extracted from the socioeconomic part of the survey questionnaire. The sequential approach of considering the data has been adopted. Accordingly, three models have been developed. The first contains only transit characteristics; several socioeconomic traits have been added to configure the second model. Finally, several attitudinal factors have been added to the second model in order to specify the predictors of the third model.

According to Table 7-48, only the parking space variable is significant and with a tangible and sensible impact (p-value = 0.000; Exp(b) = 10.975). This implies that households with apartments provided with car parking spaces are more likely to own a car than those households without a parking space. In numbers, the odds of owning a car are about 11 times higher for a household with a parking space provided with their apartment compared to one without a car parking space. In contrast, the accessibility to the tram stops and train station have shown no interesting impacts. The relatively well scattering of these transit provisions over the city centre could be the reason behind there being negligible effect. This strong impact of the availability of car parking within apartments blocks could be highly informative and useful for parking policy and local planning authority stakeholders in Manchester city centre.

Comparatively, the results of the second model reveal that attributes such as the number of driving licence holders and the household income have a significant and quite strong impact on the household tendency of getting a car even after controlling for the spatial variables. Generally, the increase in the number of driving license holders in a household is found to be linked with the increase in the tendency of the household of having a vehicle. A similar effect is found with the households with high income (> £50,000). In numbers, the odds of owning a car for a household with specific driving licence holders are 3.267 times the odds of a household with one less driving licence holders. Likewise, concerning annual household income level, the results of the second model reveal that a rise in the income level for a household from the low level (< £30,000) to the high one (> £50,000) would increase its odds to have a car by a factor of 7.6.

Table 7-48: The sequential logistic regression results for the household car ownership model.

Reference category = no car	Model No. 1				Model No. 2				Model No. 3			
	B	S.E.	Sig.	Exp(B)	B	S.E.	Sig.	Exp(B)	B	S.E.	Sig.	Exp(B)
Constant	-1.489	0.749	.047	.226	-2.780	1.173	.018	.062	-2.900	1.323	.028	.055
Distrain	.002	.002	.356	1.002	<.001	.002	.907	1.000	<.001	.002	.912	1.000
Distram	<.001	.001	.827	1.000	.001	.002	.408	1.001	.001	.002	.656	1.001
Park_no	0[a]											
Park_yes	2.396	.450	**.000**	10.975	2.142	.521	**.000**	8.520	2.196	.578	**.000**	8.993
HHSize					-.522	.561	.352	.593	-.199	.596	.738	.820
DLHolders					1.184	.480	**.014**	3.267	.985	.499	**.048**	2.679
Low HHincom					0[a]		.026				.094	
Mid HHincom					.958	.604	.113	2.607	.628	.665	.345	1.873
High HHincom					2.029	.751	**.007**	7.606	1.756	.821	**.032**	5.790
Employees					-.057	.416	.890	.944	.063	.447	.887	1.066
F5 access									-.513	.280	**.068**	.599
F1 pro-driving									.456	.266	**.087**	1.578
F2 pro-sustain									.254	.265	.338	1.289
F3 pro-vmob									-.324	.258	.209	.723
Chi-square test of model significance	$X^2(3) = 37.462$; p-value = 0.000				$X^2(8) = 61.758$; p-value = 0.000				$X^2(12) = 72.410$; p-value = 0.000			
-2 Log likelihood	135.624				111.328				100.677			
Cox & Snell R Square	0.259				0.390				0.440			
Nagelkerke R Square	0.345				0.520				0.587			

Finally, in the third model, attitudinal factors have been included to represent the householder perception towards four housing and travel aspects. These are perceived accessibility, pro-driving, pro- sustainability and pro- virtual mobility. Of these factors, only the first two are statistically significant at the 10% significance level. Regarding accessibility, the results reveal that householders who agree that Manchester city centre is a ward where most of the public amenities and work/study places are accessible on foot are less probable to own a car compared with householders without such a perception. In particular, a one unit increase in the perceived accessibility factor is found to be associated with a decline in the tendency of owning a car by a factor of 0.599. In other words, there is 40% reduction in the odds of owning a household car for each one unit increase in the factor of accessibility. Furthermore, based on Table 7-48, logical evidence has also been found regarding the pro-driving factor. It is useful to recall that the pro-driving agreement scale includes items which attempt to measure to what extent householders are car dependent and positively appraise driving. The tabulated results suggest that households with high pro- driving householders have been found more likely to own a car than those with householders who are not pro-driving. In numbers, the odds of owning a household vehicle are 1.578 times higher for a family with a householder of certain pro- driving factor score compared to one with one unit lower factor score. The third model presents empirical evidence regarding the influence of the travel attitude and neighbourhood preferences on the likelihood of owning a car.

According to the chi-square test of significance, the three models are statistically significant (p-value = 0.000). In addition, moving from model no. 1 towards model no. 3, a continuous reduction in the (-2 Log likelihood) statistic can be easily noticed. Statistically, this implies the existence of a proportional increase in the total variation explained by the model's predictors and accordingly a reduction in the unexplained variation. This is, in addition, supported by the increase in the pseudo R-square which also indicates the model's goodness of fit.

To sum up, several interesting points can be outlined based on the analysis results of the sequential regression analysis. The most notable point in the first model is that it presents evidence about the impact of parking availability on the tendency of car ownership. Furthermore, two points are worthy to be highlighted in the second model. First, the previous impact of parking is still present even after adding the socioeconomic variables.

Second, there is evidence that the socioeconomic circumstances of the household, in particular number of driving licence holders and income level, significantly affect the tendency of owning a car even after controlling for the spatial variables in the first model. Finally yet importantly, the tabulated results of the third model emphasise two points. The first is that the previous influential spatial and personal features still show a significant effect even after including the attitudinal factors. This would imply that their effect is quite essential and not because of a confounding (spurious effect by an extraneous variable). In contrast, the second point is that the individual's perception and attitude have shown a notable effect even after controlling for the previous spatial and personal characteristics.

7.7.2.4 Mode choice behaviour

Three mode choice models have been developed using the Generalised Linear Model approach. The first two are for modelling the mode choice behaviour of the city centre households for weekly shopping and leisure journeys (n = 125). In contrast, the third one is to model the main daily mode for working journeys conducted by the city centre respondents (n = 140). As stated previously, for sample size adequacy issues, the outcome variable is combined to be dichotomous and the two levels are active transport vs motorised transport. While active transport obviously includes walking and cycling, the motorised transport includes travel by car (driver or passenger) and by public transport. For the same reason, a conservative number of predictors has been employed. Finally, the generalised linear model algorithm has been specified by choosing the binomial as the probability distribution, logit as the link function and maximum likelihood as the parameter estimation method.

(A) Typical weekly household shopping mode

The choice model data is extracted from the weekly travel patterns section of the survey questionnaire. The outcome variable is the typical weekly shopping mode of the households in the Manchester city centre sample. The descriptive analysis indicates that the modal shares are 75% active and 25% motorised transport. Only three predictors have been utilised; number of household cars, distance to the nearest train station and distance to the nearest tram stop. Table 7-49 displays the analysis output. Among the included explanatory variables, only the number of cars are significant at the 5% level. The distance to train station is only significant at the 10% level and it is impact is trivial. The effect of household cars is quite tangible and with a sensible direction of influence. An increase in the household vehicles is associated with a rise of propensity of choosing the motorised mode for shopping activities. In numbers, for example, holding everything else constant, the odds of choosing a vehicular mode goes up by 103% [(2.028 – 1)*100%] when the number of household cars increases by one unit (one car).

Table 7-49: The binary logistic regression results for the household's typical weekly shop mode model.

Reference category = active transport	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower	Upper
Constant	-.086	.015	.902	.918		
HHcars	.707	5.018	.025	2.028	1.092	3.763
Distrain	-.003	3.037	.081	.997	.994	1.000
Distram	-.001	.768	.381	.999	.996	1.001

Model likelihood ratio Chi-square (3) = 7.368 with p-value of 0.061.
Cox & Snell R Square = 0.057; Nagelkerke R Square = 0.081

Statistically speaking, the overall model is marginally significant (p-value = 0.061) and with quite a small R-square coefficient.

(B) Typical weekly household leisure mode

Similarly, a binary logit model has been also developed with the same predictors but for modelling the typical household weekly leisure mode. The descriptive modal shares analysis reveals that 73% of households choose active travel modes while only 27% of them choose vehicular modes for leisure activities. Table 7-50 presents the modal analysis output. Only the number of household cars has shown a considerable effect; however, it is marginally significant (p-value = 0.059).

The effect is realistic; the growth in household vehicles would raise the probability of selecting vehicular modes for leisure journeys. In other words, holding everything else constant, the odds of selecting a motorised mode increase by 74.5% when there is a one unit rise in the number of household cars. Finally, the overall model is not significant at the 5% level (p-value = 0.061) and it has a low R-square coefficient.

Table 7-50: The binary logistic regression results for the household's typical weekly leisure mode model.

Reference category = active transport	B	Wald Chi-Square	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
					Lower	Upper
Constant	-.724	1.223	.269	.485		
HHcars	.557	3.570	.059	1.745	.979	3.110
Distrain	<.001	.003	.958	1.000	.997	1.003
Distram	<.001	.132	.716	1.000	.997	1.002

Model likelihood ratio Chi-square (3) = 3.675 with p-value of 0.299.
Cox & Snell R Square = 0.029; Nagelkerke R Square = 0.040

(C) Main daily individual work Mode

The descriptive analysis shows that while 52% of the individuals choose active travel modes as their main daily commuting means, the rest (48%) opt to commute using transit or by car. A binary mode choice model has been developed to examine the potential impact of several spatial, socioeconomic and attitudinal features on the individual's choice behaviour. The sequential approach of data entering is adopted specifically to investigate the expected impacts of the individual's perception and attitude on the choice behaviour after ruling out the effects of the other variables. Hence, two models have been constructed. The first for the spatial and socioeconomic traits; these are distance to workplace (in miles), distance to the nearest train station (in metres) and the number of household vehicles. In contrast, the second model comprises the two attitudinal factors; pro- active and pro- sustainability.

Table 7-51 lists the analysis output. The results of the first model illustrate that both the distances variables are significant. However, while the distance to station is with negligible effect, the distance to workplace is with considerable impact. There is a notable increase in the odds of using a motorised mode by a factor of 12.743 when the distance to the work increases by one mile; while the direction of influence is expected, the effect size seems to be a very sensitive response.

Regarding the second model, two points are useful to be underlined. First, the effects of the initial three variables almost stay as they are; both distances are still significant and only the commuting distance has a large influence. Second, while the sustainability factor is not significant, the pro- active factor is significant at the 10% level and with rational sign. Individuals who are in support of walking and biking modes are less likely to use motorised modes for daily commuting. In numbers, there is a reduction in the odds of using motorised modes by a factor of 0.267 when the individual's score on the pro-active factor goes up by one unit.

To conclude, first, the spatial separation between individual's residence and workplace in addition to the individual's attitude towards active modes are both influential in the mode choice process. Second, their impacts are quite independent (essential not spurious); that is, including the attitudinal factor does not cancel the distance effect. Similarly, there is an effect of the individual's attitude even after controlling for the impacts of other non attitudinal variables. This extra effect of attitude can be statistically proven by noticing the reduction in the (-2 Log likelihood) statistics or, alternatively, the moderate increase in the R-square coefficient.

Table 7-51: The sequential logistic regression results for the main daily individual work mode model.

Reference category = active transport	Model 1			Model 2		
	B	SE	Exp(B)	B	SE	Exp(B)
Constant	-3.399	1.435	.033	-3.330	1.811	.036
Diswork	2.545**	.742	12.743	2.906**	.940	18.282
Distrain	-.012**	.005	.988	-.015**	.007	.985
HHcars	.818	.977	2.267	1.107	1.209	3.024
F4 pro-active				-1.320*	.772	.267
F2 pro-sustain				-.522	.746	.593
Chi-square test of model significance	$X^2(3) = 114.8$; p-value = 0.00			$X^2(5) = 119.9$; p-value = 0.000		
-2 Log likelihood	24.709			20.450		
Cox & Snell R Square	0.679			0.692		

* Significant at 10% level of significance.
** Significant at 5% level of significance

7.8 Summary of main findings and policy implications

The quantitative analysis performed in this chapter was based on the data extracted from the household travel survey questionnaire. To achieve better insights regarding living characteristics of Manchester city centre and its residents' travel behaviour, the analyses output were compared with the 2011 National Travel Survey results. Having said that, this section outlines the central findings of the descriptive and predictive statistical analyses run in order to address the objectives and research questions already set for this chapter.

7.8.1 Exploratory analysis

7.8.1.1 Personal characteristics of residents

(A) Socioeconomic and sociodemographics

According to the exploratory analysis and the comparisons with the national averages extracted from the 2011 Census results, several informative points can be outlined. First, according to findings extracted from Table 7-4, it can be stated that Manchester city centre in particular and urban centres in general are not attractive living places for households with dependent children or for elderly people; instead, they are obviously so for young people. According to Table 7-5, about 97% of the participant households are either one or two people households.

Second, depending on Table 7-7, almost 75% of the city centre respondents are either in employment or self-employed. This is much higher than the averages in Manchester and over England; 50.7% and 61.9% respectively. Moreover, the economically inactive people due to being retired (5.0%) or unemployed (4%) are lower than the local and national averages. Overall, the findings support the literature in that the vast majority of the people living in the city centre are economically active. Furthermore, Table 7-8 revealed that people in the high occupational rank (such as professionals, seniors, managers and directors) represent nearly two-thirds of the participants. In comparison, the Manchester equivalent average is 27.5% and the England average is 28.4%. This evidently implies that Manchester city centre is a strong attractive place for people with high occupations.

Third, regarding the highest educational level, Table 7-9 shows that 80% of individuals claimed that they are at least with an under-graduate (UG) or equivalent degree. This proportion is much higher than local average in Manchester (29%) or the national one over England (27.4%). Moreover, whereas the ratio of people without qualifications in Manchester or England is about 23%, the corresponding percentage in the city centre survey is only 1.0%.

(B) Attitude and preferences

1) Perception

According to the opinions of the respondents as residents of Manchester city centre (see Table 7-10), there is a general perception that Manchester city centre is a vibrant place whereby many facilities such as public amenities, retailers and leisure places are accessible by foot. This is also true but to less extent concerning the accessibility to the work/study places. Regarding the affordability and availability of off-street car parking, the majority of residents are not agreed that off-street parking is available or affordable. These two aspects could be useful for the parking policy makers who utilise car parking as an effective tool in the travel supply management. Finally, a minority of residents expressed their disagreement about the three safety statements that Manchester centre has a low crime rate, and is a safe place to walk and with well-lit streets.

2) Neighbourhood preferences

Table 7-12 lists the resident's responses towards aspects that were important for them before relocating to Manchester city centre. About living near the city centre, 94% of respondents addressed the importance of this aspect. In consequence, it is sensible to conclude that residential preferences play a main role when people are deciding to relocate.

With regard to how important the proximity and adequacy of transit are, about 75% of the respondents have agreed the importance of them per se during the relocation-process decisions. This empirical finding evidently addresses the vital position of transit on people's relocation decisions and hence its expected role as an effective urban planning policy tool.

The proximity to the public amenities, retailers and leisure facilities has been assessed as either important or very important by about (70% – 85%) of the respondents. This provides a powerful indication for urban regeneration stakeholders that one of the reasons for a prosperous residential sector in Manchester city centre is its current recognised diversity.

In addition, findings highlight the existence of the self-selection effect. That is, for more than half of the respondents, the matching of the urban form of Manchester city centre to their travel preferences is one of the important factors that have essentially been taken into account before relocating. This is supposed to bring the attention of the urban planners and relevant policy makers about the anticipated impact of resident's perception on their personal travel behaviour.

Finally, while the availability of parking is central for only 28%, over third of the respondents appraised the affordability of parking charges as a key issue. These figures are quite considerable especially when recalling that about half of the households now have actually no car (Table 7-20). Consequently, the previous two percentages highly likely reflect the other half – those who are with at least one household car. Hence, adequacy of parking is quite an important issue for people who drive.

3) Travel attitude

Table 7-14 reveals the travel attitude of the Manchester city centre's residents. Regarding residents' willingness to reduce their car dependency, they were placed in a trade off between adequate transit service and giving up driving. The frequency analysis results showed that about 50% of them have declared their readiness to reduce their car use. This finding could be quite informative as it substantiates the potential role of public transport as a policy tool in reducing car dependency. In the same context, interesting evidence is found about the potential flexibility between parking policy in Manchester city centre and car ownership changes of its residents. Further, 48% of the respondents confirmed the considering of fuel consumption when buying a car. This could speak to the impact of fuel pricing on car ownership, model and size. On the other hand, using the principal components analysis technique, the city centre's respondents were possible to be categorised according to their travel attitude into four different principal groups. These are pro-active transport, pro- driving, pro- virtual mobility and pro- sustainability.

7.8.1.2 Travel characteristics of residents

(A) Household car ownership

According to Section 7.7.1.3(A), nearly 50% of the contacted households has no access to a household car. Based on the 2011 Census results, this is substantially less than the average over England (25.8%). Additionally, whilst city centre households with two or more vehicles comprise only (9.6%), the equivalent average in England is about 30%.

(B) Car driving licence status

It is worthwhile noting that whilst approximately 90% of the households have at least one driving licence (Table 7-25), only just over half (52%) of them actually have at least one car (Table 7-20).

(C) Travelling frequency

According to Section 7.7.1.3 D, the descriptive analysis of the city centre sample pointed out the average total daily trips is 3.25 for individuals and 5.26 for households. In addition, the analysis found that the individual daily work trip rate is 1.25 for the city centre respondents; it is notably higher than the British average of 0.40 extracted from the 2011 NTS. The daily frequency of individual trips for education purposes (0.33) is also found to be twice the national average. No such discrepancy is found for shopping trips.

(D) Transport mode

According to the Table 7-30, over 60% of the respondents' daily trips are on foot. This is much greater than the national percentage (23%). Travelling by car has been found to comprise 20% of the total journeys which is considerably less than the British national average (64%). Furthermore, the use of bike, bus and train in Manchester city centre is moderately higher than the corresponding national averages.

(E) Journey purposes

In Section 7.7.1.3 E, several analyses were performed regarding reasons for travel. According to Table 7-32, commuting comes in the first place with about 40% of the conducted daily trips being work-related. This is much higher than the national average of (15%) according to the 2011 NTS tables. On the other hand, Table 7-33 illustrated that nearly 50% of the commuting journeys are on foot and over 33% of them by car. This is noticeably in contrast with the equivalent national averages for walk (10%) and by car (67%). Similarly, the vast majority of the shopping and leisure journeys have been conducted by walking. In comparison, car is the dominant mode for these journeys over Britain. Furthermore, walking is also found to be the dominant typical weekly mode for commuting, shopping and leisure trips. To conclude, the comparisons with the 2011 GB national Travel Survey results brings the attention towards the compact nature of Manchester city centre and its impact on promoting walking as the most typical mode.

(F) Journey length – distance and duration

The objective is to examine to what extent could the built environment of the city centre as a high density and mixed use neighbourhood help in reducing the journey distance or duration and hence the corresponding negative impacts.

Table 7-36 shows about 70% of the whole daily mobility happens within two miles of the respondent's residence. In comparison, the corresponding national British average is only 39%. This finding could add to the compact city concepts in that promoting the intensification of a neighbourhood to be akin to the Manchester city centre one could assist in reducing the miles travelled. Moreover, commuting trips are the most distant ones in comparison with the shopping and leisure trips. That is, while only half of the journeys to jobs are within 2 miles from the residences, the parallel percentages for shopping and leisure trips are 88% and 84% respectively. Nevertheless, trips of the Manchester centre residents to their workplaces are still considered notably shorter in comparison with the national GB average. In numbers, according to Table 7-36, the median of commuting distances is about 2 miles while the national average is nearly 9 miles.

Table 7-37 demonstrated that over 66% of the walking trips of the Manchester centre respondents are within up to 0.75 mile long; i.e., within the boundary of the city centre. According to the 2011 GB NTS, this is higher than the national equivalent average of 52%. The table also confirmed that the residents of Manchester centre are less car dependent than the national average, especially for short distances. For instance, up to two miles the proportion of car trips for the centre residents is only 13% which is almost half the corresponding national British average of 24%.

Finally, while the city centre sample shows that the average journey duration is 15 minutes, the parallel British average is 22.8 minutes.

7.8.2 Inferential Analysis

7.8.2.1 Journey frequency

Several journey trip models have been developed by running the negative binomial regression using the GsLM procedure. Overall, all the models were not statistically significant although some of their predictors were significant or marginally significant. The results could be useful for the policy makers by enlightening them about the appropriate characteristics that should/should not be utilised as policy tools in reducing trip frequency.

First, a frequency model was developed for the daily household total journeys. Seven personal and spatial features were chosen as predictors. These are, household income, availability of parking, household size, household cars, employment status, distance to train station and lastly distance to bus stop. According to Table 7-40, household size is the only predictor with a significant effect. One adult increase in the number of household members would lead to 70% increase in the number of daily trips. However, the whole model is statistically not significant.

Second, with the exception of the parking variable, the same predictors were used to develop two extra trip frequency models for daily household shopping and leisure trips per se. According to Table 7-41, the analysis output of the shopping model reveals that all the predictors are not significant at 5%. Likewise, according to Table 7-42 only two variables are significant in the leisure model; household size and number of household members in employment. The results suggested that there is about a 77% rise in the leisure trip rate when the number of the 16+ adults increased by one. The table also revealed that the presence of employed people in a household would in general reduce its outdoor leisure activities. A two-employed family would conduct about 33% fewer leisure trips than the one-employed one.

Third, Table 7-43 and Table 7-44 show the statistical output of the weekly household shopping and leisure models respectively. The same previous predictors have been utilised in both negative binomial regression models; these are income level, household size, household cars, people in employment and accessibility to train stations and tram stops. The results revealed that these variables are not statistically influential.

Finally, A travel behavioural model has also been developed for the total daily individual trips. Several personal, spatial and attitudinal attributes have been utilised as indicators. According to Table 7-45, these indicators are education level, driving licence status, annual household's income, number of cars, distances from individual's residence to train station and tram stop, pro-driving factor and lastly pro-active factor. According to the analysis results, all the mentioned variables and factors have shown no significant impact on the individual's daily trip incidence rate.

7.8.2.2 Vehicle miles travelled

Two vehicle miles travelled models were developed; one for the households and one for the individuals. In both models, the sequential multiple linear regression has been employed for the statistical analysis.

Table 7-46 displays the sequential regression analysis results for the household VMT model. Among the examined spatial variables (first block), only the availability of a car parking space is found to be significantly and positively linked with the household vehicular movement. Households with a car parking space provided with their apartments conduct 13 miles motorised travel more than those without parking provision. That is probably because households who decide to live in an apartment provided with a car parking space usually have a car and probably use it. The rationality of this justification was approved based on the results of the second block where socioeconomic data are added. Table 7-46 shows that the number of household cars has a significant influence. One car increase in the vehicle ownership status is found to be associated with more than fourteen miles rise in the household motorised distance.

In contrast, Table 7-47 lists the statistical results for the individual total daily VMT. Two key points are worthwhile mentioning. First, a significant impact of number of cars on an individuals VMT was evident and considerable even after controlling for some spatial predictors. The presence of a car/or an extra car was found to be associated with nearly a ten miles rise in the individual vehicular distance. Second, evidence was found regarding the influence of the attitudinal factors on the individuals VMT even after controlling for the influences of spatial and socioeconomic predictors. In particular, the perceived accessibility factor was found statistically influential. The results revealed a connection between the individuals, who perceive Manchester city centre as a place where public amenities and work/study places can be accessed by foot, and their daily vehicular travel. A one-unit rise in such perception is found to be notably correlated with a 6.6 miles reduction in the individual vehicle miles travelled. This is quite self-evident in that when most of the everyday-life destinations are within walking distances, this would most probably reduce the propensity of using vehicular modes of travel. In the policy implications context, increasing the compactness of a neighbourhood would reduce the vehicular travelled distance of its residents.

7.8.2.3 Car ownership

The propensity of a household to own a car was modelled using a sequential logistic regression analysis. The first block of predictors is devoted to spatial variables, the second for socioeconomic while the third for the attitudinal variables. According to the analysis output listed in Table 7-48, several key points were noticed. First, households living in apartments provided with a car parking space are much more likely to own a car than those without a parking space. This considerable effect of parking availability could be highly informative and useful for parking policy and local planning authority stakeholders in Manchester city centre. Second, the socioeconomic circumstance was also found to have a notable effect on the likelihood of households to have a vehicle; this is particularly true for the number of driving licence holders and high-income households. Both of them are found to have a positive and strong connection with the tendency of owning a household car.

Finally yet importantly, the tabulated results of the attitudinal sub model emphasise two points. The first is that the previous influential spatial and personal features still show a significant effect even after including the attitudinal factors. This would imply that their effect is quite essential and not spurious. The second point is that the individual's perception and attitude have shown a notable and sensible effect on owning a car even after controlling for the spatial and personal characteristics. The specific attitudinal factors are the perceived accessibility factor and the pro- driving factor. Regarding the individual's perceived accessibility of Manchester city centre, households in which their householders approve the accessibility of the centre are found to have less of a tendency of owning a car. On the other hand, the tabulated results showed that those households with high pro- driving householders are found more likely to own a car than those with householders who are less pro- driving.

7.8.2.4 Mode choice behaviour

Three mode choice models have been developed; household weekly shopping, household weekly leisure, and individual daily working journeys. Logistic models were developed whereby the choice set is active versus motorised transport modes.

For the two household models, Table 7-49 and Table 7-50 illustrated that the effect of number of household cars is quite substantial and rational. The increase in the household vehicles is highly associated with the increased propensity of choosing a motorised mode for shopping and leisure activities per se. In numbers, for example, holding everything else constant, the odds of choosing a vehicular mode for shopping and leisure trips increase by about 103% and 75% correspondingly when there is one unit rise in the number of household cars. On the other hand, for the main daily individual commuting trips, a sequential logistic model was developed and several key points can be highlighted (see Table 7-51). First, there is an expected notable increase in the odds of using a motorised mode by a factor of 12.743 when the distance to the work increases by only one mile. Second, an additional influence of the travel attitude is noticed even after ruling out the impact of car ownership and the distances to work and to a train station. Specifically, individuals who are in support of walking and biking modes (pro- active modes) are less likely to use motorised modes for daily commuting. A drop in the odds of using motorised modes by a factor of 0.267 for each one-unit increase in the individual's score on the pro-active factor.

7.9 Summary

This is the last analytical chapter; the focal interest was to examine to what extent the living characteristics of Manchester city centre could influence the personal travel behaviour of its residents. Furthermore, it is also to examine the relative importance of these socioeconomic, spatial and attitudinal characteristics. This would, accordingly, help in achieving the targets of the transport strategy of Manchester city centre of supporting smarter travel choices. This is by understanding and identifying the characteristics and factors that are influential on people's travel options and decisions, consequently, paving the way for policies and schemes that are effective in encouraging people to change their travel habits to more eco-friendly ones. An original household travel survey has been conducted in Manchester city centre to form the analysis dataset. It is difficult to obtain a reasonably sized sample for city centre household travel surveys. The current general unwillingness to respond to such surveys is compounded by the characteristics of this specific population which is more likely to include vacant properties and transient occupants. This places an extra importance on achieving a high quality response, which is complete and representative. This was achieved in this original survey. Both descriptive and predictive statistical techniques have been utilised. In particular, the Generalised Linear Model procedure has been mainly employed to develop the required personal mobility measures models. The exploratory analysis findings presented empirical-based evidence about the distinguishing characteristics of urban centre living in general and Manchester city centre in particular. In contrast, the developed travel behaviour models revealed the major role of several personal, attitudinal and spatial features on the travel of city centre residents'. The relative influence of these features was also revealed.

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

8.1 General

The overarching aim of this study has been to identify and understand city centre living in UK cities from a travel behaviour perspective. The intended contribution of the research outcome is to enlighten UK planning policy in setting out city centre renaissance schemes with reference to the sustainable transport agenda. Several main objectives with their precise research questions have been set. The study has been designed and structured to develop and address these research questions which were initially set out in Chapter 1 and will be revisited later in this concluding chapter. This chapter endeavours to draw a spectrum of conclusions from the whole study.

In so doing, the chapter is organised into three main sections; addressing the research questions, policy implications and recommendations. Section 8.2 presents the answers for the preset research questions. Section 8.3 addresses the key policy implications of the findings of the current study. Finally, recommendations for future work are discussed in Section 8.4.

8.2 Addressing the research questions

In the following subsections, the research questions of the three major objectives of the whole study are considered.

8.2.1 Objective -A

To conduct a comprehensive thematic review of the published empirical literature, and to explore recent developments in travel behaviour theory in order to identify the current state of knowledge and to learn from previous research.

This objective has been achieved by addressing its five relevant research questions as follows:

8.2.1.1 Research question A1

What are the variables and factors that typically have potential impacts on the sustainable travel behaviour of people in general and on city centres' residents in particular?

The goal is that the findings would contribute in specifying travel models adequately; i.e., to develop parsimonious models in which only relevant travel variables are included. This research question has been addressed in the second chapter.

The research reviewing process has indentified three dimensions of factors which have been found to be associated with travel behaviour. Almost all the recent travel behaviour studies have included at least one of them. These dimensions are urban form, socioeconomics and demographics, and attitudes and perceptions. Hence, it was decided to utilise them as explanatory variables in the travel models developed in this study. The review process has revealed one or more key reasons that highlight the importance of the utilisation of each dimension.

(A) Urban form characteristics

The importance of including urban spatial features is found to be grounded on three bases; empirical, theoretical and policy-related. The empirical-based basis is that the literature reviewed has shown empirical-based evidence regarding the impacts of the spatial characteristics of a neighbourhood (site development) on the travel behaviour of its residents (section 2.4.1). Theoretically, several researchers have suggested that land use variables can be used as a substitution (proxy) for the key travel cost element of the utility-based travel behaviour theory. That is, providing that the need for travel has a derived nature in that people travel to reach destinations where their pursued activities are located, then the built environment characteristics of neighbourhoods where people live or activity centres where people travel to are most likely to be important for travellers when making decisions that maximise their utility (Section 2.4.1 and Section 4.2).

Finally, the planning policy-related reason is that including spatial variables that policy can control in order to shape the travel is highlighted in both the policy statements (Section 2.4.1) and in the initial theory of travel behaviour (Section 4.2). Generally, urban form features are often broken into three main aspects; land use patterns, transport system and urban design (Section 2.4.1).

(B) Socioeconomics and demographics

Two bases have been found for the inclusion of these personal attributes. Empirically, a large amount of the literature reviewed has shown the potential influence of socioeconomic and demographic attributes (Section 2.4.2). Theoretically, the inclusion of the income variable is essential in any utility-based travel demand model in order to reflect the resource aspect; others attributes are equally important to shape the differences in preferences of choices among travellers (Section 4.2).

(C) Attitudinal factors

The literature review stage showed that recently several researchers have pointed out the importance of including people's attitudes and perceptions towards several travel and housing aspects in travel behaviour models (Section 2.4.3). Empirical evidence has been found about the possibility of these factors for intervening in the relationship between the socio-spatial variables and the travel behaviour indicators.

8.2.1.2 Research question A2

To what extent are the findings of previous travel behaviour research certain and consistent? In addition, what are the most likely reasons behind uncertainty and inconsistency?

The initial goal was to help in the creation of an adequate conceptual framework and modelling strategy. This research question has been addressed in the second chapter.

The literature review of the study has revealed a certain amount of discrepancy in the findings of the recent travel behaviour research. This conclusion has been reached by two ways: first, several studies have reported mixed results; second, the findings of the studies which have been reviewed in this study have themselves confirmed the absence of harmony in the research findings. Furthermore, the literature review has identified several expected reasons behind this uncertainty and inconsistency in results (Section 2.4.4). These are; mixing the analysis level (aggregate and disaggregate), data-related issues, model misspecification, misleading interpretations of results and failure to adequately address the impact of the geographic scale.

8.2.1.3 Research question A3

What are the factors that have affected urban sprawl in general and the vibrancy of the city centre in particular in the early part of the last century and in the recent past?

Outputs relevant to this heading can inform the urban renaissance policy makers in investing in factors where literature-based evidence about the effectiveness of their influence exists. This research question has been addressed in the second and third chapters.

The brief historical review based on the relevant literature has revealed that the evolution of transport technology, and thereafter the popularity of private cars had a crucial role on the amount and extent of decentralisation. The movement from urban centres towards suburbs and exurbs was tangible in most of the western major cities including London and Manchester, especially after the Second World War. In contrast, recently in the 70s until early 90s, other factors, often spatial, have been found to make an essential contribution to the depopulation of city centres in most large European and British cities. The literature review has shown that the absence of a diversity of land uses, including, especially, a severe deficiency in residential development, has played a significant role (Section 2.3 and Section 3.3.1).

8.2.1.4 Research question A4

What are the recent typical policy countermeasures that have been adopted in UK city centres in order to attain a sustainable urban regeneration agenda?

Consideration of this research question will help in developing models that are policy-sensitive by incorporating variables that are controllable by the policy makers. This research question has been addressed in the third chapter.

The review of the relevant national and local UK planning documents has shown that planning and implementing sustainable urban regeneration schemes in city centres is the ultimate policy goal. Furthermore, the review has revealed that reviving the residential sector has been a typical decline countermeasure in the current renaissance agenda for UK city centres. This sort of mechanism for tackling decline has been found to be recognised by several UK city councils including Manchester, Birmingham, Nottingham, Liverpool, Glasgow and Leeds (Section 3.3.2). Moreover, empirical-based evidence has been noticed regarding the effectiveness of the revitalisation in the housing sector in attracting people back to the centre. The city centres of several major UK cities such as Manchester and Liverpool have witnessed a significant increase in their population since the 90s (Section 3.4). However, the review also indicated that it is more likely, as will be empirically confirmed later in the section on research question C1, that this attraction appeals only to a specific set of residents with particular characteristics.

8.2.1.5 Research question A5

Taking into account the preceding research questions, what, if any, are the most appropriate UK travel survey data sources? In addition, what is the methodology of analysis capable of achieving the research objectives utilising these data sources?

This twofold research question has been addressed in the fourth chapter (Sections 4.3 & 4.4). Research has revealed few existing UK data sources which satisfy the requirements of this study in terms of scope of data collected, specific relevance to urban centres and suitability for rigorous statistical analysis. Relevant national UK surveys including the GB National Travel Survey (NTS) and British Household Panel Survey (BHPS) have a total sample size that is only nationally representative. Moreover, most of the city centre surveys conducted by the city councils (local planning authorities) are actually city centre user surveys or, at best, living and perception surveys. In spite of the best endeavours, it has proven to be very difficult to obtain a household travel survey in a city centre with an up to date and accessible dataset. Two surveys that provide a partial but useful contribution have found to be TRICS and the SHS, and hence the relevant part of their datasets have been extracted and utilised. Additionally, an original household travel survey has been conducted in Manchester City Centre. It was designed to include the full range of variables and to relate to a more appropriate case study location. The nature of the data collected is suitable for rigorous quantitative analysis using established statistical techniques mainly available through the SPSS software package. This allows a comprehensive and informed interpretation to be made of the exploratory and inferential statistics, resulting in appropriate conclusions about the importance of and relationships between predictor and response variables.

8.2.2 Objective –B

Initially, to investigate the impact of the location of a housing development on its households' travel characteristics; that is, to compare sites located in city/town centres with sites located out-of-centres. Next, to examine the specific personal and spatial features that might explain (as mediators) why there is a variation in the travel behaviour of households located in different site locations.

Two related research questions were addressed during the achievement of this objective. This objective has been tackled in the fifth chapter using the UK TRICS trip generation database.

8.2.2.1 Research question B1

What are the residential neighbourhood (development) features and travel patterns that vary notably across site locations? What are the neighbourhood and travel characteristics that typically shape each site location; in particular, in central and outer areas?

A thorough descriptive analysis using the TRICS (2012a) dataset has been carried out and the full set of results and relevant discussion is listed under Section 5.5.1. The analysis findings empirically revealed the existence of a notable variation in several spatial and household travel characteristics of the neighbourhood sites located within the main four TRICS site locations. These site locations are town centre, edge of town centre, suburban area and edge of town. In consequence, two location categories have been identified and formed based on these differences in the characteristics: central locations (especially city/town centre) and outer locations (especially edge of town).

Central locations include residential neighbourhood sites located in or near a town/city centre. In comparison with sites in outer locations, these sites have been found to have very high housing density and with a considerable proportion of flats which are typically with only one or two bedrooms. Unlike sites located in the suburbs and edge of town, the frequency of public transport (bus, tram and train) in the central locations is significantly high with a recognised provision of a train station. With respect to car parking, on-street, garages and driveway parking spaces are found to be low in the centre; also the availability of free off-site parking is highly limited. The relatively limited provision of parking in town centres is to be expected because of the use of parking management such as controlled parking zones which is found to be very common in the CBD areas.

With respect to personal mobility, the central locations have been found to be correlated with several distinct travel behaviour aspects. Households located in the inner areas generally travel less than those in the outer areas. The centre’s households have been observed that they typically conduct more walking and fewer driving journeys than those in the suburbs and exurbs. Regarding the modal split, walking is the most common mode in the town centre location. This is probably because of the urban environment nature of the city/town centres where most of the daily activities can be reached on foot.

8.2.2.2 Research question B2

If there is a significant relationship between household's travel behaviour and the location of their place of residence, then what are the neighbourhood characteristics that might mediate this relationship and hence explain how it has happened? Are these features statistically significant? What is their relative effect size and direction of influence?

The statistical analysis, results and discussions relevant to this research question have been listed under the mediation analysis section (Section 5.5.2).

The first part of the current research question has been dealt with in the first step of the mediation analysis whereby the multi-modal trip rates have been regressed on the main location types. The regression analysis results have revealed empirical-based evidence about the impact of a site location on the travel patterns of its residents. In particular, daily household travel frequencies in terms of several indicators including total people, total vehicles, vehicle occupants and pedestrians have shown significant variation with site location. The pattern of variation is consistent with that revealed by the descriptive analysis. That is households located in outer locations take more daily total journeys than their counterparts in the central area. Additionally, on a daily basis, households residing in the centre perform fewer motorised and more walking journeys than those located in out-of-centre locations.

Given that empirical evidence has been found about the influence of site location on the daily household trip rates, the second part of the above research question (mediation and mediators) has been handled accordingly. According to the analysis results, statistical evidence has been found regarding the existence of mediation effects between site location and five of the multimodal travel counts; these are total people, total vehicles, motor cars, vehicle occupants and pedestrians. That is, neighbourhood features explain some of the differences in trip-making characteristics. Some of these features are to be expected. For example, the ratio of flats (which tends to indicate smaller household sizes) corresponds to fewer total trips per household. The presence or absence of parking or transit provision such as bus stops or rail stations indicates particular trip-making outcomes by different modes.

Variables such as car ownership and some urban design factors have been found to have trivial influence, which contradicts the literature. However, further investigation has shown that this is because of the way they have been measured and specified in TRICS. Further discussion can be found in Section 8.4. Finally, the mediation analysis also reveals that the built environment only partially accounts for the differences in trip frequency. This is clearly evident in the results of the pedestrian trip rate model whereby the regression coefficient of the town centre variable in the location model has maintained its significance even after the inclusion of the neighbourhood features. This is in agreement with the literature review-based findings in that the potential influences of socio-demographic and attitude/perception factors are recognised.

The data specification problems in TRICS and its limited capability for explaining the spatial characteristics have implied an urgent need to identify other travel surveys, in particular, household travel surveys with a travel diary component.

8.2.3 Objective -C

To understand city centre residents' personal mobility by developing a variety of travel behaviour models that are within the general context of travel behaviour theory. This implies specifying the best set of predictors that significantly associate with a specific mobility measure.

Three related research questions were planned to be addressed during the achievement of this objective. These questions have been tackled in the sixth and seventh chapters using the Scottish Household Survey dataset in addition to data extracted from an original survey which has been conducted in Manchester city centre specifically to inform the research objectives of this study.

8.2.3.1 Research question C1

Who lives in UK city centres such as Manchester city centre?

In this case, the intention is to investigate the socioeconomic and demographic attributes of city centre households and individual residents and, in addition, to shed light on the residents' lifestyles and perceptions towards several travel and housing aspects.

The findings of the descriptive analysis for the characteristics of city centre residents from the SHS dataset are consistent with those which have emerged from the Manchester city centre survey (Sections 6.5.1.1 and 7.7.1.1). Both datasets confirm the differences in the attributes of the city centre residents compared to those found typically in the population as a whole. For example, such residents are much more likely to be young adults, modern and well-qualified, economically active and with management type jobs. Moreover, the analysis results emphasised that while urban centres are more attractive for households with single persons or childless couples, this is not so for families with children or elderly people.

For the attitudes and perceptions, the findings of the Manchester travel survey revealed that residents have a general perception that Manchester city centre is a vibrant place whereby many facilities such as public amenities, retailers and leisure places are accessible by foot (Table 7-10). In the neighbourhood preferences context, most of the residents have revealed that issues such as living near the centre, adequacy of transit, proximity and diversity of essential activities and safety were important for them during the relocation process; adequacy of parking was quite an important issue for people who drive (Table 7-12). There is evidence that Manchester city centre residents may be grouped according to their travel attitudes into four categories: pro-active transport; pro-car; pro-virtual mobility and pro-sustainability.

8.2.3.2 Research question C2

What are the key travel characteristics of the city centre residents?

(A) Car ownership

The analysis results confirmed that there is a unique pattern regarding car ownership in urban centres (Sections 6.5.1.3(A) & 7.7.1.3(A)). City centre households have less propensity to have a car. The range of city centre households with no car (48%-55%) is considerably higher than the national averages over Scotland and England. Similarly, the range of city centre households with two or more cars (6-10%) is much lower than the corresponding national averages.

(B) Travelling frequency

Based on the travel diary analysis results of the SHS and Manchester travel survey datasets (Sections 6.5.1.3(D) & 7.7.1.3(D)), the mean individual weekday total trip rate is about 3.30 and the corresponding household rate is (5 - 6) daily trips. The SHS analysis also revealed that a small amount of grocery and food shopping, using a cash machine and utilising banking services are the most frequent weekly activities for the city centre individuals. The

Manchester survey analysis pointed out that city centre residents commute (work/education) more than others in the population.

(C) Mode of travel

The travel diary analysis also revealed that the city centre residents are typically walking much more and driving much less than their counterparts who living in out of centre locations (See Sections 6.5.1.3(E) & 7.7.1.3(E)). According to the SHS and Manchester survey, 50% and over 60% of the daily journeys have been conducted on foot respectively. This is much greater than the GB national percentage (23%). In contrast, travelling by car has been found to comprise 30% of journeys made by the residents of the Scottish city centres; in a mature city centre such as Manchester, the parallel percentage was only 20%. These percentages of car journeys are considerably less than the British national average of 64%. Overall, the use of public transport in city centres, specifically buses, could compete and be a strong alternative for driving a car.

(D) Travel purpose

For both the SHS and Manchester city centre surveys (Sections 6.5.1.3(F) & 7.7.1.3(F)), the analyses showed that among travel purposes, 'for work' is the most common travel activity. The proportion of education journeys in city centres is found to be notably higher than the national average. The activity-mode cross-tabulation analysis also confirms that walking is the prevailing mode for commuting, shopping and leisure trips for urban centres' residents.

(E) Journey length

According to Sections 6.5.1.3(G) & 7.7.1.3(G)), one of the interesting findings regarding the spatial distribution of people's activities is that 53% of all the journeys taken by the respondents in the Scottish urban centres were either inside the centre boundary or within the immediate surroundings (within 1 mile). The corresponding percentage in Manchester city centre is 57%. This may reflect the effect of the thematic compact nature of vibrant and mature centres such as in Manchester.

Overall, the analysis results confirmed that the characteristics of city centre living can reduce the spatial dispersion of the generated journeys. For instance, while about 73% of journeys in the city centre were found to be within 3.0 km, the corresponding Scotland average percentage is only 50%. Likewise, whereas about 70% of the total daily mobility happened within two miles of the Manchester city centre respondent's residence, the equivalent national British average is only 39%.

The table also confirmed that the residents of Manchester centre are less car dependent than the national average, especially for short distances. For instance, up to two miles the proportion of car trips for the centre residents is only 13%, which is just over half the corresponding national British average of 24%. Finally, commuting trips of those residents are the most distant ones in comparison with shopping and leisure trips.

8.2.3.3 Research question C3

How much variation in a specific mobility measure can be accounted for by the urban form characteristics of a city centre and the socioeconomic and attitudinal attributes of its residents? Additionally, where viable and sensible, what is the relative contribution of spatial, socioeconomics/demographics and attitudinal characteristics per se?

The latter research question would help in examining the relative impacts of people's attitude and preferences on their personal travel options and decisions after controlling for socio-spatial features.

(A) Trip frequency

Using the Scottish Household Survey dataset, a total daily individual journeys model was developed (Table 6-23). The analysis results revealed that an increase in the income of a random adult's household is associated with an increase in the daily journeys of the adult. Furthermore, for the bus stop accessibility, the results stated that an increase in the walking time to the bus stop would reduce the total daily individual trips. A second model was developed for the non-work daily journeys and the results indicated that adults in paid work conduct fewer non-work journeys than those not currently in paid work (Table 6-24). One of the expected reasons is the typical lack of spare time for individuals in employment.

Using the Manchester city centre dataset, several journey frequency models have been developed including daily frequency models for total household journeys and daily and weekly models for shopping and leisure journeys (see Table 7-40 to Table 7-45). Overall, all the models were not statistically significant. Nevertheless, some predictors were individually significant and with logical influence. For example, for the total daily household journeys, the results of the log-linear regression model revealed that a one-unit increase in household size would lead to a 70% increase in its total daily trips.

(B) Public transport use

Employing the SHS survey dataset, several personal and spatial characteristics have shown notable effect on the frequency of city centre residents of using local buses and trains (See Table 6-25 and Table 6-26).

The statistical output indicated that an increase in the number of household cars is associated with a significant decrease in the monthly rate of using local buses and trains alike. This is probably because of the fact that the increase in the household car ownership would increase the car access likelihood for the adult. On the topic of educational qualification, the results confirmed that adults with a degree or professional qualification use buses less frequently than their counterparts with lower educational levels. In contrast, the results also confirmed that adults with high educational levels do use local trains more than those in lower levels. One explanation is that individuals with high academic/professional qualification might consider the symbolic value of trains or simply they may appraise travelling by a train to be more convenient than by bus.

Attitudinal factors have also shown an interesting role. For instance, the safety perception of travelling by bus after dusk was found to have a positive impact on the monthly rate of bus use. Similarly, moving one step towards public transport dissatisfaction would also notably reduce the monthly frequency of bus use. Additionally, the frequency and accessibility of public transport have found to have concrete impacts on the city centre resident's bus use behaviour. Increasing the time headway between two successive buses is found to reduce the monthly rate of using buses. Individuals for whom the nearest bus stop is more than three minutes walking time from their homes have been found to conduct fewer monthly bus journeys than those with closer bus stop.

With regard to local rail use, two traveller personal attributes have been found influential; working status and marital status. Individuals in employment use the train much more than their unemployed counterparts. This finding could indicate the working journeys conducted by the city centre residents using trains. For the marital status of the urban centre's adults, divorced, separated or widowed adults are conducting notably fewer train journeys than those who are single.

(C) Vehicle distance travelled

Using travel data from the SHS and Manchester surveys, the motorised distance travelled was modelled (Sections 6.5.2.3 and 7.7.2.2 respectively). Evidence has been found about the impacts of socioeconomic, spatial and attitudinal characteristics. Based on a sample of residents of Scottish city centres, it was found that socioeconomic attributes such as car ownership and working status have produced significant impacts on vehicle kilometres travelled of those residents (Table 6-27). In particular, a one-unit increase in the number of household cars was found to be positively associated with 12.6 kms increase in the motorised distance travelled. Moreover, residents in paid work have found to travel more vehicular distances than those who are not in paid jobs. This is consistent with the descriptive statistics regarding the mode and spatial dispersion of vehicular commuting trips.

For Manchester city centre, two vehicle miles travelled (VMT) models were developed; one for the households and one for the individuals. For the household model, the sequential regression analysis has shown that among the spatial variables only the presence of a parking space with the household's apartment/flat was found significant (Table 7-46). The distances from the place of residence to the nearest tram stop or train station has shown no significant effect. The almost even and adequate distribution within the city centre is the most probable reason. Among the socioeconomic variables, only the household number of cars has shown significant effect even after controlling for the spatial characteristics. One car increase in the vehicle ownership status is found to be associated with 14.4 miles rise in the household motorised travel distance.

On the other hand, the individual total daily VMT model also confirmed the considerable effect of the number of household cars on the individuals VMT even after controlling for the impact of distances to tram stops and train stations (Table 7-47). The presence of a car/or an extra car was found to be associated with almost a 10 miles increase in the daily vehicular distance. Additionally, the relative importance of residents' perceptions was found to have a strong effect even after allowing for the socioeconomic and spatial variables. That is, the results revealed that individuals who perceive Manchester city centre as a place where most of the public amenities and work/study places are within easy walking distance perform less vehicular travel. Specifically, a one-unit increase in the accessibility perception factor is found to be significantly correlated with a 6.6 miles reduction in the individual VMT. This is quite self-evident in that when most of the everyday-life activities can be reached on foot, this would most likely reduce the need for motorised travel.

One of the interesting points drawn from the above is the concrete impact of car ownership on the increase in motorised travelled distance. It is worthwhile noting here that in spite of this being the total motorised rather than driven distance, this solid link would still refer to city centre households deciding to get a car (or an extra car) only when they need to use it for non-short distances. This could also be supported by the frequency analysis where it states that about 54% of the car travel is of more than 5 miles distances, with 30% more than 12.5 miles (Table 7-37).

(D) Household car ownership

The car ownership model developed using the Scottish survey revealed that among the socioeconomic attributes only the household income and the internet access status have shown significant impact (Table 6-28). An increase in the annual income of a household is found to be linked to an increase in the likelihood of having a car. Likewise, internet access has been found to be associated with a high likelihood of owning a car.

On the other hand, using the Manchester city centre survey dataset and the sequential logit regression approach, empirical evidence was found regarding the relative contribution of the socioeconomics over spatial characteristics on the one hand and of the attitudes and perceptions over socio-spatial characteristics on the other hand (Table 7-48).

Households living in apartments provided with a car parking space are found to be much more likely to own a car than those without a parking space. Moreover, the number of driving licence holders and high-income households (>£50,000) are also found to have positive and notable effects on the likelihood of owning a household car. Finally, attitudinal factors such as the perceived accessibility factor and the pro- driving factor have been found influential. Households where householders have a positive opinion about the accessibility of the centre are found to have less tendency of owning a car. Additionally, households with pro-driving householders are found to be more likely to possess a vehicle than others.

(E) Bike ownership

The SHS dataset-based logit model implies that income, economic status and internet access status are all found to be positively related with the probability of a household to own a bike (Table 6-29). Such a probability increases with an increase in household income, being a householder in employment, and with the presence of access to the net.

(F) Mode choice

A case-specific discrete choice model was developed to model the probability of choosing mode to travel for work/education journeys. The choice set of the Scottish city centre random adult included active transport, transit and by car. The multinomial logit model revealed that household car ownership and travel distance are central in the adult's process of mode choice decision (Table 6-30). For vehicle ownership, the results revealed that when the number of vehicles in a city centre household increases, this would dramatically raise the probability of an adult to choose a car rather than walking or cycling. The same effect is also noticed but to a lesser extent regarding choosing car over transit. With respect to distance to work/education destination, the choice model disclosed that when this distance becomes longer, the propensity of adults towards adopting motorised transport rather than active transport notably increases. No analogous influence has been noticed for travelling by car versus public transport; this sounds reasonable providing that international journeys have been excluded.

In addition, three supplementary choice models were developed for modelling the propensity of the Manchester city centre residents of choosing motorised modes over walking/cycling. These models are; household weekly shopping, household weekly leisure, and individual daily working journeys. The number of household cars was influential in the shopping and leisure models. Holding everything else constant, the odds of choosing a vehicular mode for shopping or leisure journeys increase by about 103% and 75% correspondingly when the car ownership increases by one car (Table 7-49 and Table 7-50). For the individual main commuting mode, the commuting distance was found to be very influential (Table 7-51); when the distance increases the likelihood of using a vehicular mode considerably increases. In numbers, the increase in the odds of choosing car or transit corresponding to a 1-mile increase in the commuting distance is 12.743. Moreover, regarding attitude and perception, people who are pro-active modes are less likely to use motorised modes for daily commuting.

8.3 Policy implications

The results of the travel analysis and modelling can be transformed into an array of indicators that can inform the policy makers and urban planners. This is achieved by enlightening them about the appropriate characteristics that can be utilised as policy tools in reducing motorised travel and encouraging sustainable modes in the city centres.

8.3.1 Sustainable urban regeneration context

8.3.1.1 Land use diversity

Based on the SHS city centre dataset, the analysis of the travelling frequency revealed that there are activities that are found to be essential for the city centre individuals in that they are made frequently in a typical week. Such activities are a small amount of grocery and food shopping, using a cash machine and utilising banking services (see Table 6-18). This finding can be informative in terms of sustainable urban regeneration, in that, the effective policy intervention could be more investment in the land use sector in order to assure that high frequency activities are within walking distance from people’s housing units.

8.3.1.2 Accessibility

In the attitudinal questions of the Manchester survey, most of the respondents have stated the importance of the proximity of retailers, leisure facilities and other public amenities during their relocation process into Manchester city centre (Table 7-12). This provides a clear indication for the urban regeneration stakeholders that one of the reasons for the present prosperous residential sector in Manchester city centre is the recognised ease of reaching essential activities. In other words, one of the mechanisms to accomplish a thriving housing sector in a city centre is to boost the accessibility to everyday activities.

On the other hand, promoting the perceived accessibility inside the city centre area would also mitigate the tendency of owning a car and hence boost the sustainable transport agenda. Households with householders with a high accessibility factor, (that is, who perceive positively the closeness of work/study and other public amenity locations), are found to have less tendency of owning a car (Table 7-48). Additionally, city centre respondents with a high accessibility factor were found to conduct less vehicular travel. That is, increasing the compactness of an urban centre neighbourhood would reduce the vehicular travelled distance of its residents and accordingly lessen related transport externalities such as emissions and fuel consumption (Table 7-47).

8.3.2 Parking management context

According to the attitudes and perceptions analyses based on the Manchester survey dataset, the importance of off-street car parking availability and affordability for respondents as city centre residents was retrospectively investigated during their relocation process to the centre. Whereas the availability of parking was essential for 28% of the total respondents, 35% of them reported the affordability of parking charges was a key issue (Table 7-12). The indications of these statistics seem much stronger when taking into account that nearly half of the households actually have no car now (Table 7-20). As a result, the previous percentages may reflect the other half – those who are with at least one household car. Thus, adequacy of parking is a central issue for city centre drivers. Another different but related issue is that most of the current Manchester city centre respondents (70%) do not agree that off-street parking is available; also the vast majority (91%) do not agree that it is affordable.. Finally, in the same context, interesting evidence is found about the potential elasticity between parking policy in Manchester city centre and car ownership changes of its residents. That is, 56% of the total respondents explicitly stated that proximity and pricing of parking influences their car ownership status (Table 7-14).

Similarly, the quantitative travel behaviour analysis also emphasised the key role of parking availability. The results showed that households with a car parking space provided with their apartments conduct more motorised mileage than others without parking provision (Table 7-46). Moreover, such households are much more likely to own a car than those without a parking space (Table 7-48).

The previous empirical-based evidence can be useful in informing those parking policy makers who utilise car parking as an effective tool in the travel supply management, and hence help in shaping sustainable transport.

8.3.3 Public transport management context

Both the travel analysis and modelling results address empirically the vital impact of transit on people's mobility and accordingly its expected role as an effective policy tool in promoting driving-competing alternatives.

Based on the Likert-scaled attitudinal questions, about 75% of the city centre respondents in Manchester have approved the importance of the proximity and adequacy of transit during the relocation-process decisions (Table 7-12). In addition, almost half of the residents claimed that the availability of an adequate public transport service would lead them to giving up driving (Table 7-14).

Empirically and based on the SHS city centre sample, the findings of the bus use behaviour modelling indicated the importance of the frequency and accessibility of public transport (Table 6-25). That is, increasing the time headway between two successive bus services by 1 minute was found to reduce the monthly rate of using buses by 7%. In contrast, people for whom the nearest bus stop is more than three minutes walking time from their homes conduct 54% fewer monthly bus journeys than those with a closer bus stop.

In the same context, the travel behaviour of the Scottish city centres respondents were found to be significantly influenced by their attitudes and perception towards transit. For example, the increase in safety perception of travelling by bus after dusk was found to have a positive impact on the monthly rate of bus use. Similarly, the degree of dissatisfaction towards public transport may also clearly reduce the monthly frequency of use. The policy-related finding drawn from this is that interventions to raise the safety perceptions and investing in improving the reliability, frequency, punctuality and accessibility of public transport would increase the use rates of local buses.

8.3.4 Perceptions and attitudes context

The impacts of the attitudinal factors on people's travel-related decisions have been addressed and summarised previously; nevertheless, most of them require physical interventions including enhancing transit services and provisions and promoting land use diversity. Having said that, another sort of impact of attitudes and perceptions on travel was also recognised. This sort mainly only requires government intervention based on encouraging awareness programmes to help and inform urban centre individuals and households regarding how adopting eco-friendly choices could enhance the amenity for the urban community.

Additionally, there is evidence that residents may be grouped according to travel attitudinal aspects into four categories: pro-active; pro-car; pro-virtual mobility and pro- sustainability (Table 7-15). These aspects provide the policy maker with opportunities for targeting action and information; for example a pro-active disposition increases the likelihood of selecting an active transport mode significantly (Table 7-51), whereas a pro-driving disposition raises the chance of owning a car (Table 7-48).

8.4 Recommendations

8.4.1 Recommendations arising from this research

8.4.1.1 The TRICS database and its application to research

TRICS (2012a) has provided a useful primary resource for conducting the first level of location analyses. Nevertheless, several notes and issues arose from the analysis. First of all, the excessive disaggregation in the TRICS classifications of the residential land uses was noted such that there would be advantages in terms of sample size if some of these were to be regrouped. Discarding filtering housing units by tenure is a particular example (Section 5.5.3.2(6)). Furthermore, some variables which would have been expected to exert some statistical significance such as population density and car ownership actually failed to do so, suggesting that the way these data are specified in TRICS may gave rise to misleading results if used for filtering. In particular, these two variables are measured in a scale which is too aggregated.

As well as noting these suggested improvements in TRICS, there are other limitations in its application for residential trip forecasting (Section 5.5.3.2(8)). These include: missing groups of variables (socio-demographic, attitude and perception, as mentioned earlier); the data relates to the site level rather than the household level, such that in-site variation (between households) may be large; it has a limited application being simply a trip count, with no extra information on trip length, for example, which has become more relevant in policy terms.

8.4.1.2 Travel survey design and implementation

Conducting a household travel survey in Manchester city centre that is representative and has a high item and overall response rate has been found to be a hard task, especially when travel diary and attitudes and preferences are necessary parts. However, based on the experience of this research, several recommendations may be mentioned here:

1- Applying an adequate random sampling method has been found vital to assure representativeness.
2- Utilising the internet by designing an on-line questionnaire has been found to be a very useful technique for maximising the overall response rate in two ways: first, a significant proportion of the respondents has chosen to complete the questionnaire on-line; second, those respondents were more responsive to follow-ups regarding missing items or other clarification issues.
3- Using the up-to-date electoral roll (as sampling frame), putting a label containing the name and postal address of the respondent on the letters and sending them by post are practices that have been found to increase the response rate. In contrast, sending letters with (to householder / to occupier) labels and/or dropping them by hand in the respondents letter boxes were found to be less effective practices.

8.4.2 Recommended areas for further study

8.4.2.1 Data context

As stated, one of the declared aspirations for most of the major UK city councils is to implement city centre urban renaissance schemes in which sustainable transport outcomes are assured. To achieve this aspiration and recalling the significant lack of household travel surveys in UK city centres, local planning authorities and all other city centre urban regeneration stakeholders are strongly encouraged to conduct extensive travel behaviour surveys in UK city centres.

8.4.2.2 Spatial transferability

Spatial transferability of a travel demand model is typically defined as the ability of applying a model estimated in one geographic location for prediction of specific travel behaviour in a different spatial environment. Hence, the vital practical value of spatial transferability is to save money, time an effort when barriers such as difficulties of collecting data and/or developing models are prevailing in the application location.

Relevant details regarding spatial transfer including transfer methods, model estimation and statistical assessment are out of the scope of the current research. Nevertheless, it is wise here to emphasise that caution should be not discarded when travel behaviour models developed in this study are planned to be applied in urban centre located outside the UK. That is especially true for areas outside Europe where significant differences in the personal and spatial features are highly expected. In such cases, examining the applicability of the model specification and parameter estimates are highly recommended.

Nevertheless, the knowledge learnt regarding several issues related to the overall research process which can inform planners generally are quite transferable. Such issues including what are the best data variables to investigate, how can the information be obtained and what is the best way to present the results. For further information, see Section 2.4.

8.4.2.3 Future research context

This study has examined in a comprehensive fashion the living characteristics of UK city centres from a sustainable travel behaviour angle. As shown previously, a spectrum of findings that are expected to be interesting and informative for urban planners and decision makers has been reached. As a result, this study can be seen as an effective vehicle for conducting further research studies about understanding city centre residents' mobility to inform the policy for designing and implementing the most effective intervention schemes to achieve sustainable transport outcomes. Based on the findings of this work, the researcher suggests one or more of the following topics may be addressed:

(A) The self-selection effect

The descriptive analysis carried out in the current study regarding the residential preferences of people right before relocating to Manchester city centre has revealed the presence of the self-selection effect (Table 7-12). That is, the vast majority stated that they relocated into Manchester city centre because they had already preferred to be near the centre; in addition, more than half of them stated that the fact that the urban form of Manchester centre encouraged their preferred travel mode was central during the relocation decision-making process. Having said that, in order to address a research question such as 'whether people's mobility is influenced by the urban form of the urban centre or whether travel preferences have influenced residential choice', a rigorous inferential statistical analysis is justified. It is worthwhile noting that the modelling strategy usually utilised to address such a research question requires extensive information. Furthermore, in quasi-experimental research design, an adequate sample of residents that have recently moved to the centre is required to get information about their previous location retrospectively. According to this researcher's experience, achieving such a sample in Manchester city centre is problematic[15].

(B) Choice-specific discrete choice analysis:

A case-specific discrete choice model and several binomial logit models have been developed to model the city centre resident's choice behaviour. The research findings presented empirical-based evidence about the impacts of the socioeconomic, built environment and attitudinal characteristics. However, due to sample size issues, several socio-spatial and attitudinal characteristics have been discarded. Moreover, due to the scope of the research questions and data availability issues, it was decided not to conduct alternative-specific discrete choice models based on stated preference questions. Therefore, developing choice models where the above considerations are included may expand our understanding about the mode choice behaviour of the city centre residents. Again, researchers should be aware that such models are data demanding.

[15] The researcher had initially planned and designed the questionnaire for handling such research question; however, the initial analysis revealed lack in the number of residents who have recently moved to Manchester city centre. Accordingly, the research question was ignored.

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Appendix – A: Some TRICS Terms Definitions According to TRICS 2012a Online Help File

Residential land use categories

03/A – Houses Privately Owned (GDO use class C3)

Housing developments where at least 75% of units are privately owned. Of the total number of units, 75% must also be houses (sum of “non-split” terraced, detached, semi-detached, bungalows, etc), with no more than 25% of the total units being flats. Includes properties that are privately owned and then privately rented. Trip rates are calculated by Site Area, Dwellings, Housing Density, or Total Bedrooms.

03/B – Houses for Rent (GDO use class C3)

Housing developments where at least 75% of units are non-privately owned. Of the total number of units, 75% must also be houses (sum of “non-split” terraced, detached, semi-detached, bungalows, etc), with no more than 25% of the total units being flats. “Non-privately owned” may be council rented or housing association rented/part-owned. Trip rates are calculated by Site Area, Dwellings, Housing Density, or Total Bedrooms.

03/C – Flats Privately Owned (GDO use class C3)

Housing developments where at least 75% of households are privately owned. Of the total number of units, 75% must also be flats (sum of flats in blocks and “split” houses), with no more than 25% of the total units being “non-split” houses. Includes properties that are privately owned and then privately rented. Trip rates are calculated by Site Area, Dwellings, Housing Density, or Total Bedrooms.

03/D – Flats for Rent (GDO use class C3)

Housing developments where at least 75% of households are non-privately owned. Of the total number of units, 75% must also be flats (sum of flats in blocks and “split” houses), with no more than 25% of the total units being “non-split” houses. “Non-privately owned” may be council rented or housing association rented/part-owned. Trip rates are calculated by Site Area, Dwellings, Housing Density, or Total Bedrooms.

03/K – Mixed Private Housing (GDO use class C3)

Housing developments where at least 75% of units are privately owned. Of the total number of units, less than 75% must be houses (sum of “non-split” terraced, detached, semi-detached, bungalows, etc), and less than 75% must be flats (sum of flats in blocks and “split” houses). Trip rates are calculated by Site Area, Dwellings, Housing Density, or Total Bedrooms.

03/L – Mixed Non-Private Housing (GDO use class C3)

Housing developments where at least 75% of units are non-privately owned. Of the total number of units, less than 75% must be houses (sum of “non-split” terraced, detached, semi-detached, bungalows, etc), and less than 75% must be flats (sum of flats in blocks and “split” houses). “Non-privately owned” may be council rented or housing association rented/part-owned. Trip rates are calculated by Site Area, Dwellings, Housing Density, or Total Bedrooms.

03/M – Mixed Private/Non-Private Housing (GDO use class C3)

Housing developments where less than 75% of units are privately owned, and less than 75% of units are non-privately owned. “Non-privately owned” may be council rented or housing association rented/part-owned. Trip rates are calculated by Site Area, Dwellings, Housing Density, or Total Bedrooms.

Main site location definitions

Town Centre

Within the central core area of the heart of the town/city (e.g. the primary shopping area), as defined in the local development plan (if appropriate).

Edge of Town Centre

For retail, a location within easy walking distance (i.e. up to 300 metres) of the central primary shopping area, often providing parking facilities that serve the centre as well as the site, thus enabling one trip to serve several purposes. For other uses, the edge-of-centre radius from the town/city centre may be more extensive, based on how far people would be prepared to walk. For offices this may be outside the town centre but in the urban area within 500m of a public transport interchange. Local topography and barriers will affect pedestrians’ perceptions of easy walking distance. Examples of barriers include crossing major roads and car parks. The perceived safety of the route and strength of the attraction of the town centre are also relevant.

Neighbourhood Centre (Local Centre)

Predominantly residential area, but with additional amenities like local shops, schools, etc. Could be described as a small "district" or "village" within the town/city itself. Would also apply to actual villages. The local shops serve a small catchment. These may include a general grocery store, a newsagent, a sub-post office and a pharmacy, as well as others.

Suburban Area (Out of Centre)

An area outside the edge of the town/city centre, but not at the town/city’s physical edge. This can encompass a wide range of physical locations within a town/city. Suburban Area sites can range from busy built-up areas near the centre of town (but outside of the Edge of Town Centre radius), to leafy suburbs far from the centre.

Edge of Town

At the physical edge of the town/city, where the town/city meets the countryside. The actual physical distance from the site to the beginning of the countryside can vary proportionately to the size of the town/city.

Free Standing (Out of Town)

Just beyond the physical edge of the nearest town/city, or in an isolated rural location (sites in villages are within the Neighbourhood Centre category). The distance from the edge of the town/city which qualifies a site as Free Standing is not set, and is instead judged on a site-by-site basis, proportional to the size of the town/city.

Appendix – B: Methodological Framework: Complementary Issues

B.1 Experimental and non-experimental research designs

Broadly speaking, the research design typically stands for the overall strategy adopted in conducting a research in order to address the research objectives. This strategy usually includes identifying required data, choosing an adequate method of measuring them and finally choosing the analysis method. There are several research designs which have been mentioned in the literature; however, they can generally be classified into two broad groups; experimental and non-experimental research designs.

The critical distinction between experimental and non-experimental research is whether the independent variable(s) is manipulated by the researcher (see for example Thompson, 2006; Tabachnick and Fidell, 2007, p.2). Concerning research with an experimental design, the researcher has a considerable degree of control over the experiment, by manipulating the independent variables and measuring the corresponding changes in the dependent variable. Furthermore, the effects of other experimental variables are typically controlled for. On the other hand, non-experimental research designs are those where the researcher has no control on the levels of the independent variable(s); instead, the research only observes the change in the variables without manipulating them. Non-experimental research is often called correlational or cross-sectional research; moreover, while there are many forms of such research designs, the survey is the most common one.

Accordingly, recalling that the main databases of the research conducted for the current study are coming from surveys, therefore, it is evident that the design of the current research is nonexperimental (correlational). It is worthwhile mentioning here that regardless of the statistical technique adopted, in correlational research it is tricky to imply cause and effect linkage between the independent and dependent variables. However, when the analysis shows a correlated change between the dependent and independent variables, then they can be addressed as related but with no causality being established (Tabachnick and Fidell, 2007, pp.2-3). Generally, implying causation between two variables requires three key conditions to be jointly met. First, they are associated; second, the association is not due to a confounding variable; and third, the effect in the dependent variable happens after manipulating the independent one (Frazier, Tix, & Barron, 2004). Obviously, these conditions can only hold in experimental research.

B.2 Selection of statistical approach

The selection of the approach and type of a statistical analysis in order to assure adequacy and efficiency should be central in any data analysis stage. Absence of adequate care would most likely jeopardise the reliability of the results at best. There are several criteria that have been mentioned regarding how to determine the proper statistical approach (for example see Tabachnick and Fidell, 2007; Field, 2009). For the current study, the intention of studying a number of aspects regarding city centre living and personal mobility using three different household surveys was the trigger for the need to use several quantitative statistical techniques. Following are the key criteria which have been adopted in choosing the suitable techniques:

- The type of the major research question. Specific statistical methods tackle specific research questions. Statistically, five general research questions can be recognised; these are, degree of relationship among variables, significance of group differences, prediction of group membership, structure, and questions that focus on the time course of events (Tabachnick and Fidell, 2007, p.17). The scope of the current study research questions covers only the first three.
- The measurement scale of the dependent (outcome) and independent (predictor/explanatory) variables. Overall, variables can be classified into three key groups; continuous (also called interval or quantitative), discrete, and dichotomous variables (the last two may also be called nominal, categorical or qualitative).
- The number of the dependent (outcome) and independent (predictor/explanatory) variables. The typical rule is to end up with an adequate and parsimonious model; i.e., the best solution with the fewest variables. A large number of variables could affect the degrees of freedom and accordingly the power of the analyses.
- The number of cases (sample size).
- The specific assumptions and conditions of the quantitative statistical method.
- The shape of the distribution of the dependent variable; in particular, whether normally distributed or not.

B.3 Descriptive data analysis

The purpose of conducting the exploratory data analysis in the current study is twofold. The first is statistical-specific; that is, for screening and cleaning data before conducting the required inferential analysis. The second is research-related; that is to address some of the minor research questions. Descriptive statistics techniques are the typical tool for conducting the exploratory data analysis.

Regarding the first, many researchers have confirmed that raw data should be cautiously scanned even before performing the main statistical analysis (Landau & Everitt, 2004; Tabachnick & Fidell, 2007; Thompson, 2006). That is because problems such as data inaccuracy, missing data and outliers will directly affect the average value statistic (especially the mean) and hence indirectly all other descriptive and inferential statistics. Finally, exploratory analysis is useful and effective in checking the availability of the assumptions of the employed statistical method. A thorough data screening, therefore, has been done for the data. Cases with unduly extreme values have been addressed as outliers. The typical statistical criterion has been adopted; that is, any case with a standard residual more than 3.29 is statistically an outlier. In contrast, for continuous variables, missing values that are few and randomly scattered have been imputed (replaced) by the grand mean for the specific variable. According to Tabachnick and Fidell (2007, p.62), when only a few data points (equal or less 5%) and without an evident specific pattern are missing, then roughly any procedure for handling missing values would lead to comparable results. In contrast, for categorical variables with missing cells, deleting these cells or combining them are the typical remedy adopted in this study.

On the other hand, the research purpose of conducting the exploratory analysis is descriptive. That is, it has been used to describe the personal, spatial and travel characteristics. It is worthwhile mentioning the specific job of the descriptive analysis is shown in each analytical chapter.

Several traditional descriptive analysis methods and tests have been used in the current study including bar charts, frequency tables, percentile analysis, contingency tables and the Chi-square test for independence. In addition, the more sophisticated technique of Principal Components Analysis (PCA) has also been employed for handling attitudinal variables.

B.3.1 Principal components analysis

The multivariate technique known as principal components analysis may be seen as one of the dimension reduction approaches that are quite similar to the exploratory part of the major data reduction technique Factor Analysis .That is, in contrast with its complementary part confirmatory factor analysis. Factor analysis and principal components analysis are mostly based on the underlying statement that the measured variables can be reformulated to a smaller, more interpretable and manageable set of composite variables (factors/components) that reflect the underlying dimensions. These underlying dimensions are also called constructs or latent variables whereby each of them consists of more than one correlated variable (Basilevsky, 2009, p. 351; Izenman, 2008, p.215) (Tabachnick and Fidell, 2007, p.607).

Utilising the dimension reduction procedure employed in the IBM SPSS Statistics (20), this study uses the principal components approach as the major extraction method. It is particularly used in Chapter 7 for two essential reasons. The first is to reduce the number of the attitudinal items, measured by the questionnaire of the Manchester city centre survey, into a smaller number of sets of more understandable composite variables. Each set contains several correlated variables (items) that collectively measure a similar latent dimension or underlying construct; for instance, urban form or travel perception dimensions. The second reason is to mathematically compute the scores of the developed components in order to use them as attitudinal predictors in the subsequent analyses.

The use of factor and principal components analyses in travel behaviour studies for one or both of these reasons is quite popular; for instance, see Cao et al. (2006b); Hsieh, O'Leary, Morrison, & Chang (1993); Cervero and Kockelman (1997); Bhat & Eluru (2009) and Antipova et al. (2011). The mathematical basis and derivations for the dimension reduction analysis using the principal components are beyond the scope of the current study; however, interested readers are referred to Tabachnick and Fidell (2009); IBM Corp. (2011a) and Izenman (2008). Nevertheless, the following paragraphs outline the general sequential steps of applying the principal components analysis adopted in this study along with several interesting comments.

In IBM SPSS (20), after selecting the specific set of variables, the process of the principal components analysis usually starts with calculating the correlation matrix for all the selected variables. It is evident here that based on this initial correlation matrix the principal components will eventually be constructed. Before going on to extract the components and choose the interesting one, the initial assumptions of the components analysis should be met. First, based on the correlation matrix, problematic variables such as those with very high correlations, more than 0.7 is suggested by Tabachnick and Fidell (2007, p.646), or those that do not correlate with any other variable should be removed. SPSS (20) provides a useful statistic for measuring the sampling adequacy. It is called the KMO (Kaiser-Meyer-Olkin) statistic and it should not be less than 0.5 (Field, 2009, p660); otherwise, collecting more data is recommended. Last but not least, is Bartlett's significance test of sphericity; it tests the statistical significance of the number of components, with the null hypothesis being that there are no components (Tabachnick and Fidell, 2007, p.646). Accordingly, the test should be significant (the p-value should be less than .05). Finally, it is worthwhile mentioning here that ending up with components that are conceptually interpretable is one of the important validations of the analysis (Tabachnick and Fidell, 2007, p.643).

Next, the components should be extracted based on one of several extraction methods available by IBM SPSS. For this study, the principal components method is adopted as a frequent and preferred extraction method (Field, 2009, p.637). The first extracted component is supposed to contain several correlated variables that collectively explain the greatest amount of the total variance in the dataset. Similarly, the second component is extracted which should explain the greatest amount of the remaining variance. The process continues until ending up with a number of components that is similar to the number of variables.

Rationally, only a small number of the extracted components should be chosen as underlying concepts or factors; otherwise, there is no point in conducting the whole dimension reduction analysis. In addition to the rational criterion of the availability of theoretical reasons, IBM SPSS (20) offers two methods for guiding the choice of the right number of factors or components. The first is graphical and partially subjective; it is based on a graph called a scree plot. The second is objective and depends on a statistic called the Eigenvalue (Kaiser's criterion). The eigenvalues broadly reflect the variance explained by each component; hence, only components with eigenvalues of values more than one are recommended to be retained (Izenman, 2008, p.208; Tabachnick and Fidell, 2007, p.646). In this study, both the existence of conceptual reasons from previous relevant literature in addition to the eigenvalue criterion are employed.

The typical next step is to rotate the component axes of the resulting component structure. The reason is simply that while the results are mathematically correct, they are almost always difficult to be interpreted. Thus, the goal here is to obtain a simple structure that is interpretable. IBM SPSS (20) provides several methods of orthogonal and oblique rotations. Unlike orthogonal methods, the oblique methods allow components to be correlated (not totally independent). According to (Tabachnick and Fidell, 2007, p.646), this sort of rotation is more realistic in that it is highly probable that components are correlated in reality. This proposition sounds quite sensible regarding attitudinal factors and thus the oblique rotation is adopted using the Oblimin method.

The final typical step is to interpret the resulting components and probably to name them. In oblique rotated solutions, this is usually done by exploring the Pattern Matrix (a table where the rows are the variables and the columns are the components. For each variable, the component for which the variable has the highest loading should be noted. In addition, variables with high loadings on each single component should be also noted (Field, 2009, p.631). The factor loading can be understood as the regression coefficients for each variable on each component.

Another complementary step is to compute the components scores in order to be used as predictors in the later regression models created using the Generalised Linear Model procedure. This step addresses the second reason for conducting the components analysis as stated previously. The statistical package SPSS offers three of them; regression analysis, Bartlett's method and the Anderson-Rubin method. According to the (IBM Corp., 2011c, p.159), the Anderson-Rubin method of estimating components score coefficients produces uncorrelated scores. Accordingly, it is adopted in the current study for its compatibility with the condition of the Generalised Linear Model in that cases are assumed to be independent observations (IBM Corp., 2011b, p.46)

Finally, there are two analytical issues that are beneficial to be pointed out; the first is related to dealing with ordinal variables as continuous ones. The second is the sample size. Regarding the first one, although a five-step attitudinal scale is obviously a categorical variable with an ordinal scale, it is very common to consider it as a continuous variable. This is highlighted in the travel behaviour literature (for example see (Choo & Mokhtarian, 2004). This sort of practice has been assessed by some statisticians as a custom that has been used by researchers for many years (Byrne,2010, p.148). Accordingly, this sort of traditional practice is adopted in the study to deal with the Likert-scale attitudinal items in the analysis of Chapter 7. Regarding the second issue, sample size, Field (2009, p.647) has reviewed several criteria for the appropriate sample size that have been suggested by different researchers. As an overall summary of these criteria, the minimum number of cases is highly recommended to be more than 100 and the participant-to-variables ratio is highly preferred to be more than 10. These rules are adopted in this study.

B.4 Inferential analysis

Inferential analysis refers to an array of univariate and multivariate confirmatory data analysis; sometimes called deductive analysis. Inferential statistical techniques address the problem of making inferences from sample data to the whole population; this is typically by testing hypotheses about differences in populations on the basis of measurements made on samples of subjects (Tabachnick and Fidell, 2007; Ho, 2006). In this study, the method of analysis is quantitative. Several quantitative statistical techniques have been employed. These techniques can be generally classified into two fundamental groups; General Linear Model (GLM) and Generalised Linear Model (GsLM).

B.4.1 General linear model

The general linear model is a general procedure that is typically employed for conducting several statistical techniques such as analysis of variance and covariance, multiple linear regression and factor/components analysis (Cohen et al., 2003; Tabachnick and Fidell, 2007; IBM Corp., 2011a). Whereas the components analysis technique has been reviewed previously, the next two subsections will be devoted to briefly review ANOVA and multiple linear regression respectively. It is worthwhile noting that many researchers have highlighted Cohen's seminal work published in 1968 in which he pointed out that ANOVA and multiple linear regression are mathematically identical and that ANOVA is merely a special case of the multiple linear regression (Thompson, 2006, p.359). Nevertheless, the techniques are usually reported separately in statistical publications and software. There are two possible reasons for this; first, each of them has specific and quite different research question(s) to deal with. Second, each of them has quite different assumptions; in particular, regression analysis has some distinct assumptions. For these two reasons, they will be highlighted separately in the next two subsections.

A- Analysis of variance

The main objective of the statistical analysis (ANOVA) is to evaluate the equality of means or to test the statistical significance of differences in group means. Moreover, by ANOVA it is also possible to determine which sample means are significantly different and by how much. Thereafter, inferences about the population based on the sample statistics can be proposed (Thompson, 2006). The ANOVA is a univariate technique where a dependent (outcome) variable is continuous and the independent (predictor) variable is categorical.

It is worthwhile clarifying that if the whole ANOVA model is statistically significant then this implies that the null hypothesis (Ho), (meaning that there is no significant difference between group means), is rejected. This implies the existence of one or more group means that are significantly different from others. Furthermore, in order to determine these groups and the amount of mean differences, additional analysis (tests) should be conducted. These tests are called post–hoc multiple comparison tests (Field, 2009). There are 14 posteriori tests in SPSS which assume equality in variances. According to the most relevant literature, there is constantly a trade-off between minimizing the probability of type-I error and maximizing the statistical power (Field, 2009). In so doing, both liberal tests (like Least Significant Difference (LSD) and Studentised Newman-Keuls (SNK)) and conservative tests (Scheffe and Bonferroni) have been excluded. Of the rest, and bearing in mind the unequal sample sizes within groups, Gabriel's test is found to be the most suitable and powerful one (IBM Corp, 2011, p.9).

On the other hand, according to Field (2009), the parametric quantitative ANOVA approach can provide powerful estimates as long as the main three ANOVA assumptions are not substantially violated. First, the scores within each group should be normally distributed. Second, the variances in each group have to be reasonably homogenous (equal). Third, observations should be independent. These assumptions are important for obtaining reliable F-statistics. An exploratory data analysis is usually carried out to check for normality and variance homogeneity. In the SPSS context, objective assessment for normality such as using Kolmogorov-Smirnov and Shapiro – Wilk tests is preferable (Field, 2009, p.144). Similarly, Levene's inferential test of homogeneity of variances is typically conducted to check between-groups variances.

B- Multiple regression analysis

Multiple linear regression is one of the General Linear Model's techniques through which the relationship between a dependent (or response) variable and a linear set of independent (or predictor) variables can be constructed and evaluated. The ordinary least square (OLS) method is the typical parameter estimation method in the linear regression model. In the linear regression, the outcome should be continuous while the predictors are continuous or categorical but at a binary level (Ho, 2006).

The general estimated linear regression equation for a dependent variable, Y, and a linear combination of independent variables , X_1 through X_k, can be formulated based on sample data as follows (Orme and Combs-Orme, 2009, p.11):

$$Y` = a + b_1X_1 + b_2X_2 + . . . b_kX_k + e \qquad \text{(B-1)}$$

In this equation Y` is the predicted mean value of the dependent variable in the population; $X_1$ through $X_k$ represent the linear predictor variables; a is the estimated intercept (value of Y` when all Xs are zero); b_1 through b_k are the estimated values of the slopes (known as regression coefficients); and e is unexplained variation in the dependent variable (residual term). Two things are reasonable to be mentioned here; first, the residual term is just to indicate that there is typically an error in our prediction; it is not included in the analysis. Second, the regression coefficients (b) indicate the direction and amount of change in the mean value of Y associated with a one-unit increase in the specific predictor, controlling for the other independent variables.

There are three analytical strategies in regression analysis; standard (simultaneous), sequential (hierarchical) and Statistical (stepwise). Only the first two have been employed in this study. The third one (stepwise) is discarded since it includes/removes variables from the model for purely statistical criteria; moreover, it has been assessed as a controversial procedure that should not be used unless there is no previous theory or existing knowledge to formulate the test hypothesis (see Tabachnick and Fidell, 2007, p.138; Ho, 2006, p.246).

In the scope of the current study, three general objectives can be achieved using the regression analysis:

- Formulating the best modelling equation that is capable of predicting the outcome variable depending on a linear set of predictors.
- Utilising the sequential strategy in entering variables, it is then possible to evaluate the additional influence of a predictor or a linear combination of predictors after controlling for (allowing for) the effects of other predictors (Ho, 2006, p.245; Tabachnick and Fidell, 2007, p.138).
- Implementing mediation analysis; in which the proposition of the existence of an intervening variable (the mediator) that transmits the effect of an independent variable to the dependent one is examined (Hayes, 2009). Further relevant details will be discussed in Chapter 5 where the mediation analysis is conducted.

According to (Freund, Wilson, & Sa, 2006), linear regression uses the ordinary least squares (OLS) method in estimating population parameters. These parameter estimates are the intercept (a) and the regression slopes (b-values). The principal idea in the least-squares method is to estimate regression coefficients in such a way that ensures minimising the sum of squares of the residuals (differences between the observed and estimated values of the outcome variable (Y)).

It is worthwhile mentioning that in multiple regression it is recommended to use the adjusted value of the coefficient of determination (adj. R-square). That is because the traditional R-square might become inflated with the increase in the number of variables. More details about this issue in addition to other more analytical details regarding multiple regression analysis can be found in Cohen et al. (2003).

Finally, it is also useful here to emphasise that to create a conceptually sound regression model, the assumptions underlying it should not be substantially violated. For ordinary least squares (OLS) linear regression, in particular, it is important to check the assumptions regarding outliers, residual analysis, linearity and multicollinearity. More details will be discussed in Section B.5.2.

B.4.2 Generalised linear model

The Generalised Lineal Model GsLM is typically appraised as a generalisation to the General Linear Model (GLM). Nelder and Wedderburn are widely credited for their seminal work in 1972 where the GsLM technique was proposed. This generalisation may be outlined by two essential issues; first, the generalised linear model allows for modelling discrete response variables in addition to continuous variables. Second, it relaxes the strict assumption of the GLM in that the dependent variable should have normally distributed errors with a constant variance (Cohen et al., 2003, p.534; Freund et al., 2006, p.402). The generalised linear model is a highly flexible approach which has an analytical structure that is capable of analyzing a bundle of regression models using a unified framework (Cohen et al., 2003, p.480). This unified framework is achieved by using a reversible and differentiable link function that ensures the linearity between the discrete response variable and the linear predictor variables. In addition, the link function is the mathematical transformation that makes it possible to model response variables that are not continuous (discrete) and with residuals that are not normally distributed nor with homogeneous variance (Orme and Combs-Orme, 2009; Cohen et al., 2003, p.534).

The mathematical form of a generalised linear model typically consists of three components; random, systematic and the link function (Agresti, 2007; Freund et al., 2006). First, the random component identifies the mean value of the response (dependent) variable y, (E(y)), usually referred to as (μ) (See eq. B-2); second, the systematic component specifies the linear predictor and is usually referred to as (η) (See eq. B-3); and third, a link function g() that linearly links the mean response variable (μ) to the linear predictor (η), usually written in terms of μ, g(μ) (See eq. B-4).

$$\mu = E(Y) \qquad \text{(B-2)}$$

$$\eta = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k \qquad \text{(B-3)}$$

$$g(\mu) = g(E(y)) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_k X_k \qquad \text{(B-4)}$$

It is worthwhile highlighting that OLS regression directly belongs to the GLM which in turns belongs to the GsLM. In this study, in addition to the OLS multiple regression, four statistical regression models that are components of the GsLM package are employed to develop the required travel behaviour models. These are binary logistic regression, multinomial logit regression, Poisson regression, and negative binomial regression.

Table B-1 presents a summary of the four generalised linear models that are employed in this study in addition to some key information regarding how these models are specified with the GsLM framework.

Table B-1: Key statistics regarding the specification of some regression models within the GsLM framework.

Regression	Response	Link name	Link function	Distribution
Linear	Continuous	Identity	μ	Normal
Binary logistic	Binary	Logit	$\ln(\mu / (1 - \mu))$	Binomial
Multinomial logistic	Categorical	Logit	$\ln(\mu / (1 - \mu))$	Multinomial
Poisson	Count	Log	$\ln(\mu)$	Poisson
Negative binomial	Count	Log	$\ln(\mu)$	Negative binomial

Extracted from a general table in Orme and Combs-Orme (2009, p. 14).

While in the linear regression the regression parameters are traditionally estimated using the ordinary least squares method (OLS), most of the regression models with discrete response variables including the ones employed in this study use an alternative method called the Maximum Likelihood (ML) (Freund et al.,2006, p.383; Cohen et al., 2003, p.498).

GsLMs strategy in testing the hypotheses regarding the developed model is quite analogous to the multiple regression analysis. For example, as an alternative to the t-statistic in the linear regression, the Wald statistic or likelihood ratio Chi-square ($\chi 2$) is normally employed to test null hypotheses about individual slopes (regression coefficients). Similarly, while the F-statistic is typically used in linear regression in order to test the hypothesis regarding the significance of the whole developed model, the likelihood ratio $\chi 2$ is employed as an alternative in the GsLMs. On the other hand, with respect to model evaluation, it is quite different. That is, in linear regression the coefficient of determination (R-square) gives the typical indication of goodness of the fit and the R-square statistics clearly shows the amount of variation in the response variable that has been explained by the predictor(s). Unfortunately, according to Cohen et al. (2003), there is no single agreed corresponding indicator in the GsLMs, although several different pseudo R-squares exist including McFadden's R-square, Nagelkerke's R-square and Cox and Snell's R-square.

In the following sections, a brief overview of the discrete models, which are used in the travel modelling for the current study, will be presented. These include the Binary logistic model, multinomial logistic model, Poisson model and negative binomial model. For a detailed discussion, readers are referred to specialised statistical texts including Gill (2001); Cohen et al. (2003); Agresti (2007) and Orme and Combs-Orme (2009).

A- Binary logistic regression[16]

The binary logistic regression is a versatile and frequently-used model of the GsLMs. It is employed for modelling relationships between a binary response variable and a linear predictor**.** It represents the basis for several other discrete response regression models especially the multinomial logit model. The analytical strategy of the logistic regression differs from that in the linear regression on several grounds; one of the essential methodological issues is the form of the predicted response variable and accordingly the way of interpreting the effects of the explanatory variables on it. Unlike linear regression where the effect of any quantitative predictor is directly and linearly associated with the response, in the logistic regression the effect is interpreted and presented in terms of likelihood concepts such as odds ratios and logit (Orme and Combs-Orme , 2009). That is because, as highlighted previously, the linearity is only between the linear predictor and a mathematical form of the response variable, the link function, not the response itself. In logistics regression, this link function is the logit. The general mathematical form of the logit link function is shown in Table B-1. Nevertheless, given that in logistic models the original outcome (before applying the link function) needed to be modelled is the probability of the event happening ($\hat{p}$), then the logit function can be rewritten as:

$$\text{Logit} = \ln \text{Odds} = \ln (\hat{p} / (1 - \hat{p})) \qquad \text{(B-5)}$$

In this equation, the term ($\hat{p} / (1 - \hat{p})$) is called the 'odds'. The concept of odds is a ratio of probabilities; in particular, the ratio of the probability that an event will occur ($\hat{p}$) to the probability that this event will not occur (1- $\hat{p}$)(Cohen et al, 2003, p.490). In binary logistic regression the response variable is dichotomous with (0/1) coding; where the reference category is typically coded as (0). The other category (response variable equals 1) typically addresses the presence of a characteristic or the occurrence of an event. Having that said, it is useful to report that in binary logistic regression the estimated value is the natural

[16] Also known as logistic regression or as logit regression.

logarithm of the odds (logit) that the response variable equals 1 (Orme and Combs-Orme, p38). As shown in eq. B-5, the probability range is between zero and one, the odds range is between zero and positive infinity and the logit can take any negative or positive value. Equation B-5 also implies that as the probability increases both the odds and logit increase; however, not in a linear form.

Another concept that is popular in interpreting the output of a logistic regression is the 'odds ratio'; usually abbreviated as OR. According to Orme and Combs-Orme (2009), the odds ratio is the ratio of the odds of the event for one value of a predictor divided by the odds for a different value of that predictor, usually a value one unit lower. In the logistic regression output, the odds ratio is expressed as the exponent of the specific regression coefficient (slope), exp (b) (Cohen, 2003, p.492). Additionally, it also quantifies the strength and direction of the change in the odds of the outcome to happen when there is a one unit increase in the relevant predictor (Orme and Combs-Orme, 2009). Accordingly, when the odds ratio is equal to one, this would indicate that the odds of the event occurring are the same regardless of the value of the predictor; the absence of a relationship with Y. When the odds ratio is greater than one, this implies a positive linkage between the odds of the event and the rise in predictor. Conversely, an odds ratio with values less than one implies that the odds of the event decrease as value of the predictor increase (Orme and Combs-Orme, 2009).

The output of the binomial logistic regression should be interpreted carefully. To clarify, take an example of a household car ownership model where the reference category is 'household with no car'. Suppose the odds ratio of owning a car which is associated with the household size predictor is 4.16 (exp(b) = 4.16). Then, the correct way of interpreting this is to report that a one-unit increase in the predictor (one more household member) increases the odds of a household owning a car by a factor of 4.16. Or, in terms of percentages, it can said that the one-unit increase in the number of household members increases the odds of owning a car by 316% [100(4.16 − 1)= 316]. In contrast, it is not correct to infer that households with one extra member are 4.16 times as likely to own a car. That is because this would imply a linear relationship between the probability of owning a car (response) and the odds ratio where no such linearity actually exists.

Nevertheless, reporting model results in terms of probabilities is probably more convenient and interpretable. Equations B-6 and B-7 depict the mathematical linkage between the probability of an event to happen (in the preceding example, owning a car) and the logit and odds respectively (Orme and Combs-Orme, 2009; Cohen, 2003).

$\hat{p}$ (owning a car) = $e^{Logit} / (1 + e^{Logit})$ (B-6)

$\hat{p}$ (owning car) = odds / (1 + odds) (B-7)

Finally yet importantly, the nonlinear relationship between the explanatory variables (X_1, X_2, . . ., X_k) and the probabilities makes it quite a complicated task to summarise the changes in the probabilities linked with the changes in an explanatory variable; this is especially true for continuous predictors. Thus, tables and graphs may be employed to present some key values of the predictors.

B- Multinomial logistic regression[17]

Multinomial logit regression is typically employed for modelling relationships between a polytomous categorical response and a linear combination of explanatory variables (linear predictor). According to Orme and Combs-Orme (2009), it is a versatile and popular modelling method. The multinomial logistic regression model is the natural extension to binomial logistic regression, in that, the binomial model can be considered as a special case of the general multinomial model. Moreover, it is acceptable to address the multinomial logit model as a series of binary models that are estimated simultaneously. The rational implication is that the methodological issues and concepts that have been mentioned in the binomial model section are applicable to the multinomial logit model (Orme and Combs-Orme, 2009; Cohen et al., 2003). That is, the prediction process of the response variable and interpreting the results in terms of logits, odds, and probabilities are similar.

Additionally, in both binary and multinomial models each category of the discrete response variable is compared to a reference category. Nonetheless, Orme and Combs-Orme (2009) reveal that since the multinomial model has a multicategorical response, it therefore involves two or more of such comparisons and a separate logistic equation is estimated for each comparison. It is worthwhile reporting that in this study the multinomial model is used as a discrete choice model for modelling travel mode choice behaviour.

[17] Also known as polytomous, nominal logistic, logit regression or the discrete choice model.

Over the past years, the established role of the multinomial logit model in discrete choice analysis has been recognised (Hausman & McFadden, 1984). However, the developed model is a discrete choice model that is case-specific not choice-specific. That is, only the attributes of the choosers are included; the characteristics of the choices (alternatives) themselves are not included. In addition, the multinomial logit model is assumed to have an error term that follows a Type I extreme value (Gumbel) distribution. The above two properties mean that the operation of multinomial logit model as a discrete choice model is statistically legitimate (Long, 1997) in addition to easing the modelling complications. (Shwanen and Mokhtarian, 2005b). Nevertheless, such a discrete choice model requires examining one of the interesting assumptions that is unique to the multinomial logit models, the independence of irrelevant alternatives (IIA) (Hausman & McFadden, 1984). Overall, the IIA assumption implies that the ratio of probabilities of choosing any two alternatives is independent of a third choice. In the context of transport mode choice, it can be thought that adding a new choice (mode of transport) will not alter the proportions of people's likelihoods of choosing the initial choices (Small & Hsiao, 1985). For the purposes of this study, the Small-Hsiao test is utilised to examine whether the multinomial logit model is appropriate and that the IIA assumption holds. The rationale of the test procedure is based on eliminating one or more alternatives from the choice set to see whether the coefficient estimates are affected.

Nevertheless, it might be sensible to highlight that some researchers have questioned the practicality of the IIA tests for applied statistics; others have urged that a logical approach should be adopted in order to evaluate whether the responses are distinct and independent (Orme and Combs-Orme, 2009, p.118).

C- Poisson regression

Poisson and negative binomial regressions are two of the basic GsLMs that only deal with count response variables. That is, the response variable should be integer and non-negative. Count data is characterized as the number of events that occur in a particular time period (Cohen et al., 2003) or, in other words, the occurring frequency (number of times) of a specific event usually within a defined time period, population size, or geographic area (IBM Corp., 2011a, p.391). While this subsection deals with Poisson regression, the next one will address the negative binomial regression model. Poisson regression analysis predicts the number of events that occur in a specific time period from one or more predictor variables

(Cohen et al., 2003). That is, the population response required to be modelled is the occurring frequency of an event (incidence). However, it is possible that in the sample data the frequency of events occurring is different only due to the differences in the exposure of the incidence. According to Orme and Combs-Orme (2009), the exposure is the opportunity for an event to occur; it could be length of time, population size, geographical area, or other domains of interest. It is imperative, therefore, to transform the frequency of events into rates. According to Orme and Combs-Orme (2009), the incidence rate for each case (λ) can be calculated by dividing the frequency of occurring of this case (μ) by its exposure (E), as follows:

$$\lambda = \mu/E \qquad \text{(B-8)}$$

As stated previously in Table B-1, the link function for Poisson models is the natural logarithm (ln). Hence, assuming that all the cases have the same exposure, which is the case in this study, the mathematical form of the Poisson model is (Orme and Combs-Orme, 2009; Cohen et al., 2003):

$$\ln(\lambda)= \eta = \alpha + \beta_1X_1 + \beta_2X_2 + . . . \beta_kX_k \qquad \text{(B-9)}$$

In the above loglinear model, λ is the incidence rate of the response variable when all cases have the same exposure (i.e., the expected value of the response variable Y), and η is the linear predictor. Bearing in mind the above non-linear relationship and for ease of interpreting the Poisson regression output, a concept called Incidence Rate Ratio (IRR is computed. This concept is analogous to the odds ratio concept in the categorical response models. The IRR evidently is the ratio of the incidence rate of the response variable corresponding to a specific predictor with certain value ($X_{1(i)}$) to the incidence rate corresponding to the same predictor but with one less level ($X_{1(i-1)}$). In other words, it is the change in the incidence rate equivalent to a one unit increase in a certain explanatory variable. The mathematical expression is;

$$IRR = \lambda(X_{1(i)})/ \lambda(X_{1(i-1)}) = \exp(b)$$

where b is the slope of the explanatory variable (X_1); its regression coefficient. The interpretation of the direction and strength of the IRR concept is quite similar to the odds ratio case with the exception that now the response is the rate of occurrence of an event.

That is, let the outcome be the weekly frequency of using a transit system and the IRR corresponding to an increase in monthly individual income (predictor) of say £1000 be equal to 0.45. Accordingly, this implies that a one unit increase in the predictor (£1000 rise of income) decreases the mean weekly transit use rate by a factor of 0.45. In terms of percentages, having a £1000 higher income drops the mean weekly transit use rate by 55% [100(0.45-1)] (Orme and Coms-Orme, 2009).

Finally, it is worthwhile highlighting one more interesting thing in Poisson regression models; the equidispersion assumption. In addition to the typical assumption of the generalised linear models (See Section B.5.2), the poisson regression has a strong assumption that the variance of the Poisson distributed response variable is equal to its mean (Cook & Weisberg, 2009). This assumption is typically appraised as very restrictive and thus often violated (Cohen, 2003, p.530). Accordingly, an alternative regression should be employed. The negative binomial regression model is the typical alternative (Cohen et al., 2003, p.531) and (Orme and Comb-Orme, 2009).

D- Negative Binomial Regression

The negative binomial model is more general than the Poisson model. It has less restrictive assumptions. More specifically, it works when the variance is greater than the mean (overdispersion) whereas the Poisson model does not. Accordingly, the negative binomial model is usually thought of as the standard alternative method used to model overdispersed Poisson data (Freund et al., 2006, p.410). According to Orme and Combs-Orme (2009); Freund et al., 2006, p.410) overdispersion is a common case in practice.

The negative binomial model assigns a specific statistic for specifying the type of dispersion; this statistic is called the ancillary parameter. Typically, positive values of the ancillary parameter address overdispersion, whereas the zero implies equidispersion and lead to the construction of a Poisson model. That is, a Poisson model can be seen as a special case of the general negative binomial model (IMB Corp, 2011b). Having said that, it is unsurprising that the modelling procedure of the negative binomial model is quite similar to that in the Poisson model. This is also true regarding different methodological issues including exposure, incidence rate and interpretation. In order to determine whether to construct a Poisson or negative binomial regression model, the status of overdispersion has to be investigated at first. The investigation process involves running a negative binomial regression with ancillary parameter equal to zero. Thereafter, one checks the significance of a specific test called the Lagrange multiplier test. The null hypothesis is that the ancillary parameter is zero; i.e., the response is equidispersed and hence the Poisson model assumption is valid. Obviously, rejecting this null hypothesis (typically at 5% level of significance) suggests running the negative binomial model[18] (Orme and Combs-Orme, 2009).

B.5 Sample size, regression assumptions and bootstrapping

B.5.1 Sample size

This subsection presents a brief discussion about the rules and recommendations adopted in the study to determine the sample sizes required for acceptable statistical modelling. Comprehensive discussions can be found in specialised materials including (Dattalo, 2008). Generally, determining the adequate sample size for inferential analysis is associated with several issues including the number of predictors and expected effect sizes. An analysis with a high number of explanatory variables and/or low expected effect size typically requires a high sample size (Ho, 2006, p247). Generally, it is reported that there is a link between sample size and sampling error. However, issues such as the complexity of this relationship and the typical limited sample size because of resource constraints have also been mentioned (Dattalo, 2008, p. 12).

For general linear models, specifically multiple regression, Tabachnick and Fidell (2007, p.123) reported a sophisticated formula for computing a minimum acceptable sample size (N) that involves both effect size (f^2) and number of predictors (m): $N = (8/f^2) + (m - I)$, where $f^2 = 0.02$, 0.15, and 0.35 for small, medium, and large size effects respectively. This formula is adopted in this study where the size effect is expected to be medium. On the other hand, for the discrete response models developed within this study, two thresholds related to parameter estimation using the maximum likelihood method have been adopted. First, overall the sample size should be more than 100 regardless of the number of estimated parameters and second, the sample should contain at least 10 cases for each estimated parameter (Orme and Combs-Orme, 2009, p.20).

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[18] IBM SPSS Statistics (20) allows specifying the value of the ancillary parameter and it also includes Lagrange multiplier test.

B.5.2 Regression diagnostics and assumptions

Regression models have underlying assumptions. It is highly expected that significant violation of these assumptions can lead to negative impacts on the estimation of parameters and/or the reliability of the hypothesis testing process. Overall, discrete response regressions developed based on the generalised linear model are considered more flexible than those belonging to the general linear models such as ANOVA, ANCOVA and OLS multiple linear regression. Specifically, the GsLM relaxes the OLS regression typical assumptions regarding the necessity of the dependent variable to be continuous with residuals that are normally distributed, independent and with constant variance. However, there are still some common requirements and assumptions that should be checked in all the GsLM regressions. Outliers, independence of errors and absence of perfect multicollinearity are the most effective ones.

What is pursued in the following subsections is to briefly address the key and common underlying assumptions and requirements of regression models including assumption diagnostic indices, regression outliers and residuals analysis. For relevant discussion but in a more comprehensive fashion, readers are referred to regression-specific texts including Freund et al. (2006) and Cohen et al. (2003).

A- Regression outliers

Outliers are cases with unusual values; they can be in the response and predictor variables. Regression diagnostics are employed to examine the presence of three key properties which usually accompany potentially problematic observations. These are; leverage, discrepancy and their combined effect - influence.

The leverage statistic is used to indicate extreme observations (unusual cases) in terms of their values on the predictors. According to Cohen et al. (2003, p.397), the amount of leverage is usually measured using a statistic called the centred measure of leverage. The recommended cut-offs for the centred measure is $2k/n$ in large samples and $3k/n$ in small samples; where k is the number of predictors and n is the number of cases. The discrepancy statistic measures the distance between the predicted and observed values on the response variable (residuals). Discrepancy is frequently quantified using the externally studentised residuals. A recommended cut off of the residuals is either ± 2 for a 95% confidence level or ± 3.29 for the 99.9% level (Tabachnick and Fidell, 2007, p73; Cohen et al., 2003, p.399). The second is adopted for reducing any unnecessary issues that lead to minimising the analysis dataset.

Thirdly, influence combines the effect of leverage and discrepancy. It addresses the expected change in the regression coefficients if an outlier (case i) has been removed from the data set (Freund et al., 2006, p.120). According to Cohen et al. (2003, p.402), two main kinds of measures of influence are typically used; global and specific measures. Global measures involve statistics such as DFFITS and Cook's distance. They quantify the influence of a specific case (case i) on the whole regression model.. The recommendation for small and medium samples is that the maximum value should not exceed ±1.0 for the DFFITS and 1.0 for Cook's distance. With respect to the specific measures of influence, usually a statistic known as (DFBETAS) shows sufficient information concerning how case i influences regression coefficients (B). For datasets of small and moderate sample sizes, cases with absolute value of DFBETAS > ±1 are considered to be influential. Tabachnick and Fidell (2007, p.75) recommended similar thresholds to those stated above.

B- Normality of residuals

Normality of the residuals is a common assumption in the general linear models including OLS regression. The normality assumption implies that for any value of the predictor variable X, the residuals around the regression line are assumed to have a normal distribution. If this assumption is not met, the reliability of the significance tests and confidence intervals could be affected. Cohen et al. (2003, p.120) confirmed that this is specifically true for small samples. Histograms of residuals and probability plots (for example q-q plots) are usually used to test normality. More objective normality statistical tests including the Shapiro-Wilk and Kolmogorov-Smirnov tests are employed in the current study (IBM Corp., 2011a, p.317).

C- Homoskedasticity of residuals

Also known as homogeneity of variances of the residuals. According to Cohen et al. (2003, p.119) and Ho (2006, p.248), this assumption implies that for any value of the predictor X, the variability of the residuals around the predicted value (Y) should be homogeneous (constant). This assumption is important for general linear models. Levene's test is the typical relevant method to investigate homoskedasticity. For this test the null hypothesis is that there is no significant difference between the variances of the residuals at the 5% significance level. Additionally, plotting the predicted values of the outcome against the residuals would inform heteroskedasticity if the residuals show a pattern (Tabachnick and Fidell, 2007, p.125).

D- Linearity

This is also an essential assumption in the OLS regression models. It implies that the relationship between the response and predictor(s) variables is linear. Linearity can easily be examined by residual plots (Ho, 2006, p248).The assumption can be examined simply by plotting the predicted values of the outcome (Y') against the residuals. If the general shape of the plot is curved rather than rectangular, a non-linearity can be inferred (Tabachnick and Fidell, 2007, p.127).

E- Independence of errors

Also known as autocorrelation in residuals. Orme and Combs-Orme (2009) have reported that this assumption should be examined in all regression models with continuous and discrete response variables. However, some researchers argue that it is important and exists specifically in time-series data. Cohen et al. (2003, p.120) reported that the assumption implies that the residuals of the observations must be independent of one another; i.e., the errors for each case are independent from the errors of all others. However, it is expected that datasets taken from surveys based on a random sampling procedure are less likely to experience such issues. The Durbin-Watson test addresses the issue of auto-correlation between residuals; test scores noticeably far from two would indicate autocorrelation (Cohen et al., 2003, p.137).

F- Multicollinearity and singularity

Multicollinearity is a requirement for a sound regression model rather than an assumption per se. The multicollinearity effect is present when there are two or more predictor variables that are highly correlated (multicollinear) (Freund et al., 2006, p.177). Two test statistics are typically employed to examine multicollinearity; these are tolerance and the variance inflation factor (VIF). According to Ho (2006, p248) and Freund et al. (2006, p.191), the tolerance value for a specific predictor provides information about the proportion of variance in the predictor that cannot be explained by the other predictors. A predictor with a tiny tolerance score may be redundant. In numbers, tolerances of less than 0.10 may highlight collinearity. In contrast, the variance inflation factor is simply the reciprocal of the tolerance; VIF with values greater than 10 would also indicate multicollinearity.

B.5.3 Bootstrapping

The bootstrap has recently become quite a popular statistical procedure. Several famous statistical packages now incorporate bootstrap as either an option or a subdialog in analysis including IBM SPSS and AMOS. In the IBM SPSS, there is a separate manual for bootstrapping (IBM Corp., 2011d). According to this manual, the bootstrapping method can be used for achieving several tasks. First, it is an approach for deriving robust estimates of standard errors and confidence intervals for estimates such as the mean, odds ratio and regression coefficient when the populations are unknown and the parameters are ill-behaved. Second, it can be used for constructing hypothesis tests as an alternative to parametric estimates when the assumptions of those methods are in doubt. Mooney and Duval (1993) presented a comprehensive text about the use of the bootstrapping approach. They illustrated in quite detailed fashion the capability of the bootstrap method in handling the OLS regressions when the normality assumption is violated.

Having said that, the bootstrap method is employed in the current study in the OLS linear regression models where the normality and homoscedaticity assumptions of residuals are not met. Examples of the utilisation of bootstrapping in travel demand/behaviour studies have been found in the recent literature. For example, Broadstock (2008, p.166) in his PhD study of travel demand has employed the bootstrap method for dealing with similar issues of variables with variation and distribution violations.

Appendix – B: Manchester city centre survey – Hard copy questionnaire form

Manchester City Centre – Household Travel Survey – Questionnaire

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Dear , thank you for returning your consent form and accepting to participate in this household travel survey. I am pleased to remind you that by completing and returning this form you will automatically be entered into the draw for £50 shopping vouchers.

Please complete this questionnaire to help in providing a better understanding of Manchester city centre residents' travel behaviour. It will only take few minutes to fill in. If you have any problems filling in the questionnaire please contact the helpline number on 0161 295 4498.

HOUSEHOLDER usually is the person in whose name the accommodation is owned or rented, or who is otherwise responsible for the property. Otherwise, it is the highest income household member.

Section 1: Household Characteristics

Ref. No.

Dear respondent please be aware that the word HOUSEHOLD in this survey is defined as:

Either a ONE person living alone, or a GROUP of people (not necessarily related) living at the same address with common housekeeping - sharing either a living room or sitting room, or at least one meal a day.

Hence, if you live with other people but the second condition above is not satisfied then please consider only yourself as the household when answering the questions in this questionnaire unless otherwise stated.

Q1. How many people, including yourself, are currently in your household? Age 15 or under Age 16 or over

Q2. How many bedrooms are in your current property?

Q3. How can you describe the tenure of your current property? (Privately owned/rent, social housing). Please specify.

Q4. Is a car parking space provided with your apartment (Yes/No)?

Q5. How many bikes do you and the second adult have? YOU Adult No. 2

Q6. How long have you been living in Manchester city centre?

Now, please complete the overleaf table for all your household members (including YOU) who are 16 or over. Consider the options and the example

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Per. No.	Age and Sex	Person's Relationship to You	Employment Status	Use of household car as a driver?	Highest Educational Qualification	Occupational Status	Driving Licence Status
Options	16 – 24 F or M 25 – 34 F or M 35 – 44 F or M 45 – 54 F or M 55 – 64 F or M 65 plus F or M	Householder, Partner/Spouse, Other relatives, Other unrelated	Employment (full/part time) Unemployed, Student (working/not), Retired, Other-Please specify	Full use, Partial, None, Have no car	GCSE, A-level or eq. U.G degree or equiv. P.G degree or equiv. Others (please state)	Professional, Senior management, Middle management, Clerical/Administrative, Skilled manual, Other Manual	Full Provisional Never held a UK DL Given up driving
Exa.	35 – 44 F	Householder	Employment -full	Full use	U.G degree	Middle manage.	Full

Per. No.	Age and Sex	Person's Relationship to You	Employment Status	Use of household car as a driver?	Highest Edu. Qualification	Occupational Status	Driving Licence Status
1							
2							
3							
4							
5							

Q7a: What best describes your current household total annual income?

Less than £ 10,000 ☐ | £ 10,000 – 19,999 ☐ | £ 20,000 – 29,999 ☐ | £ 30,000 – 39,999 ☐ | £ 40,000 – 49,999 ☐ | More than 50,000 ☐

Q7b: Has your total annual income changed over the past year?

Increased ☐ | No change ☐ | Decreased ☐

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Section 2: Travel diary

This part of the questionnaire should be filled by the HOUSEHOLDER and any other 2nd adult if any.

Ignore any walking trip less than 5min. duration (1/4 mile distance).

Be aware that a journey home and back again counts as **TWO** SEPARATE TRIPS.

PLEASE DON'T FORGET YOUR TRIPS BACK HOME.

Trip: A one-way journey between two places. Any change in mode or purpose will imply a new trip.

Modes : Walk, Bike, Bus/Coach, Tram, Train, Car driver, Car Passenger, Taxi, Motor Bike and Others.

Purposes: Home, Work, Education, Shopping, Change, Recreational, Escort and Others.

Distance: Approximate travelled distance.

Place: Any location you travel to whether for few minutes (like petrol station) or for hours (like workplace).

Occupants: total number of occupants if the mode was car.

EXAMPLE – My Travel Yesterday

Trip No.	From- place	To-place	Departure Time	Arrival time	Main Mode	Purpose	Distance (miles)	Occupants
1	Home	Train Sta.1	7:20 am	7:35 am	Free Metroshuttle Bus	Change	0.75 m	----
2	Train Sta.1	Train Sta.2	7:55 am	8:07 am	Train	Change	2.5 m	----
3	Train Sta.2	Workplace	8:07 am	8:20 am	Walk	Work	0.5 m	----
4	Workplace	Food shop	4:30 pm	5:10 pm	Bus	Shopping	3 m	----
5	Food shop	Home	5:30 pm	5:45 pm	Walk	Go home	0.5 m	----
6	Home	Restaurant	7:45 pm	8:00 pm	Car passenger	Eating/Drinking	2 m	2
7	Restaurant	Home	9:15 pm	9:30 pm	Car passenger	Go home	2 m	2

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ADULT No.1 (YOU – Householder) - Your travel day should be a normal weekday of travel for you. If yesterday was not, please choose another day.

Trip No.	From- place	To-place	Departure Time(min.)	Arrival Time(min.)	Mode	Purpose	Distance (miles)	Occupants
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

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ADULT No.2 - Your travel day should be a normal weekday of travel for you. If yesterday was not, please choose another day.

Trip No.	From- place	To-place	Departure Time(min.)	Arrival Time(min.)	Mode	Purpose	Distance (miles)	Occupants
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

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Q8: In a typical (7-days) week, how many trips do you do TO the following places using the following modes?
N/A means Not Applicable; for example if you are a student and don't work then a tick should be put in the N/A column in front of work journeys.
If in some journeys you use more than one mode, record only the mode used in the LONGEST (distance) part of your journey (main mode).

Journeys	Currently							One year ago							If any, why have you changed your mode of travel?
	N/A	Car driver	Car passenger	Bus - Tram	Train	Bike	On foot	N/A	Car driver	Car passenger	Bus -Tram	Train	Bike	On foot	For example; → Get/give up a car, Destination changed, More convenient mode, Cheaper, Healthier, Faster, More reliable mode, City centre living support this mode, Parking issues at home, Parking issues at destination, More friendly-environment, I always prefer this mode but my previous neighbourhood design did not encourage it.
Work – you															
Work – Adult 2															
Education – you															
Education – Adult 2															
Shopping															
Leisure															

	Currently	One year ago	If any, why have you changed your car ownership status?
Q9: How many cars does your household have?			

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Section 3: (A) Attitudinal questions

Neighbourhood is the area surrounding your property.

Q10: Now please state to what extent the following statements are true to describe your *CURRENT* (city centre) neighbourhood.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Public transport (bus, tram, train) stations are nearby					
Easy access to the motorway					
Colleges, offices and public amenities all within walking distance					
Variety of retailers is within walking distance					
Adequate public transport services					
External network of cycle routes provides adequate access to the area surrounding my neighbourhood					
Suitable pavements (footways) for pedestrians throughout the neighbourhood					
There are plenty of off – street parking options available					
Entertainment and leisure facilities are nearby					
Buzz of city living					
Close to where I work/Study					
The design of the neighbourhood encourages my preferred mode of travel					
Good street lighting					
Crime rate is minimal within the neighbourhood					
I feel safe to walk within the neighbourhood					
Off – street parking charges are affordable					

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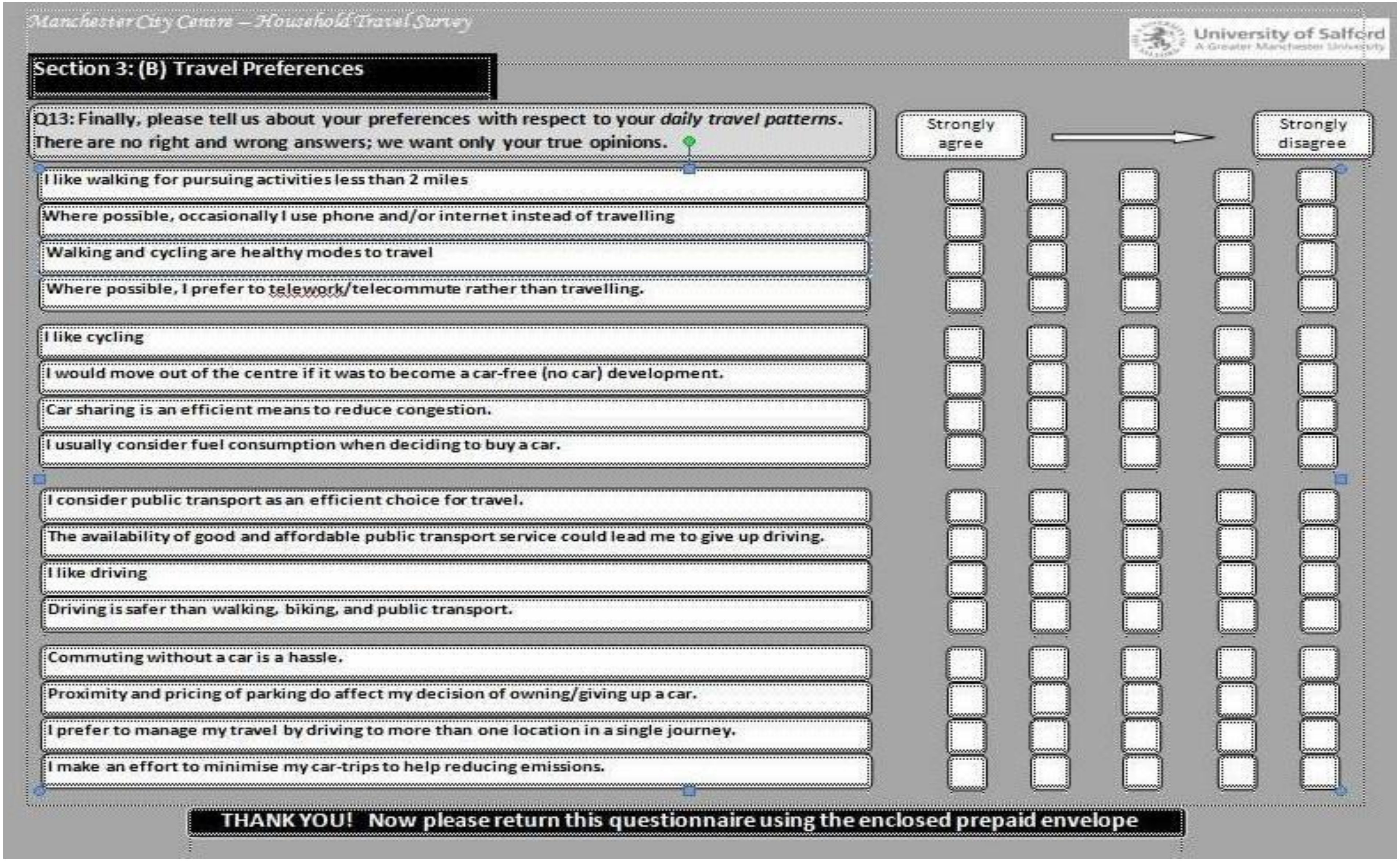
Q11: Now we are interested in knowing your perception of neighbourhoods. Please state to what extent the following statements are true to describe your *PREVIOUS* neighbourhood.
Please SKIP this question in case you have been living in Manchester city centre for more than 1 year.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Public transport (bus, tram, train) stations are nearby					
Easy access to the city centre					
Colleges, offices and public amenities all within walking distance					
Variety of retailers is within walking distance					
Easy access to the motorway					
Adequate public transport services					
External network of cycle routes provides adequate access to the area surrounding my neighbourhood					
Suitable pavements (footways) for pedestrians throughout the neighbourhood					
There are plenty of off – street parking options available					
Entertainment and leisure facilities are nearby					
Buzz of city living					
Close to where I work/Study					
The design of the neighbourhood encourages my preferred mode of travel					
Good street lighting					
Crime rate is minimal within the neighbourhood					
I feel safe to walk within the neighbourhood					
Off – street parking charges are affordable					



Manchester City Centre – Household Travel Survey

University of Salford
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Section 3: (B) Travel Preferences

Q13: Finally, please tell us about your preferences with respect to your *daily travel patterns*. There are no right and wrong answers; we want only your true opinions.	Strongly agree				Strongly disagree
I like walking for pursuing activities less than 2 miles					
Where possible, occasionally I use phone and/or internet instead of travelling					
Walking and cycling are healthy modes to travel					
Where possible, I prefer to telework/telecommute rather than travelling.					
I like cycling					
I would move out of the centre if it was to become a car-free (no car) development.					
Car sharing is an efficient means to reduce congestion.					
I usually consider fuel consumption when deciding to buy a car.					
I consider public transport as an efficient choice for travel.					
The availability of good and affordable public transport service could lead me to give up driving.					
I like driving					
Driving is safer than walking, biking, and public transport.					
Commuting without a car is a hassle.					
Proximity and pricing of parking do affect my decision of owning/giving up a car.					
I prefer to manage my travel by driving to more than one location in a single journey.					
I make an effort to minimise my car-trips to help reducing emissions.					

THANK YOU! Now please return this questionnaire using the enclosed prepaid envelope

Appendix - D: Manchester city centre survey – Participant information sheet and consent form

Manchester City Centre – Household Travel Survey
Appendix A: Participant Information Sheet

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Research into the Travel Behaviour of Manchester City Centre Residents

Invitation Statement

I am Firas Asad, a PhD researcher at the University of Salford and I would like to invite you to participate in a household travel survey as part of the research for my doctorate degree. It takes about 15 minutes to complete and asks about your personal travel patterns. As a thank you for your time, completed survey questionnaires will be entered in **a prize draw worth £50**. Your participation is greatly appreciated.

I understand that before deciding to participate in this survey you may need to know more about how beneficial this travel survey is for city centre residents and why your decisions and opinions are important. Thus, please take time to read the following information carefully and feel free to contact the supervisor Ralph Henson (Senior Lecturer in Transport Studies on 0161 295 4498 or at R.R.Henson@salford.ac.uk) or the researcher Firas Asad (on 07799 27 45 95 or at F.H.A.Asad@edu.salford.ac.uk) if you have any questions.

So what is the aim of the study?

The aim of this study is to help planning policy makers to adopt transport and housing agendas that can enhance city centre living. This target can be achieved using the survey results to answer the following research questions:

1. What sort of people choose to live in city centres?
2. What are their personal daily travel patterns?
3. What are their attitudes to travel and residential location?

Do I have to take part in the study?

No, your participation in this survey is voluntary and you may withdraw at any time, without giving a reason. However, the success of the research depends on a good response to our survey request so your support is highly valued.

What will happen if I opt to withdraw?

You will be offered two options to ensure the confidentiality of your data. The first is that I (the researcher) will destroy your consent and questionnaire forms using a paper shredder, while the other offered option is to mail you back these forms. In both cases, your data will be deleted from the database file.

What will happen if I agree to take part?

1. You will need to read and sign the Consent Form and return it using the attached prepaid envelope. Alternatively, you can complete an e-copy of this consent form by typing the following link in your internet browser:

   http://www.smart-survey.co.uk/v.asp?i=39250hwstk

2. After receiving your completed consent form, we will make arrangements for one of three options for the survey questionnaire to be completed. Firstly, this can be by pre-arranged interview (preferred); secondly, by completing and returning a hard copy of the questionnaire which we will mail to you. The third option is to complete an e-copy of the questionnaire online. In this case, we will send the questionnaire to the e-mail address you have provided on your consent form.

1

Manchester City Centre – Household Travel Survey

Appendix A: Participant Information Sheet

University of Salford
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What am I going to be asked about?

The questionnaire is structured in three parts:

Part 1: general information about you and your household.

Part 2: a brief description of the trips you make on a typical day.

Part 3: the views you have which affect your travel choices.

Will my taking part in this study be kept confidential?

All data collected for this study will be treated confidentially. The research process has been approved by the Research Ethics Panel at the University of Salford.

Finally:

Thank you for your time reading this information sheet. If you have any questions at all please do not hesitate to contact us at

Ralph Henson (Supervisor)
School of Computing, Science and Engineering
University of Salford
R.R.Henson@salford.ac.uk
Tel.: 0161 295 4498

Firas Asad (Research student)
School of Computing, Science and Engineering
University of Salford
F.H.A.Asad@edu.salford.ac.uk
Tel.: 07799 27 45 95

Your opinion will help in the renaissance of your City Centre

2

Manchester City Centre – Household Travel Survey
Appendix B: Consent Form

University of Salford
A Greater Manchester University

CONSENT FORM

Ref. No.

Title of Project: **Travel Behaviour of Manchester City Centre Residents.**

Name of Researcher: **Firas H. Asad**

	Please Tick all boxes
I confirm that I have read and understood the information sheet for the above study and have had the opportunity to ask questions.	☐
I understand that my participation is completely voluntary and that I am free to withdraw at any time, without giving any reason and my data will be destroyed or mailed back.	☐
I understand that any data that might identify me will be anonymised and treated as confidential.	☐
I understand that other genuine researchers from Salford University may have access to this data only if they agree to preserve the confidentiality of the information as requested in this form.	☐
I agree to take part in the above study.	☐

Name of participant (printed) Date Signature

(The Researcher will sign below, when you return your form)

Firas H. Asad
Researcher Date Signature

Please tick the box and give the information required below if you would like to enter our **prize draw for £50 vouchers**. ☐

Flat No ______ Building Name ______ Postcode ______

Phone contact No. ______ E-Mail Address ______

To ensure that we can send you the survey questionnaire that best suits your case, please fill the following:

- How many adults live in this flat ______ , I can walk for 5 minutes without help (Yes/No) ______.
- How long have you been living in Manchester city centre?
  Less than 6 months ☐ Less than 1 year ☐ less than 2 years ☐ 2 years or more ☐
- Which method of contact do you prefer?
  Interview (Preferred) ☐ Questionnaire (Hard copy) ☐ Questionnaire (Online) ☐

NOW PLEASE RETURN THIS FORM USING THE ATTACHED PREPAID ENVELOPE.

Household Travel Survey

University of Salford
A Greater Manchester University

I am Firas Asad, a PhD researcher at the University of Salford and I would like to invite you to participate in a household travel survey as part of the research for my doctorate degree. It takes about 15 minutes to complete and asks about your personal travel patterns. As a thank you for your time, completed survey questionnaires will be entered in a prize draw worth £50. Your participation is greatly appreciated.

Your Opinion Matters

* 1) **Now, if you are happy to participate in this survey please complete the Consent Form below:**

	Please tick all boxes
I confirm that I have read and understood the information sheet for the above study and have had the opportunity to ask questions.	☐
I understand that my participation is completely voluntary and that I am free to withdraw at any time, without giving any reason.	☐
I understand that any data that might identify me will be anonymised and treated as confidential.	☐
I understand that other genuine researchers from Salford University may have access to this data only if they agree to preserve the confidentiality of the information as requested in this form.	☐
I agree to take part in the above study.	☐

Finally, please answer the following three questions to help me in checking your eligibility to take part in the survey and/or sending you the questionnaire that best suits your case.

* 2) **How long have you been living in Manchester city centre?**

	<6 months	6 - <12 months	12 - <24 months	>24 months
Period	○	○	○	○

* **3) What best describes your housing unit?**

	House	Flat/Apartment	Others
Housing type	○	○	○

* **4) Now please tell me your contact details especially if you would like to enter the prize draw.**

Full Name

Tel. Number:

Email:

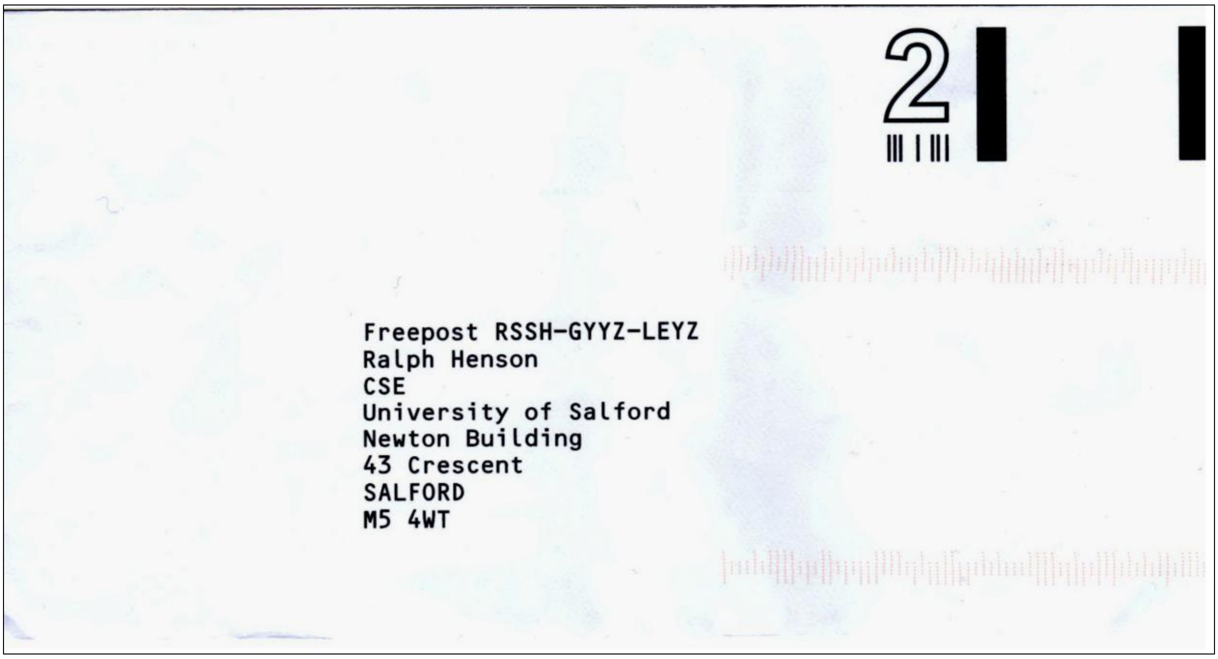
* Ref. No. - written in red in the upper-right corner of your participant info sheet.

* **5) Which method of contact do you prefer to complete the survey questionnaire?**

NB: If you prefer the third option (online questionnaire), please make sure you have written your e-mail address in your answer to Q4 above.

☐ Interview (preferred) ☐ Questionnaire - Hard copy ☐ Questionnaire - Online

Finish Survey



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Freepost RSSH-GYYZ-LEYZ
Ralph Henson
CSE
University of Salford
Newton Building
43 Crescent
SALFORD
M5 4WT

Appendix – E: Manchester city centre survey – Online copy questionnaire

C - Manchester City Centre - Household Travel Survey

Section 1: Household Characteristics

Page 2 of 4

Manchester City Centre - Household Travel Survey

University of Salford
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Dear HOUSEHOLDER, thank you for returning your consent form and accepting to participate in this household travel survey. I am pleased to remind you that by completing and returning this form you will automatically be entered into the draw for £50 shopping vouchers.

Please complete this questionnaire to help in providing a better understanding of Manchester city centre residents' travel behaviour, many thanks in advance! It will only take a few minutes to fill in. If you have any problems filling in the questionnaire please contact the helpline number on 0161 295 4498.

HOUSEHOLDER usually is the person in whose name the accommodation is owned or rented, or who is otherwise responsible for the property. Otherwise, it is the highest income household member.

Your Opinion Matters

A HOUSEHOLD is:

- One person living alone, or
- A group of people (not necessarily related) living at the same address with common housekeeping - sharing either a living room or sitting room, or at least one meal a day.

Dear respondent, if you live with other people but the second condition above is not satisfied then please consider <u>only</u> yourself as the household when answering the questions in this questionnaire unless otherwise stated.

2) How long have you been living in Manchester city centre?

	<6 months	6 - <12 months	12 - <24 months	>24 months
Period	○	○	●	○

3) How many people, including yourself, are currently in your household?

	Age 15 or under	Age 16 or over
No. of people		2

4) Including yourself, what is the total number of people (regardless of the household definition above) who currently live in your House/Flat?

	Age 15 or under	Age 16 or over
No. of people		2

5) **How many bedrooms are in your current property?**

2

6) **What best describes your housing unit?**

	House	Flat/Apartment	Student accommodation	Others
Housing type	○	●	○	○

7) **How can you describe the tenure of your current property?**

	Privately owned	Privately rented	Social housing	Others
Tenure	○	●	○	○

8) **Is a car parking space provided with your apartment?**

	Yes	No
Answer	○	●

9) **What are the age and gender for each adult member of your household including you (the householder)?**

	You	2nd adult	3rd adult	4th adult	5th adult
Age and gender	25 - 34 M	16 - 24 F			

10) **What best describes this person's relationship to you?**

	2nd adult	3rd adult	4th adult
Relationship	Spouse/Partner		

11) **What best describes the employment status of you and your household members?**

	You	2nd adult	3rd adult	4th adult
Employment status	Employment - full time	Employment - full time		

If other, please specify:

12) **Now, if you are employed, how would you describe your occupational status?**

	You	2nd adult	3rd adult	4th adult
Ocupational Status	Professional	Clerical/Administrative		

Other (please specify):

13) What is the highest educational qualification of each member of your household?

	You	2nd adult	3rd adult	4th adult
Highest edu. qualif.	P.G degree or equivalent	U.G degree or equivalent		

If other, please specify:

14) What is the Driving Licence (DL) status of each member of your household?

	You	2nd adult	3rd adult	4th adult
Driving licence status	Full	Provisional		

15) What best describes the bike ownership status of each member of your household?

	You	2nd adult	3rd adult	4th adult
Bike ownership status	0	1		

16) What best describes the status of the use of household car as a driver?
(*If your household does not have a car available, please select Have no car*)

	You	2nd adult	3rd adult	4th adult
Car use	Full use	None		

17) What best describes your current household total annual income?

	Less than £ 10,000	£ 10,000 – 19,999	£ 20,000 – 29,999	£ 30,000 – 39,999	£ 40,000 – 50,000	More than 50,000
Annual total income	○	○	●	○	○	○

18) Has your income changed over the past year?

	Increased	No change	Decreased
Income status	○	●	○

Save and Continue Later   Previous Page   Next Page

C - Manchester City Centre - Household Travel Survey

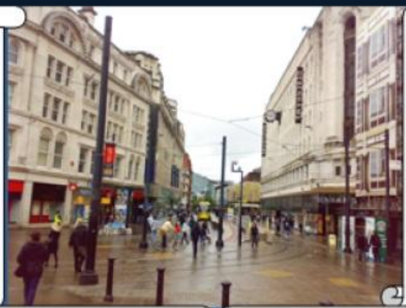
Section 2: Travel Diary

TRAVEL DIARY - NOW PLEASE TELL US ABOUT YOUR OWN TRAVEL YESTERDAY

Modes: Walk, Bike, Bus/Coach, Tram, Train, Car driver, Car Passenger, Taxi, Motor Bike and Others.

Purposes: Home, Work, Education, Shopping, Change, Recreational, Escort and Others.

Distance: Approximate travelled distance.



Trip: A one-way journey between two places. Any change in mode or purpose will imply a new trip.

Place: Any location you travel to whether for few minutes (like petrol station) or for hours (like workplace).

Occupants: total number of occupants if the mode was car.

This part of the questionnaire should be filled by the HOUSEHOLDER and any other second adult if any.

Ignore any walking trip less than 5 minutes duration (1/4 mile distance).

Be aware that a journey home and back again counts as TWO SEPARATE TRIPS.

PLEASE DON'T FORGET YOUR TRIPS BACK HOME.

EXAMPLE – My Travel Yesterday

Trip No.	From- place	To-place	Departure Time	Arrival time	Main Mode	Purpose	Distance (miles)	Occupants
1	Home	Train Sta.1	7:20 am	7:35 am	Free Metroshuttle Bus	Change	0.75 m	----
2	Train Sta.1	Train Sta.2	7:55 am	8:07 am	Train	Change	2.5 m	----
3	Train Sta.2	Workplace	8:07 am	8:20 am	Walk	Work	0.5 m	----
4	Workplace	Food shop	4:30 pm	5:10 pm	Bus	Shopping	3 m	----
5	Food shop	Home	5:30 pm	5:45 pm	Walk	Go home	0.5 m	----
6	Home	Restaurant	7:45 pm	8:00 pm	Car passenger	Eating/Drinking	2 m	2
7	Restaurant	Home	9:15 pm	9:30 pm	Car passenger	Go home	2 m	2

19) ADULT No.1 (YOU – Householder) - Your travel day should be a normal weekday of travel for you. If yesterday was not, please choose another day.

	From - place	To - place	Departure time (min.)	Arrival time (min.)	Mode	Purpose	Distance (miles)	Occupants
Trip No.1	home	office	8:30	8:45	walk	work	0.75	
Trip No.2	office	foodshop	1:10	1:20	walk	shopping	0.40	
Trip No.3	foodshop	office	1:30	1:40	walk	work	0.40	
Trip No.4	office	home	16:30	16:45	walk	home	0.75	
Trip No.5	home	resturant	20.00	20.15	car driver	eating out	5.0	2
Trip No.6	resturant	home	21.50	22.10	car driver	home	5.0	2
Trip No.7								
Trip No.8								
Trip No.9								

Trip No.10								
Trip No.11								
Trip No.12								
Trip No.13								
Trip No.14								
Trip No.15								

20) ADULT No.2 - Your travel day should be a normal weekday of travel for you. If yesterday was not, please choose another day.

	From - place	To - place	Departure time (min.)	Arrival time (min.)	Mode	Purpose	Distance (miles)	Occupants
Trip No.1	home	workplace	8.00	8.30	walk	working	1.5	
Trip No.2	workplace	market stree	15:00	15.20	walk	shopping	1.0	
Trip No.3	market stree	home	15.50	16.00	walk	home	0.5	
Trip No.4	home	resturant	20.00	20.15	car passeng	eating	5.0	2
Trip No.5	resturant	home	21.50	22.10	car passeng	home	5.0	2
Trip No.6								
Trip No.7								
Trip No.8								
Trip No.9								
Trip No.10								
Trip No.11								
Trip No.12								
Trip No.13								
Trip No.14								
Trip No.15								

21) Currently, in a typical (7-days) week, how many trips do you do <u>TO</u> the following places using the following modes?

N/A means Not Applicable; for example if you are a student and don't work then you should select the N/A option for work journeys.

If in some journeys you use more than one mode, record only the mode used in the LONGEST (distance) part of your journey (main mode).

	Currently - Car driver	Currently - Car passenger	Currently - Bus/Tram	Currently - Train	Currently - Bike	Currently - Walking
Work - You	1	0	0	0	0	4
Work - Adult 2	0	0	0	0	1	3
Education - You	-- NA --	-- NA --	-- NA --	-- NA --	-- NA --	-- NA --
Education - Adult 2	-- NA --	-- NA --	-- NA --	-- NA --	-- NA --	-- NA --

Shopping	2	0	0	0	0	6
Leisure	2	0	1	0	0	3

If there are any NA answers, please state why here.

Not in education

22) For your previous residence, in a typical (7-days) week, how many trips did you do TO the following places using the following modes?

* If you have been living in Manchester city centre for more than 1 year, then consider it as your previous residence.

	1 year ago - Car driver	1 year ago - Car passenger	1 year ago - Bus/Tram	1 year ago - Train	1 year ago - Bike	1 year ago - Walking
Work - You						
Work - Adult 2						
Education - You						
Education - Adult 2						
Shopping						
Leisure						

If there are any NA answers, please state why here.

23) If the mode of travel has changed for any specific type of journey, please select the most appropriate explanation that describes why this change has happened.

	The main cause of changing my previous mode of travel is:
Work - You	
Work - Adult 2	
Education - You	
Education - Adult 2	
Shopping	
Leisure	

24) How many cars does your household own?

	Currently	1 year ago
No. of cars	1	1

If your car ownership status has changed since moving to the city centre, what was the main reason for that change?

Save and Continue Later | Previous Page | Next Page

Section 3: Attitudinal questions

25) **Now we are interested in knowing your perception of neighbourhoods. Please state to what extent the following statements are true to describe your *PREVIOUS* neighbourhood.**

*** Neighbourhood is the area surrounding your property.**

**** Please SKIP this question if you have been living in Manchester city centre for more than 1 year.**

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Public transport (bus, tram, train) stations are nearby	○	○	○	○	○
Easy access to the city centre	○	○	○	○	○
Colleges, offices and public amenities all within walking distance	○	○	○	○	○
Variety of retailers is within walking distance	○	○	○	○	○
Easy access to the motorway	○	○	○	○	○
Adequate public transport services	○	○	○	○	○
External network of cycle routes provides adequate access to the area surrounding my neighbourhood	○	○	○	○	○
Suitable pavements (footways) for pedestrians throughout the neighbourhood	○	○	○	○	○
There are plenty of off – street parking options available	○	○	○	○	○
Entertainment and leisure facilities are nearby	○	○	○	○	○

Buzz of city living	○	○	○	○	○
Close to where I work/Study	○	○	○	○	○
The design of the neighbourhood encourages my preferred mode of travel	○	○	○	○	○
Good street lighting	○	○	○	○	○
Crime rate is minimal within the neighbourhood	○	○	○	○	○
I feel safe to walk within the neighbourhood	○	○	○	○	○
Off – street parking charges are affordable	○	○	○	○	○

26) Now please state to what extent the following statements are true to describe your *CURRENT* (city centre) neighbourhood.

NB - Neighbourhood is the area surrounding your property.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Public transport (bus, tram, train) stations are nearby	○	●	○	○	○
Colleges, offices and public amenities all within walking distance	●	○	○	○	○
Variety of retailers is within walking distance	●	○	○	○	○
Easy access to the motorway	○	●	○	○	○
Adequate public transport services	○	○	●	○	○
External network of cycle routes provides adequate access to the area surrounding my neighbourhood	○	○	●	○	○
Suitable pavements (footways) for pedestrians throughout the neighbourhood	○	●	○	○	○
There are plenty of off – street parking options available	○	○	○	●	○

Entertainment and leisure facilities are nearby	○	●	○	○	○
Buzz of city living	○	●	○	○	○
Close to where I work/Study	●	○	○	○	○
The design of the neighbourhood encourages my preferred mode of travel	○	●	○	○	○
Good street lighting	○	●	○	○	○
Crime rate is minimal within the neighbourhood	○	○	●	○	○
I feel safe to walk within the neighbourhood	○	●	○	○	○
Off – street parking charges are affordable	○	○	○	○	●

27) Now we are interested in knowing your residential preferences. Please state how important was each of the following neighbourhood characteristics for you *before moving* into the Manchester city centre?

	Not at all important	Not important	Neutral	Important	Very important
Public transport (bus, tram, train) stations are nearby	○	○	○	●	○
Easy access to the city centre	○	○	○	○	●
Colleges, offices and public amenities all within walking distance	○	●	○	○	○
Variety of retailers is within walking distance	○	○	○	●	○
Easy access to the motorway	○	○	●	○	○
Adequate public transport services	○	○	●	○	○
External network of cycle routes provides adequate access to the area surrounding my neighbourhood	○	●	○	○	○

Suitable pavements (footways) for pedestrians throughout the neighbourhood	○	○	○	●	○
There are plenty of off – street parking options available	○	○	○	○	●
Entertainment and leisure facilities are nearby	○	○	○	●	○
Buzz of city living	○	○	○	●	○
Close to where I work/Study	○	○	○	○	●
The design of the neighbourhood encourages my preferred mode of travel	○	○	●	○	○
Good street lighting	○	○	○	●	○
Crime rate is minimal within the neighbourhood	○	○	○	●	○
I feel safe to walk within the neighbourhood	○	○	○	●	○
Off – street parking charges are affordable	○	○	○	○	●

Others, please specifiy the reason(s) and its importance.

28) Finally, please tell us about your preferences with respect to your *daily travel patterns*. There are no right or wrong answers; we want only your true opinions.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I like walking for pursuing activities less than 2 miles	○	●	○	○	○
Where possible, occasionally I use phone and/or internet instead of travelling.	○	○	●	○	○
Walking and cycling are healthy modes to travel.	○	○	○	○	○
Where possible, I prefer to telework/telecommute	○	●	○	○	○

rather than travelling.					
I like cycling.	○	●	○	○	○
I would move out of Manchester city centre if it were to become a car-free (no car) development.	○	○	○	○	●
Car sharing is an efficient means to reduce congestion.	○	○	●	○	○
I usually consider fuel consumption when deciding to buy a car.	○	●	○	○	○
I consider public transport as an efficient choice for travel.	○	○	●	○	○
The availability of good and affordable public transport service could lead me to give up driving.	○	○	●	○	○
I like driving.	○	●	○	○	○
Driving is safer than walking, biking, and public transport.	○	●	○	○	○
Commuting without a car is a hassle.	○	○	○	●	○
Proximity and pricing of parking do affect my decision of owning/giving up a car.	●	○	○	○	○
I prefer to manage my travel by driving to more than one location in a single journey.	○	○	●	○	○
I make an effort to minimise my car-trips to help reducing emissions.	○	●	○	○	○

29) Now please tell me your contact details especially if you would like to enter the £50 vouchers prize draw.

First and last name:	xxxx xxxx
Address:	xxxx xxxxxxxxxxxxxxx
Postcode:	xxx xxx
Tel. Number:	xxxxxxxxxxxx
E-mail	