The Contribution of Teleworking to Travel Demand Management

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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Abstract

Continuously increasing demand for travel is contributing to increasing congestion on roads, especially within the urban settings. The cost of congestion is projected to rise if left unchallenged. Transport planners have limited options to tackle this situation. While exploring the various impacts of teleworking, this thesis has investigated its potential for travel demand management during the peak periods. By doing so, it seeks to increase the range of policy options to support transport policy objective(s).

Teleworking has been studied from various perspectives in the past; however, its impact on commute travel has not been modelled. This thesis has applied a policy-analysis based methodology to the study of teleworking impacts. The methodology required bespoke data to estimate an SP model of teleworking adoptin and frequency for which a survey was carried out on car commuters to the city centre of Leeds. The survey also explored the employees' attitudes towards teleworking and its other impacts. The result from these aspects of the survey have been presented and analysed.

A bespoke demand model of teleworking adoption and frequency has also been estimated from the collected data to predict the teleworking impacts. This model uses telework as a policy measure and evaluates its performance relative to three indicators: reduction in work-based travel, levels of overall car use and car use during the peak. Within an extended framework, the demand model has also been linked to a congestion response function to analyse the system-wide impacts of teleworking.

The use of the methodology has shown that it is possible to model telework as a TDM measure and use it to support transport policy objective(s). The results of the analysis indicate teleworking impact on work-based travel, car use and system performance. The extent of the impacts would depend on the nature of the telework policy, which needs to be clear and well-communicated. Further, the employers also need to address the issue of teleworkability through job redesigns. The study findings show the inadequacy of current teleworking policy and legislation, highlight the need for making telework formally available by the firms to the eligible employees and emphasise the regulator's role in this regard.

Key words: Telework, Modelling, Policy, Frequency, Cost, Attitudes, Impacts, Methodology, TDM and Tele-interventions

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Abbreviations

ABA	activity based approach
ANOVA	analysis of variance
ASC	alternative specific constant
CAPI	computer aided personal interview
CBD	central business district
CS	choice specific
DfT	department for transport
DSE	demographic and socio-economic
DSEC	demographic, socio-economic and commute
DV	dependent variable
ESIF	Environmental and Social Impact Factor
FSM	four stage model
GC	generalised cost
ICT	information and communication technologies
IIA	independence of irrelevant alternative
IID	independently and identically distributed
ITS	intelligent transportation systems/institute for transport studies
IV	independent variable
LCC	Leeds city council
LUTI	land use and transport interaction
MNL	multinomial logit
N	number of observations
ONS	office of national statistics
POET	Prediction Of impacts of the e-Economy on Transport
RP	revealed preference
RUT	random utility theory
SD	standard deviation
SEG	socio-economic group/ing
SLM	single link model
SP	stated preference
SWOT	strengths, weaknesses, opportunities and threats
TDM	transport demand management
TW	telework, teleworking, teleworkers
VMT	vehicle miles travelled
VOT	value of time

1 Introduction

The subject of traffic congestion on the road network, especially in urban areas, has been of enduring interest to all the stakeholders within the road transportation system due to its multi-dimensional consequences. This thesis adds to an existing body of literature on the transport policy and planning options aimed at congestion reduction and specifically concerns itself with the use of Information and Communication Technologies (ICT), particularly its teleworking application affecting travel and location behaviours of individuals and/or businesses which in turn affect the demand for travel and traffic on roads.

1.1 The Problem

Although congestion is almost a daily experience of a road-user and needs no scientific evidence for its existence, yet it would be beneficial to set an academic context to the problem. In industrialised countries basic road infrastructure provision was completed and surface accessibility was established decades ago. But in many cases this network capacity is proving insufficient and there are demands for new road projects. The single most contributing factor is the use of car. This is especially the case in countries with a relatively high density of population and growing car ownership. The Netherlands, Germany and the UK are only few examples of this in Europe. The combined effect of these two factors is congestion, especially within the urban areas. Congestion is not a simple problem. It has many dimensions and comes with certain very well-documented externalities resulting in economic and social disbenefits and costs to the society. In the long run it is endangering the sustainability of the urban areas. This is largely the gist of the debate that started in the UK around the end of 1960s and start of 1970s and is still going on.

In the beginning the solution was sought by providing more road capacity. Goodwin et al (1989) give a good account of the evolution of the transport policy during the 1970s and 80s and conclude that providing new road infrastructure and increased capacity has proved counter-productive in the UK. It is likely to produce the same results in the future as new capacity attracts more traffic which in most cases will offset congestion relief and reduce benefits. May (1990) found that the problem is not with the solutions but with the approach towards the solution and proposed a new integrated approach. The new thinking gradually found its way into practice and policy interventions were sought and tried in more than one area, with a particular emphasis on public transport (PT). But such initiatives did not prove very successful in weaning people away from cars (see e.g. May and Nash 1996 and many references therein). The more pronounced effects of such initiatives were modal shifts among the competing PT modes because people who use car tend to value time over money and compared to PT users, car saves time spent in travel. The value of this time has further increased with the advent of the knowledge-based economy and due to the gains in individual productivity. When congestion on roads adds to this time, it results in additional economic cost to the individuals and the society.

Recognition of the interaction between the fields of land use and transport led to increasing the range of policy options to solve this problem and measures were identified from other areas, particularly from the land use discipline (see e.g. IHT 1996, KonSULT 2005). Some of the measures from this range, e.g. congestion pricing and reduction in the parking space in city centres, have obvious implications for business cost and might pose a risk to the economic viability of the city centres. There is also some evidence of decentralising effects of pricing measures on population and employment in inner urban areas (Grieving and Kemper 1999, SPRITE 2002). Understandably, it is not easy to cover a problem which touches almost every dimension of the transportation system in a short discussion judiciously. In this regard the reader is referred to a very good debate in a research journal {Transport Reviews vol. 22 (2-4) and 23(2)} that documented the problem very well. The majority of the leading lights in the field, especially from the UK, took part in this debate.

The debate exposed the various dimensions of the problem of congestion, issues and limitations attached to the problematic dimensions and resulting future challenges to the transport policy. The issues stem from a range of inequities: the inequities by purchasing power; between travel modes; of location; and by purpose. The debate particularly emphasised the importance of constant travel time budgets, their significance for transport policy and the implications of road pricing/congestion charging in general and towards equity in the transportation system in particular. It rightly pointed to improving the system reliability and comfort, and improving accessibility for non-car user classes among the transport policy objectives rather than a sole focus on system efficiency. Another significant point of debate was to make infrastructure investments driven by land use planning considerations, not vice-versa.

In the light of this debate, it was not very difficult to see why the different approaches to the problem at different points in time may have failed to achieve the desired results. The problem – the challenge to transport policy – if not getting bigger by the day, is sustained by a combination of factors like income led demand growth, constant travel time budgets, humans' deep-seated desire for physical mobility and our incomplete understanding of it as every effort results in yet a new congestion equilibrium. Mackie (2002) has provided a succinct description of the problem

> *on the one side, income-led demand growth [in road traffic at about 2% per annum], on the other side, social, political, economic, financial and environmental constraints. In the face of these, the system is sclerotic and sluggish.*

Lyons (2003) sounded a note of urgency about the problem and the need to tackle it when he said: 'we face a crisis or at least some major problems is undeniable'. It is also interesting to look at some of the costs of the problem. A recent report (Eddington Transport Study, 2006) put the existing cost of congestion in England at £7-8 billion per annum and concluded that 89% of the delay caused by congestion is in urban areas. It projects the cost figure to rise to £22 billion by 2025 in England alone if congestion was left unchecked and recommends a 'sophisticated policy mix'.

1.2 Research Context

This study was undertaken within some very specific contexts. Urban sustainability, particularly in a European perspective, defines its over-arching backdrop. Land Use and Transport Interaction (LUTI) is the overall perspective both for the problem investigation and search for a solution. The problem has been investigated from the demand side of the road transportation system. Finally, the solution has been explored and sought within the wider role of ICT's in affecting travel demand and the potential for a solution. The following sections explore these contexts a bit further to distil and refine the nature of the problem.

1.2.1 Urban Sustainability

Sustainable cities need sustainable transport systems. A sustainable transport system has been defined (EC, 2001, quoted in May, 2005) as one which:

- Provides for basic access and development needs
- Supports safety and human and ecosystem health
- Promotes equity within and between successive generations
- Is affordable, fair and efficient
- Offers choice of transport mode
- Supports a competitive economy and balanced regional development
- Limits emissions and waste within the planet's ability to absorb them
- Uses resources at rates which permit renewal or substitution
- Minimises impacts on the use of land and the generation of noise.

Congestion is criticised not only for its economic disbenefits but also for its harmful consequences for urban sustainability over the longer term. Urban areas all over the world are experiencing the onslaught of various natural and commercial forces. This is particularly the case in European cities which are custodians of diverse and rich historical and cultural heritage. Their sustainability, under threat from various forces, is in jeopardy.

> *There is ample evidence that European city transport systems are unsustainable, in terms of their growing levels of congestion, pollution, fuel consumption and accidents, the adverse effects on economy............ (May 2005)*

Add to this the effects of dispersed land use patterns, sometimes induced by ICT use and demands for more network capacity and infrastructure provision; and the picture gets more bleak. This situation highlights the need to study transportation from a perspective of demands it makes on society: demands in terms of social costs of land use and sustainability. The challenge here is to minimise, or if possible then eliminate, the long term social costs of congestion by reducing the demand for travel.

1.2.2 Land Use-Transport Interaction

It has been established (see references below) that problems of travel demand like congestion cannot be studied effectively within the field of transport only. It is the interaction between the fields of land use and transport that generate the demand for travel and form a correct perspective for analysis. The theory of interaction is based on the notion of the 'land use transport feedback cycle' which is based on certain distributional relationships. Driven by these relationships land use patterns determine location of activities which in turn require spatial interaction. Transport systems cater to this requirement providing accessibility and creating value for the society. Interaction is also evident from the fact that

> *both firms and households trade off accessibility for space or vice versa (Wegener and Furst 1999).*

They further continue that

> *a fundamental assumption of all spatial economic theories is that locations with good accessibility are more attractive and have a higher market value than peripheral locations.*

The argument about interaction, therefore, is simple yet potent: (travel) trip and location (of activity) determine each other. This interactive relationship sets all the ensuing dynamics of impacts and counter-impacts in motion. Three types of impacts are often mentioned. They are: from land use to transport; of transport policies on transport patterns; and from transport to land use (Ibid). The view about interaction has also been endorsed by ISGLUTI (1988), DETR (1998) and Grieving and Kemper (1999). These works provide evidence from literature and modelling studies about the interaction and its impacts. These impacts are both beneficial and detrimental in their nature and congestion and its externalities fall in latter category.

1.2.3 The Demand Side Perspective and an Integrated Approach

In their work Goodwin et al (1989) concluded that a demand management approach was likely to be more effective and efficient in solving the transport problems than catering to the supply issues. The 'New Realism' conference of 1991 acknowledged the impossibility of increasing the capacity of the road network to address both the forecast traffic levels, and the environmental problems associated with such traffic. There was a realisation (supported by the SACTRA report of 1994) that in congested areas increases in road capacity were likely to induce more traffic than would otherwise be the case. Thus, the conclusion was that if supply could not be made to meet demand, then demand would have to be changed to meet supply, hence, the need for demand management.

In the UK context, this thinking culminated in, and was adopted by, Multi-Modal Studies commissioned by the Department for Transport (DfT). These studies represent a significant new approach to developing integrated transport strategies (DETR, 2000b), a topic well-documented in many studies (see e.g. May 1990, Goodwin et al 1989, May 1992, May & Roberts 1995, May et al 2000). An integrated approach attacks the problem on a wider front and an integrated transport strategy is a set of policy measures selected from different transport impacting areas to work in coordination and to produce a better result than the mere sum of its parts.

Kitamura et al (1997) contend that land use and lifestyle, along with transportation supply, determine travel demand and are inter-connected, mutually affecting each other in an evolutionary process. ICT are a major influence on today's lifestyles. From a transport user's perspective, these lifestyles are associated with demand for increasing mobility which intensifies the demand for transportation even more. Therefore, it is not very difficult to foresee how a nexus of changing lifestyles, increasing desire for mobility, and land use under the influence of ICT is setting the agenda for transport policy. In this background, it is only surprising that on demand side of the system, the effort is lagging behind in exploring the impacts of ICTs for transport policy.

1.2.4 ICT's Relevance and Potential

ICT are relevant because of their ubiquity and omnipresence, and because of their potential to afford remote- or teleaccess to a broad range of human activities. Teleaccess to suitable activities removes any temporal, spatial and organisational restrictions, thus, making co-presence redundant and effectively reduces the need to travel (to make a trip), at least for a range of conventional purposes. Salomon (1998) and Cohen et al (2002) have highlighted the knowledge gaps in our understanding of ICT's impact on society and urban space in general while Mokhtarian (1998) has focused on the gaps in understanding their impact on transport. More recently POET (Prediction Of impacts of the e-Economy on Transport) project literature review (Rahman et al, 2006) concluded that there is little evidence on the impact of ICT on passenger and freight transport.

In view of the limitations of conventional transport policy in arresting the problem of congestion (1.1) and ICT's relevance and potential, it is evident that there is a need to broaden the research horizon in search for solutions. As this research has a stated focus on urban sustainability (1.2.1), therefore, the primary focus in investigation and discussions is on urban areas. The investigations from this perspective would also be helpful in advancing our general understanding of the impacts of ICT on LUTI, another context of the study, and reduce the knowledge gaps.

Thus, the research challenge is to investigate whether ICT can help the transport planner to redeem this situation from the demand side. Transport planners have been using various policy instruments with varying degrees of effectiveness. So far policy measures pertaining to land use, infrastructure, management, information, and pricing elements have been developed and used (KonSULT 2005). The information measures among these do make use of ICT but only in a marginal way. The need is to make their intervention direct, more specific and extract instrument(s) that could be employed to suppress the demand for travel. In their work on "Optimal strategies for European cities", May et al (2000) had also pointed to the need when they wrote:

> *it would be interesting to test land use policies and the effects of more recent measures such as telecommunications.*

1.3 Summary

The description of the problem in the first section points to the limited options available to transport planners. *Recognition* of congestion is a fundamental step towards finding a solution. The received wisdom is that any effort in search of a solution should combine the relevant and tested pieces of guidance which are: LUTI is the better framework for the study of the problem; the problem should be addressed from the demand side of the system equation; and an integrated transport strategy has better chances to succeed where the preceding approaches have failed. The principal aim of any strategy directed at congestion alleviation should be to reduce car use through relevant measures or increase the price of its use. However, car use is associated with increased gains in economic productivity.

Viewed in this backdrop, the broad problem is two-fold: to relieve urban areas from congestion and its externalities by reducing car use and to minimise the potential economic disbenefits of such a policy. The ICT applications to organised work arrangements like teleworking (which is becoming increasingly sophisticated enabled by advances in technology) seemingly fit well as a prescription. The existing arsenal of policy options is currently lacking in this. Thus, the research should address this gap and the limitations of transport policy by investigating the potential of ICT-enabled teleaccess to activities requiring travel, particularly during the peak.

1.4 The Research Objective

The discussions in the previous sections and an initial literature review (Chapter 2) have led to the conclusions that:

- It is a limitation of transport policy that urban transport problems are not being effectively solved and the search for solutions to this situation continues in different fields;
- ICT and transport interaction is one such field where there is need to advance current understanding, especially relative to ICT's contribution to transport interaction and specifically to travel demand management; and
- Teleworking as one of the examples of this interaction has a growing following in the UK and its full impact has not been investigated for its implications for transport policy.

In this context the main objective of this research is to investigate the potential of telework in the UK to address some of the limitations of transport policy and it has been broken down into the following study tasks:

- 1 – To make an assessment of potential of telework for addressing the limitations of transport policy by looking at its impacts;
- 2 – To explore responses to telework availability and assess their impacts on transport and allied fields;
- 3 – To define a framework that could capture these impacts and to employ it for analysis of the impacts;
- 4 – To investigate how the responses to telework availability, particularly teleworking adoption and frequency, can be influenced through policy intervention;
- 5 – To test how sensitive the responses of teleworking adoption and frequency are to changes in the policy;
- 6 – To use the framework defined in (3) to model the result of the investigation in (5) for assessing the potential of telework as an instrument of transport policy;
- 7 – To develop estimates of teleworking impacts on travel demand and congestion time in a given transport system; and
- 8 – To identify policy changes which might increase the take-up and hence benefits of teleworking.

1.5 Methodology and Thesis Structure

These objectives will be researched by:

- making an assessment of the dynamics of the impacts of ICT in general and of telework in particular on the travel and land use behaviour; defining a conceptual framework for telework adoption and assessment of its impact (Chapter 2);
- exploring how employee and employer uptake of teleworking might be modelled, looking into the relevant policy modelling paradigms and discussing how teleworking might be represented within each of them (Chapter 3);
- developing a framework for impact forecasting that is responsive to tests of changes in policy options (Chapter 4);

- designing a stated preference (SP) experiment on behavioural responses to congestion including adoption of teleworking (Chapter 5);
- carrying out a survey to obtain data on stated and revealed preferences (RP) of respondents' choices (Chapter 6);
- analysing some non-SP data to draw conclusions about the characteristics and attitudes of teleworkers and estimating the teleworking impacts (Chapter 7):
- estimating a model of behavioural choices that could predict teleworking adoption levels and frequencies (Chapter 8);
- calibrating the framework developed in chapter 4 with the results from chapters 7 and 8 to develop estimates of the system-wide impacts of teleworking policy(s) on travel demand and congestion times (Chapter 9); and
- exploring current policy planning context regarding teleworking to pave the way for discussions of the study finding.

Finer details of the individual elements of the research methodology will be presented along the way in the relevant chapters of this thesis. However, Chapter 4 will also be used to scope the study after exploring the research topic and main methodology in chapters two and three. Finally, Chapter 11 will be used to draw/consolidate study conclusions and to make some recommendations. Thus, as an output of this study it may be possible to combine ICT related policy instruments with measures from other areas into a package of integrated transport strategy in pursuit of urban sustainability.

2 ICT, Teleworking and Transportation

2.1 Introduction

While introducing this research project, the previous chapter described the specific research contexts for this study (1.2) and briefly discussed ICT's relevance and potential (1.2.4) in search for a solution to the problem under study. This chapter explores the same context in detail and reviews the literature on the topic. It has two parts. The first part (until section 2.5) develops an understanding of ICT in a broader sense and after reviewing the relationships between ICT and transport, it focuses on ICT enabled tele-interventions to perform activities currently requiring travel. The later part of the chapter zeros in on teleworking as an exponent of the interaction between ICT and the fields of transport and land use. At this stage the review looks in greater depth and into the potential of teleworking to support transport policy objectives by looking at its adoption context, its motivations, its advantages and disadvantages, and its post-adoption responses and their impacts. It also highlights the empirical evidence on teleworking estimates and impacts.

2.2 Developing a Perspective on ICT

The thesis focuses on ICT's potential to support transport policy objectives. But ICT are not a panacea. Sometimes they are also part of the problem. The rapid advancement of ICT, their applications and diffusion into the society at very micro level are instrumental in not only changing the old ways of doing things but also creating demand for emerging lifestyles and work practices. ICT-based applications are finding their way into a rapidly increasing range of human activities and their penetration in many realms of professional and personal activity is simply unfailing. This makes ICT an influential and major player in any debate about the future. Therefore, it appears useful to develop a perspective on ICT in this section.

The frequent use of the term ICT may be confusing without a formal definition. It is also beneficial to have one for reference. One source (Cohen et al 2002) which also refers to some other sources for the same purpose, defines ICT as

> *A family of electronic technologies and services used to process, store and disseminate information, facilitating the performance of information-related human activities, provided by, and serving the institutional and business sectors as well as the public-at-large.*

2.2.1 Nature of ICT Impacts

Cohen et al (2002) report a wide agreement among scientists that ICT will have important implications for society at large and for the city in particular. The diffusion process is still going on as ICT are mainly characterised by very dynamic technological changes and decreasing costs causing rapid penetration and adoption. There is little doubt about the increasing pervasiveness of the impact of ICT on economies and regions, and on their ability to alter spatial relationships in the way economies function (Grimes 2000). Use of ICT underpins the nature of business activities in the modern day economy and is spawning the phenomenon of locational dispersal of business, both short- and long-distance, e.g. establishment of call centres in low cost remote towns or outsourcing the ancillary product and services from countries with low labour costs.

It may have been a bit premature to declare the 'death of distance' but it is almost certain that future location patterns especially work related ones would be determined to a greater degree by the impact of ICT in socioeconomic spheres of life. This is already being aided by the (gradual) globalisation of world and national economies and increase in data transmission speed and features. These factors combined are creating major change in the location of work (Huws et al 1999) making the workforce increasingly mobile and allowing workers (and/or their employers) dynamically to select among a variety of work locations to suit their needs (Mokhtarian and Bagley 2000). Understanding more about these possibilities and how they are constrained or dictated by the changing nature of work,

> *will be important to monitoring and forecasting changes in commuting and work-related travel pattern, as well as changes in land use in urban and rural areas (Ibid).*

Further, the combined impact of ICT and Transport is modifying spatial relationships, redefining the urban space (Shen 1998), increasing spatial scale and favouring increased specialisation (Hall 1999). These developments have obvious consequences for the accessibility concept in its traditional sense (discussed in the next chapter). Given the strong association between people's socioeconomic status and their level of access to advanced ICT, this is important. This nexus means that not only location but also social factors including access to ICT define the urban space. Thus, traditional measures of accessibility in conceptually understanding the socio-spatial impacts of these technologies seem to have become insufficient and there is a need to modify them in such a way that they take into account likely socio-spatial consequences of ICTs (Shen 1998). However, arguably the role of transport technology to access activities requiring co-presence is likely to remain paramount.

2.2.2 Can ICT Offer Solutions to the Problem?

The previous section has highlighted the importance of ICT impact as a future determinant of location choice and its link with land use and transport. Thus, there is a need to explore this impact for its beneficial contribution towards the solutions to the problems of urban space and, within the remit of this thesis, to the urban transport problems. In this context, the conclusions drawn by the leading researchers in the transport field are important. Proposing to incorporate the travel impact of ICT, Mokhtarian (1998) concludes that

> *the potential reductions in travel due to telecommunication are of an order of magnitude comparable to the estimated impacts of other TDM strategies. A bundle of such TDM measures that includes telecommuting may collectively have some impact on congestion.*

May et al (2000) at a turning point in their long standing work on integrated and optimal transport strategies note that there is a need to test a wider range of policy measures in this regard. They go on to suggest the need for testing policy measures in ICT along with awareness campaigns and land use policies. Golob and Regan (2001), noting the relevance of ICT, especially internet based information provisions, to transport planning and policy making conclude that

> *travel behaviour researchers ignore the impact of IT, particularly the impact of the Internet, at their peril. The effects of future IT on travel behaviour is currently unknown, but we can be sure it will be substantial. Not since the introduction of the automobile age has transportation been faced with technological impacts of this scale. ....As populations increase, particularly populations within metropolitan areas, we will also increasingly rely on IT to avoid congestion on transportation networks and at activity sites.*

Finally, Lyons (2003) puts ICT at the top of the list of opportunities in his SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of British transport. These testimonies fortify the confidence that the teleaccess afforded by the advent, rapid advancement and diffusion of ICT offers a potentially interesting avenue in search for policy options to broaden the decision makers' choice.

2.3 ICT and Transportation Relationships

Research into the field began by studying the impact of telecommunications on transportation during the 1960s. But the trickle did not turn into a stream until the mid 1980s. The most focused, consistent and cited studies in this field are by Ilan Salomon and later on, by Patricia L. Mokhtarian. The former while concurring with some earlier literature identified the principal impacts of telecommunication on transportation in the form of substitution, complementarity and enhancement (Salomon 1986). Mokhtarian (1990) drawing on his work has pointed to slightly different relationships. Her list includes substitution, enhancement, operational efficiency and indirect long-term impacts. The last in the list refers to telecommunication impacts on land use.

2.3.1 Types and Nature of Relationships

Relationships between ICT and transportation are mainly characterised by the purpose of ICT's use. Depending upon context and circumstances, Mokhtarian's four main types can more specifically be categorised as travel substitution, travel enhancement and generation, efficiency in resource use, and medium to long-term consequences for land use and transport. It is also possible to study these relationships from the demand and supply sides of transportation management. While efficiency in resource use helps in managing the supply of resources to the transportation system, the other three relationships deal with demand management. In the literature a wide support for, and commentary on the nature of, these relationships are available (see e.g. ECMT 1984, Salomon 1986, Mokhtarian, 1990 & 2003, Marvin 1994, and Lyons and Ury, 2005).

2.3.2 Supply Management based Relationship

Employing ICT for efficient use and management of the resources of the entire transportation system by all the stakeholders is perhaps the most comprehensive of the relationships and yields system wide benefits. The ICT-enabled telematics increase the operational efficiency and productivity of transport resources and network through Intelligent Transportation Systems (ITS) which have been defined as:

> *an umbrella term for a range of technologies including processing, control, communication and electronics, that are applied to a transportation system. It also includes an advanced approach to traffic management (Road traffic-technology, 2006).*

The range of technologies includes communications, control, electronics and computer hardware and software (Sussman, 2005). These telematics help manage, improve and enhance the service provision and transport quality, e.g. through provision of real time information about the conditions of the networks, availability of services, updated timetables, routing and scheduling to the system users which enable people to make smart travel choices. The ITS program is a worldwide initiative to add information and communications technology to transport infrastructure and vehicles. It aims to manage factors that are typically at odds with each other such as vehicles, loads, and routes to improve safety and reduce vehicle wear, transportation times and fuel costs[1]. In UK context, MSI (2001) has divided ITS' impacts on transportation system into five segments:

- o traffic management;
- o payment systems;

[1] *Ref: http://en.wikipedia.org/wiki/Intelligent_transportation_system*

- freight and fleet management;
- road safety and incident management; and
- information and in-car navigation and guidance systems.

This relationship essentially operates on the supply side of the system and the range of ICT applications encompassed by it makes it a really vast field of study with far-reaching multidimensional impacts on the transportation system, especially in capacity building. Significance and potential for developments in ITS field was so evident that a dedicated scientific *Journal of Intelligent Transportation Systems* was launched in 1993. Later on government transport departments, academic and research institutions set up dedicated departments and websites[2] to explore, exploit and promote its potential impacts and benefits. As this research takes the demand management perspective to the problem, this supply-side relationship has been excluded from further discussion on the topic.

2.3.3 Demand Management based Relationships

The rest of the relationships, i.e. travel substitution, travel enhancement and generation, and indirect effects on land use and transport, can be comfortably categorised as demand side relationships. All of them relate to and affect travel and travel behaviour and have significant consequences for transport demand management (TDM) and are explored in more detail in next sections. The nature of these relationships indicates a definite and substantial impact on land use and transport which has both positive and negative consequences. However, the magnitude of these consequences is less clear.

Also, sometimes there might be impacts from two different relationships, or from the same relationship in different circumstances, operating in opposite directions. This is what has been referred to as a 'notion of counteracting forces' (Mokhtarian 1998) in the literature. Four counteracting forces have been identified. These forces originate from, and can be related back to, the concepts of constant travel time budgets, time space for activities, increased spatial dispersion of activities and induced demand (due to increased interaction of ICT and transport in various forms). These concepts underlie most of the identified relationships between transportation and ICT and their role is important in the determination of the net impact of ICT-transport relationships.

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[2] *Some very useful sites with good quality material are: www.its.washington.edu/, www.its.dot.gov, www.its-uk.org.uk/about.html*

2.3.3.1 Indirect Consequences for Land use and Travel

Of all the relationships between ICT and transport, ICT's impact on land use is relatively much less clear. It may be so because this impact is mediated by land use patterns. ICT's impact upon urban space by reducing the importance of physical accessibility to certain types of jobs/activities and it is possible that through medium to long-term adjustment processes, this may result in consequences for sustainable land use patterns. The workers with jobs requiring low physical accessibility might move to less congested, low density areas for quality of life reasons which may result in decentralisation, urban or suburban sprawl and reverse migration to rural areas.

Writing on rural areas' potential under the influence of ICT, Grimes (2000) notes that teleworking has mainly evolved as an urban or suburban form of decentralisation and despite all the speculation there is little evidence to support the view that it is most likely to be found in rural areas. In support of his conclusions, he refers to the findings of the 1996 report of the Rural Development Commission of the UK. Gillespie et al (1995) in a review of the geography of teleworking have also shared similar views by suggesting that

> *although teleworking is often perceived to be a rural-based phenomenon, in fact it is a predominantly urban and suburban phenomenon, and is likely to remain so.*

This observation was made in view of the low accessibility to reliable and high speed ICT networks in the rural areas more than a decade ago. However, it may still not be easy for a large majority of highly skilled professionals, who often rely more on their personal networking skills in urban areas, to sustain economic activity in remote areas.

Neither Grimes nor Gillespie et al base their conclusion on detailed analysis and, while scenarios of large scale reverse migration to rural areas under significant teleworking arrangements seem inflated, the longer term land use responses remain unclear.

2.3.3.2 Travel Enhancement and Generation

Another ICT-Transport relationship affecting transport demand is its role in the enhancement of travel experience through in-cabin entertainment system and facilities for external plug-ins. Use of ICT also complements travel by enhancing the travel experience and keeping passengers especially travelling by public transport engaged or busy in different activities during the travel. In this regard a recent study by Lyons et al (2007) found that

> *over a fifth of rail passengers considered having electronic devices (PDA, laptop, mobile phone, personal stereo etc) with them made the time on the train a lot better.*

Understanding the significance and use of (travel) time is fundamental in this regard and Lyons and Urry (2005) point to the need to understand to *what extent ICT used on the move will influence the pool of social practices. Yet again the call for empirical evidence is made – not only do we need to develop the productivity distributions but we need to see how they are changing, or not, over time and determine to what such change is attributable.*

Access to ICT brings in better information about travel services, service availability and features. The other dimension of this relationship is its role and potential for the generation of travel due for example to "cabin fever", a feeling caused by being indoors most of the day time glued to the working desk. It may also create new travel opportunities as availability and use of ICT facilitate and increase new contacts and long distance communication. That in turn creates or increases the desire for physical co-presence in many instances.

2.3.3.3 Travel Substitution

Perhaps the most significant demand side relationship is substitution of travel by the use of ICT where such an option is available and feasible. Thus, instead of making a trip, ICT may be used to access and perform the required activity and examples can be easily found in daily life. Advances in internet have further increased the opportunities for, and potential of, teleaccess which is being used with increasing frequency as a substitute for travel. The teleaccess potential of this relationship between ICT and transport has made it the focus of increasing attention by researchers. The significance of this relationship is so profound that a substitution rate as low as 5% of the total daily commute trips has been considered to have significant impact (Nilles 1988). (More specific evidence has been provided in 2.10.2.) Before travel substitution is further explored through various manifestations of ICT applications for its implications for the demand for travel and transportation, a look at aggregate studies of ICT impacts is useful.

2.3.4 Aggregate Studies of ICT Impacts

The investigation in this regard found at least four studies which have attempted to study the interaction of ICT with transport and economy at the macro level. Selvanathan and Selvanathan (1994) estimated a simultaneous equation system of the consumer demand (in terms of per capita consumption expenditures) for four kinds of goods: private transportation, public transportation, communications, and all others. They used 1960-1986 time series data from Australia and the United Kingdom, and found that private transportation, public transportation, and communications have a pair-wise substitution relationship, showing positive cross-price elasticities among those three (meaning that an increase in the price of one kind of good increases the consumption of the other kinds).

Plaut (1997) identified the relationship between transportation and communication services in industry for nine countries of the European Community in 1980, emphasising that about two thirds of all transportation and communication services are used by industry rather than by end consumers. Using input-output analysis, this study examined the correlations of the input coefficients for transportation and communication, across all industrial sectors (classified into 44 categories). These correlations were predominantly positive. Another aggregate study (Choo and Mokhtarian, 2004) developed a conceptual model and considered causal relationships among travel, telecommunications, land use, economic activity, and socio-demographics using structural equation modelling of national time series data spanning 1950-2000 in the U.S. They concluded that travel and telecommunications are complementary. That is, as telecommunications demand increases, travel demand increases, and vice versa.

More recently EU's POET project (Rahman et al, 2006) covered the impacts of developments in the e-Economy on both passenger and freight transport through specific case studies. The passenger case studies addressed the impact of application of information technology tools, intelligent transportation systems and advanced telecommunication programmes on travellers' choices based on empirical evidence. The freight cases similarly addressed the impact on the choices of firms and organisations. Using so-called front-end models estimated on new stated preference data, de Jong et al (2006), as part of the same project, modelled the impacts of the e-Economy on urban transport (passenger kilometres, vehicle kilometres, etc.) and the outcomes were translated into relevant impact indicators: energy use, emissions and accessibility for five urban areas within EU between 2004-2010.

They found that the net effect for most combinations of passenger and freight scenarios is a (small) decrease in total (passenger and freight) vehicle kilometres while the reductions in passenger car kilometres will outweigh the increases in lorry kilometrage. The expected reductions in vehicle kilometres lead to less energy use and emissions of greenhouse gases and local pollutants compared to the reference for 2010. Congestion decreases because of the e-Economy (Stockholm, Randstad) and in Stockholm accessibility increases in spite of the decrease in the number of tours made. The project also concludes: that evidence on the impact of specific ICT-applications on transport is scanty, and more research needs to be done to fully understand this relationship; that ICT is primarily an enabler and not a driver of changes in the transport system; that e-Economy developments may lead to replacement of passenger transport by freight transport; and that the potential impact of ICT on transport volume could be substantial, if there were a wide uptake of ICT-applications. A significant observation of the study was that the final outcomes depend crucially on the impact of the e-Economy on relocation. Given this outcome, the need to further investigate the impacts of the e-Economy on land-use both in greater depth (a full-scale residential choice model based on a larger database) and in a broader sense, (in POLIT only population was shifted, not employment) is obvious.

2.4 ICT Enabled Teleaccess to Activities

ICT's use for a host of activities with a potential for travel substitution spawns a number of terms. It may be useful to define an umbrella term for this group of activities. Using ICT to access, participate and complete an activity which may be spatially, temporally and physically separated by a significant distance from the accessor may be regarded as a remote intervention into that activity. The capability and availability of a particular ICT or group of ICTs made this intervention possible. Therefore, the use of term tele-intervention(s) appears more appropriate to describe the ICT-enabled teleaccess to activities at remote places. The following list of tele-interventions, though not exhaustive, can be identified as potential stimulants of travel substitution:

- Teleworking/telecommuting
- Teleconferencing (special case: tele-education, telemedicine and tele-justice)
- Telemarketing
- Teleshopping
- Tele-banking
- Tele-entertainment

These tele-interventions have some common characteristics. Some of the activities through these interventions are performed within an individualistic framework, e.g. teleshopping while the performance of the others requires a contractual framework, e.g. teleworking. A common consideration that characterises them all is the generalised cost of the trip foregone, often over a fairly long distance. A common perspective to all the tele-interventions is of the planner's or regulator's perspective. This topic is taken up in a later part of the chapter. Golob (2000) gives a good discussion of various possibilities in this regard.

This section is intended only as a general commentary on the tele-interventions making travel for various activities redundant. As teleworking and teleshopping are now rather established fields of study, the focus of this section excludes discussion on both these tele-interventions here. They will be taken up for exploration and discussions in the subsequent sections. The rest of this section is devoted to the rest of the tele-interventions which can be conveniently grouped into three major categories and are discussed next.

2.4.1 Tele-conferencing and its Variants

Video or teleconferencing is a tele-intervention that facilitates simultaneous and two-way transfer of both voice and image, thus making it possible to conduct remote audio-visual communication. The manifestations of this ICT application can be seen in tele-business meetings, tele-education, tele-medicine and tele-justice. Until recently, teleconferencing technology has been relatively awkward and expensive. Following teleworking and teleshopping, this is one of the most researched topics in travel demand modelling. The consensus to date is that teleconferencing has little overall influence on business travel (Golob, 2000). For specific references see e.g. Bennison (1988), Button and Maggi (1994), Plaut (1997) and Salomon, et al. (1991). However, research involving impacts of IT become obsolete quickly and more recently, Bonsall and Shires (2005) have studied this phenomenon under assumptions about future travel conditions and increased availability of ICT. Their results suggest that business related travel would reduce by 5% under a do-nothing scenario. However, the size of this impact can reach up to

> *17.7% if the capability of ICT rises in line with the most bullish forecasts and its costs decrease significantly and journey times increase by 20%.*

In the area of education, ICT has a history of use for remote learning over fairly long distances often stretching over thousands of miles (see e.g. Kerr 1986). Currently, the use of ICT for tele-education is more common in the medical field where cutting edge expertise is rare and expensive and available at advance centres of learning in developed countries at distant places (Marescaux et al 1999). By their very nature teleconferencing and all its variants are long distance phenomena.

Primarily, the cost of travel over long distance overrides the co-presence requirement in case of the replaced activities. Otherwise these activities may have been a more worthwhile and valuable experience to be involved in. Alternatively those activities might not have been thought of in the first place; technology availability and application has made them possible. There might not be as many motivating factors as, e.g. for teleworking. Therefore, the distinction between teleworking on one hand and tele-education and tele-entertainment on the other on the basis of their character also appears necessary and useful.

2.4.2 Variants of Teleshopping

The popular perception of teleshopping is that of grocery shopping but in reality it covers a broad range of product groups and service sectors. All the products and services that can be purchased/acquired on/enjoyed through the use of a tele-intervention can be regarded as teleshopping. Thus, tele-booking (especially of travel services), tele-banking, and tele-entertainment may all be regarded as variants of teleshopping. The list of such products and services may be fairly long and the range of such products and services may still be increasing. In this regard tele-services offered to the general population over the internet by the public sector organisations and other government agencies or City Councils have significant potential as these agencies are increasingly exploiting the ICT for this purpose. Unlike teleworking and its variants, teleshopping and the rest of the tele-interventions operate within a totally individualistic framework. Consent of another party is not required. It is often only the personal will that decides when, where and how to perform these activities.

2.4.3 Variants of Teleworking

Teleworking may be regarded as an ICT application to work organisation and management and its variants may include telecommuting, telemarketing and call centres. To this there are both employee and employer perspectives. As mentioned before, these may be regarded as contractual activities in nature because consent of both employer and employee would be required to establish an operational framework for these tele-interventions as they operate within a non-individualist framework. Often the consent of others who are linked to the activity either as task-giver or recipient of the activity output is required to engage in the activity. Therefore, the context within which teleworking is to be conceptualised, defined and analysed becomes significant.

2.4.4 Nature of the Impact of Various Tele-Interventions

Depending upon the degree of penetration and take-up, ICT-enabled tele-interventions have the potential to affect established patterns in various spheres of life, especially those pertaining to the use of the transportation system. A proper analysis of this impact should start by distinguishing and understanding the operational frameworks of these interventions. From a travel perspective, a distinction among the impacts of various tele-interventions can be made on the basis of long and short distances. Travel impacts of teleworking, teleshopping and their various variants are more short distance and urban in their character while tele-conferencing and its variants are often needed to bridge the co-presence requirement over long distances. Another distinction can be made over the frequency of performing the activities replaced by these interventions. Interventions over short distance appear to be more frequent in nature while the longer distance interventions are likely to be needed on a less frequent basis. Further, tele-interventions other than teleworking and teleshopping have implications for travellers using both air and surface transport modes.

The long distance nature of teleconferencing and its variants excludes any discussion regarding their land use impact as residence location decisions by the majority are and perhaps would always be made on the basis of some short distance accessibility criteria defined in relation to performance of some daily activities irreplaceable by virtual access. A careful comparison of the respective impacts of these interventions reveals that teleworking has cross-dimensional impacts. In the context of this study, teleworking impacts upon households, firms, travel and land use. Any other tele-intervention may not be so 'rich' in its impacts. Teleshopping is also likely to have some land use impacts for the firms offering their product and services in the virtual market space. But there is no speculation yet about the corresponding impacts from the household perspective.

2.5 Teleshopping

Various observations in the previous section have highlighted the distinct dynamics of teleshopping and teleworking. It was, therefore, considered helpful to assess them separately from the other tele-interventions. Hence, this section explores teleshopping in more detail. Lyons (2002) quoting from DETR (2000a) for 1997-99 noted that in Britain 21% of all journeys were for shopping (the most journeys for any kind of activity), followed by commuting at 16%; and 58% and 70% of these are undertaken by car respectively in the UK's context. Quoting another source (Retail Logistics Task Force, 2001), he projects teleshopping grocery sales at £4.96 billion in 2005 increasing from £0.53 billion in 2000 with a corresponding increase in the number of deliveries attributable to teleshopping from 6.6 million in 2000 to 62.5 millions in 2005. Noting the differences between the natures of teleshopping and teleworking, he concludes that

> *the latter may not have the same size of potential market as the former (Lyons 2002).*

According to Cairns et al (2004) e-shopping from home currently accounts for less than 5% of the grocery market in the UK, but is estimated to reach 10%-15% over the next decade.

Books and electronic products top the list of things bought online while grocery is at or near the bottom of the list. This was the pattern of online or teleshopping in the US and all over the EU countries (UCLA 2003, Gertz 2002, Verdict 2002, Hesse 2002). In line with the purpose of this study, grocery shopping is of main interest due to its frequency and involvement of car-based trips. Put into perspective the entire volume of teleshopping including grocery is around 1% of the total retail sales in the US, 'the most developed online shopping market' and is not projected to cross the 5% mark in the near future (UCLA 2003, Hesse 2002, Keskinen et al 2001). The explanation for this may be found in non-realisation of another ICT-related myth, i.e., the death of the middleman.

Presently, constraints on teleshopping also seem stronger than the motivators compared to teleworking, e.g. concerns about payments and personal data security (Guan and Yang 2002, Hesse 2002). Another study showed that the life content of products, transaction security, price, vendor quality, IT education and internet usage significantly affect the initial willingness of Singaporeans to teleshop (Liao and Cheung, 2001). Lim (2003) has found technology, vendor, and product among the sources of risk that consumers perceive in business-to-consumer e-commerce.

Establishing a distribution system for teleshopping was until recently the bane of Amazon.com which achieved profitability for the first time in its business history in 2000 (Hesse 2002). Although one consolidated delivery by the retailer would be replacing many individual car trips for shopping, teleshopping is still expected to further strain the already lengthy business/transport supply chains with consequent implications for freight and urban delivery traffic. A possible solution to this has been suggested as setting up dedicated Delivery Collection Points. Compared to teleworking, teleshopping is a relatively less developed field of study with significantly less research effort. Field boundaries are more blurred with even more serious definition and data problems. All this line of argument does not in any sense mean to deny the existence of a travel substitution effect of teleshopping but to highlight the relatively more fluid state of knowledge that makes any analysis extremely difficult and any definitive conclusion regarding the scale of impact almost impossible.

However, there are some studies with very limited empirical evidence from small samples that support the existence of a substitution effect of teleshopping and very little reallocation effect on generation of further travel due to time saved by teleshopping (see e.g. Murti, 2003). There are very few references available on teleshopping, its operational mechanism, take up rates and size in literature as Mokhtarian (2000) points out that

> *our understanding of the impact of e-commerce and teleshopping on travel is limited.*

A more recent EU level study (Papola and Polydoropoulou 2006), as part of the POET project, concludes that the substitution of in-store shopping trips with e-shopping was found 'prominent' for different types of product categories (especially grocery products) and the highest percentage increases in e-shopping were observed for the purchase of electronic goods and computer software product categories respectively, while the smallest increase found corresponds to leisure products. However, the number of trips for other than shopping and work trip purposes (such as leisure trips) was not influenced by e-shopping. This also points to the general but inconclusive nature of the evidence.

This section has shown the state of the art and practice in teleshopping, groceries' share in it and growth potential of the phenomenon at the time of literature review. These observations coupled with what was observed at the end of the previous section give reasons to conclude that it would be difficult to implement teleshopping as an instrument of transport policy at this stage in its development. This leaves only teleworking for further investigation to achieve the study objectives.

2.6 The case of Teleworking

Teleworking can be considered an embodiment of the interaction of ICT and transport technology, collectively termed as spatial technologies by Couclelis (1994), and has been regarded as a 'social construct'[3] (Risman and Tomaskovic-Devey, 1985). Salomon (1998) sees teleworking as a 'complex solution'[4] and advocates a multidimensional approach to its study as such, rather than a purely technological one. It is not only the availability of technology that makes teleworking possible but the phenomenon has some inherent value that creates demand for it. This complexity can be attributed to teleworking affecting a variety of domains of life; namely: self image, work, relationships with family members and others, spatial behaviour, firms and their organisational behaviour and, above all, transportation. It

> *"has a very wide range of direct and indirect impacts, to which actors may assign different weights. The incidence of costs and benefits across actors is diverse, and to further complicate the matter, short and long term impacts may act in reverse directions or different intensities" (Salomon 1998).*

The notions expressed above convey an image of teleworking being anything but a simple arrangement. However, the approach to its study and investigation need not be equally sophisticated at the start. Therefore, the next section looks at the previous and contemporary efforts in the field and the section that follows investigates some of the empirical issues surrounding teleworking, in line with the applied nature of this research.

2.6.1 Overview of Previous Research on Teleworking

Summarising the previous research on teleworking, it is possible to group it by the nature of the studies, e.g. speculative and exploratory research (most of the early research by Nilles and Mokhtarian), behavioural modelling and methodology development (see e.g. Sullivan et al, (1993), Mokhtarian and Salomon (1994, 1996a, 1996b and 1997), Mannering and Mokhtarian (1995), Brewer and Hensher (2000), Shen (2000), Ellen and Hempsted (2002) and Nagurney et al, (2002)), empirical research using large samples (Drucker and Khattak, 2000, Popuri and Bhat, 2003) impact studies

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[3] *An idea which may appear to be natural and obvious to those who accept it, but in reality is an invention or artifact of a particular culture or society*

[4] *This is in contrast with 'a complex problem' that usually requires more than one intervention for solution.*

(Nilles, 1991, Koenig et al, 1996, Henderson et al, 1996, Hopkinson and James 2003), and literature reviews (Börjesson, 2003, Cairns et al, 2004 and Walls & Safirova, 2004).

The earliest studies by Nilles, Mokhtarian and others are understandably speculative and exploratory in nature in view of the unfolding nature of the phenomenon. The studies on behavioural modelling have made very significant contributions to the study of teleworking adoption and frequency, and development of methodology. Particularly influential in this regard have been studies by Mokhtarian and Salomon, and Mannering and Mokhtarian cited above. Impact studies and empirical research have obvious importance for the overall development and significance of a discipline of study. The three literature reviews of teleworking cited above have served the very useful purpose of collecting most of the literature and evidence in the field in one place.

The review by Börjesson (2003) from a Swedish perspective has particularly focused on empirical and behavioural modelling studies and gives an accurate account of most of the major efforts in the field. Walls & Safirova (2004) have given perhaps the most comprehensive of the treatments to the review effort. Their review from the US perspective covers all the aspects of teleworking except the debate on the definition of the term. However, they have just summarised the developments in the field in a chronological order under appropriate headings and did not offer any critique of the studies they reviewed. The review by Cairns et al (2004) from the UK perspective is primarily a comprehensive review of (mostly travel) impacts of teleworking and its characteristics. Besides, papers by Popuri and Bhat (2003) and also give a good succinct summary of important developments in the field.

The review by Cairns et al (2004) has been selected for detailed scrutiny due to the UK focus. In addition to the above observation, their review also provides a critique, sometimes to good effect, of the studies under their review, especially of US origin. On page 254 of their report, in section 10.2.1, they say

> *An influential school of thought in the US (Ben Akiva, Mokhtarian, Nilles) seem to have formed the view that while the direct effects of teleworking maybe to reduce travel, the wider effect of telework and other ICT use is to generate a sufficient number of new trips to eliminate the benefit (which is seen as marginal in any case) or even to increase traffic levels...*

While the overall conclusion here is right, they incorrectly attribute the 'thought' to Ben-Akiva and Nilles. Current research has not found any such assertion by these two authors. On the contrary, Nilles is a great proponent of using ICT as a substitute for travel. On the same page, Cairns et al also try to chart a different course for themselves diverging from the above influential thinking, mainly led by Mokhtarian, about complementarity between ICT and Transport and assert that

> *The problem is, however, that the evidence for the traffic-generation effects of teleworking is partly anecdotal, partly speculative modelling, but mostly repeated assertion by experts. We have not found any compelling evidence (or much evidence at*

> *all) in empirical studies for the speculated generative effects. This is not to say that there are no such effects, as common sense would indicate that there are likely to be. But they have not as yet been measured."*

The above assertion is refreshing and nearer the reality. However, their review of teleworking impacts on travel overlooks any particular definition of commuting or the time of the day variations about it. They do not make any distinction among the regular employee and other working persons. This has obvious implications for impact measurement. They re-work the data from SUSTEL (Sustainable Teleworking, an EU project, 2003) reports, DETR (2003), Geraghty (2004) and Fogarty (2004) for their conclusions. Quite often they rely on these two studies for their conclusions; one of these, Geraghty (2004), in turn relies on a National Opinion Polls (NOP) survey. Neither of these studies is in the public domain and there is insufficient information about their accessibility under the Other information about this survey in their review also raises questions.

For example the methodology used to conduct the NOP survey is not mentioned. It involved interviews with 1,600 Internet users in December 2003. NOP concluded that 24.9 million GB adults were Internet users, and 66% of these were in employment – i.e. approximately 16.4 million people. Here, distribution along industry sectors, an important parameter for estimation of teleworkers, is absent. Meanwhile, for those Internet users who are in employment but do not currently work from home (estimated to be 12 million employees), the NOP survey suggested that 77% do not want to telework. This is questionable in view of finding by Mokhtarian and Salomon (1996a) who found that for 57% of their sample, teleworking is a preferred alternative. Basing analysis on sources like these and drawing conclusions is risky. Other notable work on the topic in the UK is by Dodgson et al (2000) and a study by HOP Associates for DTLR (2002). These sources, discussed later, have hypothesised about the impacts of ICT and teleworking on travel and, in some cases on, freight transport.

More recently, Bonsall and Shires (2005) as part of an EU project have studied the employers' response to teleworking through an SP ranking experiment with a sample of 233 employers. Besides responses from other countries, 86 responses from UK employers were included in the study. They found that employers expect a modest increase in teleworking between 2004 -2010 ceteris paribus. Using stepwise regression analysis they estimated a model of teleworking prediction from the employer's perspective which suggests that increased availability of ICT

> *is likely to lead to reductions in commuting and business related travel, particularly in smaller organisations*

and these reductions are expected to be much more significant if travel conditions deteriorate markedly. They also report that issues of cost are much less influential than the speed and security of the communications. They also found that assumptions about future travel conditions were seen to have considerable influence on future level of teleworking.

Four studies deserve special mention for their significance. Yen et al (1994) and Bonsall and Shires (2005) have studied teleworking from employer's perspective which is perhaps a more relevant perspective to study the potential of telework as a TDM measure because it brings teleworking supply into focus. Studies by Bernardino and Ben-Akiva (1996), and Brewer and Hensher (2000) have added significance because they studied teleworking availability and adoption in an interactive context though following different methodologies. The former's value is in its comprehensive framework using data from a substantial sample while the latter's contribution is in terms of advancement of the methodology despite using data from a very small sample.

2.6.2 Use of Teleworking for Transport Policy Support

The discussion about whether ICT can substitute travel has been appearing in transport literature since the 1970s. According to Mokhtarian (1998) the oil crisis was the start of it all, which coincided with the start of the information era. Nilles et al. (1976) was one of the first studies in the field. Since then to the latest recommendations by Rahman et al, (2006) as part of work on EU's POET project, teleworking has invariably been referred to as a TDM measure directed particularly at congestion reduction.

Gillespie et al (1995) list legislation and state government initiatives from several of the United States that either encourage employers to set up teleworking schemes or require state agencies to set up teleworking schemes as means of reducing traffic congestion and improving the environment. Way back in 1988, Nilles noted that Los Angeles in the US specifically included teleworking as a congestion reduction option for prospective developers of large office buildings. Some of the other options proposed at that time, according to the same author, were related to mandatory parking fees for workers in the CBDs and preferential business telephone rates for teleworkers and/or their employers. The latest and specific legislation on the subject is National Telecommuting and Air Quality Act of 1999 in the US that introduces a market-based incentive program to encourage teleworking. The pollution credit program allows businesses with teleworkers to gain pollution credits that can be sold to other businesses. This topic has been explored further in Chapter 10.

Daniels et al (2001) in their model of organisational adoption of teleworking also propose and predict that transport legislation and policy aimed at reducing traffic volume will influence more rapid adoption of home-based and remote office teleworking. Recently and more specifically, Hopkinson and James (2003) in their inputs for policy recommendations proposed that

Telework reduces transport and can be more cost effective than alternative ways of managing transport demand.

2.6.3 Some Empirical Issues

The overall conclusion that can be drawn from section 2.6.1 is that there is a lack of definitive opinion about adoption levels of teleworking and its impacts on travel patterns and volumes, and any conclusion about the magnitude of the impacts, based on empirical studies, is even rarer. Researchers are understandably cautious in this regard. This wisdom is partly the result of non-realisation of expectations, especially about teleworking take-up rates during the early 1990s. These rates in many cases were simplistically assumed to be based on ICT diffusion rates. Some other possible reasons for unrealistic expectations have been provided by Salomon (1998). Besides, the wrong projections can also be attributed to certain empirical issues e.g. data collection methodologies and format.

The foregoing observation, however, does not apply to the problem of the definition of teleworking which is perhaps the most significant of empirical issues and lately has received added attention. There is a debate over the use of the term 'teleworking' right from the time when Nilles (1976) coined telecommuting as a parallel term. These debates still continue and an entire issue of New Technology, Work and Employment (special issue, Vol. 18:3, 2003) was devoted to them. This thesis recognises these on-going debates and has no intention to enter them. In this regard, the reader is referred to two excellent papers by Sullivan (2003) and Haddon and Brynin (2005).

The issue of definition is important because it entails measurement implications and has consequences for data availability/collection and data formats. The definitions to be found in the literature or other sources obstruct any meaningful analysis of impact of teleworking on travel. For example, this is evident from the definition used in the British Labour Force survey in the UK by Office of National Statistics (ONS, 2002) which defines 'Teleworkers' as paid or unpaid workers who use a phone and a personal computer, whether they work at home full-time or occasionally (at least one day in the reference week). A narrower group called TC teleworkers, for whom a telephone and a computer are essential for their work, is also defined in this survey. Some specific difficulties in this regard also relate to lack of consensus on the nature of job and technology used. Amount, purpose and location of work done are also major definitional problems.

In essence, the term teleworking is currently being used to denote any business or office activity that can be performed at a location other than at a 'traditional office space' regardless of the nature or ownership of the business and/or job description and it encompasses three broad categories of work practices: home-based work, remote-office-based work and mobile work (Daniels et al 2001). Corresponding confusion results in the data collected using different definitions which shows the data-gathering difficulties faced by the collecting sources/agencies. Daniels et al (2001) highlight the issue with an example, while quoting an EU source, that the numbers of teleworkers within EU in 1998 were between 1.1 million and 4 million where lower and upper bounds of the range indicated variations in the term's definition.

Another issue is of the unit of analysis. Some studies focus it from the employers' perspective while most investigate it from the employee's perspective. See for example Huws et al (1999) which for the UK did a study at the national level for the entire workforce and classified 5% of them as teleworkers. One methodological issue is that surveys on the incidence of teleworking have tended to be descriptive (Daniels et al 2001). Tregaskis (2000) has mentioned concerns about the rate of change in the discipline which has tended to be rapid and does not seem to trust teleworking statistics which are even two years old. This suggests that there is a case for current, authentic and relevant data.

The real issue, however, remains the definition. In this regard, this thesis agrees with Sullivan (2003) whose key conclusion is that

> *project-specific decisions about what to include when measuring various forms of remote working depend on the interests of the researchers and the questions they wish to address.*

In line with this, there is a need to define the term from a perspective that focuses on the transport and travel impact of teleworking and excludes all other non-travel-affecting definitions which should also specifically demarcate and guide the data requirements and collection. Hence, to move forward a purpose-specific definition of the term is needed that captures the essence of teleworking by noting a switch in travel behaviour of the teleworker.

2.6.4 Teleworking Defined

Teleworking is a theme that originated and developed within Business Management and Work Organisation disciplines where it is more widely studied for its socio-behavioural and control implications. Thus, the majority of the debate on the issue of definition has been conducted in the disciplines other than transport. Sullivan (2003) notes the problem in this regard that

> *as a result of the nature of telework itself (or ework), being a concept with very vague boundaries, it is extremely difficult to define and measure it.*

Therefore, while defining telework there is a need to make the

> *distinction between viewing telework as a characteristic of the worker as opposed to characteristics of the work. When we discuss the general concept of telework, are we talking about its organisational and perhaps technological parameters, or about the people who do the work? (Haddon and Brynin, 2005).*

This observation is potentially important. For the purpose of this study that takes a land use and transport perspective on urban congestion and other transport problems, teleworking may be defined from the perspective of a person whose travel or more appropriately commute behaviour is likely to change as a result of availability of teleworking option to her and her acceptance of it. Hence,

> *A person is a teleworker if a policy decision by her employer results in full or partial relocation of work, facilitated by ICT-use, to her home.*

This definition emphasises, inter alia, the 'work relocation'. It may, however, be noted that from the employee's perspective work relocation is a first order effect while her office or residence relocation as a result of this is a second order effect. From the employer's perspective work or office relocation or both are first order effects. A further phrase 'place-nearer-to-home' could have been added to this definition at the end to allude to the possibility of teleworking from a Telework Centre. But such a possibility is currently virtually non-existent in the UK.

2.6.5 Teleworking: Adoption Context

No doubt ICT's role in making telework possible in all its present variations is paramount. However, technology does not make things happen in a vacuum. Mokhtarian and Salomon (1994) have mentioned three factors which they consider are important in determining an employee's preference and choice for teleworking: Drives, Constraints and Facilitators. Among drives, they found the preference for telework strongly correlated with the variables of personal benefits, stress (general or work related), commute stress and amount of teleworking the job allows and negatively correlated with household distractions (Mokhtarian and Salomon 1997).

Constraints to teleworking can be both internal and external. Among factors relating to the constraints that have been repeatedly mentioned in studies of teleworking include: awareness, organisational/managerial support, job suitability, technology availability, cost, social/professional interaction, household interaction, unsuitability of home environment for telework, dependent care and insufficient space at home. The last four of these constraints are internal to an employee's home environment and the rest are present in her external environment. Both types of constraints may affect an employee's choice to telework. Mokhtarian and Salomon (1997) found external constraints less significant than the internal ones for teleworking preference. However, the external constraints are likely to play a more prominent role in *actual adoption* of the practice and the policy interventions directed at the greater encouragement of teleworking need to reduce those external constraints.

Facilitators are the presence of (various types of tangible or intangible) incentives (to be realised from teleworking practice) in a person's environment that aid in translating a drive into action. As shall be seen in the next sections, the results from studies on teleworking take up and experience in different geographic locations highlight the stability of these facilitators over a range of spatial and temporal variations. Policy makers' role in this regard is also important. As a recent empirical study from the US documents, regional or national legislation is also instrumental in persuading organisations to adopt teleworking arrangements (Atkyns et al 2002). US examples of this are 1990 Clean Air Act Amendments and 1999 National Telecommuting and Air Quality Act as mentioned in 2.6.2.

2.6.6 Principal Motivations for Teleworking

Three principal beneficiaries of teleworking are repeatedly mentioned. They are the transportation sector, the business sector and society at large (Belanger 1999). All these beneficiaries share congestion as a common concern and see benefits from teleworking as a possible remedy. The triggers of teleworking adoption are present on both cause and effect sides of the equation. Almost every author has noted congestion, its externalities and resulting commute stress on the cause-side. Travel reduction and resulting time saving can be counted on the effect-side. All the beneficiaries can benefit from these cause and effect side incentives of teleworking adoption to varying degrees. There exists a wide agreement that these incentives are the most common reasons for adoption.

However, sometimes cause and effect sides are so intertwined that they pose complexities for any effective analysis and are difficult to study simultaneously. It is clear that teleworking *effects* on transportation is a more relevant perspective to take as Salomon (1998) has asserted that growing congestion may increase the inclination to consider teleworking. But this author is of the view that teleworking adoption may be considered even in the absence of significant travel costs as perceptions about the costs and benefits of telework vary among individuals depending upon their socio-psychic orientations. Thus, savings in travel time and cost are not the only benefits to be realised from teleworking adoption.

In a study of potential strategies to cope with congestion, Mokhtarian et al (1997) evaluated different strategies' implementation costs and timescales and identified teleworking as a medium to long term solution. Mokhtarian and Salomon (1996b) have shown the importance of attitudinal factors over simple socio-demographic and economic variables in a behavioural model of telecommuting. However, there may be multiple drives for teleworking beyond congestion: family, leisure, work, ideology and travel related drives being the major ones (Christensen 1988, Dyck 1990, Duxbury et al 1992, Mokhtarian and Salomon 1994). Drives can also be expected to determine and shape after-adoption response, e.g. whether the practitioner would continue, drop out, increase or decrease the frequency of teleworking. Essentially underpinning these drives or motivations are the potential advantages and disadvantages of teleworking for the principal beneficiaries which is the topic of next section and section following that look at the available teleworking estimates.

2.6.7 Attitudes towards Teleworking

Attitudes to teleworking have also been studied in the transport literature and in non-transport fields like Management and Information Technology (IT) Sciences. Both employee and employer perspectives have been considered. The earliest study is by DeSanctis (1984) who studied attitudes of managers and programmers in the US and found that programmers were more likely to favour teleworking than managers. When asked an open-ended question about teleworking, she found that programmers were more likely to mention advantages, whereas managers would mention disadvantages. However, the two groups did identify many of the same advantages and disadvantages. Duxbury, Higgins, and Irving (1987), who studied teleworking attitudes of both managers and employees also in the US, found that employees were more attracted to teleworking programs than were the managers of this potential group. However, their findings were inconclusive regarding the desirability of such programmes.

Yap and Tng (1990) analysed attitudes of programmers and systems analysts in Singapore. They found that 73% of the respondents favoured teleworking. Those favouring teleworking cited care for children and families, flexible work schedules, and increased freedom as the major benefits. The concerns listed by the respondents included potential communication barriers, lack of social interaction and professional isolation. From a transport perspective, Mahmassani et al (1993) studied employees in the US who were not teleworkers for their attitude towards different teleworking options. Their results suggest that successful teleworking programmes are likely to require some job redesign and means of fair performance evaluation. They also concluded that employees seemed reluctant to trade income for the flexibility afforded by teleworking, majority would expect employers to pick up any additional associated costs and a teleworking programme would be more successful in most cases when telework is limited to several days a week.

From the same perspective, Yen et al (1994) studied employers' attitudes in the US. The sampled employers did not have any teleworking programme. They found that management issues such as employees' productivity, managers' ability to supervise teleworkers and data security remain barriers to employers' adoption of teleworking. They further suggested that managers' awareness of teleworking might reduce these barriers and there should be greater effort to inform managers on the issue. Khalifa and Etezadi (1997) studied managers and non-managers to determine if their beliefs about the potential impact of teleworking were different. They found that the two groups had similar expectations with regard to teleworking's impact on quality of life, society, career development, and company appeal. Non-managers expect teleworking to have a more positive effect on the environment than the managers. Managers, on the other hand, anticipate more negative results concerning management and control than do the non-managers.

Mokhtarian and Salomon (1997) studied similar attitudes through a range of attitudinal statements (25 in total). They found drives and constraints strongly correlated with generally perceived advantages and disadvantages of teleworking respectively. Teo et al (1998) studied attitudes of ICT personnel towards teleworking in Singapore and concluded that teleworking can be extremely useful: for companies which would gain from a more satisfied and productive workforce; for employees for whom it can reduce certain work-related problems and enhance their morale; and for the society at large.

Ellis and Webster (1999) studied the potential impact of organisational size and the existence of a formal teleworking programme on the perceptions of IT managers. They found that neither was a significant variable in explaining the perceived importance of the advantages and disadvantages of teleworking. This suggests that IT managers from organisations of all sizes view the advantages and disadvantages of teleworking similarly. However, possible neglect of career aspirations of teleworkers by management was viewed as more important by those IT managers in organisations without a formal teleworking programme than by those with a formal programme. This may imply that experience with a teleworking programme tends to assuage concerns associated with the possible neglect of management. Another study within management field, (Stephens and Szajna, 1998) reports that managers are also concerned that telework may require them to change their management style since they cannot rely on visual contact for monitoring and control. More recent data (Perez et al. 2002) from Spain on employers' attitudes show that the companies

> *with employee training programmes perceived lower barriers to telework adoption. The variance of telework barriers was better explained by technological factors than by human resources factors. Additionally, telework feasibility was found primarily in companies that had more percentage of tasks that could be teleworked and in companies that used more ICT.*

Peters et al (2004) in the Netherlands after an extensive review of teleworking literature suggest that compared to non-teleworkers, teleworkers more often had positive attitudes with regard to the benefits of teleworking. Moreover, attitudes may influence both preferences and practices, but the relationship is not straightforward. On the basis of a dataset of 849 employees, they concluded that employees who commuted more than one hour were 50% more likely to be given an opportunity to telecommute, they were nearly 70% more likely to prefer teleworking and they were 65% more likely to practise it.

Overall, the foregoing review suggests that though both employee and employer are convinced of the advantages of teleworking and the resulting impact on different aspects of life, they also have some differences in perceptions, especially regarding employee productivity and managerial control. A successful teleworking programme would require some degree of job redesign and should address career concerns of teleworkers. Creating awareness about teleworking among all the stakeholders is likely to allay most of their respective concerns, while care and creativity in designing teleworking programme is likely to contribute to its success. Longer commute distance increases the likelihood of teleworking being offered, preferred and practised.

2.7 Teleworking Advantages and Disadvantages

Empirical and other evidence on teleworking advantages and disadvantages is a relatively well-researched field. A look at the cost and benefits of teleworking would not only help develop a better understanding of the phenomenon but also provide some idea about its potential as a substitute for travel and conventional office location. There are three levels at which these advantages and disadvantages are perceived and experienced.

2.7.1 For Employees

At the employee level, perceived advantages of teleworking include commute stress avoidance, saving commute time and control over time management (Teo et al 1998); greater job satisfaction, increased personal productivity (Venkatesh and Speier 2000, Atkyns et al 2002), greater flexibility in balancing family and work lives (Atkyns et al 2002), money saved on commute trip, and extended job market. Belanger (1999) counts the money saved on office clothing also among the advantages for an employee. Some other positive dimensions of teleworking for an individual found in an empirical study were: showing that the company cares about people, helping the company keep and attract the best people, giving employees more personal time by reducing their commute time and making employees feel trusted (Atkyns et al 2002). Many employers advertise the possibility of teleworking as a benefit of employment in their effort to recruit professionals (Belanger 1999). However, the most important general impact of teleworking from an individual's perspective is the flexibility it affords in work and time management (Mokhtarian 1990).

On the other hand disadvantages mainly pertain to possible disturbances to family life and relationships due to overlap of home and work roles especially if one person in the household is a conventional worker (Salomon & Salomon 1984), potential loss of social interaction at work and isolation (Salomon & Salomon 1984, Teo et al 1998), potential costs of establishing office infrastructure at home in terms of space and office equipment and potential loss of career or promotion opportunities.

2.7.2 For Employers

It is the businesses that seem to hold the key to the entire telework-based trigger mechanism. Until they make the teleworking option available to their employees formally (as a matter of policy) or informally (as a matter of understanding between the employee and her manager), no amount of enthusiasm on employees' part can make any difference. A firm's perspective on teleworking is likely to be shaped by its business strategy which in turn is based on the dynamics of the market it is competing in, on its business cost concerns and/or the type of technology it uses to gain competitive advantage. Therefore, in the firms' case it is all the more important to look at potential advantages and disadvantages.

Advantages perceived by the firms included savings in overhead costs related to office space and other infrastructure and parking space (especially in prime commercial areas), increased employee productivity, easier staff recruitment and efficient use of IT resources. The average teleworker is 20% more productive than an office counterpart (Cross and Raizman 1986). Two thirds of teleworkers experience productivity gains; only 7% report a loss (Pratt 1984). One reason for productivity increases is better use of shared resources through teleworking. One two-year study showed a net productivity increase of 38% due to teleworking (Cross and Raizman 1986). They also claim a net saving of 50-67% in overhead costs per teleworker for an average metropolitan firm, based on reduced costs for office space that makes teleworking apparently very cost-effective. Kinsman (1987) reports cost savings in salaries by contracting out the jobs or tasks to teleworkers at 30% with the rest accruing from reduced overhead.

However, all the aforementioned studies are relatively old. The advances in ICT, their diffusion and consequently the telework practice have gone through a sea change during the intervening period. Therefore, the findings from these studies should only be taken as indicative of the potential benefits. The new perspective on ICT and telework clearly indicates a knowledge gap here and there is a need to systematically study the impact of teleworking adoption by the employers.

Other benefits to the employers include extended labour market, flexibility in managing division of labour and decreased employee absenteeism and turnover (Pratt 1984, Venkatesh and Speier 2000). Companies are also using telework to reduce cost by contracting out work (Burrows 2001). According to Nilles (2000), increased effectiveness, enhanced retention/attraction of employees, and cost reduction are the top three motivators. Hence, by offering telework employers can make jobs more attractive and attract better staff.

It is interesting to note in the literature that disadvantages to the employers have only been expressed in terms of opinions and speculations without any effort at properly documenting them. They include disruptions associated with the switch to teleworking, security concerns related to data and system access, additional cost of infrastructure provision at the telecentre or employee's home, loss of supervision and control of teleworkers (Teo et al 1998).

2.7.3 To Society

Advantages and disadvantages to the society are discussed in detail in section 2.9 on the impacts of teleworking as they are not as direct in their nature as they are for the individuals and the firms. However, some general benefits of teleworking to the society as whole may include less fuel needs (JALA 1983), reduced social cost of transportation, new opportunities for jobs through teleworking, more equitable distribution of these opportunities for home bound, mobility impaired and other relatively deprived sections of the society, and extended labour/skills market space for the society.

2.8 Estimates of the Number of Teleworkers

The figures presented in this section are just to give a general idea and should be read along with the caveat about definition. According to Nilles (2000), teleworkers were to exceed 10% of the US workforce, at about 21 million, by the end of 1999. His projection was that almost 29 million US teleworkers (22% of the US workforce) were expected to be regularly engaged in some form of telework by the end of 2003, and at least three of every five teleworkers will be employed by small and medium sized enterprises. The growth rate in adoption of teleworking in the US was reported as above 10% per annum, though it was expected to fall below this figure by 2003 (Nilles 2000).

The results of a survey commissioned by the EU Commission (ECaTT 2000) reported that 9 million residents of the EU did some telework in 1999, 6 million of whom spent at least one full day per week at home or at some telefacility. For the UK, 55 % of all the employers were practising some kind of telework, 7.6% of workforce were teleworkers in 1999 as compared to 5.4% in 1994 with an annual increase of about 8% during this period. Based on the result of these surveys, Greis and Kordey (2000) developed two extrapolation models. The models project their results based on two well-known assumptions in the discipline, i.e. knowledge workers are more suitable to adopt telework and diffusion of technological innovations in ICT would continue at the present pace. Their result showed that the teleworkers' share of the workforce in the UK may rise to 11.2% or 11.7% in year 2005 depending upon which model is used for prediction.

Going by the definition of ONS in section 2.6.3, data from the Labour Force Survey showed that 2.2 million people in the UK (7.4% of the labour force) worked from home at least one day a week using a telephone and computer by 2001. Since 1997 the number of teleworkers in the UK had increased by on average 13% a year, giving an overall increase between 1997 and 2001 of 65%. A later analysis by Ruiz and Walling (2005), also based on ONS data, reports almost the same growth rates for the next four year period from 2001 to 2005. Their figures are: a total increase of 60% and an average annual increase at 12.7% for this period. If growth rates of 12-13% p.a. continue for about 6 more years, this would result in approximately 30% of the UK workforce teleworking for at least some of the time by 2011 (Cairns et al, 2004). Bonsall and Shires (2005) found, from employers' perspective, that 9.1% of workforce was working from home in their sample on a typical day in 2004. However, this figure was not a formal count of home workers rather it was based on the best guess of senior managers who responded to the survey.

2.8.1 Demographic Socio-Economic Characteristics and Trends

The demographic and socio-economic (DSC) characteristics that affect the propensity to telework have also been researched in different studies. For example, Belanger (1999) found that gender and job type influenced the choice to telework for Virginia corporate managers, but that age, years of tenure with the current organisation, and years of personal computer ownership did not. Handy and Mokhtarian (1996) summarised the results of several California studies, indicating that higher household incomes, longer average commute distances, and supervisory occupation had significant positive influences on rates of working from home. Drucker and Khattak (2000) indicated that educational attainment and the presence of small children in the household encourage working from home but they could not differentiate between employees and self-employed individuals. Haddon and Brynin (2005) analysing the data collected from five EU countries including the UK show that there are gender, educational, occupational and pay differences between different categories of teleworkers. In other words, the categories are populated by different people with different personal or occupational characteristics.

In line with some previous studies, Walls et al (2006) analysing data from a 2002 survey of Southern California residents found that the propensity to telework increases with worker age and that educational attainment, and education, age, and race were found all statistically significant in explaining teleworking choice. They also concluded that the propensity to telework depends to a large extent on a worker's job characteristics. The industry and occupation categories also play a significant role in affecting propensity to telework. Particular industries appear to be more likely to have teleworkers, and certain types of jobs are more conducive to teleworking, in particular jobs in sales, education and training, and architecture and engineering. In contrast, some jobs – for example, those in health care – are less conducive to teleworking. Individuals who work at mid-size firms (those with 25–250 employees) are less likely to telework than individuals who work at very small (< 25 employees) or very large firms (> 250 employees). Walls et al did not find a statistically significant effect from gender – i.e. women are no more likely to telework than are men – or for the presence of children in the household.

An analysis of DSE characteristics of teleworkers in the UK from 2001 data, obtained from an internet source,[5] indicates that seven out of ten teleworkers (69%) are men, over a quarter of all teleworkers (27%) work in the business services sectors with another 25% in the public and voluntary sectors. Most teleworkers (68%) are in senior jobs, they are more likely to be graduates, married and in mid-career (in their thirties or forties). Similar data for two previous years is also available from the same source and the trends show that the adoption rate among women is increasing and the fastest-expanding teleworking occupation is management, with an annual increase of 25% in managers working from home. The growth has been especially strong in the financial services sector which has seen a yearly increase of 34% in teleworking and teleworking is increasing more rapidly amongst employees (at 22% p.a.) than the self-employed (at 15% for the same period).

2.8.2 Estimates of Teleworking Frequency

From a travel substitution perspective, the teleworking frequency is more significant. Evidence in the literature for a potential average figure is between 30-40% of a workweek (Yap and Tng 1990, Handy and Mokhtarian 1996, Mokhtarian 1998, Teo et al 1998). A US report (USDOT 1993) forecast an increase in frequency to 3-4 days per week in 2002. Owing to its significance, various studies have explored this aspect of teleworking in terms of DSEC variables that might influence it.

For example, Olszewski (1994) found that participants teleworked about 6 days per month on average and there was no significant impact of demographic variables on it. Mannering and Mokhtarian (1995) found that teleworking frequencies were associated

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[5] *http://dialspace.dial.pipex.com/town/parade/hg54/twstats00.htm Accessed on 31-07-03.*

with personal control over job-task scheduling. However, small sample size was an issue. Further, the frequency was represented as a binary variable (infrequent versus frequent), rather than as the number of teleworking days per time unit. Bagley and Mokhtarian (1997) modelled frequency preferences as a function of individual socio-economic and job-related variables as reported by the respondents. Drucker and Khattak (2000) found that males and drivers choose to work from home more often than females and non drivers, and that the lack of free parking at work promotes telework. At AT&T in the US, 27% of its teleworking population teleworked more than one day per week in 2000 (Atkyns et al 2002).

The main limitation of these studies is that they do not quantify teleworking frequency precisely. Instead, teleworkers are classified as being frequent or infrequent, similar to the studies cited above. Popuri and Bhat (2003) addressed this limitation by defining teleworking frequency as the "number of days of teleworking per week" and recognised that the teleworking adoption and the frequency of teleworking may be governed by quite different underlying behavioural processes. Their results indicate that individual demographics, work-related attributes and household demographics are significant determinants of teleworking adoption and frequency.

It is difficult to estimate exact teleworking frequency from the BT case study by Hopkinson and James (2003) in view of the wide range of types of teleworking to be found there. Cairns et al (2004) put the 'reasonable' estimate at an average of about three days a week. Lake et al (1997) (cited in Cairns et al 2004) suggested an upper limit of three days per week (or 60% of the time of a full-time worker) for local authority workers. The NOP results (Geraghty, 2004 also cited in Cairns et al 2004) suggested an average frequency of 3.1 days per week for the teleworkers in their study.

Walls and Safirova (2004) on the basis of their teleworking literature review report the significance of the various factors in increasing both the likelihood of teleworking and its frequency. They conclude that more research is needed with larger and more broadly based datasets across employers that include both individual employee characteristics and employer and job characteristics. This would, in their opinion, allow a better analysis of teleworking choice and frequency as well as more reliable estimates of VMT and emissions impacts. Walls et al (2006) conclude that explaining the frequency appears to be more difficult due to methodological issues in data collection and suggest that the industry and occupation categories that play a significant role in affecting propensity to telework do not have similar effects on the frequency.

2.9 Responses to Telework Adoption

The very basic response to the advent of teleworking is to adopt it or not. This section starts by assuming the availability of telework to firms and individuals, and thus is concerned only with those within the two populations who will adopt telework. Adoption both by the firms (making it available to their employees as a policy) and the individuals (who practise it) triggers some responses. This section explores those responses and captures them into a theoretical framework for assessment of their impacts on transport and land use systems.

2.9.1 Individual Level Responses

Responses at individual level are both numerous and diverse, and thus complex, as teleworking is not merely the penetration and adoption of technology into the household,

> *but a trigger for a wide set of impacts on employee-employer relationships and the individual's position vis-à-vis her social environment' (Salomon 1998).*

Some of these responses are a direct result (first order effects) of telework adoption while the others are indirect (second order effects) and related to the results of adoption process and practice. It appears that differences among various individual triggers stem from the differences between individuals' accessibility and mobility needs. ICT enabled accessibility substitutes for commuting while the desire to be mobile aided by the time and cost saved on commuting and increased availability of car to car owning households may result in increased non-work or non-urban or leisure travel or other unplanned trips.

Switching the commuting mode could be another possibility. However, Batty (1990) has suggested that teleworking may cause a future decline of public transportation. The reason may lie in longer distances travelled, more diffuse and less nodal journey patterns associated with new ways of working which are more difficult to accomplish by public transport (Gillespie and Richardson 2000).

It may be speculated that adoption by individuals would affect car ownership behaviour which is yet to be investigated. In the presence of DSE variables that favour car ownership, all the motivations for teleworking except the ideology are likely to work to retain or further induce car ownership. On the other hand, car ownership in multicar households may actually reduce as commuting to work is among the major reasons to own a car. Thus, there is a clear case for some empirical investigation as the knowledge gap is quite evident.

Allied to the car ownership response is the possibility of residence relocation as teleworking dilutes the importance of job accessibility as a determinant of residence location. Teleworkers may prefer bigger residences to have additional space for an office at home to offset some family and home related disadvantages of teleworking.

It can also be speculated that experienced teleworkers might move in and out of full- or part-time work intermittently or for longer periods of time as personal situations change. They may change jobs to suit their newly acquired teleworking skills simultaneously satisfying their residence location preferences. All these are speculations about the remote but possible responses to adoption by individuals and need empirical evidence. However, the remote responses may not be ripe for impact study at present.

Further complicating the above picture would be a range of behavioural/attitudinal and DSE factors. Thus, at micro level, the range of responses is only limited by the diversity of teleworking population and composition of segments and subgroups (e.g. households) to be found at different levels within it. Internal decision processes leading to these responses, as Mokhtarian and Salomon (1997) have also pointed out, will be initiated by some threshold level of dissatisfaction.

2.9.2 Firm Level Responses

Seemingly, firms' adoption of teleworking does not have any direct transport related triggers except perhaps in cases where transport is provided by the employer to its employees. This again is an avenue for cost cutting by firms. Most of the firms' responses would be triggered by profit/cost considerations. However, a firm may act to create a green/soft image of a socially responsible entity for itself by participating in teleworking programmes encouraged by municipal authorities and claim, as a PR exercise, a contribution towards better air quality and business environment due to reduction in congestion and its externalities. This appears to be the only but very significant transport related response to teleworking.

The more tangible benefits from teleworking for firms are in the domain of land use. Firms' main location responses to teleworking could be of two types: absolute reduction in demand for office space and displacement of office space demand due to potential full or partial relocation, especially by the firms located in CBD moving to relatively cost-effective, suburban or other similar area. Both types of responses by firms are of interest as they would trigger another indirect land use response effecting a corresponding decrease in parking space. Here the potential effect of the location response by firms due to the twin triggers of savings on floor space and related overheads, is likely to be stronger than household location response under a significant teleworking scenario.

A firm's location response may also be driven by the nature of its business. Generally, business operations of a firm are divided into core and non-core categories. The latter may be relocated to suburbs or other cost effective areas which might trigger urban decentralisation. However, there is a counter argument to it. Negative transport externalities have also been found to have an influence on firms' location or relocation decisions. If congestion is reduced considerably then as a result it will also reduce transport externalities, thus removing a trigger for relocation and effectively checking centrifugal forces and the tendency towards urban sprawl. This will not only promote sustainable land use patterns but also contribute to urban sustainability in the long run.

2.9.3 Development of a Theoretical Framework for the Study

At this stage it appears useful to distil the understanding developed so far in the previous sections of this chapter into some kind of a theoretical framework for telework adoption by the two main actors. The foregoing discussion of their responses also serves this purpose usefully. However, only the relatively significant responses have been considered in this framework. The purpose of this framework is to guide the further research work.

Figure 2.1 illustrates the relationships and interactions among the actors and the various markets which their adoption of teleworking might trigger. The figure only shows the first order effects and excludes environmental impacts which though potentially significant are considered second order effects of teleworking adoption.

The framework assumes the existence of enablers and prerequisites within ICT and economy (the upper most box) and a continuation/intensification of current trends therein. Besides the two main actors in the teleworking market, the figure also recognises the role for the market regulator/planner with specific policy responsibilities who acts to ensure the collective welfare and beneficial impacts on the transport and land use systems through the actions of the main actors (the middle part of the diagram). Besides the aspirations of the main actors, the changes in the job and property markets also inform the adoption response/process by them (on the either side of the diagram). The rest of the boxes for both main actors establish the causal links between the adoption and motivations/benefits, and resultant responses which impact upon the two systems and different markets.

2.10 Empirical Evidence of Transport and Land Use Impacts

Finally, evidence on teleworking impacts on travel and land use in the literature is reviewed to make an assessment of the potential of teleworking relative to the objective of this study. The discussion on evidence is set up in the context of the significance of teleworking and determinant of its impacts.

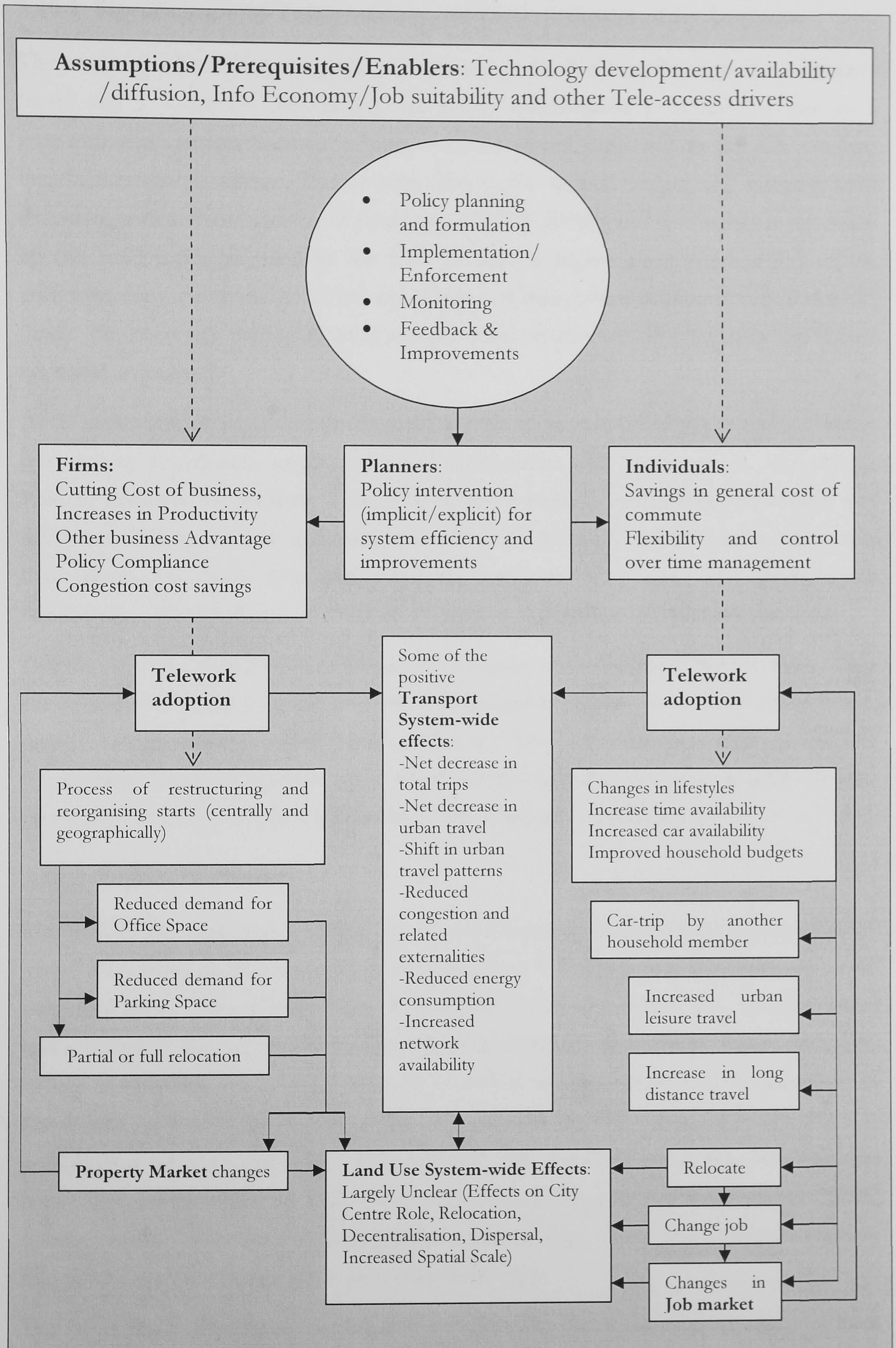

Figure 2.1: A theoretical framework for telework adoption by the individuals and the firms and its impacts on transport and land use systems

2.10.1 Significance of Teleworking and Determinants of its Impacts

The study of teleworking is significant because of its direct implications for commute travel and a focus on commuting for policy intervention is significant due to a commute trip's unique features of temporal and spatial regularity. In the UK context, two factors are significant. First, commuting is the second largest trip category after shopping with a share of 16% of total trips (DETR 2000b) and the largest if measured by the total miles travelled in the UK. Second, a higher proportion (70%) of the commute trips, compared to all the other types of trips, is undertaken by car in the UK (ibid). This indicates the significance and potential of teleworking for making an impact on travel reduction.

As determinants of impacts three factors are important: rate of adoption and/or size of teleworking population, degree of travel substitution and frequency of teleworking. Rate of adoption is primarily a function of job suitability, technology availability and diffusion. This means that information workers are more amenable to teleworking and their share has been estimated anywhere between 50% and 70% (Handy and Mokhtarian 1996, Mokhtarian 1998, and Cairns et al, 2004) in the modern economy.

Degree of travel substitution is important because of two considerations. First, there exist no standard teleworking practice and definition. Teleworkers do it from home, nearby centre or some other place. There are also instances of partial or full day teleworking. Second, commute travel characteristics and distances vary greatly. The last factor, i.e. frequency is a direct measure of the intensity of the impact.

2.10.2 Travel Impacts

The bulk of the empirical evidence about travel impacts of teleworking is from the US. The US evidence is not necessarily applicable to the UK. However, this evidence has an indicative value. Two studies from there deserve special mention due to their sound methodologies. In one study, the results of a comparison between teleworking and before-teleworking on a single day of a control sample show a 27% reduction in number of personal vehicle trips, and a 77% decrease in VMT (Koenig et al 1996). On a disaggregated level, the same study showed that for daily travel the 34.6 mile per person per day reduction in VMT on telecommuting days comprised a decrease of 29.3 miles commute miles and 5.3 non-commute miles though there was a daily increase of 0.5 trips in absolute numbers for non-commute trips.

The other study (Henderson et al 1996) put the increase in absolute numbers of non-commute trips at 0.3 trips per day while being consistent with regard to other results. However, the former of these two studies concluded that the non-work trip generation potential of telework is

> *not expected to negate the transportation and emissions benefits of teleworking.*

This is potentially a very significant conclusion on the net impact of teleworking. For a good review of the overall evidence from the US, the reader is referred to the study by Walls and Safirova (2004).

Of late, some evidence from the UK has also started to emerge. Earlier studies, however, were mostly econometric modelling estimates. For example, Giuliano and Gillespie (1997) report from a study (Brameur Limited 1994) for the DfT which estimated that "early adopters" of telework contributed a net saving equating to 1% of total car miles, but that with the widespread diffusion of teleworking amongst those who make longer commute journeys, the total savings could be in the order of 5-12% of total car use. Estimating future potential of teleworking Dodgson et al (2000) suggest that teleworking could lead to a reduction in car commuting traffic of 10% by 2005 and 15% by 2010. (This would be equivalent to a reduction in traffic for all trip purposes of about 2.5% in 2005 and 4% in 2010.) It is notable that they have revised their estimates slightly upwards from their original 1997 report, on the basis that teleworking is becoming easier due to technological development.

There are a few studies showing empirical evidence also. An earlier study (Mitchell and Trodd 1994, cited in Cairns et al, 2004) examined the travel behaviour of a small sample of existing UK teleworkers. It found an average reduction in travel of 113 miles per week (after allowing for remaining travel to work and additional non-work trips). Half the sample reported no extra non-work trips. The journeys of this sample were significantly longer than the average journey to work – 21 miles compared to the national average at the time of 8.3 miles. On the assumption that long distance commuters might be more likely to find telework attractive, the study estimated a saving in car use nationally of 5 – 12%.

Hopkinson et al (2001) on a sample of 103 AA call-centre staff (a firm in Insurance business) found that 3680 vehicle miles were saved per employee per year. This was offset by occasional employee visits to the office and home visits by managers, which came to about 30-40% of the miles saved. Of 29 employees who gave information about their non-work travel, most said that this had also fallen but nine said they now made longer or more frequent journeys.

Hopkinson and James (2003) studied ecological and social benefits of teleworking for the UK, as part of an EU project, on a convenient sample of existing teleworkers in two organisations: BAA and BT. The BAA dataset from 20 staff, all of whom reported their commuting had decreased since becoming a teleworker, showed mean reductions in travel at 61 miles per week. This was partially offset by additional non-work trips, giving a net weekly travel reduction of 45 miles per person. The BT dataset (199 responses) found that about 90% of respondents had reduced their commuting travel with mean commute mileage reduction per respondent at 253 miles per week, although there was no data on whether these journeys involved passengers or car sharing. Taking account of the offsetting trips, they suggest the net effect was to reduce travel by 193 miles per week per teleworker. Savings associated with rail travel were even greater.

Glogger et al. (2003), cited in Cairns et al (2004), examined the travel behaviour of teleworkers in eight large organisations in Greater Münich, using travel diaries before and after teleworking was introduced. Based on a sample 37 teleworkers and 29 members of their households, they found that people who began teleworking reduced their total number of trips (for all purposes, not just for work) by 19%. The number of trips made by other household members also fell. Taking the household as a whole, the total number of trips for all purposes fell by 14%.

2.10.3 Land Use Impacts

This is one of the under-researched areas in the discipline, therefore, significant evidence is lacking. All the available evidence is mentioned starting with studies from the US. Nilles (1991) analysed data from a two-year test of teleworking in California - the California Telecommuting Pilot Project - and compares the actual mobility patterns of teleworkers with those of a control group. He found no evidence that teleworkers move further from their offices in response to the opportunity to work at home, at least within a two-year period. Only 15 per cent of teleworkers from a total sample of about 200 moved during the two-year period and, of these, only half moved further from their central office. One study (Lund and Mokhtarian, 1994) exploring the residential choices of teleworkers in San Diego suggested that there is some impact of teleworking on residential choices. It found a small number reporting that the opportunity to telework was prompting them to consider moves that were two to three times farther away from their workplace.

A modelling study (Ellen and Hempstead, 2002) on the residential location of teleworkers specifically comparing geographical distribution of teleworkers with that of the workforce at large and with the universe of potential teleworkers showed that there is virtually no evidence in support of decentralisation towards rural areas though teleworkers appear slightly less likely (21.8%) to live in central cities than the workforce as a whole (23.8%). Shen (2000) developed an analytical framework for understanding changes in residential location flexibility that result from the direct travel substitution effect. He found that residential location options are increasing for people equipped with ICT but not for others, and that the geographical extent of the public transportation service is a stringent constrain on the location flexibility of some population groups. More recently Mokhtarian et al (2004) analysed retrospective data on telecommuting engagement and residential and job location changes over a ten-year period. Their results could not establish the direction of causality between teleworking and relocation.

The MWCOG (1999, cited in Cairns et al (2004)) study included 22 teleworkers who had recently moved or were planning to move. The direction of their move was equally likely to be closer to work or further away from work. Similarly, Jensen et al. (2003) found that amongst people who said teleworking influenced their choice of where to live (or would do so in future), the move was as likely to be closer to work as further away. For the SUSTEL study, Hopkinson and James (2003) also tried to estimate the associated impact on land use. For BAA, they estimated resultant savings on account of reduced space requirements to the tune of £400,000 per annum. While in BT's case they felt that teleworking had contributed space savings of £180 million per year, it was not possible for them to disaggregate telework savings and savings arising from other re-organisations. Their methodology to reach these figures is not clear and though these figures visibly look at the top of the range, however, they still provide a measure of the magnitude of land use impact of teleworking.

Teleworking and other tele-interventions are perhaps better understood not as developments which suppress the demand for mobility, but, rather, as forms which might best be described as 'hyper mobility' (Gillespie and Richardson 2000, p. 235). It is an indirect reference to expanding activity space under the influence of and choices made possible by the use of ICT, particularly by the option of teleworking.

2.11 Conclusions

The nature of ICT impacts on urban space and travel makes it a potentially significant avenue for search of solutions to urban transport problems. ICT have four types of relationships with transport: travel substitution, travel enhancement and generation, efficiency in resource use, and medium to long-term consequences for land use and transport. All of these except the 'efficiency in resource use' have implications for TDM. However, some aggregate modelling studies of these relationships suggest complementarity between ICT and transport without much hard evidence.

For TDM, various types of tele-interventions are possible. However, apart from teleworking their study has not been considered beneficial, especially from a policy perspective, due to a number of reasons including difficulties of study design.

The studies of teleworking were started during the 1980s in the US where the majority of the work has been done. However, the practice has also been attracting interest in Europe and the UK during the last decade and its potential as a TDM measure is being recognised. Evidence on teleworking take-up and impacts is encouraging from the US but may have localised tendency due to differences in the system characteristics.

Understandably, the nature of discourse about teleworking has changed significantly over the years. From the speculative and exploratory research of the late 1980s and early 1990s, the emphasis now is more on quantifying the teleworking impacts. Largely, the imprecise methodologies were the reason behind enthusiastic estimates of adoption during the early days and misleading projections of the magnitude of teleworking impacts. The problem still persists to some degree.

From an applied perspective, there are issues surrounding the investigation of teleworking. There is no clear definition of the term and its use mainly depends upon the user's perspective which poses measurement problems across disciplines. This has implications for data collection and impact determination. A practical definition of teleworking for use in this study has been formulated (see 2.6.4).

There have been constraints to teleworking which are becoming less active with the passage of time. Evidence regarding the characteristics of teleworkers is inconclusive. Different studies have found different DSEC variables as significant toward choice and adoption. Similarly there is no conclusive evidence on figures about teleworking frequency and the factors that might influence it.

The benefits of teleworking are influenced by the frequency of teleworking. The figures available in this regard from different sources varies greatly. Plausible estimates of adoption levels and frequency are important for impact assessment. Another significant finding from the review is that though the potential of teleworking as a TDM measure has been speculated upon, no known attempt has been made to systematically study, model and quantify its impact as a policy instrument. This is what differentiates this study from the similar efforts in the field.

The review of employee and employer attitudes towards teleworking suggests both are convinced of its advantages and resulting impact on different aspects of life. However, they do have some differences of perceptions, especially regarding issues of employee productivity and managerial control. A successful teleworking programme would require some degree of job redesign and should address career concerns of teleworkers. Creating awareness about teleworking among all the stakeholders is likely to allay most of their respective concerns. Care and creativity in designing teleworking programmes are also likely to contribute to their success. Longer commute distance increases the likelihood of teleworking being offered, preferred and practised.

Available evidence on teleworking take-up from both supply and demand perspectives points to fact that teleworking in the UK is growing steadily though the estimates from the supply side are more conservative. ONS figures suggest that teleworkers are growing at an annual rate of 13% in the UK. However, ONS' definition of teleworking raises questions. The review also shows that there are clear benefits for all the stakeholders in making teleworking a feasible alternative to conventional work arrangements. Exploring the responses to teleworking adoption by the individual and the firms and the review of evidence on impacts reveal that teleworking can have significant impacts both on travel demand and the land use.

The significant impacts of teleworking through travel substitution make it possible to address some of the limitations of the transport policy. However, there are gaps in our current understanding of the teleworking impacts, especially in the UK context. To expose these gaps and inform the study design, a theoretical framework has been developed which also captures the significant responses to telework adoption and interaction among the main actors and markets. The interplay of responses underlies the impacts on transport and land use systems.

System wide impacts, as Figure 2.1 illustrates, include reduction in congestion and a corresponding decrease in transport externalities, reduction in energy use, reduced demand for additional infrastructure through the release of existing network capacity, reduced social costs and decrease in demand for office space particularly in congestion-hit urban areas.

The framework in Figure 2.1 makes it possible to study and model the impact of teleworking adoption on travel and land use. The feasibility of doing so has some profound implications for the methodology that has been employed in the next chapters to capture, assess and translate these impacts into policy support. One immediate implication is the requirement of a combined (land use and transport), instead of a single, modelling framework for impact assessment and policy analysis. The use of a combined framework would entail assessment of individual modelling approaches and the implications of their use for this study. Subsequent to this, it would also require the adaptation of these approaches to accommodate telework adoption, responses to it and to model the impacts in a policy responsive manner. There may be a need to develop purpose specific models and modelling framework.

Other implications pertain to developing plausible estimates of the number of current teleworkers and of projections of its future take-up which in turn have implications for data collection strategy. Thus, the impacts of teleworking can be usefully harnessed to inform and buttress the policy analysis and support policy objectives. The methodology can have at least two aspects: how to investigate and isolate the impacts and how to analyse and model the impacts. The former again has implications for the data collection while the latter has consequences regarding the choice of analytical framework and modelling methodology. Overall these conclusions feed the belief that teleworking has significant potential relative to the objective of this research.

3 Modelling Teleworking

3.1 Introduction

The previous chapter identified substantial travel and land use impacts that can result from teleworking adoption and the different responses to that adoption. These responses were captured in Figure 2.1 which takes a holistic view of teleworking impacts and forms the theoretical foundation for this study. Another potentially very important response which Figure 2.1 did not mention explicitly but is implicit in teleworking practice is the changes in frequency of teleworking. Thus, the range of responses to telework availability includes the following:

- Adopting teleworking by employees and employers
- Commute trip reduction/suspension
- Changes in teleworking frequency
- Changes in non-work travel/time saving response
- Changes in residential location behaviour
- Changes in car ownership
- Changing the job location
- Changes in office space needs and office location preferences
- Changes in cost structure of firms' overheads
- Changes in demands for car parking space
- Hiring from a geographically extended skills market

This chapter looks at the possibility of modelling employee and employer uptake of teleworking and starts by making some general comments how this might be represented within a modelling framework in section two. Section three discusses the relevance of various modelling paradigms to teleworking. It also presents a brief discussion of the ways in which teleworking might be represented under each of these paradigms. Section four presents a slightly more detailed discussion of the alternative ways in which employee uptake of teleworking could be represented within a conventional travel demand model. Finally, the chapter ends with some conclusions.

3.2 Modelling Employee and Employer Uptake

Discussion in 2.9 noted teleworking adoption as a *stepping* response which was later depicted as such in Figure 2.1. This essentially means that teleworking may be modelled in two stages or separate processes: modelling of teleworking adoption by the employee and the employer; and modelling of responses to adoption by the respective actors. Modelling employees' uptake involves modelling the interplay of the job accessibility needs and the cost and benefits of teleworking. Ideally it will also require representation of second order responses, including the use of the car by the others and demand for and choice of household location affected by the range of the responses to telework adoption identified above. A decision to adopt teleworking by an employee would dilute the importance of job accessibility which may trigger a relocation response by their household. Thus, the key to modelling job accessibility of a teleworker would be to determine: what is the utility and choice of household location within a particular zone or area for them; the way it is modelled in land use models; and how it is influenced by the changes in accessibility measure in general and job related accessibility in particular in the event of relocation response or absence of it.

Modelling employers' uptake of teleworking is to address the supply side of the teleworking equation and involves modelling changes in their floor space demand and location preferences. This will have to be tackled exogenously or within a land use model because a firm's responses to telework adoption are independent of job accessibility constraints experienced by the households. There would also be an issue of modelling firms' accessibility to skill markets which can be incorporated within the labour market component of a land use model.

The more direct implications of modelling employers uptake would be when modelling their response to changing demands for location and office/floor space. Within a modelling framework, these are likely to be driven by the changes in production capacity status by the economy sector and the study area. Traditionally, production capacity has been a function of the number of employees working at a particular place. In the event of telework adoption, this may change and the demand for floor space might become independent of production capacity. This demand will result in changes for floor space demanded and consequently the change in the rents in the property market. The rest of the location process is similar to but simpler than that for households.

Another important consideration is the treatment of car parking spaces used by the firms. Car commuters are likely to be the great majority of potential teleworkers. In this way teleworking impact on demand for space would be even more pronounced and more parking spaces would be expected to be released than office space. The majority of land use models do not handle this aspect of land use explicitly. The implicit assumptions in this regard seem to correlate parking space availability positively to the demand for office space. To effectively analyse the results of a telework friendly policy, the land use for parking spaces would need to be modelled explicitly.

3.3 Representing Teleworking within Modelling Paradigms

This section discusses the relevance of various modelling paradigms. It also presents a brief discussion of the ways in which teleworking might be represented under each of these paradigms. The following modelling approaches are discussed:

- the conventional transport or four stage model;
- the activity analysis approach;
- a land use model, or a land use and transport interaction (LUTI) model;
- the constant travel budget approach; and
- models of organisational behaviour.

The discussion within each paradigm is set up with regard to the modelling principles from the relevant literature (listed below) that are potentially applicable to teleworking. To model telework, the relevant operational models of land use and/or transport should recognise:

- Firms/jobs based on economic sectors, households based on SEG and members of household as different age/gender groups;
- Travel within different trips/tour categories/purposes and time of the day;
- Different travel modes and car ownership categories;
- The principles of principal activity, travel time budget, time saving and income effects;
- The principle of trip/tour counting and suspension/reduction;
- A particular model's needs to iterate to equilibrium or otherwise; and
- Measures of accessibilities (generalised cost of travel) among all the zone-based possible combinations of OD pairs as model output.

3.3.1 The Four Stage Modelling Approach

Developed as a tool for the evaluation of transport investment, especially large infrastructure projects, classical four stage (FSM) has been in use for travel demand forecasting since the late 1950s in the US and the tradition came to the UK in early 1960s (Bates, 2000; McNally, 2000b). Initially 'introduced piecewise', the simple FSM evolved fairly quickly and started to develop into a more comprehensive and 'unifying framework compatible with economic theory' by 1970s. This development has been regarded as 'an ex post rationalisation of pre-existing practice' (Bates 2000). The main characteristics of the approach are: a zonal base; demand measured by trips or tours; and travel choices offered in a static structure that iterates to equilibrium.

Application of the FSM approach is near universal as it has been 'extensively used and extensively criticised' (McNally, 2000a). During the 1970s, general criticisms of aggregate methods of planning and forecasting contributed to its developments while during the 1980s its static nature and trip-based analysis came under critical focus and the approach was further improved. Finally, from the start of the 1990s, the FSM approach developed in response to environmental pollution and helped by US legislation on environment like CAAA (1990) and ISTEA (1991) and policy shifts towards travel demand management. FSM also served as a springboard to spin off new approaches which reveal the evolution of intellectual thought that contributed to its development over the years. In 1986, Atkins compiled all the major criticisms of the FSM approach in one document and

> *exposed the redundancy, inefficacy and wastefulness of mainstream methods in transport planning.*

Criticisms like this provided impetus to the development of dynamic and activity-based approaches in the 1980s and 1990s. The majority of the criticism was directed at the application of the concept rather than at the underlying principles (Bates, 2000). A fairer assessment would be to question the laziness of the practitioners who remained addicted to it despite its certain incapabilities in the face of their requirements. Thus, most of the criticism directed at FSM seems unjustified. FSM did the job it was designed to do with great success.

However, it may be argued that FSM is incapable of comprehensive analysis and of examining potentially complex behavioural responses to demand management policies due to its many simplifying assumptions and narrow "individual-trip" perspective. One can fairly subscribe to the criticism that FSM tries to predict without properly understanding the need or desire for travel. And this is a very fundamental criticism. Perhaps the greatest contribution of FSM is that it provided the critics with something to start with and, later on, to benchmark against it.

3.3.2 Representing Teleworking within the FSM Approach

The FSM approach has been criticised for its simplicity while the substitution of travel with the use of ICT depending upon the range of responses to be modelled is a complex phenomenon. Arguing for developing and incorporating choice dimensions within the FSM approach, Algers (2001) regards substitution of trips in the face of advances in ICT as an increasing possibility

> *but how to model it, and how to (if possible) include it in the mainstream approach is still a challenge.*

He regards the paucity of research as the main obstacle. An implication of using an FSM to represent teleworking is that the travel substitution patterns as a result of changes in teleworking frequency relative to all the existing travel modes might not be incorporated in an adequately rich way. Further, there are different user classes with different sensitivities to changes in the transportation system. Introducing an option for travel substitution, i.e. teleworking, would bring changes in the dynamics of the system. It has been demonstrated in 2.8.1 and 2.8.2 that prevalence of teleworking varies among different SEGs. An FSM based approach with its simplified assumptions and aggregate modelling may not be able to capture all the effects of the substitution. This could potentially lead to inappropriate evaluations of TDM policies to be tested.

A critical issue in this thesis is the study of short-term versus long-term impacts of teleworking. So, if the purpose of policy impact analysis is short term congestion management, then the use of the FSM approach may not reveal all the changes in travel behaviour in response to such a policy due to its focus on trip counting. Take, e.g. the case of travel potentially displaced by the adoption (and its other associated consequences) to other times of the day due to a change in activity patterns. This displacement impact on time intervals cannot be examined by a conventional FSM unless it has a time of day module attached to it.

It is also significant to note here that traditionally travel demand within the model run has been treated as fixed and essentially independent of the transportation system (McNally 2000b) in a standard FSM due to the static nature of the modelling logic, though there are many FSM that accept changes in overall demand. Modelling changes in teleworking frequency within the model run can potentially address this limitation. The changes in frequency would affect the size of the total travel demand which in turn would change the generalised cost of travel in the network. This effect may be quite difficult to model and would pose even greater difficulties for an FSM that needs to achieve equilibrium. However, if done successfully, modelling teleworking frequency within a standard FSM this way has the potential of addressing the criticism that the potential contribution of generalised cost of travel at the trip generation stage was ignored (Bates 2000).

3.3.3 The Activity Based Approach

The activity-based approach (ABA) emerged in the late 1970s and early 1980s in response to the limited behavioural theory underpinning the conventional aggregate four-stage models. In ABA, the observation of the trip is replaced by a detailed consideration of the activity which leads to the trip. ABA rests on very strong basic tenets: travel being a derived demand (though this is being questioned now (see e.g. Mokhtarian and Salomon (2001) and ICT pervasiveness in the society is expected to further strain the validity of this tenet in future) and spatio-temporal constraints faced by humans (a theory put forward by Hägerstrand (1970)). The main characteristics of ABA are: focus on trip chaining; activity sequences; timing and duration of activities; and interaction among individuals (de Palma and Fontan 2001). ABA holds promise to further the science and art of transportation analysis and forecasting.

Fundamental contributions to the intellectual roots of activity analysis were made by Hägerstrand (1970) and Chapin (1974). A seminal work in this regard was done by Transport Studies Unit at Oxford (Jones et al, 1983). This work defined and empirically tested the approach. CARLA by Jones et al (1983) and STARCHILD by McNally and Recker (1986) and Recker et al (1986) are among the earliest practical applications of the concept. Functionally, ABA employs a micro simulation technique to move activity-travel models into operational practice which according to Miller (2003) provides a means of forecasting the impacts of a given policy at the disaggregate level, so that detailed analysis of model results can be performed in ways that are generally infeasible with the conventional FSM.

A general criticism of ABA is that it lacks a solid theoretical basis (see e.g. Haraldsson 2003 and references quoted therein). However, McNally (2000b) does not agree with this view and attributes it to a lack of understanding of the incredible complexity of the phenomenon of treating the 'whole' of travel that precludes the application of a cohesive theory. ABA's data requirements are exceptionally demanding and it fails to follow the implications of predicted travel demand through to supply conditions within the transportation network. In it nature and duration of the activity are the major interest whereas travel between activities is only a minor detail (McNally 2000a, DSC 2001). One exponent of ABA notes that the core of the approach is ambitious and that it cannot be fully realised.

> *The number of endogenous variables, the long timeframes of analysis and the social context are just too complex for today's analytic modelling tools; even the descriptive work does not fully live up to the demands, but for a large part because of the lack of suitable data sets (Axhausen 2001).*

The 1990s, especially the latter half, has witnessed a real thrust towards the strengthening of the theoretical basis of ABA and broadening of its methodological applications. More recent emphasis in ABA seems more towards designing more effective data collection systems. Computerised Household Activity Scheduling Elicitor (CHASE) by Litwin et al (2004) and Comprehensive Econometric Micro-simulator for Daily Activity-travel Patterns (CEMDAP) by Bhat et al (2004) are example of these.

More recently there has been a quite healthy activity towards the development of operational tools based on the ABA. Vovsha and Bradley (2004) have estimated and applied an advance time-of-day choice model based on the ABA for a US Regional Planning Commission. In a wider context, Salvini and Miller (2005) have developed ILUTE, an operational prototype of a comprehensive microsimulation model of urban systems based on the ABA which simulates the evolution of an integrated urban system over an extended period of time and is capable of analysing a broad range of transportation, housing and other urban policies. Bradley et al (2007) present some more evidence and experience from the application of a number of activity based models from the US. In this regard, the successful examples of activity-based model applications include various environmental impact studies, road-pricing projects and policies, large-scale rail transit projects. Davidson et al (2007) present a synthesis of the research in this regard so far. In their opinion, the new generation of ABA travel demand models are characterized by three features:

> *(1) an activity-based platform, that implies that modelled travel be derived within a general framework of the daily activities undertaken by households and persons, (2) a tour-based structure of travel where the tour is used as the basic unit of modelling travel instead of the elemental trip, and (3) micro-simulation modelling techniques that are applied at the fully-disaggregate level of persons and households, which convert activity and travel related choices from fractional-probability model outcomes into a series of discrete or "crisp" decisions.*

However, there are room for improvement and challenges before the activity based models can fully replace conventional models. In this regard a significant work is by Vovsha et al (2005). In their opinion, the most promising directions for principal improvement of road pricing models, a theme relevant to this research, are associated with advanced network simulation tools (dynamic traffic assignment and micro-simulation) and advanced activity-based, tour-based demand models. Major breakthroughs in these direction has the potential of providing for the incorporation of heterogeneity of road users with respect to various modelling features. Another significant challenge is to apply microsimulation-based models within the pre-existing framework of demand/supply equilibration (i.e. traffic assignment) and model calibration and validation methods (Bradley et al 2007).

3.3.4 Representing Teleworking within the ABA

From a wider perspective, investigation of the substitution of out-of-home activities by in-home activities afforded by ICT-enabled teleaccessibility is fundamental to the understanding and modelling of travel employing ABA. Teleworking adoption in the modelling sense is the antithesis of conventional work because it changes the employment from an out-of-home activity into an in-home activity. This has far-reaching implications for how the travel behaviour and demand are analysed following ABA. It has been recognised that in-home and out-of-home activities have quite different implications for travel, and participation in these activities has an impact on the generation of trips. Another aspect of the adoption is the change in the temporal aspects of activity. The removal of temporal constraints on job related activities will change them from fixed to flexible activity.

Further, the status of employment activity as a pivotal activity for an employed person, around which almost all the other activities are scheduled, introduces a extra element of complication to these implications. The resulting implications for decision logics in the modelling of activity participation, scheduling and re-scheduling as a consequence of telework adoption by a household member seem quite profound. In ABA, three major factors – 24 hour limited time-budget, personal characteristics, and household characteristics and interaction between household members – can be assumed to have influence on activity participation and travel behaviour for individuals. In this context, introducing the concept of multitasking to the study of the impacts of ICT, Kenyon and Lyons (2007) contend that

> *participation in activities and, thus, change in activity participation will not be fully measured without consideration of multitasking.*

In the above context, there are two obvious limitations of ABA. First, it does not take the time-space interaction fully into account despite recognising it as one of the key concepts. Second, despite the importance of substitution of activities requiring travel by the use of ICT and opportunities for substitution continuously increasing, this area of research in AB analysis is still weak and one of the impediments to a detailed analysis is extensive data requirements (Bhat and Koppelman 1999). Despite these weaknesses, they are of the opinion that relative to traditional methods (assume FSM), the ABA due to its behavioural strength offers advantage in the evaluation of the travel impacts of teleworking.

It is likely that trip generation within a model following ABA should be based on analysis of time used for activities requiring travel and, in the case of telework, time saved from giving up commuting; and a model system based on time-use data can be used to estimate the number of induced trips that would result from such travel time savings. This has obvious implications for the data collection and model calibration provided a modelling tool based on the ABA is available.

The data collection would need to be undertaken ideally within the overall perspective of a time use analysis of all the activities – not just teleworking – performed with the help of ICT access and usage, and implications of those activities for travel and consequently for travel time budgets. Here the concept of multitasking referred to above has added implications. And in any study of ICT or teleworking impacts, to follow this time use paradigm would need a link between activity analysis and trip inducement which is either weak or completely missing (Kitamura et al 1997) within ABA's modelling framework. Despite these limitations, an AB operational tool, subject to availability, could still be adapted to model the impact of teleworking on travel demand with certain qualifications.

3.3.5 The LUTI Approach

The pitfalls of large-scale urban models were convincingly articulated almost three decades ago (Lee, 1973), and some of them remain significant concerns even today. The efforts of the International Study Group on Land Use Transport Interaction (ISGLUTI), set up in 1981, played a significant role in development of this approach. At the base of the LUTI framework are economic linkages of goods, services or labour which connect the location of activities which in turn produce demand for transport.

This demand is then assigned to modes and routes on the transport network taking account of congestion and changes in accessibility that in turn affect location of activities. This framework has been used to develop a wide range of models for different applications (Hunt and Simmonds 1993). The models representing this approach are distinct through their emphasis on spatial representation of producers, residents and transport supply activities and links between different markets. The principal markets within this framework are: property markets; labour markets; producer markets; financial markets; and transport markets. Models are based on a partial economic perspective of the inputs and outputs and operations of markets between various actors. These actors include residents and producers, developers and transport suppliers and also the interventionist role of government.

LUTI models calculate the impact of land use on transport demand using measures of generalised costs or disutility to produce a matrix of interactions in activity or economic units. These are converted into matrices of travel demand. With this given travel demand, travel choices are therefore mode, route and time of travel. Another approach is to use vectors of accessibility to output vectors of future land use in an area. This can then be used to generate travel or modify existing matrices of travel demand.

The majority of LUTI models deal with the relocation of economic activities with fixed values for each point in time, or vary these only by marginal location change. Also, they have tended to focus on the behaviour of individual actors, such as residents, transport suppliers and government at the expense of analysis of the operations and features of the product and labour markets that they represent (McQuaid et al 2004).

Choice theory is central to the development of LUTI models. However, only a small proportion of choices are modelled explicitly in many models. This is especially true of urban components of the models, where production is not modelled as a function of producer choice but as a result of interaction between the decisions of customers and developers. Hunt and Simmonds (1993) have identified integration of planning within a single and theoretically consistent framework, combination of simulation models based on market concepts and a highly synthetic nature which makes lower demands on data as major strengths of the approach.

Woudsma and Jensen (2003) identify a number of gaps in empirical research on the transportation/land use relationship like the lack of understanding of the causal links between urban form and travel behaviour; the lack of a common view about how to model land use response to transportation change; and the under-representation of the movement of goods as a factor influencing the relationship. Given the variety of factors influencing the role of transport, there is also a need for greater use of multidisciplinary, micro-focused studies looking at specific issues (Simmonds, 1999), an improvement of the associated research tools and improved modelling in terms of challenging basic assumptions and utilising different methodological approaches (McQuaid et al 2004).

3.3.6 Representing Teleworking within the LUTI Approach

The distinctive feature of this approach is its combined framework which integrates the 'activity systems' with the 'transportation networks'. Modelling telework is concerned with the former which is represented by the land use component of the framework. By modelling teleworking within a land use model broadly two processes would be affected. They are location of productive facilities (activities) and location of workers (residences). All land use models model these processes. More specifically, there are three main implications of modelling teleworking within a land use model:

- Scale implications (whether the model employed is aggregate or disaggregate)
- Process implications (how many processes are affected and to what extent)
- Agent implications (how many categories of each of the two main agents can be modelled and what factors are considered when they make their choices)

In other words, modelling would affect the utility and choice of location by teleworkers, location of telework friendly jobs within the industry sectors and the resulting demand for location by the firms. In most models, economy sectors are very broadly defined and representation of the firms is also absent within the majority of the models. This leaves an important level of analysis/modelling out of the scope of study. Usually, only three types of industrial/business activity are represented, namely office, retail and manufacturing, which are insufficient for modelling of telework.

Data requirements and calibration demands are two other important considerations that have considerable implications when it comes to practical use of any model. Within a LUTI framework, this means calibration of the land use model with study area inputs as it provides the travel demand to the transport component. At what level of details this input is provided also has important implications for impact analysis.

Under a scenario of unrestricted supply, for eligible employees teleworking is seemingly very attractive due to its various benefits. During the modelling exercise this would need to be controlled by imposing some saturation levels on adoption by the economy sector and by SEG of households. Depending upon the design and construction logics of the model to be used, this would require more care and complexity in behavioural response of the model. A more extensive description of how to introduce teleworking into LUTI models has been presented in Rana et al (2005).

3.3.7 The Constant Travel Budget (CTB) Approach

This approach was also borne out of the similar criticism and dissatisfaction with FSM models which helped develop the ABA and the LUTI approaches, and was proposed in

Zahavi's working paper for the world bank (Zahavi, 1976). The specific reasons given for its genesis by its proponent were: failure of FSM to allow for consequences of change; no explicit relationship with land-use; absence of causality; excessive complexity and cost; and difficulty of checking results (Roth and Zahavi, 1981). This approach is based on the "budgets" under which travel choices are made. The budgets allocated to travel include the daily mean expenditures on travel, per traveller and per household, in terms of time and money, and are a function of factors like the socioeconomic characteristics of the household, transport system supply and urban structure.

Early contributions towards the development of the concept of travel budgets were made by Tanner (1961), Halder (1970) and Kirby (1974) who explored its theoretical dimensions and suggested ways to improve conventional travel demand models by employing travel time budgets. Wigan and Moris (1981) soon criticised the simplicity of the approach in these words

> *The broad stability of time allocation to transport purposes has been picked up and used (for example, by Zahavi (1976)) as a basis for transport analysis without a great deal of attention being paid to the competing activities, or indeed the appropriate groups with homogeneous characteristics for these purposes.*

The absence of rigor is also evident from loosely defined 'traveller' and her travel which is all embracing in terms of travel mode and time used

> *a person who made at least one motorized trip during the day, although the daily travel times also include walking times as well as the access and egress times (door-to-door times) (Roth and Zahavi, 1981).*

Owing perhaps to these reasons, the approach did not gain much popularity within the transport modelling community. Major reviews of transport modelling approaches hardly mention it among the main approaches, e.g. DSC (2001) which reviewed and made an inventory of all the modelling approaches and techniques did not include it in its study. However, the concept of travel time budgets has stood the test of time. Whether these budgets are still constant, especially in the face of teleaccessibility, is being questioned and researchers are increasingly critical and sceptic about this claim, see for example an excellent paper by Mokhtarian and Chen (2004) and the references contained therein.

3.3.8 Representing Teleworking within the CTB Approach

The fundamental thesis about this modelling approach when it was proposed was built around the concept of the stability of travel times over time and geographic regions which in other words means that these travel budgets are constant regardless of changes in other factors. Following this thesis, forecasting travel demand should be linked directly to the projected changes in DSE variables of the population of interest. Commute or travel characteristics of an individual or household have no role to play.

Perhaps that is the reason this concept is more used in simpler predictive tools like sketch planning models, e.g. MARS (Shepherd et al, 2007).

Based on this approach, Golob et al (1981) proposed a utility model with four fundamental properties which are: travel can never decrease as income increases; travel can never decrease as available time increases; travel decreases with increasing costs; and finally, travel increases with increasing speed. Clearly, the impacts of teleworking on travel demand cannot be fully predicted with the use of a model based on these properties as teleworking adds to both income and time. Teleworking is about commute substitution. In the face of a constant travel budget, it would mean only displacement of travel which is clearly in conflict with the range of evidence reviewed in 2.10.2 on the travel impacts of teleworking.

3.3.9 Models of Organisational Behaviour

The possibility of modelling teleworking adoption by firms through organisational behaviour models was also explored. This strand of research was considered relevant because the research withing Management and Human Resource disciplines looks at teleworking adoption within an organisational context and draws on a synthesis of a raft of theories to explain the phenomenon. For example, Clark (1998) presented a synthesized model for the decision to telework which drew on economic theory, institutional theory, and the theory of planned behaviour. Employing neo-institutional theory, Daniels et al (2001) developed an explanatory framework of organizational adoption of teleworking and use it to develop a model and a series of propositions concerning the adoption of different forms of teleworking.

Parez et al (2003) analysed the teleworking adoption issue from an organisational theory perspective and tested the hypotheses developed from the agency, institutional and resource-based view theories with empirical data from industrial and service companies. However, three limiting factors restricted work in this direction. It was found that: these models deal with management and organisational behaviour issues of emloyers; no mention of such models has been made within the literature on the main modelling paradigms discussed in the previous sections; and while such models might explain employer policy it is difficult to see how travel implications would be addressed.

3.3.10 Summary Assessment of the Approaches

The discussions in the previous subsections reveal that the FSM approach has been severely criticised for predicting travel demand without properly understanding travel behaviour. However, its deceptive simplicity and ease of use have contributed to its great success over the years. It also served as a benchmark for the other approaches. On the other hand, although ABA has analytic strengths and its underlying tenets are also strong and may have been a preferred choice for this study but the availability of software of a fully operational model acts as limiting factor. The models that follow the LUTI approach are more fully developed. However, there remain gaps among the causal links between land use and transport fields. The CTB approach which was also proposed as an alternative to the FSM has not gained much acceptance. Besides, the discussion found it too simplistic and inherently flawed to model the travel foregone/saved while teleworking, thus unsuitable for this study. Thus, only the FSM and the LUTI can be considered for practical use in this study.

3.4 Possible Ways to Model Telework

This section looks into a range of possibilities to model employer and the employee uptake of teleworking within the two shortlisted approaches and later on it presents a slightly more detailed discussion of the alternative ways in which employee uptake could be represented within a conventional travel demand model. Depending upon the scope of the activity, the modelling objective can be realised in a number of ways. Discussion of the responses to teleworking in 2.9 and 3.2 showed that teleworking may be modelled in *two stages or separate processes*: modelling of teleworking adoption by the respective actors and modelling of responses to adoption. Adoption modelling could possibly be attempted through the following options:

- Modelling telework adoption by the household within a transport model;
- Developing a stand alone model of telework adoption both by the firms and the households and linking it either to an FSM or LUTI framework;
- Modelling telework adoption both by the firms and the households within a land use model; and
- Modelling the data on teleworking take up as an exogenous input either to an FSM or to a land use model.

Note that modelling of telework adoption by the firms is not possible within the transport model due to its design and scope limitations. In essence, the last option in the above list is not telework modelling which this study is attempting as one of its objectives. Doing so would also impose a straightjacket upon the framework being used and severely limit the model response. Therefore, this option was ignored.

For modelling the full range of the responses to teleworking adoption identified in 3.1, Table 3-1 shows the range of possibilities. Note that the table excludes the first response in the list given in 3.1 because it has been addressed as a separate process above. The table points to the fact that non-work travel response will always be modelled within the transport model. Similarly, location response will always be modelled within the land use model. It is helpful to note that the possibilities in Table 3-1 have been considered purely from a theoretical perspective. In reality it may be a bit too optimistic to expect a particular model to accommodate the entire range of responses listed for that model. For example, it would take time to develop land use models which would be capable of modelling changes in car ownership or changes in an extended skills market.

	Modelling Options		
Response to be Modelled	Land Use Model	Transport Model	Standalone model of Telework Adoption
Hiring from a geographically extended skills market	Yes	No	Yes
Changes in office space needs and location preferences	Yes	No	No
Changes in demands for car parking space	Yes	No	No
Changes in cost structure of firms' overheads	Yes	No	No
Commute trip reduction/suspension	Yes	Yes	Yes
Changes in teleworking frequency	No	Yes	Yes
Changes in non-work travel/time saving response	No	Yes	No
Changes in location behaviour	Yes	No	No
Changes in car ownership	Yes	No	No
Changing the job location	Yes	No	No

Table 3-1: Possibilities for modelling responses to telework adoption

3.4.1 Modelling Teleworking within a Conventional Transport Model

The possibilities discussed in the regard include:

- treating teleworking as a different type of trip at the trip generation stage;
- treating teleworking as equivalent to an alternative mode; and
- using a separate model of teleworking to produce factors which are then applied to a trip matrix.

The first two suggestions would bring changes in the model's internal design and enhance its response while the third suggestion would provide the specific input needed to model the travel impact. The remaining subsections present more details about how possibly each of these suggestions may be implemented in a conventional travel demand model. The option of dealing with telework data as an exogenous input, as mentioned above, can be followed at all the stages except the assignment stage. The later this stage is in an FSM the more complicated and tiresome it would be to handle. This is excluded as an option from further discussion.

3.4.2 Modelling at Trip Generation/Attraction Stage

For modelling adoption at the trip generation stage, the starting point is the recognition of SEG based household and employment sector-based job categories within all the traffic zones in the study area. Understandably the first step is to ensure that teleworking friendly SEG and job zones are identified as an output at this stage and linked into origin-destination (OD) pairs. To model adoption, a telework adoption routine (programmed on theoretical logic about telework adoption and having provision for appropriate growth factors) can be introduced to this output that would separate the total demand into the *commuter and teleworker categories of households passed on to the distribution matrix*. An illustration of this approach has been shown in Figure 3.1. These categories would be continuously adjusted with each iteration within the model run until the model is in equilibrium with predefined (GC or some other) criteria. (The shares for the respective categories in the figure are illustrative only.)

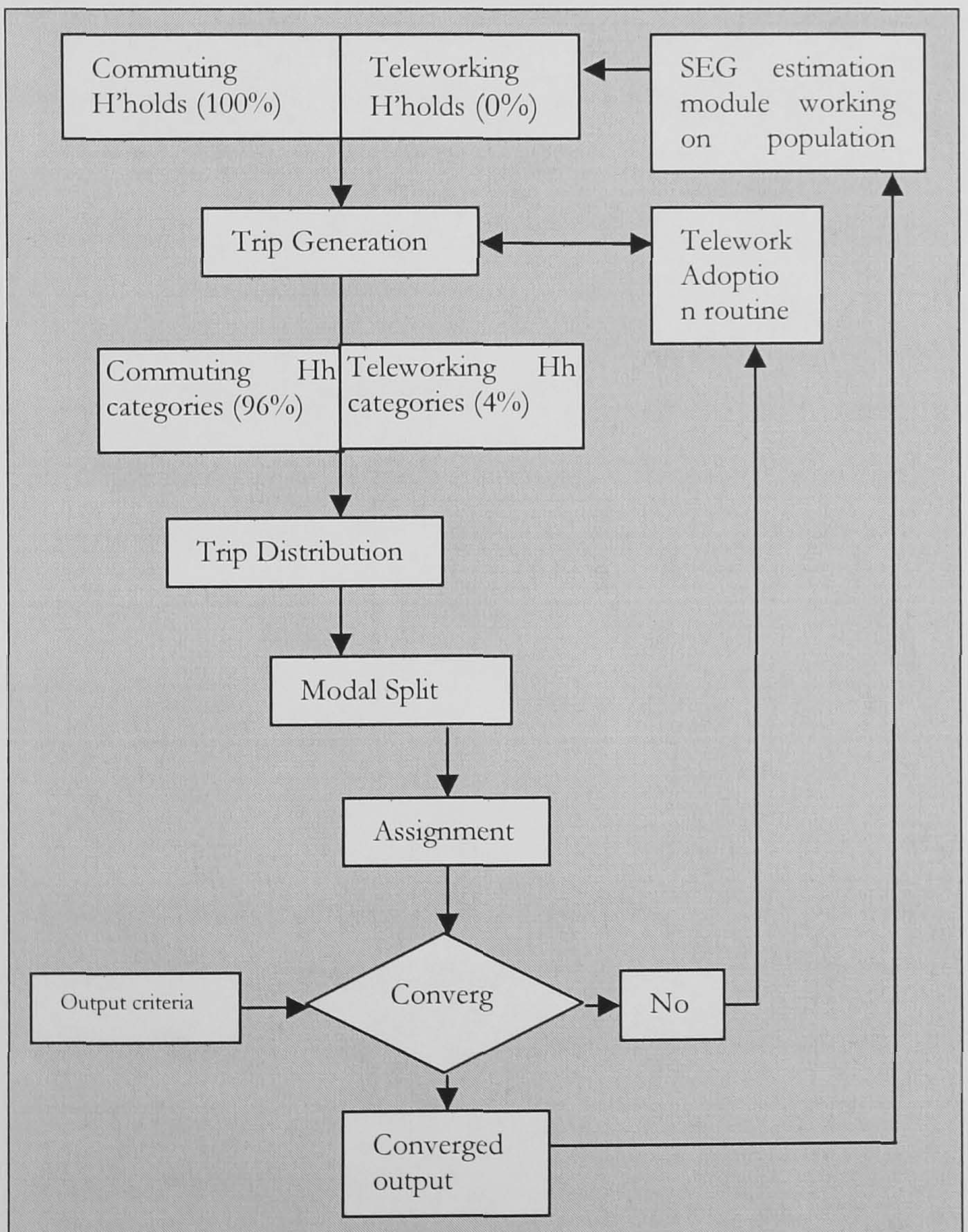

Figure 3.1: Schematic diagram of modelling telework as household category (Boxes and figures shown for household categories are meant only for illustration and do not constitute a real or a separate process or stage)

Appropriate trip rates for different trip purposes are applied to the trip matrix at this stage and depending upon the particular convention followed by a model, commute trips by teleworkers are suspended from the network or discounted from the total demand. After this the particular model would follow its usual logic to perform the remaining operations. This may be called an SEG based or disaggregate approach to modelling of telework adoption.

The other responses to telework adoption are long term in nature and would be the result of end-of-model-period GC (accessibility measures) output. The respective effects of these responses would be incorporated into the input data for the next model period run.

3.4.3 Teleworking as a Travel Mode and Role of Teleworking Costs

For modelling teleworking as a travel mode, a choice option to 'travel' by such a mode would need to be created within the modelling framework to be used. This would require defining the utility of such a mode that would determine the relative attractiveness of this model. This utility would be based on a generalised cost function similar to functions for the competing conventional modes. Based on its relative utility, the teleworking mode would attract travellers and the trips by 'travellers' using this mode would be suppressed or suspended from the total travel demand. This would be done at the modal split stage of model operations. The costs of teleworking would have an important and explicit role in representing teleworking in this way.

Teleworking costs would have an explicit role if teleworking is to be studied using a choice modelling framework (consisting of conventional travel choices). The teleworking costs will have an implicit role if the frequency choices are studied and modelled within the framework of a predictive model. This role would amount to making all the (teleworking as well as non-teleworking) choices being studied comparable with regard to the cost of a particular choice as was eventually done in this study (section 8.5.1). This needs a look at the genesis and composition of teleworking costs.

Teleworking costs can be viewed as the sum of tangible and intangible components. Tangible costs can be further conceptualised as a sum of fixed and operational/variable components. Looking at the actual costs involved, the fixed component appears to far outweigh the variable component in terms of magnitude. Once an employee has decided to adopt teleworking, cost analysis suggests that she would try to maximise her frequency unless constrained by own career ambitions or/and some other external factors imposed by the job nature and/or employer attitude and culture. These costs are explored next.

3.4.3.1 Tangible Fixed costs

The costs under the following heads may be regarded as tangible fixed costs:

- Equipment cost regardless of who bears it

- Network access cost (this is also usually a fixed periodical payment and is not affected by short term (daily or weekly) behaviour)
- Cost of space allocated to work at home (employer might partially contribute).

Allocating cost of internet access at home to teleworking appears trivial here in view of its use for various activities other than office work. It can be assumed that the decision to have internet access at home in a majority of cases is independent of decision to adopt telework.

3.4.3.2 Tangible Variable Costs

The variable part of tangible cost may consist of

- Energy cost (electricity, heating, etc.)
- Cost of phone and fax use if required in addition to internet.

Arguably, calculation of the teleworking costs for frequency adjustment purpose, if needed, would only involve the variable component of the total cost per teleworking occasion. Therefore, from the tangible category, the only cost heads which appear relevant for frequency modelling are tangible and variable costs. Arithmetically, the motivating factor towards increased frequency by a teleworker would be the net savings in GC realised by her. These savings would be equal to the difference between GC of travel by her usual mode of travel and variable cost of teleworking. However, it appears that neither the fixed nor the variable components of these costs are likely to influence the frequency in the short term in majority of the cases, since the fixed component is sunk cost and the variable part is negligible compared to GC by the usual travel mode.

3.4.3.3 Intangible Costs of TW

This cost component may have a significant role within the predictive choice modelling framework for frequency response in view of the tangible variable cost component being almost negligible. Further, this cost component is also envisaged to be constant for each teleworking occasion, i.e. it will increase by a constant factor when summed over all the occasions and, perhaps most significantly, it will not be affected by changes in transport network conditions. On the other hand, network conditions often have a significant effect on GC of travel by the conventional travel modes. (This observation feeds the scepticism about the whole idea of comparing costs of two alternatives, i.e. teleworking and travelling, operating in two completely different environments.)

However, if teleworking is to be modelled as a mode competing with the conventional travel mode within the choice modelling framework, the role of intangible cost factors will become additionally significant. It would require careful consideration, especially of any assumptions to be made, to avoid any potential risk to the stability of the model. It may require defining and specifying GC of teleworking taking into account all the possible impediments to teleworking so that it does not appear disproportionately attractive in comparison to other alternatives in the choice set. (However, defining a true measure of job accessibility of teleworkers would require a separate research effort.) For any potential use of this concept in this thesis, potential impediments and disincentives to telework may include:

- Risk of telework being viewed negatively for career and re-employment opportunities
- Risk of telecommunication network breakdown
- Lack of self-supervisory skills
- Developing a sense of cabin fever
- Loss of opportunities for social interaction/professional networking
- Risk of diminished peer support
- Risk of being offered reduced pay for teleworking occasions
- No or reduced liability for occupational health and safety issue
- Absence of legislation protecting employment conditions for teleworkers
- Distractions by household members while teleworking
- Inability to manage time/work at home (over-worked or being less productive)
- Risk about security of information and data transfer
- Loss of learning opportunities through interaction with colleagues

This list may be read in descending order of effects of these factors. Many of these may have already been considered by an employee at the adoption stage. Therefore, cost on account of many of these factors may have to be considered from a marginal perspective as it will not be a total loss/risk, e.g. regarding loss of learning opportunity, a teleworker may be able to learn through experience how to maximise the benefits of her attendance at the usual workplace during the week. To avoid double counting of such marginal effect(s) would require due diligence. Also the assumption here is that the available teleworking option is completely flexible and has no binding frequency which may not be the case in reality in a majority of cases, especially regarding the upper limit on frequency. This issue can be partially covered by imposing a ceiling on choice of frequency.

3.4.4 Using a Standalone Model

This suggestion means the development of a complete new model in contrast to the capability enhancement suggestions. If pursued, it would in principle be developed as a simple but adequate tool along the suggested outlines of the general framework presented previously. This model is envisaged to accommodate both modelling processes: teleworking adoption in its standalone mode and teleworking frequency when linked to a transport model of the type of FSM.

The standalone model of teleworking adoption would be incapable of modelling teleworking effects on the travel behaviour like increased availability of car, time and the income effect resulting in increased leisure/recreational, trips unchained from commute and shopping trips. These effects can only be modelled within an FSM based transport model by adjusting the appropriate trip rates for the relevant travel generators.

3.5 Conclusions

Modelling employer and employee uptake of teleworking require developing new models of teleworking adoption or enhancing the response of existing operational land use and/or transport models. Understanding of how telework adoption affects job accessibility and whether adoption also induces relocation, which again affects the overall accessibility to activities requiring travel, is fundamental to realise that end. So far modelling of the teleworking impacts as one specific application of the ICT has not been attempted within a LUTI framework or within a transport model. Considering the cross dimensional nature of these impacts it would be worthwhile to do so.

The discussions of different travel demand modelling paradigms reveals that the FSM approach has been severely criticised for predicting travel demand without properly understanding travel behaviour. However, its deceptive simplicity and ease of use have contributed to its great success over the years. It also served as a benchmark for the other approaches. On the other hand, although ABA has analytic strengths and its underlying tenets are also storng and may have been a preferred choice for this study.

The models that follow the LUTI approach are more fully developed than ABA models. However, there remain gaps among the causal links between land use and transport fields. The CTB approach which was also proposed as an alternative to the FSM has not gained much acceptance. Besides, the discussion found it too simplistic and inherently flawed to model the travel foregone/saved while teleworking, thus unsuitable for this study. Hence, the FSM, the ABA and the LUTI can be considered for practical use in this study.

With regard to the ABA, availability of software of a fully operational model is a limiting factor. The LUTI framework also appears a natural choice due to the cross disciplinary nature of teleworking impacts. Its use is rather essential from a behavioural perspective if the impacts of the location related responses to telework adoption as well as on travel substitution are to be analysed and understood in greater detail. However, there are considerable implications of doing so from various perspectives which might make such an effort a daunting task.

Concluding from the discussion on relevant modelling paradigms and how teleworking might be represented within the alternative paradigms, a list of options was drawn. The range of options includes modelling both the adoption and responses to the adoption. Finally, three specific suggestions on how possibly to represent teleworking within a conventional travel demand model were considered in slightly more detail. Treating teleworking as a different type of trip at trip generation stage or as equivalent to an alternative mode would bring changes in the model's internal design and enhance its response; while using a separate model of teleworking to produce factors which could then be applied to a trip matrix would provide the specific input needed to model the travel demand in conventional FSM.

Modelling teleworking as a travel mode has also highlighted the increasingly important issue of teleworking cost within the transport modelling paradigm. This concept has particular significance if teleworking has to compete with the conventional travel modes. Various types of teleworking cost have been identified and some speculations have been made regarding their role. The concept of the intangible cost of teleworking is particularly important. It has been conceived as a component that is the sum of costs assigned to all behavioural and technological factors acting as impediments and disincentives to teleworking adoption and increase in its frequency. Understanding the dynamics of teleworking cost behaviour also offers insight into potential frequency levels.

The use of any of the FSM, the ABA and the LUTI approaches to model telework would generate a substantial workload which has to be balanced against the project resources. The availability of software for an operation land use model or model based on the ABA is also a limiting factor. These aspects have considerable implications for the course of the study from a practical perspective. All these issues are related to the scope and scale of the study and are taken up in the next chapter.

4 Study Scope, Modelling Framework and Data Requirements

4.1 Introduction

This chapter defines the study scope out of the responses identified in 3.1 and identifies the feasible approach to modelling teleworking within the available resources. It starts with an outline of what would have been an ideal study in line with the original research idea in the next section. Originally, the use of a combined LUTI model and/or a FSM model were intended, but neither was in practice available. Hence this section also prioritises research into the responses identified in 3.1 in the light of the joint constraints of costlier data requirements, availability of the models and project resources. In section three, adapting the original modelling methodology, a framework for forecasting of the impacts of teleworking has been developed. Finally benefiting from the defined study scope and clear boundaries of the proposed framework, the data requirements are explored, evaluated and defined.

4.2 Study Scope: Prioritising the Research Questions

The battery of responses to telework availability and adoption, identified in 3.1, if translated into actions has the potential of bringing about changes in transport, property and job markets. To evaluate the full impact of these responses on respective markets, both the actions of the firms and individuals and reactions of affected markets need to be modelled. Thus, it can be argued that an ideal study would: investigate teleworking from both the households' and the firms' perspectives; model all the responses at a disaggregate level; and assess and analyse their impacts on both transportation and land use systems. A modelling exercise that encompasses all these would provide a better and fuller basis for understanding and forecasting the impact of teleworking. The foremost requirement of such an exercise is the availability of a comprehensive LUTI modelling tool which had originally been envisaged but proved not to available to the project. Further, the data requirement of a study at this scale are also obvious. This situation forced a prioritisation of the research questions.

The teleworking frequency of an individual is the most significant of responses due to its direct impact on travel demand during peak traffic hours. Similarly, among all the travel modes the car used by a single person for commuting contributes most to congestion. Non-work related travel as a result of the released time and car was also potentially important for its impacts on the overall demand for and displacement of travel opportunities. Similarly, location behaviour of teleworkers was considered important because of its implications for accessibility and contraction or dispersion of activity space for teleworkers.

On the other hand, changing job as a result of the decision to be a teleworker requires greater commitment to the practice and takes a longer time to be reflected in the behaviour. Similarly, studying changes in car ownership patterns, also being a long term decision, as a result of adopting teleworking would be more appropriate for study once teleworking population has established itself as a significant segment of the market. Therefore, these two responses are presently less important and can be excluded from the investigations. However, the case of modelling firms' adoption and responses is not only different from these responses but potentially quite significant also. The impacts of firms' decisions relative to telework can be understood through the use of a land use model. The unavailability of such a model and the cost of data collection have checked this ambition and a fuller perspective on firms had also to be excluded from the scope.

Another important consideration was the decision regarding the unit of modelling, i.e. whether to model telework adoption at the individual level or at the household level. Both units of modelling have their respective sets of implications. Briefly, from an individualistic perspective, the telework adoption is a household decision due to caring needs, car and space uses, and income effects. On the other hand, in the event of modelling it at household level, the adoption propensity of all the members in a multi-worker household needs to be considered. This in turn has implications for data collection methodology. After careful and comparative evaluation of all the implications of both the units of modelling, modelling at individual level was considered more appropriate. In this regard other members of a multi-worker household who could be potential adopters were assumed to be the part of the population who were out of the sample frame.

The above reasoning means that the study would focus on an individual within a household who is a regular commuter and in fulltime employment. This individual would be studied for their adoption and post-adoption responses to telework availability which would include teleworking frequency (to be studied and modelled in detail); non-work travel; and location/relocation responses. The last two will be explored in less detail. Relocation behaviour as a result of adopting teleworking will not be modelled due to unavailability of a modelling tool. In terms of travel mode, primarily the responses of car users (focus of this study) to telework availability and adoption would be considered. However, depending upon the nature of study results, there is an option to apply those results to other user classes and develop estimates of the impacts of teleworking.

4.3 Developing a Framework for Impact Forecasting

Three possible options for modelling teleworking were identified in 3.4. In the available circumstances, only the last option i.e. using a separate model of teleworking to produce trip factors (see section 3.4.4) was considered feasible. To develop this model, discrete choice modelling methodology was used in which adoption and frequency responses to telework availability were combined. The modelling framework finally used comprised a discrete choice model (DCM) and a single link model (SLM) form. A predictive model of adoption and frequency was developed based on SP data collected for this purpose to work within the DCM convention.

To model the system wide impact of teleworking on congestion the output from the DCM model was fed into an SLM which represented the second order convergence to changes in congestion. The proposed framework could also be made to accommodate the analysis and impact of non work travel and location responses. Depending upon the availability of evidence from the data to be collected, the estimates of the impact of adoption and frequency on non work travel can be exogenously incorporated to reflect the net impact. In the rest of this section, the logit model is first described and after that the SLM is introduced. Finally, a description of the combined framework has been provided accompanied by a flowchart diagram.

4.3.1 Logit Model Form

This section presents the form and structure of a logit model which is a popular form of DCM. Variant forms of logit model such as multinomial logit (MNL) and nested logit along with its theoretical foundations will be explored in chapter 8. The logit model is represented as:

$$P_i = \frac{e^{\mu Ui}}{\sum_{i \in J} e^{\mu Ui}} \qquad (4.1)$$

Where *Pi* is the probability of choice i being chosen, μ is the scaling factor and *Ui* is the utility of choice i out of a set of *J* choices entered into the specification. A common simplification is to assume that μ is constant across all the choices in a given choice set (DfT 2006). After this simplification the logit function assumes the following form:

$$P_i = \frac{e^{Ui}}{\sum_{i \in J} e^{Ui}} \qquad (4.2)$$

This form takes in utilities of choices being compared and evaluated and returns the relative probability, *P*, for each choice which the population of the data sample may make. This requires the utility of each choice to be estimated, the function for which is written as:

$$U_i = \alpha_i + \sum_k \beta_{ik} X_{ik} \qquad (4.3)$$

Wherein α represents the alternative specific constant (ASC) in a particular function if needed, β_{ik} represents the coefficients for choice i and attribute k and X_{ik} are the parameters for all the attributes entering in the function for choice i. All the utility functions in a model structure are specified in this way. For segmentation analysis relative to DSEC variables, equation (5.3) takes the following form:

$$U_i = \alpha + \sum_k \beta_{ik} X_{ik} + \sum_{y=1}^{n-1} \gamma_y d_{ky} X_{ik} \qquad (4.4)$$

Where the index '*y*' in the second additive function represents the number of categories in a DSEC variable, γ_y is the coefficient for the *y*th category of the categorical variable, d_{ky} is the parameter entering for a particular dummy variable for all the n-1 *y* categories and *k* categorical variables to be studied and interacting with the parameter for one of the main attributes (*X*). However, dummies can also enter in a function on their own as shall be seen in the case of the teleworking policy variable (section 8.6.1). In that case the equation (4.4) would become:

$$U_i = \alpha + \sum_k \beta_{ik} X_{ik} + \sum_{y=1}^{n-1} \gamma_y d_{ky} \qquad (4.5)$$

Only the relevant explanatory variables are entered in a utility function and sometimes an alternative specific constant (ASC) is also specified to obtain a better model fit. As output, logit estimation provides coefficient estimates, t statistics and standard errors, log-likelihood measures, Rho Squared goodness of fit and matrices of correlations of estimated coefficients. Unlike regression analysis, in logit analysis the coefficients obtained are scaled (Ortuzar and Willumsen 2001) relative to the variance of unobserved factor(s).

4.3.2 The Single Link Model

The SLM uses a speed flow relationship which represents all demand and supply in a given area by an aggregate 'single link'. The SLM function is based on empirical research (Hall et al, 1992) and can take different formulations depending upon the context of the study. Some of the better known formulations include HCM curve, BPR curve and MTC curve and all have their respective limitations. To go into their details is the beyond the scope of this study which uses a BPR (Bureau of Public Roads) type function. The BPR function is written as

$$v = \frac{v_f}{1 + \alpha (q / C)^{\beta}} \qquad (4.6)$$

In which v is congested speed, v_f is free flow speed on the link, q is flow, and C is capacity. The parameters α and β are either user-specified or obtained using a nonlinear least squares, Marquardt-Levenberg algorithm (Martin, 1998). The capacity C is estimated to be the maximum hourly flow observed during the 30-day period, and the free flow speed is the median speed when the network occupancy is below 10% (Chen et al, 2005).

The SLM uses an area speed-flow curve and as such predicts facility speed as a function of traffic flow. It has its own properties and works under certain assumptions. The function represented in equation (4.6) assumes a demand dependent delay on a link resulting in congestion. It also assumes that there are no obstructions, bottlenecks, or controls on the link, including at the link exit, other than any that may be interpreted as being implicitly present in the form of the function. Traffic enters and leaves only at the beginning and end of the link. The mathematical function which was ultimately used has been given in section 9.6.1 (equation 9.2).

4.3.3 Description of the Resulting Framework

The framework in Figure 4.1 takes in the entire travel demand in the study area and disaggregates it into two categories along the time of day division, i.e. peak and off peak. The peak category is further divided into the car commuters (focus of this study, thus, sampled population) and the rest (non-sampled population). (In retrospect it is useful to note that the study should have covered the PT users as well.) The two populations have been disaggregated along the main possible responses (travel choices) to avoid congestion. Public transport (PT) users from the sampled population have been pooled with the non sampled population. Thus, the framework has three main modelling links: the left link (non sampled peak), the right link (off peak) and the middle link (sampled peak). The framework is capable of predicting for different user classes and analysis at the disaggregated level given the availability of the data.

As modelling tools, the framework will employ two mathematical functions: MNL and SLM. The MNL component of the framework will be used for demand forecasting. For congestion forecasting, three SLM functions haves been linked to the output from the MNL model to make the framework comprehensive though only SLM for car travel during the peak was used in the end. Given predefined criteria for allowed travel time on the network links being modelled, the combined MNL-SLM model will converge to equilibrium travel flow/demand on the link through successive iterations. This has been shown through a feedback loop (dashed line) to the MNL model for the sampled population.

For the sampled population (the middle link), the framework separates the commute demand during the peak by mode choice, i.e. car and PT. The car users are subjected to policy analysis and fed into MNL which provides the distribution of their propensities for all the choices. At this stage, the impact on the travel demand of various policies can be determined (for further details, see section 9.5) and all travel categories will be distributed into their respective SLMs. To determine the impact on congestion times, the propensities of those commuting by car, fully or partially, are fed into SLM for car users (for further details, see section 9.6).

The PT users in the sampled population are pooled with the PT users of non sampled population (the left link). The entire non sampled population along with the PT users in the sample population can also be subjected to policy analysis and fed into the same or separate MNL if required. After the policy test, this population can also be distributed to respective SLMs as for the sampled population.

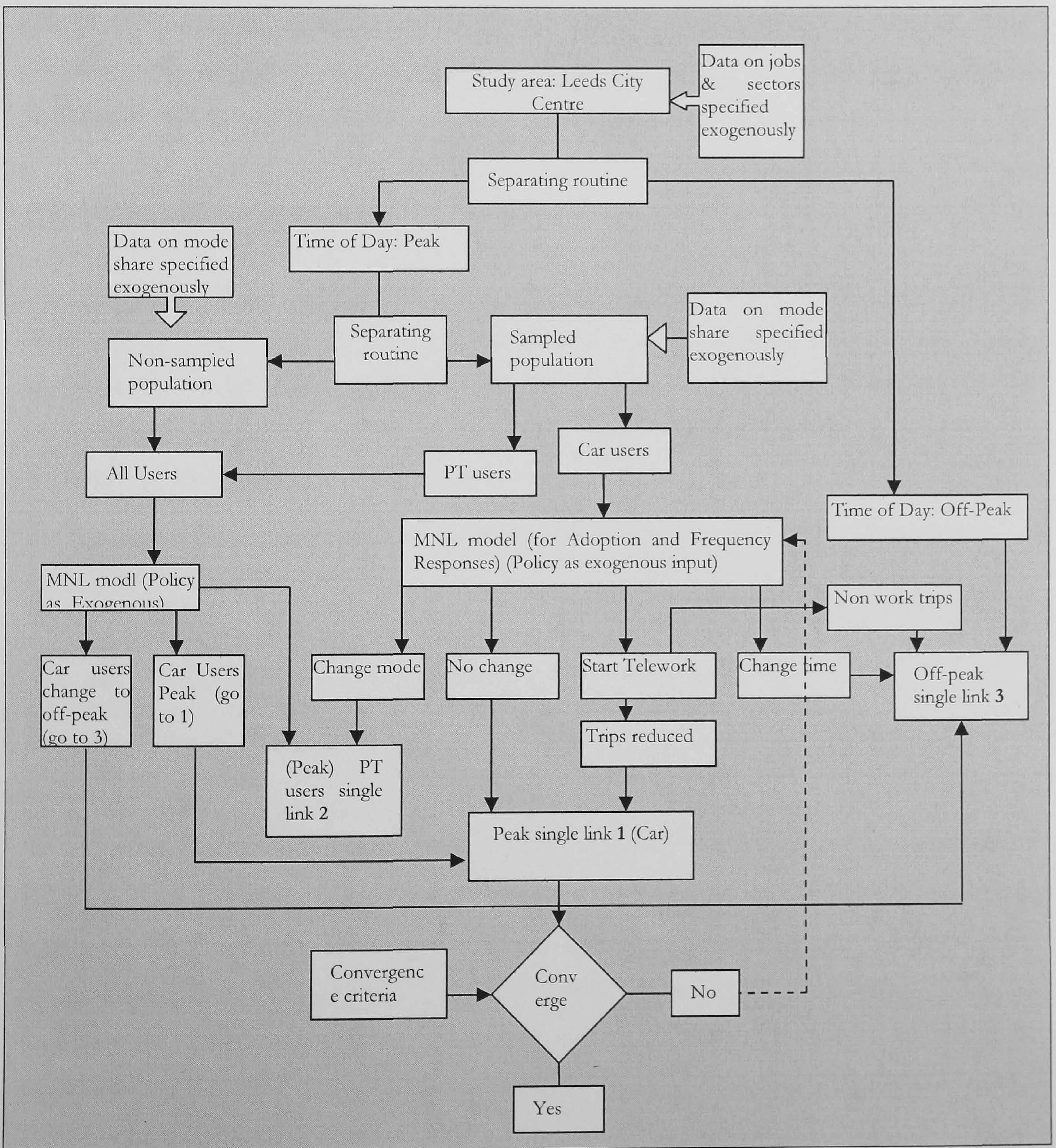

Figure 4.1: The framework for forecasting teleworking impacts on travel demand and congestion times.

The right link in the framework models the travel demand during the off peak and is mainly of interest due to car commuters switching to that time of day and for accommodating the extra non work travel by teleworkers if any.

However, the framework, in the event of a model transfer, can also cater to the combined travel demand (both sampled and non sampled populations) during the peak by pooling the demand for different travel categories (i.e. car commuting during the peak, car user during off peak and PT users). In this situation the left and middle links would be combined and the total demand fed into one combined MNL and then feeding the distributions for different travel choice categories into respective SLMs marked as 1, 2 and 3 and extending the feedback loop to the combined MNL model.

This framework is also capable of accommodating the non work travel response (shown by the appropriate box in the figure) and location response (by linking it and providing the data on accessibilities to a land use model and receiving inputs on population and economic data).

4.4 Data Requirements

Generally the data requirements are steered by the study objective, research methodology and scope of the investigation. The three elements are in place now, therefore, it is possible to outline the data needs at this stage. Looking at the methodology being used for the investigation, the need for the following data can be envisaged at this stage:

- current estimates of teleworkers (preferably by SEGs and job/industry sector)
- (preferably disaggregated) historical annual growth rates of teleworkers
- aggregate (and disaggregate if possible) travel demand data (by time of the day and modal shares) from the study area
- data on speeds, flows and distances for the links to be modelled
- projections about future adoption rate of teleworking
- current data on the frequency of teleworking by the teleworkers and projections on the changes in this frequency affected by different factors/conditions
- data on job accessibility for different user classes in the study area
- data on current and future impacts of the non-work travel and land use responses

The first four elements of the above bullets are needed to calibrate the framework in Figure 4.1 for forecasting both travel demand and congestion impacted by teleworking for the base situation/year. By its very nature these data would be researched from the literature and other secondary data sources. Historical growth rate factors would be needed to explain the future projections and, if preferred, to strengthen the behavioural response of the modelling system.

Owing to the innovative nature of this study and for the reasons discussed in section 2.6.3, the rest of the data items in the above list are envisaged at this stage to be obtained through a survey. Projections about the future would be needed to feed the travel demand forecasts. One of the objectives of this study is to test teleworking adoption's response to policy and subject it to changes in the policy. This also necessitates the collection of fresh data. Collecting these data along the segmentations within the mode choices and job types would make the analysis and the projections about teleworking and its impacts robust and more useful. However, depending upon the study scale and characteristics of study area, preferred level of disaggregation may have additional implications for the survey content, design and management.

The teleworking frequency is the most important impact factor. Therefore, its current estimates and plausible future projections are very critical elements in the whole data collection strategy. This type of data currently does not exist. Similarly, the data on non-work travel and location behaviour of teleworkers are needed to quantify the nature, direction and magnitude of these impacts. Further, it may be appropriate to briefly explore employers' perspective on teleworking policy and take-up. All these requirements have considerable implications for the data collection strategy and exercise and precise details in this regard have been dealt within the next chapter.

5 Data collection and Survey Development

5.1 Introduction

The availability of the data is a major concern in a majority of applied research projects and this thesis is no exception. Section 4.4 clearly outlined the data requirements for this study and their rationale. Out of the eight bulleted points, the first three points are contextual data while the rest relate to the core study requirements. Of methodological necessity, the contextual data, mainly to calibrate the impact forecasting framework including a model of telework adoption (section 4.3.3), were obtained from secondary sources. The sources for secondary data include DTLR (2002), SUSTEL (2003) Cairns et al (2004) and Wilson et al (2004). The data on travel demand was sourced from the relevant department of Leeds City Council.

At its core this study seeks to understand the telework adoption under explicit policy interventions to encourage teleworking as an alternative to commuting. This essentially requires study-specific data to estimate a choice model of telework adoption and frequency as noted in 4.3. The reasons mentioned in section 2.6.3 also made a strong case for fresh data. The last element of the defined data requirements (section 4.4) pertains to data on the non-work travel and land use impacts of the responses to teleworking adoption. Hopkinson and James (2003) studied non work travel impacts of teleworking in the UK but in a quite different study context. However, section 2.10.3 identified that the location behaviour of teleworkers has never been studied in the UK, hence there are no secondary data. Similarly, employees' attitudes towards teleworking were also not studied in the past in the UK (see 2.6.7). Therefore, these three elements were also made part of the primary data collection exercise which in its entirety would seek to:

- estimate the number of current teleworkers and potential adopters;
- estimate current teleworking frequency;
- estimate how adoption and frequency would vary in the context of changes in policy on travel conditions;
- have the data on non-work travel and location behaviour as a result of telework adoption or preference; and
- study employees' attitudes towards teleworking.

A brief survey on employers' perspective on current and likely future teleworking uptake (first bullet point) and factors influencing it has also been planned and would be described in Chapter 10. This chapter has the following structure: section two covers the approaches to primary data collection, evaluates the RP and SP approaches by reviewing the literature and selects the appropriate approach; section three focuses on issues of designing a choice experiment using the SP method; section four reports on the survey formulation process; and finally some brief conclusions are drawn.

5.2 Approaches to Primary Data Collection

The specified elements of primary data can be obtained in a variety of ways. Primarily, three types of survey are used: revealed preferences (RP), stated preferences (SP) and attitudinal surveys. Generally, RP and SP methods are used to predict behaviour of the respondents given the choices available to them and forecast demand for each alternative in the choice set. Attitudinal surveys are employed to explore the attitudes and factors shaping the behaviour towards a choice or a set of choices. Ben-Akiva et al (1999) are of the opinion that attitudes and perceptions have been proved to strongly influence individuals' choices. All these methods have previously been applied among employees to the study of teleworking and its different aspects. Attitudinal surveys are grounded in socio-psychological theory of attitude-behaviour relationships developed by Ajzen and Fishbein (1977), applied to transportation choice decisions by Koppelman and Pas (1980) and used to explore attitudes towards teleworking by Mahmassani et al (1993), Yen et al (1994), and Mokhtarian and Salomon (1997).

Previous studies which used RP data to explore teleworking adoption and/or teleworking frequency on small samples are Mannering and Mokhtarian, (1995) Bagley and Moktharian (1997), from large samples Drucker and Khattak (2000), Popuri and Bhat (2003) and Börjesson, (2003). Bernardino et al. (1993) and Sullivan et al. (1993) initiated the use of the SP method to predict teleworking adoption. Later on Bernardo and Ben-Akiva (1996) and Moktharian and Salomon, (1997) used SP data in their studies. All these studies were in US settings. More recently Bonsall and Shires (2005) used this method to estimate models of teleworking from an employer's perspective. It is significant to note that the SP method has not been applied to the study of teleworking frequency.

Recently an extension to the SP method, called IACE (interactive agency choice experiments), has been proposed and empirically tested, incidentally on flexible working practices including teleworking, by Brewer and Hensher (2000) and Rose and Hensher (2004). The approach is characterised by offers and feedback and may be more suited to study the group economic decision behaviour. It is born out of the criticism that SP experiments are suitable only to study processes where the agents have no external restrictions on their capability. To some extent, this criticism may be valid regarding telework adoption as the choice process in this case is not independent.

This advance in methodology, however, removes only a minor degree of constraint as the choice process still has to be studied in controlled conditions and with only a finite number of choices. Although the framework adds value to the study of the choice process it is still not free from limitations. It is suitable only for very small samples, adds more complexity to an already cluttered methodology characterised by a battery of respondents' biases, and is thus of limited practical value. However, the really competing methods, due to their very nature, are SP and RP though there is growing interest in, and a body of literature on, their complementary character. The next section critically looks at both the methods.

5.2.1 An Overview of RP and SP Methods

RP is the preference of the actual choice while SP is a statement of choice. SP experiments offer the decision maker hypothetical scenarios and the preferences expressed indicate the relative importance of the attributes that characterise these scenarios. SP provides better data due to experimental design as it is characterised by more variation and better trade-offs and it avoids correlation problems while major drawbacks relate to non commitment bias and habit. However, the SP approach is more suitable to situations where there is no existing market for an alternative or it is relatively less established. Over the years SP has increased in its acceptance and popularity. Which of these approaches is better? A decision in this regard is not an easy one.

Louviere et al (2000) list an array of characteristics of RP and SP methods. According to them RP data typically:

- Depict the world as it is now (current market equilibrium)
- Possess inherent relationships between attributes (technological constraints are fixed)
- Have only existing alternatives as observables
- Embody market and personal constraints on the decision makers
- Have high reliability and face validity
- Yield one observation per respondent at each observation point.

While SP data typically

- Describe hypothetical or visual decision contexts (flexibility)
- Control relationship between attributes which permits mapping of utility functions with technologies different from existing ones
- Can include existing and/or proposed and/or generic (i.e. unbranded or unlabelled) choice alternatives
- Cannot easily (in some cases cannot at all) represent changes in market and personal constraints effectively
- Seem to be reliable when respondents understand, are committed to and can respond to tasks
- (usually) Yield multiple observations per respondent at each observation point.

SP data has advantages in that the choice situations presented to respondents can be carefully controlled in a number of ways to maximise the amount of information collected from each respondent (Daly and Rohr 1998). It is rich in attribute trade-off information, produces more robust models than estimated on RP data and can capture a wider and broader array of preference-driven behaviour than RP data (Louviere et al. (2000). However, it also has disadvantages relative to RP data, particularly that it is hypothetical and experiences difficulty in taking into account certain types of real market constraints; it is hence not good for prediction in existing markets without calibration of alternative specific constants (ASCs) (Louviere et al. (2000). It is also not certain whether the results obtained can be applied in a way that can inspire confidence (Daly and Rohr 1998).

For the above reasons there has been significant recent interest in the use of RP and SP data together, attempting to use the better aspects of each data type. Essentially, the two data types are complementary, i.e. the strengths of the one cover the weaknesses of the other. In particular, the credibility and realism of the RP data combines well with the efficiency and flexibility of the SP data (Daly and Rohr 1998). There also have been special issues of academic journals on the topic which give an overview of the state of practice and the problems for their times of publication. See for example, issues of *Journal of Transport Economics and Policy*, (in January 1988) focused on SP models' external validation issues, of *Transportation* (in May 1994) which focused on issues on combined use of SP and RP data, and more recently of *Environmental & Resource Economics* (2006, issue no. 34) which focused on issues of model uncertainty and techniques like response pooling and model averaging. In summary, best practice is to use SP only when it can be scaled to RP, otherwise it would be automatically assumed that RP and SP errors are equal. The best use of SP data is for trade-offs while forecasts should rely on RP data as much as possible.

5.2.2 The Suitable Approaches to Data Collection and their Rationale

The choice of a data collection approach is a function of the study objective. The teleworking responses to be studied are quite different in nature. This difference would influence the selection of the approaches to data collection. This study is not only interested in current teleworking adoption levels but also in the potential market for teleworking, i.e. those who would prefer to telework if it is available to them. This requires the use of both RP and SP approaches.

For policy analysis, control over the experiment conditions (attributes, their levels and choices) is required. The responses generated in this way give valuable insight regarding the effectiveness of the policy set being tested or its individual components and ultimately its acceptance. For example, studying effects of generalised cost of travel on teleworking frequency essentially would require creation of hypothetical scenarios. Further, there are intentions to test a new attribute (employer's policy on telework) for its effects on the given choices. Like untested markets and products, untested sensitive and costly policy can perhaps best be tested through the application of SP techniques. One such technique is designing choice experiments which cater to these requirements in the best possible manner. Most often such a choice experiment needs a context and data on contextual variables, e.g. the characteristics of an alternative in the choice set. This again requires the use of an RP approach.

The purpose of studying non work travel and location responses is to develop estimates of the impacts of teleworking in these two areas. This can best be done with RP data on a sample of teleworkers who have been in the practice for a fairly long period of time. Perhaps the best approach to study the true impacts of teleworking on the location choice behaviour is a before-and-after approach through panel data in which the survey explores the characteristics of commute distance and residence location relative to the urban human geography. It appears from the literature review in Chapter two that this has never been done before.

For non work travel, a one-shot survey approach would be a very poor indicator of reality. The best thing to do is a before-and-after panel data through travel diary on a sample of teleworkers or at least a travel diary across a week's period on current teleworkers. In earlier studies, both approaches, i.e. a diary based and a snapshot RP survey, have been used. The studies by Hamer et al (1991) in the Netherlands and Pendyala et al (1991) in the US were based on the former while Hopkinson and James (2003) in the UK used the latter approach.

The discussion in the last two paragraphs means a completely different methodology towards data collection which in turn have obvious implications for project resources and the remit of this study. These considerations require that these non work travel and location responses be treated simply. The intentions are to combine RP and SP approaches into a hybrid approach to elicit responses on these two aspects of teleworking by adjusting the wording of relevant questions to suit both existing teleworkers and those who would indicate a preference for teleworking. The discussion in this subsection so far leads to the conclusion that depending upon a particular response being studied and modelled, both RP and SP data types can be used to achieve the study objectives.

Exploring the perceptions that shape attitudes and behaviour towards teleworking would give insight into the reasons that underlie the choices made by respondents. Indirectly, this would also serve to internally validate the SP data. This means that all three (RP, SP and Attitudinal) approaches would be used depending upon the requirement of a particular aspect of the study. However, the main thrust of the approach is SP in nature. Two reasons, potentially very potent, have motivated this. Firstly, in more than one way the study of teleworking adoption and frequency is similar to the choice of a new mode. Secondly, this study seeks to understand policy interventions to encourage adoption and changes in teleworking frequency as referred to in section 5.1.

5.2.3 Some Implications of Designing Choice Experiments Using SP Method

There are concerns regarding the use of SP experiments in demand forecasting studies. For example SP methods are characterised by imprecise coefficient estimations due to random error in the responses obtained which is called the scale factor problem (Wardman 1991). This problem cannot be estimated separately from the coefficients and can be tackled by rescaling the model with the help of RP data. If there are too many attributes in a design then the respondents may ignore some of them to simplify the task (Fowkes and Wardman 1988). Hensher et al (1988) advised that designs with more than three attributes are quite difficult to understand, and results may be unreliable. The designed experiment may be tested by a simulation test for realistic estimates of boundary values for attributes (Fowkes and Wardman 1988). However, the simulation test cannot guarantee that the design will have no problems, particularly where there is a lack of previous information regarding magnitudes and ratios of coefficients in the study (Jaensirisak 2003). Further, the simulation cannot test whether the respondents find the experiment realistic.

The major source of bias and error in an SP exercise emanates from design dimensions (numbers of attributes, levels, alternatives, etc.) and how the experiment is presented to respondents (Widlert 1998). This usually occurs in complex designs. However, provision of an increased number of alternatives in the design has been associated with better quality of SP data as this increases the choice span of respondents and they are not forced to choose from a limited set (Ortuzar 2006). The other sources of error could be from unreliable data or wrong or silly answers by respondents (Bonsall et al 1992). Intentionally incorrect responses may be provided for some reasons, e.g. policy bias (with the intention to influence the policy being studied), affirmation bias (desire not to be considered odd), habit or status quo bias (exhibiting a tendency towards the actual behaviour) and/or rationalisation bias (excuse for current behaviour). Another drawback of the method is that individuals' SPs may diverge because of systematic bias (assuming one thing and then building upon that) (Bonsall, 1983). Unintentionally provided wrong answers may be due to misunderstanding, unconstrained response bias (simplifying the situation) or lexicographic answers (sorted or based on the importance of one attribute).

5.3 Designing an SP Experiment

This section describes the development of the design of a choice experiment using the SP method. The experiment is aimed at testing car users' sensitivity to behavioural choices they make when faced with congestion. SP designs are a well established topic of study within many disciplines and a wide variety of guidance is available in the literature. Some authoritative and often consulted sources are Pearmain and Kroes (1990), Louviere et al. (2000) and Bateman et al. (2002). It is, however, important to recognise that SP design is a developing discipline, and that there is some disagreement as to the most appropriate methods. In this regard, DfT (2006) sounds a note of caution regarding the three texts cited above as in their judgement they show significant differences in respect of the methods they promote. There are some primary issues, called steps in the design process, to be considered in any design exercise. A summary of the guidance on the steps involved in the design of an SP experiment is presented next.

5.3.1 Steps and Issues in the Design Process

A context to the experiment design needs to be defined first. Formulation of a choice set comes next and it should be based on, but certainly not limited to, RP evidence on existing behaviour and policy interest in the new choice being tested/marketed. Guidance from earlier literature and focus group investigations can also be helpful in this regard. The number of alternatives included in the final design could be a subset of the choice set and is a function of experimental demands on respondents (cognitive effort required, number of replications), of considerations, of realism and of the means of presentation. The option of 'not travel' if relevant should always be included in the choice set (DfT 2006).

This is followed by the selection of an appropriate response method from three of the potential methods (rating, ranking and choice). However, choice is considered the most natural and most reliable for the study of new/uncommon/unconventional choices. Next are the issues of which and how many attributes to be included in the design. These issues are a function of policy objective/interest. Usually in travel choice studies GC components of interest are included. Numbers of levels for each attribute are specified next and depend upon the scope of policy interest but have implications for other aspects of the design and effects on task complexity. However, there exists a controversial literature on this (ibid) and as a general rule it is a function of the number of alternatives, attributes and their levels.

An important issue is the number of replications to be presented to the respondents. This also is a function of the numbers of alternatives, attributes and their levels, and any orthogonal technique adopted to combine the attributes and the levels. The final number is the result of a trade-off between certain pros and cons (mentioned in 5.2.3). Usually between 5-16 replications are given in the experiment depending upon the means of implementation and other issues like cognitive rigour, respondent fatigue and repeated measurement problem. It is important to note that task complexity can have considerable impacts on the response rate. However, the good thing is that the whole process can be refined and adjusted through testing procedures of: focus groups; simulation; and piloting at different stages. Focus groups are useful where a wholly new product or methodology is planned. However they are less necessary where the analyst has good understanding of the new mode (ibid).

5.3.2 The Design Context

The principal motive behind designing the experiment is to collect bespoke data for a bespoke SP model of teleworking choice with a predictive capability. The choice context is considered the fundamental element in the design of such a model and affects the choice of SP type. The context of study is to test the viability of teleworking as an alternative to travel and, thus, as an instrument of transport policy. This thinking has steered the design and determined its dimensions. More specifically, much of the impact of the adoption on the transportation system is through commute trips which are further influenced by the changes in teleworking frequency. A discussion on how the changes in teleworking frequency might influence generalised cost (GC) of travel and commute conditions and as a result might affect the level of teleworking adoption is provided next.

It may be argued that teleworking adoption and (change in) frequency are the result of separate decision processes with the latter dependent on the former. For the theoretical basis of a frequency projection model, this thesis relies on the well established concept of job accessibility which is modelled as GC of travel. It is postulated that the degree of teleworking frequency affects the job accessibility of a teleworker. It is also hypothesised that changes in GC through changed commute conditions are likely to influence the frequency or latent frequency – the frequency a teleworker would consider optimal relative to network conditions of her commute journey. It is also intuitively plausible looking at the sequence below:

Base GC of Travel → Teleworking adoption and (initial) frequency → changes Modal Share of commute trips → changes in flow → changes in congestion level (network conditions)→ new GC → new teleworking frequency

To reflect the proportionate effects of the travel demand reduced by the above sequence in the network conditions, it is suggested to be modelled in two stages: first, calibrating the proposed frequency projection model with the *initial* frequency in the base case and then letting it determine the *adjusted* frequency through an iterative modelling process. For this an understanding of the role of GC of travel in deciding whether to make a commute trip or telework is important. Here both elements of GC, i.e. travel cost and time, in contrast to DSE variables which may also have influence on the frequency at the adoption stage, will be treated as dynamic variables due to policy makers' control over them. Modelling frequency in this manner has at least three implications. It may influence the (further) adoption, may bring changes in the frequency of current teleworkers and in case of significant improvements in network condition may reverse the trend in adoption with people opting for car commuting again.

5.3.3 Design Dimensions

Four elements define the design dimensions. They are the choice set (number of alternatives to be presented to the respondents), (number of) attributes that define the choices, (number of) levels for each attribute and (unit) values that define the levels for each attribute. The development of the design is inherently an iterative process. After exploring many, often competing, ideas and issue related to them, the design elements shortlisted for final consideration are presented in Table 5-1. The discussion next evaluates each of the dimensions for its fitness for the final design.

5.3.3.1 The Choice Set

The behavioural responses which people exhibit to avoid congestion other than adopting teleworking are diverse and complex. There is some speculative literature and empirical evidence on these responses (see e.g. Salomon and Mokhtarian 1997, Mokhtarian et al 1997, Salomon and Mokhtarian 1998, Raney et al 2000, Cao and Mokhtarian 2005a, Cao and Mokhtarian 2005b). The list in the literature extends from various work arrangements to the potential strategies that can be adopted to avoid congestion or minimise its adverse impacts on a daily basis. Some of these, e.g. changing job and/or house require greater commitment besides being interconnected to other household factors. Buying an expensive car may not be possible for a great majority of commuters. Therefore, the responses which are expensive and have long term connotations about them are excluded from the list of potential alternatives for the design.

However, options like changing the departure time, changing the travel mode and opting for flexible work arrangements including a compressed workweek are relatively more feasible choices. Hence, the tentative choice set in Table 5-1 consists of eight alternatives (right most column) based on the notion of behavioural responses to congestion. Depending upon the perspective, six of them (four teleworking frequency choice plus work flexiweek and change travel time) can be regarded as belonging to flexible work arrangements. Four of them relate to teleworking choices or frequencies (telework 1-4 day).

Besides the argument mentioned in 5.3.2, there are other compelling reasons for inclusion of the frequency alternatives in the choice set. As the review of data collection approaches highlighted in 5.2, the potential link between the teleworking frequency and changes in commute cost and time, has not been investigated so far; particularly, not using the SP method. To collect RP data on this particular aspect appears quite difficult as travel cost and time do not vary significantly in reality over a shorter period of time. Finding an adequate sample of teleworkers who have been teleworking for a longer period of time, during which there are perceptible changes in travel times and cost, is the main obstacle. Add to this the inaccuracies in recalling the changes in travel time and cost by the respondents and the task becomes almost impossible.

Attribute levels	**Employee orientation**	**Teleworking cost payer**	**Employer's policy on telework**	**Total daily commute cost**	**Total daily commute time**	**Alternatives (Choice set)**
1	Family more important	Employee	Willing to permit those with needs	Stays same	Goes down by a quarter	Change departure time
2	Career more important	Employer	Allows everyone who wishes to telework	Up by 50 %	Stays same	Change mode
3		Shared	Promotion linked to employee attending usual workplace	Up by 100 %	Goes up by a quarter	No change
4			Employer permits but does not like it	Goes up by £2	Goes up by a half	Telework 1-day
5				Goes up by £4	Decreases by 15 min	Telework 2-day
6				Goes up by £6	Increases by 15 min	Telework 3-day
7					Increases by 30 min	Telework 4-day
8						Work flexiweek

Table 5-1: Tentative elements considered for the SP design

Section 2.6.5 established that an employee may be inherently constrained by one or other characteristic of her own environment to reject any or all of the alternatives. To ward off this possibility, it is necessary that the choice set must include alternative(s) which a respondent can choose regardless of experiment conditions. The alternatives of 'change mode', 'change travel time' and 'no change' have been included to cater to such eventualities. Changing time of travel and changing means of travel are relatively well established topics of study within the transport discipline, not necessarily from a congestion perspective but also in other contexts.

The various work arrangements have been given different names in the literature. The names include telework, telecommute, compressed week, flexiweek and flexitime. The difference between the first two is only a matter of definition. This thesis regards the compressed week and the flexiweek also as identical from the commuting frequency perspective though the former may mean an extended weekend. However, there is a need to recognise the difference between flexiweek and flexitime in terms of commuting frequency. In the latter an employee commutes all the days of the workweek while in the former situation, an employee performs all or the main tasks of her job at the workplace but commutes one or two day(s) less as the case may be. From a commuting perspective, this essentially means that telework and flexiwork are interchangeable terms while flexitime and 'changing travel time' are also close substitutes for each other because the commuters who are able to change their commute times are doing flexitime in practice. For this reason teleworking < 1 day per week was also treated equivalent to flexitime. This analysis shows that inclusion of flexiweek in the choice set would make little meaningful contribution towards policy analysis and run the risk of increasing complexity in the design. Therefore, flexiweek has been excluded from the final choice set.

5.3.3.2 The Attributes

Table 5-1 lists (the upper most row excluding the left and right most columns) five attributes which were considered for inclusion in the design. Two of them, employer's policy on telework and employee orientation, are categorical while the rest are continuous. However, the aim was to have three attributes at most due to considerations of simplicity and means of presentation for the experiment. Travel time and travel cost are natural selections as attributes not only because they are measures of accessibility in line with GC elements of the output of most demand modelling tools but also because they are the foremost policy levers of use under the control of a planner. Further, they are most commonly used in travel choice studies and have direct implications for policy intervention. For the one remaining attribute, the competition was among potential future legislation on telework, teleworking cost, and employee orientation.

The employee orientation attribute was thought of as having an influence on frequency from the employee's perspective and as providing an insight into their attitudes and behaviour towards teleworking. This insight could be helpful in predicting demand for teleworking and consequently for travel. The attribute was considered as having two levels in terms of an employee's relative preference for career or family.

Whether teleworking can be studied as a travel mode motivated the consideration to have teleworking cost as an attribute. As has been seen in section 3.4.3, it is difficult to capture teleworking cost quantitatively and its operational costs are likely to be negligible or quite small.

Traditionally telework adoption has been constrained by option availability, job suitability and technology availability (Mokhtarian and Salomon, 1996). The last of these constraints is becoming less and less active by the day. While some limitations of job suitability are inherent, the rest are a matter of management attitude and a function of job design. In this context option availability is the only area which could and should be the target of policy intervention. In this context and in line with the policy focus of the study, the employer's policy on telework was thought of as an attribute. It is significant to note that different levels of this attribute in terms of categorical policy statements would provide the planner with a control lever. This lever can be used to remove any constraint regarding telework availability. This is not the case with other two attributes as their dynamics were beyond the planner's control. 'The employer's telework policy' attribute was also thought of as 'future legislation on telework'. However, the use of the latter term does not offer the same flexibility as the former in terms of defining attribute levels. Thus, in the final assessment, employer's policy on telework was included as the third attribute along with travel time and cost and the attributes set thus contained both continuous and categorical attributes.

5.3.3.3 Levels of the Attributes and Values for the Levels

The next step in the design process involved a decision regarding the number of levels and selection of values for the chosen levels. Only the attributes selected in the preceding subsection are discussed. The main concerns here were that the levels themselves and values selected to represent them are realistic, are non-linear for continuous variables and have sufficient variations (in the numbers and unit values) to stimulate choice. For example, it is possible for travel time to go down as a result of management efforts or infrastructure and/or network improvements while travel cost has seldom shown a tendency to go down. For employer's policy on telework various combinations containing soft and harsh wording, giving monetary incentives, keeping it general or making it very specific were tried. But in the end after considerable deliberations a more generalised and softer version of four discrete levels was preferred to provide an adequate balance between the positive and negative connotations of the statements.

Similarly, for levels of travel time and cost both absolute values and relative values were considered (as shown in Table 5-1 under respective column heads). Both options have respective merits and demerits. Further, discussion with some participants in the pilot survey also helped in this regard. It was found that for the majority of the respondents it was easier to relate to absolute cost values. On the other hand, they found it easier to relate to travel time changes in terms of relative values. This is also understandable from the perspective of a transport policy planner who traditionally has more specific control over travel cost than travel time in terms of TDM measures. For example, a congestion or cordon charge will be expressed in absolute monetary units rather than relative to the travel cost. On the other hand it is hardly possible to determine the exact absolute time change resulting from a policy measure aimed at affecting travel times. Absolute values for the cost attribute were also preferable in view of car users' low ability to estimate their exact travel cost. Thus, it was decided to express travel cost changes as absolute values and travel time changes as values relative to current journey times.

Units for all the attributes, their levels and alternatives were also carefully considered and specified. For teleworking alternatives, the unit defined is a full day on the basis of a workweek of five days while travel time and cost have been specified for the complete return journey to and from work on daily basis. Different levels of each attribute included in the design are combined to create a hypothetical scenario to measure the response to given choices. Another important issue is to watch for correlations among the attributes when creating potential scenarios. This is discussed next.

5.3.4 Orthogonality in the Design

The principle of orthogonal design ensures that there are no correlations among the hypothetical scenarios tested in the experiment. There are potentially three ways to do this: full factorial design, fractional factorial design and determining the threshold of boundary values (Louviere et al 2000). This experiment has used the full factorial type of design. A full factorial design combines each level of one attribute with all the levels of all the other attributes to create the total number of hypothetical scenarios or situations (also called replications in the SP literature) to be presented to the respondents to consider and make a choice out of the given alternatives. This experiment has been designed with three attributes, each having four levels which under a full factorial design gave a total of sixty four replications. These are too many for a respondent to go through and make meaningful choices.

A large number of replications is a common problem when an experiment is designed with a degree of sophistication. Usually a medium of presentation can afford 9-12 situations meaningfully. This experiment presents nine replications to a respondent at a time. How the problem of sixty four replications was managed simultaneously making use of almost all the replications in the data collection exercise is described in the next chapter as part of the survey management strategy.

5.3.5 The Final Design Elements

The reasoning in the preceding sections motivated a final design whose dimensions include seven alternatives, three attributes and four levels for each attribute as presented in Table 5-2. The presentation of alternatives in the design is envisaged at two levels. An upper level of choices will study responses to the adoption and a choice set in the lower hierarchy will determine the response to varying degrees of frequency along with other behavioural responses to congestion.

Level	Total daily commute cost	Total daily commute time	Employer's policy on telework	Alternatives
1	Stays same	Goes down by a quarter	Willing to permit those with needs	No change
2	Goes up by £2	Stays same	Allows everyone who wishes to telework	Change travel time
3	Goes up by £4	Goes up by a quarter	Promotion linked to employee attending usual workplace	Change mode
4	Goes up by £6	Goes up by a half	Employer permits but does not like it	Telework 1-day
5				Telework 2-day
6				Telework 3-day
7				Telework 4-day

Table 5-2: Dimensions of the final SP design

5.3.6 Some Implications of the Final Design

Offering the flexibility of changing travel time or mode along with teleworking in the choice set has the potential of making the design more robust and less biased towards teleworking. From another perspective, it is also fruitful to test the acceptability of teleworking if the commuters are also offered the choices that relate closely to their existing travel behaviour. To have alternatives to teleworking in the design is also necessary for the sake of realism in the experiment.

To measure teleworking frequency response, the design presents four discrete choices of 1-4 days per week, hence assuming that teleworking on all 5 days of a 5-day workweek is a practical impossibility. The choice of one of the teleworking alternatives by a respondent, if made, would indicate three things: capability of adoption; propensity to adopt; and preferred weekly frequency of teleworking under a given set of conditions/scenario.

In principle the policy intervention should aim at testing the strength of teleworking adoption as an alternative in comparison to other behavioural responses to avoid congestion. This design not only explores telework adoption but also exposes the congestion problem from the inside out and focuses on the respondents' behavioural dimensions from a wider context giving them a broader range of choices.

Another implication of this design is that the inclusion of the attribute of employer's policy on telework may introduce a bias in respondents' choices as they might be predisposed towards their respective employer's existing policy on telework despite being given a free choice.

However, this experiment design, particularly the composition of the choice set, raises some issues that might have wider implications for data quality or model estimation at a later stage. These issues include:

- why only one response to each SP situation was allowed;
- why a combined choice like changing both mode and time at the same time was not allowed;
- why teleworking choices were constrained to 1, 2, 3 or 4 days per week; and
- why a continuous response variable such as "n times per month" was not considered.

Considering the composition of the choice set, the alternative interpretation of the first issue is to allow more than one choice response at a time. Within the presentational limitations of an SP experiment and considering all the possible combinations of choices of such a scenario, it was practically difficult to present a replication with such a complicated choice set. For example, it was easy for a respondent to make their teleworking choices over the week in such a way. There was, however, no easy way to elicit their responses to a particular non teleworking choice over a week. Besides requiring a sufficiently large sample base, this would have presented further difficulties in data coding and generating the data file for model estimation process under such a scenario. So, this option was considered not practically feasible.

On the second issue in the above list, a combined choice of simultaneously changing both mode and time could have been allowed as an additional choice in the choice set. However, it was not considered for a variety of reasons. It is seldom possible to design an SP experiment which could capture and *present* all the potential choices in the choice set to a replication. In this regard primary choices take precedence. This survey was aimed at car commuters, not at PT commuters. Therefore, the primary choices of interest in this study were car travel and teleworking. Mode switch studies cited in chapter one have indicated very little tendency for car users to change to PT. This tendency is likely to be stronger when travelling outside the peak. It is thus unlikely that many respondents would have selected a combination of change of mode and time of travel rather rather than neither option on its own. Therefore, it can be assumed without any great risk that no valuable data was lost from this survey by the absence of such a combined but additional choice.

The teleworking choices in the choice set were constrained to 1, 2, 3, or 4 days per week (the third issue in the list) for a variety of reasons. The choice set left out 5 days a week, which was considered unlikely for the reasons mentioned in the second paragraph of this subsection, and < ½ day a week which was omitted as having a limited impact on travel. Further, given its concern for reduced car use the study was interested only in whole day telework which implied one less commute trip per teleworking day. Part day teleworking was assumed to be treated as changing time of travel. Increasing the time scale to a month for the similar discrete choices on teleworking would have confronted the experiment design with the same range of problems as pointed for the above issues, i.e. those teleworking on full days of < ½ day per week would have required analysis over a month rather than fortnight.

The last issue in the list is about employing a continuous choice of frequency rather than four discrete levels. A response variable like "drive in the peak n times per month" might have some merit in the present situation as it might have given a respondent a broader range and fuller choice set to reveal her SP choice behaviour. However, the "n days per month" option would not capture the distinction between teleworking and other alternatives which is sought within this study design.

Further, the study decided on a modelling framework (ref 4.3) that uses the discrete choice modelling paradigm and logit model for analysis. In discrete choice analysis using the logit technique, estimating a model from data on combined discrete-continuous responses is rather complicated. This type of response is more frequently handled through regression analysis which is less complicated to apply. In the final assessment it is difficult to say whether important data on less than weekly teleworking will be lost through this design, especially in view of low teleworking frequencies to be found in the previous RP studies. This remaining dimension of the issue can only be addressed at the data analysis stage once the response patterns from the survey are known. This will be taken up again in sections 7.2.5 and 8.8.2.

5.3.7 The Design Testing Procedures and Limitations

Various considerations did not allow for formal *design* testing by focus groups, simulation and piloting though the final survey instrument was pilot-tested (section 6.6). An important issue regarding the presentation of an SP experiment within the vehicle carrying it is how the 'story' about the experiment is told to the respondent. The significant features of this 'story' are to keep explanations (instructions) about the experiment succinct, they should explain the choice context and alternatives, and why/how the attributes vary. It also describes the assumptions made and what was within the controlled experiment and what was not. All these aspects were taken into account while presenting the experiment to the respondents.

Given reasonable freedom of resources, the design could have been made more robust and comprehensive. This could have been done by putting the whole exercise through a staging process. It would have involved first recruiting a convenient sample and getting some exploratory details about them and then doing an SP study in the second stage on a full sample. During the first stage potentially some important information could have obtained and it may have been regarded as a quite reasonable RP study. Based on the information processed from these data, an 'adapted' preference experiment could have been designed in the second stage. This approach could have taken care of the potential sample bias problem arising from the exercise not interesting to the respondents because they would not telework.

Still another but relatively less robust option to deal with the issue of design testing could have been to find a sample of, say, 20-25 current teleworkers and to do the RP part of exploration on them. This would have provided the basis for the design of an SP experiment to be performed on a representative sample of the larger general population. However, it is helpful to note that though the situations created by the design are hypothetical, the choices are real. Thus, the experiment designed offers a combination of both RP realism and SP flexibility and control.

Some limitations of the design and the way it was presented to the respondents are also recognised. They include a certain element of difficulty and complexity, a somewhat unfamiliar choice context, and package effects of bundling information on different aspects of the study within one survey instrument. The limitations of presenting the experiment include relatively inadequate provision of information in the face of complexity of the design which at times required detail explanations (refer to the survey formulation process in the next sections), and a survey form which is a bit cluttered looking and daunting to respond to at the first sight (see Appendix V at 13.5). The final design is a departure from the dominant practice for similar studies where typically two alternatives are offered, is based on *choice* experiment as distinguished from other types (of *rating* and *ranking*) and offered four primary choices with a further four secondary choices if a respondent happened to choose telework as their preferred alternative.

5.4 Formulation of the Survey Vehicle

This section starts by exploring the influences on the formulation which were experienced during the process. This is followed by a description of the formulation process per se. Here issues like determinants of survey contents and structure have been considered and the work on individual tasks in the process has been reported.

5.4.1 Influences on the Formulation

The freedom to formulate a survey was constrained by many influences on the data collection exercise. The consideration of conducting a paper based survey with a modest budget (an issue addressed in detail in the next chapter) pre-determined the survey size (four A-4 pages) to avoid a low response rate. The rest of the internal and external issues to the formulation process flowed from the allied considerations of the survey budget and the response rate. Elements internal to the process include:

- study needs (the range of responses)/nature (more information to the respondents) and survey size considerations were pulling in opposite directions;
- type of survey instrument influenced the volume of the contents, how and in what sequence they might be presented;
- survey size imposed restrictions on the layout/presentation; and
- presentation of the SP experiment to target population and sampling strategy forced the structuring of the contents.

External elements were:

- Working under time and money constraints (which influenced all the theoretical issues on the subject and controlled all practical steps);
- Requirements of contextual, disaggregated data for modelling;
- Two approaches (RP and SP) being followed simultaneously for some responses (phrasing/text adjustment problem); and
- Generalisation and acceptability of the results (influencing the process through response rate issue).

5.4.2 The Formulation Process

Four distinct tasks characterised this process:

- determining the contents to be included in the survey,
- arranging them in a suitable order/thinking of a survey structure,
- conveying them through the use of an appropriate language; and
- presenting them in a proper and suitable layout.

All these tasks were taken care of in detail at every stage in the process and are described next.

5.4.3 The Survey Contents and the Structure

The formulation contained a preamble about the purpose of study and the respondent it was aimed at. The whole content of the formulation was structured into six sections. The first section captioned as ABOUT YOUR JOURNEY TO WORK contained following questions:

Q1 In a normal week how many days do you work? ______ How many days do you travel to work? ___ If you travel fewer days than you work, please specify why:___

Q2 At what time do you normally set off from home to work? _____ Am or pm (please delete as appropriate)

Q3 At what time do you normally leave work for home? _____ am or pm (please delete as appropriate)

Q4 How long does it normally take from your home to reach work (in minutes) ?.....

Q5 How long does it normally take you to get home from work (in minutes)? ......

Q6 What is the approximate daily petrol cost of your return journey? £______

Q7 About how much per day does it cost you to park at work? £______

The purpose of Q1 is to obtain data on work pattern (i.e. fulltime, telework or part-time), Q1a is to identify commute patterns and to correctly calculate the weekly generalised cost of commute while Q1b is to verify the reason for difference between the work and the travel patterns. Q2 and Q3 are to ascertain the actual commute behaviour by time of day and set a context for Q8. Q4 to Q7 are to determine the actual time and cost of the commute journey by car.

The next section of the formulation was structured to obtain revealed preference data about the travel alternatives available to a respondent in the face of congestion on their journey to work and is accordingly named as ABOUT YOUR ALTERNATIVES. It was split into groups of questions on change of time of travel, change of mode and availability of teleworking. It included the following questions:

Q8 Would it be possible to save travel time by changing the time at which you depart to or from work? Yes.... □No /already departing at optimum time... □(Please go to Q10)

Q9 If you were to change departure time to save travel time, compared to your usual time about how much: A) Earlier/later would you set off for work? __ Min. earlier/later (please delete as appropriate) B) About how much time would you be able to save? ___Min C) Earlier/later would you return to home? ___Min. earlier/later (please delete as appropriate) and D) about how much time would you be able to save? ____Min

Many commuters consider changing departure time as a way to avoid congestion on their journeys. This set of questions is included to confirm whether such an option would be available to a respondent in the base case and, if possible, what additional utility if any can be derived from acting upon this option. Cost savings associated with changing departure time were considered extremely small, thus not likely to affect the overall utility. Therefore, only time savings were focused on in this alternative. Q9a and Q9c are to identify the pattern of any change in travel behaviour with regard to time of the day and to permit segmentation analysis based on that pattern.

Q10 Would it be possible to save travel time by changing the means of travel you use to or from work? Yes................□ No (not feasible/already using best means)......□ (Please go to Q13)

Q11 If you were to change means of travel, which means would you use? Bus...□ Train...□ Cycle...□ other (please specify) _________

Q12 If you were to use the means of travel you indicated in Q11 in both directions for your work journey, compare to your usual means about how much more or less:

A) Travel time would it take? _____ Min. more/less (Please delete as appropriate) B) Would it cost you? £_____ more/less (Please delete as appropriate) C) Walking time (if *any) would it involve? _____ Min. more/less (Please delete as appropriate) D) Waiting time (if any) would it involve? _____ Min. more/less (Please delete as appropriate)*

The objective of Q10 and Q12 is the same (including the assumption about additional utility) as for Q8 and Q9 except that this set of questions applies to means of travel (mode) options because changing to alternative travel modes is considered another option when car commuters face congestion on their journey. In Q9, the intention was to refer to the possibility of both cost and time savings, and to ask about the scale of the associated cost and time savings in Q12. However, it was discovered later on that an error had crept in during the formatting of the survey due to the use of copy/pasting function which excluded the word 'cost' from Q10.) Q11 is to ascertain the preferred mode as an alternative to car to permit mode based segmentation analysis.

Q13 Is any type of Teleworking arrangement possible/permitted within your organisation? Formally possible (allowed as Firm's policy) .....☐Informally possible (allowed by my manager)......☐ Possible but job unsuitable......☐ (Please go to Q19) Not permitted...☐ (Please go to Q16)

Q14 Do you currently telework? Yes ......☐ No.....☐ (Please go to Q16)

Q15 If yes, how many full days per fortnight do you telework? _____ (Please skip next Question)

Q16 Suppose that teleworking is permitted, would you consider teleworking?

No...............☐ (Please go to Q19) Yes...............☐

Q17 If you were to telework how much would it cost you per day (include costs such as phone, internet, energy bills, etc.)? Zero.......................☐ Less than £1.0......☐ between £1.0—2.5........☐ between £2.5—5.0......☐Between £5—10..............☐ above £10...................☐

Q18 Who would pay this cost? Myself......☐ Employer......☐ Shared......☐

Like Q8 and Q10, Q13 is designed to check the availability of an alternative. This time it is teleworking. In view of significant variations in employers' attitudes towards teleworking and job related constraints on teleworking, respondents were given the four response options. The range of response options could have been broader and potentially the wording of the responses might also have been clearer. However, these issues have to be balanced against considerations of content size and manageability. Q14 and Q15 are to determine current teleworkers and their teleworking frequency in the sample. The use of a fortnightly scale (instead of a weekly one as used in SP design) for frequency was motivated by the fact that in the literature the frequency has generally been found low. Q16 asks about the preference for telework and is meant to identify the market for telework acceptance without any intervention. Q17 is to determine teleworking compares with the competing alternatives in terms of its costs and thus utility. The range of response categories to this question is kept deliberately broad because this question was to apply to both the current and potential teleworkers and the latter group may have no idea of such costs. Q18 is to indicate the expectations of who would pay for teleworking costs and consequently inform analysis on defining teleworking programmes for the employer or policy maker.

Besides obtaining the RP data and determining the utilities of preferred alternatives, QQ 9-18 are also meant to set a context to the SP experiment, to get the respondent into a proper frame of mind before going through the experiment and to explore their capability to use any of the available alternatives. Overall, the questions in this section are framed in such a way that a 'yes' answer would lead further to a subsequent set of 4 questions on each alternative (see Q9, Q12 and QQ 14-17 respectively for each of the three alternatives). Besides exploring the extent and strength of their RPs, Q9, Q12 and QQ 14-17 are also needed to determine the generalised cost of that alternative relative to car commuting. Also, this section contains detailed instructions regarding: explanation of the available alternatives; how to record an answer to a particular question and skipping logics if a certain alternative or question does not apply.

> *Q19 Is there any other alternative you would consider to avoid congestion or save time on your journey to and from work and/or save time? No..... ☐ Yes ...... ☐ (Please specify__)*

Q19 is included for completeness and to ascertain whether the respondents were thinking of any other alternative.

In the third section of the formulation, titled as ABOUT YOUR CHOICES, the SP experiment designed and described in section 5.3.3 is included. This is the most critical part of the formulation and is meant to produce the main output of the exercise. The purpose of the design is to estimate a model that could forecast telework adoption and frequency of teleworking in the face of imagined changes in travel cost and conditions, i.e. hypothetical scenarios created to replicate the policy intervention. This is a controlled SP experiment applied to those currently commuting during the peak periods only for whom changing to other alternatives were an option. For reasons mentioned in 5.3.6, the teleworking choices were constrained to a week in contrast to a fortnight in RP Q15.

Section four of the survey is headed as ABOUT YOUR ATTITUDES TOWARDS TELEWORKING and consists of the following eleven attitudinal statements:

> *Please think about teleworking and mark each of the following statements on a scale of 1-10 where 10 indicates a STRONG AGREEMENT while 1 indicates a STRONG DISAGREEMENT.*
>
> *Teleworking does/would provide me with more time for myself/family. ___*
>
> *I do/would lose on learning opportunities and social interaction at my workplace when/if I telework. ____*
>
> *Teleworking does/would provide me with increased flexibility in scheduling my day. ___*
>
> *Working from home does/would adversely affect my chances for career advancement or promotion.____*

I do/would like the increased independence in doing my job afforded by telework.____

Teleworking does/would increase work-family conflicts. ____

Teleworking does/would save me commuting costs and stress. ___

Teleworking does/would develop a sense of isolation. ____

Working from home does/would increase my job performance/make me more productive

Teleworking does/would help in catering to caring needs at home. ____

My manager approves/ would approve of me working from home. ____

As evident, these statements relate to different aspects of teleworking perceived as its advantages and disadvantages based on the literature review (section 2.7) and are meant to determine the respondents' liking and disliking of teleworking and to test the strength of their preferences or otherwise for teleworking. While DSEC variables indicate the degree of ability to telework, attitudinal variables in the form of drivers and constraints determine the willingness to adopt. The rationale for their inclusion has been discussed in 5.1 and 5.2.2. Similar statements have been used by Mahmassani et al (1993) and Mokhtarian and Salomon (1997) in their studies.

Section five is captioned as ABOUT IMPACTS OF TELEWORKING. It addresses the two remaining responses to telework adoption and contains the following questions on the non-work travel and the location behaviour of current and potential teleworkers:

Q20 Is/would the car no longer used by you for travelling on a teleworking day (be) used by you or another member in the household to make (tick as many as apply)? Journey to Work by someone else……☐ Shopping trip…………☐ School/escort trip……….☐ Additional leisure trip…………☐Any other unplanned trip……..☐ Would not be used………☐

Q21 As a result of your answer to Q20, do you think the number of non-work trips by car per week made by your household on average would/do change? Yes………☐ No………☐ (skip next Q)

Q22 If yes, then how much is/would be the change per week? 1-3 trips more …….☐ 4-6 trips more……..☐ Above 6 trips…….☐ 1-2 trips less ……..☐ 3-4 trips less…☐ Below 4 trips……..☐

Q23 Does/would your adoption of Telework make it convenient for you to move house to a preferred location? Yes……☐ No….☐ Don't Know……☐Very happy with my current location…………☐ (Please go to next section)

Q24 Does/would your household circumstances if you were to telework, allow you to relocate to your preferred location? Yes……☐No……☐ (Please go to next section)

Q25 Now please tick one of the following choices: I have already relocated……☐ Yes, I would relocate…☐ I am thinking/would think of relocating…..☐ No, I would not relocate…☐

The rationale for these questions has been discussed in 5.1 and 5.2.2. Q20 seeks information on the potential use of the car released by teleworking and the type of trip for which it may potentially be used. Q21 and Q22 measure the non work travel impact of teleworking. Q23 is to test the strength of the hypothesis that teleworking dilutes the importance of job accessibility in determining residence location. Q24 is to determine to influence of household circumstances on residence location decisions in the context of Q23. The rationale for this particular question is that residence relocation would not be solely motivated by telework adoption. It requires fairly long term commitment to the decision and involves other household members and factors. However, it was decided not to explore the nature of these factors in any detail. Q25 is to determine the nature of any relocation decisions and intentions.

The study scope and various constraints on the survey activity did not allow for a controlled experiment as was done for teleworking adoption and frequency. This section applies to only those respondents who are either already teleworking or have chosen to telework in any of the nine hypothetical situations administered under the SP experiment in a given survey version.

In retrospect it must be noted that questions 8, 10 and 13 are not reliable as indicators of choice set and, along with question 18, contain ambiguities. While questions 23 and 24 are open to misinterpretation due to their grammatical structure.

The final section of the survey is designed to obtain factual data for segmentation analysis. Its title is ABOUT YOU AND YOUR HOUSEHOLD. Q26 to Q37 are on demographic and socio-economic variables, and car ownership while the last three question and related sub-questions explore access to ICT. Most of the questions on these aspects of a respondent/household are included in the survey for their explanatory relevance and power, as identified in the literature on the subject. These DSE variables were segmented along the categories generally recognised by the models to be used for the analysis and forecasting.

5.4.4 Instructions/Skipping Logic

Instructions are very detailed sometimes at the cost of compromising the open spaces given to the respondents within the layout of the survey. Two (sections two and five) of the six sections of the survey include skipping logics and detailed instructions regarding how to record the answers properly. In section two of the survey the skipping logics are mainly aimed at identifying the respondents to whom the subsequent questions about a particular alternative apply. The instructions were meant to guide the respondents on how to record a response and to explore the extent and use of the three competing alternatives by them (the car commuters) compared to their current or base situation. In section five skipping logics have been used to quickly guide the respondents through the section and take them to the questions that apply to them.

5.4.5 Order and Linking of Contents

Implicitly, subsection 5.4.3 has also explained the order and linking of the survey contents. At an early stage in the survey development process, it was considered more appropriate to identify respondents whose jobs are suitable for teleworking and screen the others out. But due to considerations of non-response bias and unavailability of a sufficiently large sample of teleworkers at very low cost, this idea did not carry through. However, the issue of non response bias continued to influence the survey formulation process. For the same reason, it was decided to relate the survey to the general issue of congestion and not to reveal the focus on different aspects of teleworking until the respondents were well into half way through the survey. This consideration along with the inclusion of the SP experiment determined the order of the contents shown in subsection 5.4.3.

5.4.6 Format and Layout issues

Both these issues were given due thought. The format targeted and emphasised the significant aspects and information provision in the survey and can be viewed from a copy of the final version of the survey given in the Appendix V (section 13.5). The Institute's full name and logo was included on the first page to distinguish it from commercial studies by the respondents and positively influence the response rate. The layout managed about 65 questions in total in four A-4 size pages. This includes nine SP situations, eleven attitudinal statements, a brief introduction and detailed instructions on alternatives and skipping logics. Some space was also provided at the end for the respondent's optional comments about the survey.

5.5 Conclusion

In practice, the processes of designing an SP experiment and formulating the survey are not as sequential or smooth as appears from this description; it involves shuttling back and forth among different steps and juggling with different formulations within a particular step. The two factors that have driven the entire data collection exercise and overridden any other considerations from the start to the end are: the study objective and scope and the cost considerations. Both were pulling in opposite directions.

The resulting two factors, i.e. the sample size and the survey size have controlled and steered all the ensuing processes. The sample size determined the targeted population, sampling strategy, survey distribution and response collection (all discussed in the next chapter) while the survey size restricted the volume of the contents and influenced each and every aspect of the formulation process, from word count to layout. In the end survey size forced the changes in the structure and organisation of the formulation, and the sampling strategy.

This chapter has seen the development of a survey formulation which would be converted into an instrument using the most appropriate medium of presentation for the purpose considering various factors influencing this decision. This is taken up in the next chapter.

6 The Survey Management

6.1 Introduction

The whole data collection exercise may be separated into softer issues and harder issues for convenience of understanding. The previous chapter dealt with the softer issues. In this chapter the harder issues are taken up and the work done on the survey management activity is reported. The harder issues include: decisions on the type of the survey instrument, on the survey administration and sampling techniques; formulation of the survey strategy; and the survey administration to the selected sample. This chapter has been organised as follows.

In the next section the issues of activity scale and presentational media are explored which help identify the relevant survey administration techniques. These techniques are comparatively evaluated from a general perspective and their cost implications are also assessed. Section three looks into the budgetary issues, their implications for the initial scale of the study and redefines the focus and scale of the data collection activity to match the circumstances. In this situation a compromise has been sought while exploring the relevant sampling techniques. At this stage the issues of the type of the survey instrument, of survey administration and of sampling techniques are solved and a survey strategy emerges. The execution of this strategy is described before the chapter finally ends by reflecting upon the experience and distilling the lessons learnt.

6.2 Survey Issues and Techniques

This section first deals with some general survey issues which help identify the relevant survey administration techniques. The three shortlisted survey techniques are comparatively evaluated using a set of relevant criteria and an assessment is made. After that the cost implications of the relatively better technique for an *initially* determined scale of activity are considered.

6.2.1 Activity Scale and Presentational Issues

For data collection, the study nature requires a general snapshot of the workforce within the geographical area of interest in the absence of any particular sampling focus. The disaggregated modelling requires this snapshot to be taken from the segments of the population of interest based on disaggregation principles usually employed for transport mode choice studies. Thus, based upon four SEGs, three car ownership categories and three geographic divisions of city centre, suburban and rural areas, the count of sub-samples comes to 36. Assuming a minimum requirement of N=30 for each sub-sample for an adequate representation of the population in it, the estimated number reaches roughly 1000 responses with complete values. Richardson et al (1995) and communications with the in-house expertise (ITS, University of Leeds) suggest that a 10% response rate is likely for a survey consisting of four A-4 pages (the issue of survey size was dealt with in section 5.4.1). With this response rate 10000 potential respondents need to be contacted for 1000 valid responses.

However, the number of SEG categories can be reduced to 3 for a simpler predictive model which may be able to run with the data from fewer sub-samples. Further, N can also vary between 25-30 responses per segment. This means that the total number of valid responses may fall in the vicinity of 700 (requiring distribution of 7000 surveys at 10% response rate). This can still be regarded a very demanding scale of the exercise for a PhD project. This scale of the activity formed the *initial* basis for planning of the survey management activity and survey techniques.

With the survey formulation, a rather significant first issue was to decide about the medium of presentation for the survey contents. Besides the overall volume of the contents and inclusion of an SP experiment in it, the other criteria that could decide the selection of the survey medium include: suitability of the available media for carrying the formulation to the respondents and presenting it as required; and ability of the selected medium to generate the required number of the responses. Resource availability understandably acts as the first shortlisting factor because if resources are not available for a medium to carry through then its suitability is of no use.

Available media for carrying a survey formulation to the respondents are: paper, telephone and computer. The medium of computer offers further sub-options of presenting the survey by hosting it on an internet web page, presenting it through an e-format and sending it to the respondents as an email attachment or using software to write a programme that stores the formulation and presents one question on the computer screen at a time during a face to face interview. The last option is popularly known as CAPI (computer aided personal interview). Along with mail back surveys, it is the most commonly used medium for choice studies (DfT 2006) as it facilitates the randomisation of replications of an SP experiment and can cope with complex branching logics not efficiently possible within the competing media.

At this stage a literature review of these and other potentially relevant survey techniques was done. The use of the telephone medium was considerd much less suitable to support the communication of the SP experiment included in the formulation. Each of the computer based presentation media has different presentation requirements. Resource availability and these considerations precluded all the options from investigation except paper-based survey, creation of a web presence and presenting it in an e-format. All these options are connected to three main survey techniques. They are: household/postal survey, intercept surveys and electronic survey.

6.2.2 The Evaluation Criteria

The selection of these criteria is motivated by practicality, ease of use, and, above all, cost considerations. To evaluate the short listed survey techniques, the following criteria have been used:

- expected response rate associated with a technique
- ability of the technique to facilitate sample recruitment
- ability of the technique to yield the required sample
- ability of the technique to support/afford socio-eco and geographic representation
- legal issues involved
- level of in-house expertise and support available
- commercial Software requirements if any
- data analysis issues
- time required to complete the activity including data analysis
- ability to accommodate the survey contents and design.

These criteria are applied to the household/postal, electronic and the intercept techniques which are evaluated in Table 6-1. The first two techniques have two relevant variations each which are listed under the respective column head in the table. The last in the list also has two variations: face-to-face interviews and personal-distribution-and-mail-back. However, the problem of communicating an SP design and other limitations that apply to telephone surveys (already excluded from consideration) also apply to the face-to-face version of the intercept technique. Therefore, this version of intercept technique was also excluded. Besides the criteria applied in Table 6-1, the offer of an incentive for participation in the survey was also considered. However, it was not carried through due to considerations of funds availability, becoming legally bound to complete the exercise and its requirements being in conflict with the confidentiality promise and personal data protection guidelines.

6.2.3 Initial Assessment

The comparative evaluation in Table 6-1 affords an initial assessment. It appears that paper-based survey techniques as distinguished from their computer based counterparts within the present context, especially anonymous postal surveys, are more appropriate on most of the criteria, especially due to practicalities and availability of in-house expertise. On conceptual appropriateness all techniques score equally well. However, the electronic option has an edge on account of ease of carrying out the activity but this has to be balanced in the face of unavailability of in-house expertise and its cost. The main limitation of the electronic survey technique is its limited reach as only about 50%

Criterion	Self-completion household/postal		Electronic-internet based		Intercept*
	Postal anonymous	Postal non-anonymous	Creation of a web-presence	E-mails	
Expected Response rate	Typically around 10% for a size of 4 pages**	Typically around 10% for a size of 4 pages	Depends on the route of access, as low as 4% with direct mailing of the web-link	Depends on the route of access, as low as 4% with direct mailing	Typically between 15-25% for a size of 4 pages
Ability to reach the target population	Maximum	Maximum	Reduced, around 50%***	Reduced, around 50%	Maximum
Ability to support socio-economic and geographic sub sampling	Yes	Yes	No if direct contact. Yes if email addresses purchased from commercial firms.	No if direct contact. Yes if email addresses purchased from commercial firms.	Depends on the place of interception
Legal issues involved	No or insignificant	Yes	As above	As above	No
Level of in-house expertise and support available	Yes	Yes	No	No	Yes, but mainly personal effort required
Commercial Software requirements if any	No	No	No if done through a commercial firm	No	No
Ease of Data handling	Manual handling	Manual handling	Electronic handling	Manual handling	Manual handling
Time required including data handling	Usual (4-6 weeks)	Usual	Relatively low	Usual	Usual
Ability to accommodate the survey contents and design	Good	Good	Excellent	Satisfactory	Good
Restrictions on the size due to response rate	Yes	Yes	Can afford to be a bit flexible	Can afford to be a bit flexible	Yes

Table 6-2: A comparative evaluation of three survey techniques (Notes: * this technique involves some form of personal contact usually at a public place and has many variations including intercept interviews, ** For discussion on survey size, refer to section 5.4.1 and 6.2.1, *** As per figure quoted by Office of National Statistics (2004) at the time of planning for this task.)

of UK households had internet connectivity in 2004 according to ONS figures at the time of planning for this task. This would inevitably have biased the sample. Evaluating paper-based options only, an important consideration is the data demands of the study due to the number of responses being studied. This has to be balanced against limits imposed on the size of the survey by response rate considerations. The general rule in this regard is the larger the survey size the lower the response rate with cost implications. In this context, web presence versions of electronic techniques offer considerable flexibility through the function of branching logics. The formulation of contents can be tailored to the interactive respondent's individual preferences and data on the responses of different transport mode users can be obtained easily. The use of a branching logic function considerably affects the survey size and the size limitations of the paper based format do not appear that stringent when using electronic media. Overall, creation of a web presence appears relatively more appealing at this stage.

6.2.4 The Estimates of the Survey Costs

The total cost of employing each technique can be separated into components. Different cost components are involved in different variations of each technique. Creating a web presence for hosting an online survey using electronic techniques either requires doing it yourself or enlisting a commercial firm for the purpose. Doing it yourself requires in-house expertise, personal time and effort, and purchase of commercial software. Main cost components charged by a commercial firm are cost of conversion, cost of hosting the online survey, cost of purchasing panels of email addresses (batch based) and costing of coding (batch based). However, the use of the email variant of the electronic technique requires only purchase of panels of email addresses and it works by handing over the message to the marketing company which owns the addresses and broadcast it to the targeted respondents. In-house expertise and resources for web creation were not available. This meant hiring a commercial firm to do this. It involved obtaining cost quotes from three different vendors for the required level of activity. The response rate was estimated at 4%. The average amount from these quotes was about £9750. The use of the email variant of the electronic survey technique with the same response rate resulted in a cost outlay of about £5500.

Survey cost is mainly a function of both survey size and response rate while in a paper based survey the former determines the latter. From this perspective, the intercept technique and anonymous posting of the surveys has the advantage as any other variant of the technique would involve two processes: first recruitment process then actual survey administration. The cost components of a paper based survey are costs of printing, of reply paid envelopes, of covering letter on letterhead, of mail merge, mail back postage per reply and cost of inserting. Other specific costs involved are cost of purchase of addresses from the electoral rolls and additional postal cost of sample recruitment. The estimates of cost for defined scale of activity, i.e. sending 7000 anonymous A-4 sized 4-page questionnaires came to £2570. This outlay excludes the distribution cost following the intercept technique.

6.3 The Available Survey Budget and its Implications

Compared with the cost estimates for different survey techniques in the previous section the budget available is very small. Allocation of project funds for this purpose was indicated at about £400. Thus, the budget availability emerged as the principal limiting factor and ruled out all the options in Table 6-1. However, there is another perspective to look at the issue, i.e. in terms of fixed and variable cost components of the activity. The option of creating a web presence has a substantial fixed cost component attached to it which is independent of the scale of the activity. This technique may be more suitable where there are advantages of scale to be realised. However in the present case, its fixed cost components far exceeded the available funds. The rest of the techniques can still be relevant if it is possible to reduce the scale of the survey activity. For this reason, the creation of web presence was excluded from further discussion of the relevant survey techniques. Thus, the next issue was whether it is possible to reduce the scale of the exercise without compromising the focus and scope of the exercise.

6.3.1 Options for Reducing the Survey Cost and their Potential Implications

The cost estimates in the previous section are for obtaining 700 responses by employing different techniques at different response rates. This means that as long as the scale of the exercise remains constant, it would hardly affect the cost levels. To address the issue of scale of the exercise, the obvious option is to accept a reduced number of sub-samples required by defining the population segments broadly. This would result in fewer observations from the whole sample. The other option is to dilute the focus by reducing the number of observations required per sub-sample. As a result the number of valid responses required per sub-sample would also be lowered. The issue to be decided here is whether to use the option of defining the segments broadly or reduce the number of valid responses required per sub-sample or both.

Reducing the scale of SEG and geographic representations or thinning the focus or doing both would have implications in terms of data input for the forecasting framework and for analysis at the desired level of disaggregation. But hopefully the potential effects of these implications may not be very profound as some broad categorisation and interpretation of the data would still be possible and usable for the models. However, this might weaken the depiction of behavioural relationships. It would imply a compromise on the overall quality of the results of the study. The other implication here seems to be of a compromise on the representation of the population in the study. A compromise on focus and scope in this way is likely to result in issues of generalisation and acceptability of the study results.

So far the overall focus of the exercise has been the general population or a sample of the entire workforce. Other options to address the issue of cost may involve shifting this focus and taking a completely different approach. This approach may involve focusing on a sector(s) within the economy or subgroup(s) within the workforce and segmenting it along SEG and other categories represented in the modelling tools to be used. This approach may focus on those groups within the economy wherein the incidence of teleworkers is likely to be greater. For example, this can take the form of targeting non-manual workers or university graduates in the workforce.

Still another option could be to do completely away with the SEG and geographic representation and define some other criteria to achieve the objective that may also have fewer implications. One such avenue could be to target specific businesses or firms. However, targeting only one business or organisation would impose severe limitations on the study results. The entire exercise may result in a largely bland data set unable to exhibit adequate behavioural diversity and, thus, in problems in isolating the effects of various variables at the analysis stage. A further implication of the results obtained from such data would be whether the results and conclusions drawn from them would be transferable to other populations. A potential way out of this might be to recruit a roughly representative sample of firms.

For all these suggested options, both types of survey instrument i.e. an electronic or paper-based survey can be employed. However, the foregoing discussion has identified another related issue, i.e. of sampling. This means that the issue of the suitable survey technique also needs to be evaluated from the sampling perspective. In this regard it is helpful to review different sampling strategies to see if a suitable strategy can be helpful in solving the problem of balancing a limited budget against the objectives of the exercise.

6.3.2 Redefining the Focus and the Scale of the Exercise

In any case the available budget is not expected to support a relatively diversified and broad based sample of the general population and the previous section has speculated on the different options to redeem this situation and their respective implications. In more than one way the design of the SP experiment to be carried out through this survey is similar to the choice of a new mode. Mode choice modelling will often involve choice-based sampling, whereby the existing users (i.e. choosers) of a mode will be surveyed (DfT 2006). Drawing a parallel from this the survey can be directed at those groups of people who are either currently practising this choice or can be reasonably expected to be capable of choosing it.

Further, during the discussions with the experts it emerged that a robust choice model of behavioural response could be estimated from 200 observations. Therefore, it is very reasonable if the study focus is narrowed down to those who have the propensity to choose telework and can also yield the required number of observations within the available budget. This moves the focus of investigation towards exploring the techniques which could be relevant for sampling this group. A review of the topic considered all the potentially relevant sampling techniques and shortlisted three competing strategies for further investigation to see which strategy fits the requirements and circumstances best and can be trusted to yield the required sample in a more cost effective way. They are:

- Intercept sampling through brief interviews and questionnaire distribution at car parks or activity centres
- Contacting relevant firms and enlisting their support in the survey administration
- Targeting higher SEG households through a postal survey in specific locations

6.4 A Comparative Evaluation of the Relevant Sampling Techniques

The shortlisted techniques are evaluated using 12 criteria in Table 6-2. The criteria are again motivated by theoretical and practical considerations, particularly cost of the activity. These techniques were subjected to further investigations which included on-site observations, literature review (Richardson et al, 1995) and key resource person interviews and the results of the effort are summarised after the table.

6.4.1 Intercept Sampling in Car Parks

The assessment and conclusions in this subsection are based on on-site visits to car parks, discussions with the supervisors of the study and interviews with the key resource persons[6] at the Institute for Transport Studies, the University of Leeds. This technique was particularly explored because the survey is aimed at car commuters. The idea here was to select a sample of car parks from all the car parks in Leeds, particularly in and around the city centre catering to different types of businesses. Still another idea

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[6] *Prof Peter Bonsall (Professor of Transport Planning), DrPaul Firmin (Lecturer), Ms Nusrat Walid (Survey Officer), all from Institute for Transport Studies, University of Leeds, England*

was to have equal representation of respondents recruited from car parks and businesses (6.4.2) in the final sample.

Criterion	Intercept Sampling (in car parks)	Sampling through Businesses	General Household Sampling
Relative Cost in monetary terms	Somewhere below average	Lowest	Highest
Response rate in relative terms	Somewhere in the middle relative to the competing techniques, More than 25% can be expected	Highest, more than 50% can be expected, depends on if there is a personal contact or contacted through a liaison	Lowest, About 10-15 %, in view of car focus would drop even further
Socio-economic representation	Not possible	Not possible	Possible
Geographic representation	Not possible	Not possible	possible
Non-response bias as a problem	Yes	Yes	Yes but less than the others
Sample selection bias	Yes	Yes	No
Self selection bias	Yes, to some extent	Yes, to a large extent because of choosing a particular firm	No
Sampling nature and management	By its very nature, it is random sampling but some rigorous statistical sampling is still possible but logistics would be a big problem	Non-probability, stratified and convenient sampling, probability sampling is possible but respondent or firm recruitment would be a big problem	Probability sampling possible
Control over the sample	Minimal control	Considerably controlled sample	No control over the sample
Time required to complete the activity	3-4 weeks	1-2 weeks	1-2 weeks
Respondent's expected difficulty level in completing the survey	Average or below average	Low	High
Changes needed in the current survey content/additional questions required	No	No	Yes
Summing up	Practical but some aspects are difficult to manage	Also practical but some biases are unavoidable	Theoretically sound but costly

Table 6-2: A comparative evaluation of three sampling techniques

For sampling in car parks using an intercept technique, formal permission from the car park manager is needed which is sometimes refused. In Leeds at least three types of parking arrangements are available: Public off street parking accounts for about 30% of the total parking spaces available in the city area controlled by both public and private owners; Private off street parking which has a share of about 60% of the total spaces; and the rest (about 10%) of the spaces are regulated by parking meters. However, a large proportion of commuters (population of interest) uses private off street parking and it is less likely to get the permission for distribution of an intercept survey at these facilities. The commuters who use these parking places can also be recruited through business based sampling.

Once allowed in the car park, three potential ways can be used to contact the potential respondents: fly posting the survey on the windscreens, distribution at the exits and approaching and engaging the potential respondents individually. With the first and second, there is no or minimum personal contact with response rate between 10-15%. One expert's experience has proved that it is difficult to engage people in interview in car parks. Being in a hurry during the peak periods only adds to this difficulty and it is also very awkward to manage the interception logistically. If the right respondents are targeted and a minimum personal contact is established, then about 20-25% response rate can be expected. The morning peak is recommended for conducting the activity. It is definitely the most time consuming of the three options. There are enough car parks in and around the city centre for the distribution of 2000 questionnaires. In conclusion, 'it is quite difficult to conduct' sampling in this way.

6.4.2 Business Based Sampling

This technique can be executed by either focusing on just one large organisation or by recruiting a sample of firms, thus ensuring an adequate representation of the workforce from all the relevant industry sectors. Its use has consequences for geographic representation of the population if a particular LUTI model or component calibrated on a specific study area is used in this study. The underlying premise here is that a sample of firms is easier to recruit than a sample of individuals.

Successful use of this technique depends upon the degree to which potential firms can be convinced of the utility of the research and the ability to sell the research idea as if it fits within a firm's business objectives. Selling to, and acceptance by, the firms would also depend upon the nature of their businesses. Organisations like Leeds City Council (LCC) are more likely to cooperate as are large firms compared to the smaller firms with fewer employees. A key factor in this regard would be to try to minimise the man-hours required from a particular firm.

For actual management of the survey activity following this technique, it is recommended to have one liaison point within each firm instead of making personal contact with individual respondents. Either way, any particular bias creeping in through the contacting activity must be watched for. The response rate with this strategy could be the highest possible through a sampling technique. However, a reasonable estimate could be put at above 50%. An effective way to do this could be to enlist the support of someone higher in the firm's hierarchy. Personalised letters to identified persons could be followed up by phone calls (this order can be reversed) for further motivating them to support this activity. Given the circumstances, it is probably the most practical way of doing the exercise. However, in the opinion of one expert, it can be recommended only it if the study is prepared to accept certain biases.

6.4.3 General Household Sampling

The most random form of sampling with no control over the sample, it also causes a respondent relevancy problem as irrelevant people might fill the questionnaire. In view of the content and design of the survey instrument to be used in this exercise, it may not be easy for the general population to complete it. This is likely to affect the response rate which is already low for this type of sampling. An offer of some incentive could have been an option to influence this but budget limitations foreclosed this consideration. Further, the offer of an incentive may bias the responses positively.

One source says that 80-90% of total responses are received within one week and an overall response rate of 20% can be achieved. There is also the relatively big problem of missing data with this approach which adds to 'waste of resources'. However, another source thinks that, 'for validity and grossing up, household sampling is the best technique' for this study.

6.4.4 Suitable Sampling Strategy

The bottom row of Table 6-2 summed up the relative worth of each of the evaluated strategies. The previous three sub sections have further looked into the practical aspects of implementing these strategies. On the basis of these investigations and assessments and judging by the ultimate criterion of cost of implementation, business based sampling has been concluded as the best technique. Thus, it was decided to conduct the survey activity through business based sampling.

6.5 Defining the Sampling Frame

The next step necessitates the defining of a sample frame in accordance with the redefined study scale and selected sampling technique. Following the argument about 'existing users' from section 6.3.2, the potential sample frame may be a population of existing teleworkers and potential adopters who use the car as their usual means of travel, to be found at employers in and around Leeds city centre which employ knowledge workers in considerable numbers. This is further motivated by the following considerations:

- There is a greater likelihood of the target population being found within these firms;
- Travellers to the city centre and surrounding area are likely to experience more congestion than others; and
- It is relatively easy to establish contact them due to their convenient location.

6.5.1 Sample size and Selection

Sample size is a function of model estimation requirements and the required minimum number of observations with complete values for this purpose has been set at 200. Further considerations in this regard are to ensure: adequate representation of segments within the sample (30 per segment); efficiency (procedural and design related) in carrying out the survey activity; and adequate means of analysis (segmentation of analysis). Therefore, out of the total sample, sub targets can be set to diversify the sample over the population within the sample frame. Intentions are to have representation of firms from all those sectors of the economy which employ knowledge workers. As regards the sample selection, this is going to be a convenient sampling and convenient samples are often non-representative. Therefore, the proposed sample of respondents is a non-random sample consisting of everyone within the sample frame who agrees to fill in the survey. It is recognised that this sampling method would have some significant implications with regard to the acceptability of the results. These implications have been discussed in section 6.3.1.

6.5.2 The selection of the Study Area

Initially it was thought that the study would be done on Strathclyde conurbation, Glasgow metropolitan area being the centre of it. This consideration was based on the supposition that the strategic transport model which was initially expected to be used for forecasting had been calibrated with the household data from this conurbation which would have saved a lot of resources. However, when this study was delinked from the use of any such model, this straightjacket also disappeared. This situation gave back the freedom regarding the choice of the study area and the focus moved nearer to home and West Yorkshire area with Leeds city centre becoming the ultimate choice. It was not just the proximity to the work station that favoured the selection of Leeds. According to the claims by the City Council (on its website), Leeds is the second fastest growing centre to attract business activity for financial and related services after London in England.

6.5.3 Logistics and Cost Estimate

At this stage a paper based survey distribution was envisaged with a personal delivery/mail back arrangement. However, at the time of actual management of the survey activity, depending upon the preferences of the participating organisations the option of an email distribution was also explored. The selected sampling technique is associated with very high response rates due to a combination of factors. For example, the survey is being aimed at a specific group of people instead of the general population; the response rate from such samples employing similar survey techniques is relatively much higher. Personal contact/delivery during the distribution is further likely to enhance the response rate.

However, assuming a very conservative response rate of 25% and the study's need for 200 valid responses, 1000 questionnaires were to be distributed. This conservative assumption could prove beneficial if the eventual response rate turns out to be higher than expected. The survey would be distributed either by the surveyor or through a liaison point within the firms which gave their consent for participation in the study. Personal delivery would save the distribution/postage cost of 1000 C4-size deliveries. If the survey is delivered to the respondents without an envelope, further cost saving can be made by avoiding the cost of 1000 C4 envelopes. However, this may slightly affect the response rate negatively. The following were the estimates of the total cost for getting 1000 surveys ready for distribution:

Cost head	Cost estimate
Cost of 4 printed pages	£70
Cost of C5 reply paid envelopes	£45
Cost of covering letter on letterhead	£42
Cost of Mail merge	£55
Cost of Inserting	£50
Mail back postage (approx. 200 replies)	£ 50
Total Cost of a 4-page survey (with a covering letter)	£312
Total Cost of a 4-page survey (without a covering letter)	£215

These cost estimates are within the range of the available budget for the purpose. In the event of the assumption of a conservative response rate not being met, a second round of the activity at a reduced scale can be planned and executed within the available budget. Another option to address the problem of a potential lower response rate is to have a respondent tracking and follow-up mechanism. This mechanism can be in the form of a short slip attached to the actual survey and marked by a serial number or unique code. While delivering the survey the phone or email contact of the person who has agreed to fill in the survey can be recorded on this slip. In this way non-replying respondents can be traced and followed up for eliciting the response. However, there are down sides of this suggestion as it may result in difficulty in recruiting the respondents, additional cost, and extra time and effort to wait for responses from non-replying respondents.

6.6 Piloting of the Survey

The data collection exercise is not using an ordinary survey. The survey formulation obtained at the end of the previous chapter also contains an SP experiment. Piloting of the SP experiment design is important and is essential for novel/complex applications (DfT 2006). Usually a two-stage survey procedure/activity is recommended in the literature for complex SP applications such as this. Time resource did not allow for a full pilot including statistical analysis of responses. Instead some space was provided for respondents to comment for the purpose of assessing the quality of the data being generated.

With the selection of a sampling technique and the decision on a sampling strategy, the paper based survey emerged as the primary choice as the medium of presentation. This cleared the way for a piloting exercise. The formulation was realised on paper and was put to the test of a pilot before distributing it to the respondents in the actual data collection exercise. The survey piloting involved small scale testing of the target population and the survey instrument itself with regard to: its wording; the clarity of instructions; that it elicits the data which it is designed for without ambiguities, its understanding by respondents, also as an indicator of response rate by examining the responses.

6.6.1 Pilot Survey Report: Diagnostics

Nine people within the University agreed to participate in the exercise, of the total three were males and six females. Four were from other departments. From the completed survey, it is evident that all the participants have higher degrees except one who has a degree. Most of them are in high income groups and all are without small children. They are fairly evenly distributed over the age groups included in the survey except 16-24 age group which has no representation. On average, car ownership is just about one car per person per household. Five of the respondents currently practise some form of telework while the rest do not.

6.6.2 Ability of the Survey to Get Desired Information

From the analysis of responses to individual questions in all the sections of the survey, it appeared that all the respondents had responded:

- Well to 1st section on 'journey to work'
- With little to moderate difficulty to 2nd section on the 'alternatives' (2 or 3 of the respondents experienced difficulty)
- With no particular difficulty to 3rd section on the 'choices'
- Well to 4th section on the 'attitudes'
- With interest to questions on non-work travel and without particular interest to questions on location response in 5th section 'teleworking impacts'

- Well to last section on 'household' information.

As a result reply options to Q8 and Q10 in the survey were reduced and instructions for recording responses made clearer in the section on alternatives. One respondent marked two choices for every replication of the SP experiment and as a result the instruction in this regard was made clearer. The wording of the instructions for section 5 was changed as it was sensed that respondents were having difficulties in following the instructions. For a copy of the final survey version refer to Appendix V (section 13.5).

6.7 The Survey Management

In May 2006, the research project entered its field data collection management phase. This involved recruitment of a sample of business organisations in line with the defined sample frame, the sample diagnostics to evaluate the fitness and requirements of the consenting organisations with regard to the management of the activity, distribution of the survey to the respondents and the collection of the responses.

6.7.1 Sample Recruitment

Leeds Initiative was identified as the key source of help for sample recruitment through internal discussions. The Leeds Initiative is the city's local strategic partnership, led by LCC and provides a strategic approach to the city's long-term development. It has a long-term plan, Vision for Leeds 2004 to 2020, for the ongoing economic, cultural and environmental development of the city. Its aim is to bring together the public, private, community and voluntary sectors to work together to achieve success, encourage improvement, and tackle and overcome problems for the benefit of all citizens now and in the future, and has a wide-ranging network of over 500 organisations under its umbrella. A key person was approached for help with sampling who was given a short presentation on the research project by the surveyor. He agreed to help and provided the contact details of the organisations from which a sample could be drawn. As a first step, a letter (given at Appendix I in 13.1) to be sent on behalf of Prof Anthony May, Principal Supervisor of the study was prepared. Broad criteria set for an organisation to be in the sample, and thus to be a recipient of this letter were:

- Business location of an organisation (City centre location or nearby was preferred and the registered business addresses starting with postcodes LS1, LS2 and LS3 were identified)
- Nature of the business – amenable to the presence of a greater number of knowledge workers among its employees
- The size of a firm in terms of total number of employees – a firm should have at least 25 employees to be in the sample

The last criterion was not strictly adhered to when it was suspected that the target of 200 valid responses might not be reached from the activity. The final sample included two organisations that did not meet this criterion. The sample was recruited in two rounds of contact making process. During the first round 21 organisations were identified as suitable subjects and a letter from Prof May was sent to them in the middle of May 2006 through email. Six consenting replies were received and all were followed through. Within three weeks it emerged that the first round would not generate enough responses and a reminder to a selection of non-responding organisations was mailed but without any further success. This situation resulted in doing a second round for recruitment.

In the second round a further list of 22 contacts was prepared from the same source and the letter was sent to them at the beginning of June 2006. One organisation (a large newspaper publisher in the region) from first round was repeated in this round but with different contact person and details due to their large size and to diversify the sample base of consenting organisations a bit more. But it did not reply to even the second round mailing. In total, 10 replies were received during this round. Two of them received the letter in error, for another three it was not relevant, and one organisation declined to participate without giving any reason. The remaining three agreed to participate and were followed through.

Since the recruited sample was still insufficient and the coordinator from one of the consenting organisations (Leeds NHS) was taking time in coordination, it was decided to include the University of Leeds in the sample. The University's Transport Coordinator was approached for help with internal distribution of the survey via email to all the staff excluding Institute for Transport Studies (the department conducting this research) and she enthusiastically supported the idea as it fitted well with the university's transport plan.

6.7.2 Sample Description

The sample recruited through the two rounds of contacting includes the following organisations:

HSBC Bank plc: Headquartered in London, is one of the largest banking and financial services organisations in the world. HSBC's international network comprises around 10,000 offices in 82 countries and territories and has a very large establishment in Leeds which provides the full range of its services. The exact number of staff in Leeds could not be ascertained.

St James Securities: has offices in London and Leeds, is in the business of acquiring and developing property in the North of England and had 13 staff members in Leeds where the survey was distributed.

The Bank of England: in Leeds is the local sub-office of the central bank of the United Kingdom where it has four employees. The Bank has two core purposes - monetary stability and financial stability contributing towards a healthy economy. It produces a large number of regular and ad hoc publications on key aspects of its work and offers a range of educational materials. The Bank offers technical assistance and advice to other central banks through its Centre for Central Banking Studies.

Pinsent Masons: is ranked among the top 15 law firms in the UK, has offices in the key economic centres of the country. Worldwide, the firm has over 250 partners, a total legal team of around 1,000 and more than 1,600 staff. It has expertise across all areas of law that are key to business in Banking & Finance; Construction (UK and international); Corporate; Dispute Resolution & Litigation; Employment, Pensions & Tax; Insurance; Outsourcing, Technology & Commercial; Projects and Real Estate. The exact number of staff in Leeds could not be ascertained.

Baker Tilly: is one of the UK's top ten providers of accountancy, consultancy, audit and business services, is an independent member of Baker Tilly International and as part of a global network has 122 member firms in 93 countries. The exact number of staff in Leeds could not be ascertained.

Park Lane College: is the largest Further Education College in Leeds and provides commercial, secretarial and general education for the citizens of Leeds. It has two main campuses in the City Centre and at Horsforth, and 16 other sites across Leeds, which the College owns and operates. The current full-time-equivalent staff employed by the College stands at 625.

Education Leeds: is a not-for-profit company, wholly owned by Leeds City Council and responsible for providing all education support services that relate to children and young people of statutory school age in Leeds. It works in close partnership with Leeds City Council, statutory and non-statutory bodies, private and voluntary organisations, schools, parents and with our communities. Over the next three years Education Leeds will implement strategic plans for the company and for the schools of Leeds. The exact number of staff in Leeds could not be ascertained.

Yorkshire Forward: is one of England's nine Regional Development Agencies and charged with improving the Yorkshire and Humber economy. It aims to help improve the region's relative economic performance, reduce social and economic disparities and support the expansion and development of business in the region by encouraging public and private investment, and by connecting people to economic opportunity. It also works to improve levels of education, learning and skills, and to enhance the region's environment and infrastructure. The exact number of staff in Leeds could not be ascertained.

The University of Leeds: is one of the largest universities in the UK and among the top ten UK universities for research. It has 7581 staff, 32241 students and is the city's third largest employer.

6.7.3 Administering the Survey

This activity was managed in two steps: following up the consenting organisations for preliminary diagnostics and actual distribution of the survey and response collection. The standard procedure of follow up consisted of sending a message to all the consenting organisations and if required a reminder to those not replying to the first message. Standard drafts (given in Appendix III at 13.2) with minor variations were used for each purpose. Keeping the cost of the activity to the minimum was a prime factor for motivating the first step. Another purpose of this step was to get an organisation ready to receive and distribute the survey. During this step consenting organisations were individually asked for their preference regarding the distribution method. They were able to choose from an electronic or paper based version of the survey. They were further requested to assign a coordinator for this activity within the organisation and provide a rough estimate of car commuters among their employees. This information was beneficial for two reasons: to avoid wastage in printing extra copies that might not be used in the end and to calculate a rough response rate with a particular firm if required.

The following activities were designed to carry out this step successfully:

- Emailing the message, outlined above, to have required information and enlisting the support of a coordinator as the first follow-up activity
- In the event of a non-response, emailing a standard reminder (draft prepared in advance with appropriate language and further motivating the firm)
- A short second email reminder if needed
- If a consenting organisation would still not respond then use of phone calls
- Further communication using the appropriate method to seek and provide clarifications during this step and the following step if needed.

6.7.4 Requirement for Randomisation in the Distribution

As mentioned in section 5.3.4, the SP experiment used a full factorial design to ensure orthogonality. The SP experiments typically used 9-12 replications to be tested on any one respondent. This required an equal chance for each of the 64 replications generated by the design elements to be presented to the respondents which in turn required complete randomisation while selecting the replications to be included in the survey. Fortunately, the selected survey strategy offered complete flexibility in this regard. The objective of complete randomisation was achieved in following way.

It was decided that the SP experiment would include only nine replications. This means that at least seven sets of replications, each representing one unique SP experiment, would be required to accommodate 63 replications out of a total of 64. One replication can be left out of the experiment without any significant risk to the study results. Presenting seven SP experiments separately meant creating seven versions of the same survey instrument each containing one unique combination of nine replications. Randomisation of replication in the experiment was achieved at three stages:

- 63 out of 64 total replications were divided into 7 combinations using an electronically generated random number for this purpose (this created 7 surveys);
- 3 out of 7 versions of the survey were randomly selected for mailing to an organisation with two exceptions where the organisation size was small and they were sent one randomly selected survey version; and
- the large organisations were further requested in the instructions to randomise the distribution of the 3 survey versions either through the use of a separate mailing list or asking the respondent to select only one survey at random from amongst the 3 surveys (s)he has received.

6.7.5 The Distribution of the Survey

Once an organisation was ready to receive and distribute the survey among its employees, it would be mailed the survey along with a message. This message was based on a draft prepared in advance for this purpose to accompany the despatch of the survey and depending upon the situation at hand would contain two sets of instructions in its body: one set for the coordinator and the other for the respondent.

The set of instructions for the coordinator contained:

- Standard instructions regarding the distribution of the survey to the final respondents;
- Appropriate timeline (usually 2 weeks) to have the responses returned;
- In the event of a low response rate, instructions for the reminder to be circulated with appropriate timeline (a further one week to10 days time);
- In the case of large organisations, a further subset of instructions regarding how to randomise the distribution; and
- A request for feedback/update about the progress of the activity at appropriate intervals.

The subset of instructions for the respondents was in the form of a draft within the body of the message to the coordinators and was also intended for their convenience. It was to be circulated along with the survey to the employees within a particular organisation. It contained instructions regarding:

- Brief introduction indicating the collaboration between the organisation concerned and the university and encouraging them to respond;
- How to randomise the survey (if applicable);
- Appropriate instructions regarding how to complete the survey and how long it would take to fill in;
- Contact information to seek clarification in case of any difficulty encountered;
- Instructions regarding the return of the responses.

6.7.6 The Collection of the Responses

For response collection the respondents were given the choice of returning the completed surveys either to the coordinator of the activity within their organisation or directly to the surveyor at his university address (however, reply envelopes were not provided for this purpose as all the organisations preferred electronic distributions). Or if a respondent chose to fill in the survey electronically, they could also return the survey as an email attachment. A full log of all the activities performed to manage the survey with the consenting organisations was maintained.

6.8 Lessons from Experience

There are some useful lessons to be learnt from the overall management of the data collection exercise. These lessons relate to different aspects of the whole exercise and are described next.

Methodology: This thesis attempts two types of modelling as parts of its methodology: behavioural modelling and demand forecasting modelling. The former required including an SP experiment and creating a context for it within the survey. From a demand modelling perspective, the model calibration requirements dictated the survey content, e.g. current adoption and frequency numbers and detailed household data for different reasons. Then there were demands due to the data validity concerns. Trying to cater to these data demands within a short 4-page survey proved daunting at times. But this aspect also stimulated a learning process and benefits.

Working with a tight budget: The internal and external issues identified in the previous chapter did not restrict the formulation process but continued to affect the thinking on the selection of a survey technique. Ideally the study objective and scope would require one approach but the budgetary consideration would force a search for other options, and required a compromise.

The survey management activity consumes a significant part of the project research resources. The experience with this study tells that it is possible to carry out a modest scale activity with a very low budget or with no financial cost at all and without any significant compromise on the quality of the data being collected.

In this strategy the cost of printing the survey for those respondents who chose to record their responses on paper was transferred to and distributed over the participating organisations. Even their material resource was used at the optimum level as only those recipients of the survey who intended to fill it in printed it. It is unlikely that those who printed it did not complete it. So, there was no wastage of resources as might be the case with competing strategies. Hence the strategy can also be regarded as the most environmentally responsible using a paper based survey.

The hallmarks of this strategy have been the complete flexibility and a greater degree of control over the whole management process. The key was asking the consenting organisations about their preferences for a paper or electronic version of the survey when requesting help with the distribution. As expected all the companies but one (Leeds NHS, which initially gave delayed replies to the request for coordination and was not followed through further) preferred the electronic version for distribution. Control over the exercise as it progressed afforded a perfect opportunity for randomisation of the different survey versions during the distribution process. Minimum personal contact during distribution and response collection also meant minimum human effort.

An even better version of the strategy could be to motivate the participating organisations for a complete electronic response by highlighting the environmental aspect of the exercise and to enlist support for a purely electronic response collection, as happened in the case of Yorkshire Forward. After giving their consent for help with the distribution, their management were apprehensive about providing responses on paper due to their organisational policy of avoiding unnecessary printing. The organisation was encouraged to return responses electronically and provided additional instructions regarding how to record responses while completing the survey on computer. However, the coding process of electronically received responses took extra time.

Making use of participating organisations' IT resources is another useful feature of this survey strategy. Very large organisations like Education Leeds and Yorkshire Forward have their own intranets. Through mutual exchange of suggestions regarding the survey distribution, it was decided to post a set of three randomly selected survey versions for each organisation at their respective intranets with all the relevant instructions. Besides posting a news item about the survey on the main home page of the organisations, the employees were encouraged to participate in the survey activity through a short email message circulated through the internal mailing system. Another worthwhile feature of the paperless approach to administering the survey is its ability to identify and track the respondents for follow up to seek any clarifications if required. In the case of Yorkshire Forward, two of the respondents were followed up for some clarifications.

The applicability of this strategy is limited perhaps to when sampling from businesses. Another downside is that the true response rate, especially in the case of this study where a niche within the sample is targeted, remains unknown. But this can be associated with the majority of sampling techniques that are characterised by convenient sampling. Further, the survey was not intended for electronic distribution and completion from the start. The layout of the survey in this regard was a problematic area and prone to disturbance by the slightest of the insertions. With regard to its contents and presentation, it was also not an easy survey to respond to, as envisaged beforehand in view of its SP content and volume of the data being sought, and as emerged from the comments of the respondents. This may have affected the response rate. But other features like the ease of access and complete freedom regarding the return of the responses may equally have added to the response rate.

The details of the strategy have been described in the section on the survey management. The following key factors contributed or were likely to contribute to the overall success of the strategy:

- Design a strategy-specific survey instrument and be prepared to tailor it to the needs of individual organisations;
- Enlist the support of someone in authority in the organisational hierarchy;
- Request appointment of an activity coordinator;
- Make it convenient and easy for the coordinator;
- Effective communication and follow-ups; and
- Be flexible all the time to accommodate the demands of the organisations.

The target for the activity was 200 valid responses. The cost outlays for this level of activity through conventional strategies were between £310 and £700 subject to the estimates about the response rates. In the end the whole activity was managed without any cost and was successful in generating 219 responses. The sample-wide distribution of these responses is given in Table 6-3. How the quality of the resulting dataset was ensured has been described in the next chapter. It is believed that with some extra effort and time, a similar activity but with a considerably higher scale could be managed with very little cost.

Employer's Name	Responses Received
Bank of England	3
St James Securities	3
Baker Tilly	6
Pinsent Masons	26
HSBC Plc	36
Park Lane College	25
Education Leeds	56
Yorkshire Forward	30
University of Leeds	34
Total	219

Table 6-3: Detail of responses received from each organisation in the sample

7 Analysis of Non-SP Data

This chapter is devoted to descriptive and statistical analyses of largely the non SP data which also include the data on teleworking attitudes and on teleworking impacts on non work travel and residence location decisions. The first section presents the details of the data handling activities, the quality checks on the dataset and the profile of the final dataset; and discusses the response rate issue. The next section presents the sample in a tabulated form, explores the degree of association between various independent and dependent variables and the significance of any such association through non parametric tests. It also analyses the data on ICT variables and other teleworking characteristics. The third section through factor analysis procedures seeks to confirm the logic behind the design of the attitudinal section and analyses the respondents' attitudes toward teleworking after dividing the sample into various groups. The analysis of the teleworking impacts on non-commute travel and location behaviour of current and potential teleworkers is presented in the fourth section. The chapter ends with the conclusions drawn from the battery of analyses.

7.1 Data Management and Processing

The raw data were subjected to a number of procedures to ensure quality control and transparency in its handling. The section particularly details how the collected data were handled with regard to: coding and arranging them into a spreadsheet; data quality issues; and biases. The coding scheme and the data handling protocol used for these purposes are also described.

7.1.1 The Coding scheme

The responses were coded as they came in into a spreadsheet. For this purpose a coding scheme was designed. Each returned survey was assigned a unique case code to trace back and check for any inaccuracies encountered in the data set later on. Each question or sub-question was treated as a separate data item and given a unique variable name. All blank and inappropriate (values which were not recorded as instructed) responses encountered in a returned survey were also coded with unique codes. Similar treatment was given to a question that was not applicable to a particular respondent as per the survey design logic. These aspects of the activity have been given a fuller treatment in section 7.1.3. This arrangement was to ensure that the final data sheet did not have any cell with a missing value. At the end of the coding process, the data sheet consisted of 219 cases of responses from returned surveys.

7.1.2 Dealing with the Non-response and other Biases

When it comes to dealing with the biases in a freshly collected data set, the first main issue is to consider the non-response bias. Many studies have attempted to determine if there is a difference between respondents and non-respondents. One text, (Walonick, 2004) has summarised the opinions on the issue. It reports that some researchers have reported that people who respond to surveys answer questions differently from those who do not. The differences between the responses of any two groups of respondents may be due to the different levels of interest in the subject matter. Demographic characteristics of non-respondents have been investigated by many researchers. Most studies have found that non-response is associated with low education. However, one researcher (quoted in Walonick, 2004) reported that demographic characteristics such as age, education, and employment status were the same for respondents and non-respondents. Another study (Ibid) found that non-respondents were more often single males.

The above opinions point to an inconclusiveness and lack of any definitive evidence on the issue. This study was particularly sensitive to non response bias and tried to incorporate the main concerns in this regard at the survey design stage (section 5.4.3 and 5.4.5). Further, at the distribution stage (section 6.7.5) all possible care was taken to keep the publicity and the invitation to complete the survey general in character. However, it is possible that there may still be some difference between the respondents and the non-respondents in this sample.

The survey undertaken consisted of a mix of both RP and SP data, though the latter had a predominant bearing on the nature of the exercise. SP data are well known for the presence of certain biases in them. Two forms of error are common: the random error which affects scale of coefficients and the systematic error which affects scale of coefficients and relative values. Random errors relate to misunderstanding, uncertainty/unfamiliarity, fatigue, unconstrained response error, not taking the experiment seriously, individual idiosyncrasies, randomness in behaviour and the bias which is random across respondents though not random within the respondents (Wardman, 2004).

The majority of these are survey design issues and were taken care of during that process. However, some of these errors were still observed in the collected data. For example fatigue among the respondents may be evident from the pattern that 31 respondents (out of 192 clean cases) did not respond to the section on teleworking impacts without any apparent reason (see also section 7.4) while they did answer the section on attitudes which is perhaps the easiest of the sections in this survey. By reaching the section on impacts a respondent would have gone through the cognitive demands of the SP experiment and about 40 questions in total. This was the penultimate section in the survey. The survey contained space for respondents' comments. This provision proved very helpful in detecting most of the above errors. This was particularly true in identifying the random errors due to the comments on the difficulty the respondents experienced while completing the SP exercise.

Systematic error, on the other hand, is bias in answers which is not offsetting across respondents and affects the relative values. Sources of this bias include affirmation, justification, information (habit), instrument (money), focus, social norm, framing, strategic, ignoring small/unrealistic changes and status quo (Ibid). These errors are also a function of the contents and the design of the instrument and are hard to detect and correct post hoc. They must be taken care of at the survey formulation and design stages. Any attempt at correcting the systematic errors in the collected data may introduce the surveyor's personal bias into the data. These forms of errors are mentioned here because of the context which is the description of the full dataset, otherwise this chapter is only concerned with the analysis of the non SP data. How these forms of error were dealt with has been covered in the next chapter (section 8.2.1) which analyses the SP data.

7.1.3 Ensuring the Data Quality

Two procedures have been used for this purpose during the combined data collection and management processes. From the experience of coding the first few responses, it was considered beneficial to categorise the observed inaccuracies and inconsistencies among the responses and to define them with appropriate codes, later called data quality codes. Seven such quality codes were defined and used during the data coding process to control the quality of the emerging data set. For this purpose a separate variable 'data quality' was included in the data sheet. The following key was used to indicate this:

- Complete and accurately filled or with some very minor illegibility: 1
- Selected more than one choice in some or all situations: 2
- Inconsistency among RP and SP: 3
- Values missing for one or more sections: 4
- Inexplicable & doubtful answers: 5
- Inconsistent answers or did not follow/understand instructions: 6
- Significantly Incomplete: 7

These codes informed the judgement when deciding the fate of a doubtful case in the dataset. This process is described in the next sub section. The second procedure relates to the use of respondents' comments about any aspect of the survey in the space provided for this purpose. A considerable number of respondents used this provision to record their perceptions. A further variable/column was included in the data sheet to accommodate such comments by picking up key word(s) from the comment(s). Both provisions significantly helped in identifying the biases and other such issues among the responses and in taking the appropriate corrective measures. One such measure was to define the data handling and cleaning protocol.

7.1.4 Data Handling Protocol and Cleaning Process

Once the coding was complete, a data handling protocol was defined to clean the data set of unusable responses and any biases discussed in section 7.1.2. It had two parts. The first part dealt with cleaning the data of unusable responses while the second part specified how to handle the inaccuracies, inconsistencies and irregularities in the usable responses that might bring bias into the data set. The inaccuracies, inconsistencies and irregularities mainly resulted because some respondents did not follow the survey instructions or skipping logics in the survey design and because of the difficulty faced by them in catering to the conflicting response demands of RP and SP.

In the first stage, following the procedures mentioned in the previous sub section, the data cases with data quality codes 7 and 5 were removed from the dataset. For example, in the definition of one of the data quality codes, a returned survey was classed as significantly incomplete if a respondent failed to go through the SP experiment or did not provide current journey and household data or both. Further, there were five cases where the respondents had made more than one choice. Although the relevant instruction clearly asked for only one choice from the given alternatives, some respondents still made two choices. These data cases fell under quality code 2 and were also removed from the final dataset. Thus, in total 27 data cases were removed from the final dataset this stage. However, deletion was regarded as the least preferred option due to the overall sample being not very large. This left 192 usable cases of data in the remaining dataset which was close to the target of 200 which would be adequate for an SP study. This slight deficit was considered not to affect the forecast estimates significantly.

The second phase of the data handling process consisted mainly of dealing with inconsistencies between RP and SP responses (section 2 and 3 of the survey, ref to Appendix V at 13.5) and blank responses to some vital questions on teleworking. Excluding all such instances would have meant reducing the data set significantly as many data cases included one or both of these instances. The inconsistency between these two types of responses initially caused considerable concern. However, the explanation was found in the different ways the respondents perceived both RP and SP situations.

The data obtained from answers to the questions in first and second sections of the survey were treated as RP data. There is no doubt about the first section as it reflected the responses on the current commute journey characteristics. The second section included questions on changing departure time, changing travel mode and (adopting) teleworking: the strategies usually adopted by a commuter to avoid congestion depending upon availability. The reasons for treating the second section as RP are rooted in the pattern of detailed responses provided to the questions in the second section of the survey. It was assumed that a respondent who has answered 'yes' to any of the alternatives and provided the follow-up data has most probably been practising it in the past.

The responses to the questions in the second section reflected that a respondent was in equilibrium with regard to their current commute mode choice and behaviour. However, putting the respondents through the SP experiment disturbed this equilibrium with respect to commute travel. The SP exercise made them make a hypothetical choice which was not always in line with their RP behaviour at least with regard to departure time and travel mode choice. In line with this explanation, the data handling protocol stipulated that all such responses where a respondent has changed her mind relative to her responses in section two while going through the experiment (code 3) would be treated as valid.

The issue of blank responses to some questions or sections of the survey (code 4) concerned only non-SP analysis. These responses have some obvious implications for frequency distributions of dichotomous or pluralistic variables, e.g. availability of teleworking option with four possible responses, and for further inferential analysis based on the distributions. It was decided that such cases would remain in the dataset. Inconsistent answers or answers that did not follow/understand instructions (code 6) in 12 cases occurred in conjunction with other violations of quality codes. In the remaining 4 cases of the violation of this code it was observed that the nature of the violation was not very serious. Hence these cases were also allowed in the sample.

7.1.5 Other Immediately Obvious Data Quality Issues

Here it is useful to evaluate the overall performance of the survey instrument and comment on the different aspects of the survey content and design. The diagnostics and comments below may also be viewed as a *post hoc* analysis of the fitness of the survey vis-à-vis its purpose and design.

The survey design could not capture all the answering possibilities to some of the questions. For example some attitudinal statements were not applicable to all the respondents, e.g. due to differences in job and family circumstances, but there was no instruction in this regard. A few similar instances existed in the last section on household data. Further, the skipping logic was also found lacking in relation to questions on relocation in the survey section on teleworking impacts. The pilot had failed to detect these unintended dynamics.

Perhaps a rather significant issue was about who pays for fuel and parking cost as it directly impacts upon a respondent's ability to trade off with the available options in the face of upward changes in the GC of travel. To ascertain this would have required additional questions in the survey contents which were already very tight. In the final assessment, this was left to the respondent's perception of their travel cost. Further, monetary cost is only one element of the total GC of travel and was potentially a less serious issue in the study as teleworkers are likely to belong to those SEGs which value time over money.

Another weakness in the contents was the absence of a specification of the peak, since the experiment particularly mentioned that travel time and cost changes only applied to peak hours. This may not be a serious weakness. A strict specification of the peak could have worked both ways. A respondent's peak might have been different from the given specification of peak. Instead this was left to be decided by a respondent's own experience of peak traffic on their commute journey. How this issue was ultimately dealt with in the analysis has been covered in section 9.3.4.

7.1.6 Profile of the Data Set

After performing the above procedures, the data sheet still reflected a random order as to manage time efficiently the completed surveys were coded as they came in. As noted in section 6.7.4 the distribution of the seven different survey versions was randomised among the participating organisations. Hence, the next step required sorting the surveys by the survey version they belonged to and based on the organisation they were received from and assess the effectiveness of the randomisation approach. Sorting by survey version was also necessary because the model estimation process through logit analysis required a data file in which all the travel time and cost data are related to each observation on SP choice. This process which is detailed in a later section would become easier if all the completed surveys belonging to a particular version were grouped together.

Similarly, sorting the responses along organisational divisions was considered useful to see if there is a pattern among responses based on the employer variable and to record the numbers of surveys returned from each participating organisation. After these processes and in addition to quality vetting procedures described in the previous sections, Table 7-1 presents the profile of the dataset that emerged ready for analysis. In the final analysis the completed surveys belonging to survey version S6 (the bottom row of the table) were removed in greater proportions. This was investigated but no apparent reason was found.

As Table 7-1 shows, six organisations were sent more than one survey version for distribution. The remaining three were sent only one version in view of their size. The distribution of returned surveys by survey version shows that the approach to randomised distribution of the survey was completely effective in the case of four organisations. For the remaining two organisations, i.e. HSBC and the University of Leeds, the randomisation was heavily skewed towards the version S3 in the former case and toward S6 in the latter. However, the procedure was not as effective as was wished. The numbers of each version returned are very variable, as the second row from the bottom in the table shows. This means that despite the efforts, an unbiased representation of the full SP design could not be achieved and this may affect the ability of this dataset to produce unbiased models.

Employer's Name	Distributed Survey Versions	Returned by each version								Removed from dataset
		S1	S2	S3	S4	S5	S6	S7	Total	
Bank of England	S6						3		3	0
St James Securities	S4				3				3	0
Baker Tilly	S5					6			6	0
Pinsent Masons	S1, 6, 7	12					7	7	26	2
HSBC Plc	S2, 3, 5		1	34		1			36	3
Park Lane College	S1, 2, 4	7	12		6				25	1
Education Leeds	S3, 6, 7			18			24	14	56	12
Yorkshire Forward	S1, 4, 7	12			13			5	30	3
University of Leeds	All		1	1	5	1	24	2	34	6
Total		31	14	53	26	8	58	28	219	27
Removed by survey version		3	0	6	1	0	15	2	27	

Table 7-1: Survey versions distributed to, and number returned by, each organisation

7.1.7 The Response Rate

For studies using convenience samples, especially when using internet as the medium of reach, response rates cannot be computed or are meaningless (Schonlau et al 2002). In the case of this study, it was also not possible in view of the uncontrolled distribution of the survey to a convenience sample. While it was possible to know the total number of staff in an organisation, it was impossible to know the size of the target population, since the survey was aimed only at car commuters. The organisational coordinators who helped in conducting this survey at different organisations were the only source of information in this regard. The figures provided by them in most cases were only a guess of the number of car commuters in their organisations. One employer in the sample, i.e. Bank of England, has only four employees in Leeds and thus cannot be considered as representative for this purpose.

However, to make another effort to determine the indicative response rate from each organisation, a question on the share of car commuters (the target population) in an organisation was included in the subsequent employers' survey (see 13.5) which was answered by four employers only and the responses should be taken as only rough estimates. Thus, overall indicative response rate for the whole sample was still not possible. However, the individual estimates do provide some indicative response rates which for the University of Leeds is 1.0%, for Park Lane college is 3.9%, for Pinsent Masons is 13.3% and for Baker Tilly is 24.0%. This rate was calculated by dividing the number of total respondents from an organisation by its target population estimate.

In the context of the present study, it is helpful to note that the spam problem was taken care of through organisational distribution. This factor has most likely affected the response rate positively. However, the survey activity coincided with the matches for the Football World Cup competition in which the English team participated and the annual summer leave period in the months of June and July. These two factors may have influenced the response rate negatively as it is likely that the full strength of the employees of the participating organisations were not at work during this period and a considerable number of those attending may have been more interested in football matches and thus have little time to complete the survey.

7.1.8 Item Non-Response Rate

The dataset was also analysed for item non response rate which was calculated by dividing the number of missing responses to that particular question in the clean dataset by the number of respondents to whom that question was applicable. A table in Appendix VI at 13.6 provides the level of item non response to each question in the survey. Here only the questions with significant non response rate are commented upon. The highest non response rate at 50% was for Q1b which required a descriptive answer if there was a reason for difference between the number of work and travel days and was applicable to 30 respondents. This is understandable in view of respondents' tendency to avoid lengthy descriptive replies and perhaps the peculiarity of individual circumstances, e.g. one teleworker was working six days per week and another worked at four different places. However, a better response rate to this question could have provided some evidence to validate or otherwise the responses to telework frequency question (Q15), discussed in 7.2.5.

The next highest non response rate was for Q19a. This question was not directly relevant to the study purpose and was included for the sake of completeness as noted in 5.4.3. Non response rate to Q12b and Q12c was also relatively significant at 14.29% each. These questions sought information on the cost by the alternative travel mode and any walking time involved. This high rate can be explained by the fact that the sample is of car commuters and usually they are not expected to have detailed information about the characteristics of travel by PT. The last double digit non response rate at 11.98% was for the question on fuel cost for car travel. In the great majority of the non responses to this question, the answering space was question marked indicating a tendency to being unsure of the exact figure. The missing data for such respondents were eventually generated based on calculating the average fuel cost per minute over the entire sample. Non response was also observed at section level for one section as indicated in the table in Appendix VI at 13.6 and discussed in 7.4.

7.2 Analysis of the Household and Contextual Data

Looking at the breadth and depth of the variables studied and the diversity of the options in the SP choice set and of the data collection approaches used, there are potentially many perspectives that can be taken to the analysis of this dataset. The perspective on analysis in this chapter was defined by the study focus. i.e. teleworking and the rationale for survey questions. Other perspectives, e.g. a focus on mode change or changing travel time, both having already been studied extensively, have not been covered here but a summary of responses for them has been given in the next chapter (see Table 8-3 through Table 8-5). Thus, with a focus on teleworking Section 2 of the survey is analysed here, Sections 4 and 5 of the survey in sections 7.3 and 7.4 and Sections 1 and where relevant to interepret the responses in the other sections.

Both descriptive and inferential statistics have been used for the analysis. The sample diagnostics were performed using descriptive frequencies analysis and are presented in tabulated form for all the categories of all the demographic, socio-economic and commute (DSEC) variables while statistical analysis was used to identify significant variables through tests of sample independence. For the latter, the data from the first and last sections of the survey have been connected to RPs on teleworking in the second section of the survey. The objective is to look for the degree of association between teleworking practice or preference and different DSEC variables. Due to the omnipresence of ICT variables among the respondents in the sample, their role in teleworking adoption has been explored separately (section 7.2.4).

Almost all the DSEC variables are in the form of nominal data. For such data the Chi-square test is used to investigate the significance of any relationship (Brace et al, 2006) between the independent DSEC variable(s) and the dependent variable, i.e. choice of or preference for teleworking. This test required first producing contingency tables for each category of each variable relative to all the categories of all the variables to be investigated and then recoding all the data from the contingency tables into new format and variables. To avoid this large-scale recoding, a more efficient procedure has been used. Under this procedure, instead of investigating each category of all the variables for its association with the dependent variable of choice individually, the sample to be analysed is divided into subsamples along a criterion of choice and non parametric tests are performed on these subsamples with respect to independent variable(s) and their categories are investigated for significance of association.

It is recognised that this procedure is not as powerful in detecting the significance as Chi-square tests on pairs of variables are. However, it was thought acceptable for three main reasons. First, this type of analysis was not the principal objective of the study. Secondly, the choice set also included non teleworking choices. Finally, the data were collected from a non probability sample and the significance of association found between independent and dependent variables on the basis of such samples has less generalisability than found within the perfectly randomised samples.

The procedure adopted here has been further buttressed by first running the descriptive frequencies tests on sub samples and then performing statistical analysis for tests of sample independence. The non parametric tests of sample independence employed are Mann-Whitney U and Kruskal-Wallis tests. For these tests all the sub samples to be tested were treated as independent samples drawn from the same population. In the Mann-Whitney U test, 'Z' statistic and related distribution are used to test the hypothesis that any two samples are independent from each other while Kruskal-Wallis test uses 'Chi square' statistic and related distribution to confirm sample independence for three or more samples simultaneously. These statistics within their respective tests are a measure of how much different the samples within a particular set of samples being tested are from each other. The larger the value of the statistic used, the greater the likelihood that the differences among the samples are due to something other than chance alone, namely real effects (Stockburger, 1996). In this regard, the critical value of a particular statistic is represented by alpha (α) which indicates the level of confidence in hypothesis testing. Alpha value is usually set at 0.05 for a 95% confidence interval. If a 'Z' or 'Chi square' statistic has a critical value of alpha less than 0.05, the hypothesis being tested is accepted, indicating the independence of the sample being tested. SPSS software was used to perform these tests. The next subsection employs the described procedure to test the degree of association between preference for and choice (practice) of teleworking.

7.2.1 Investigating the Significance of Independent Variables

The first perspective to this investigation is that of current teleworkers (Q14) and of those respondents who given the option (Q16) would prefer to telework (called Preferrers,) and comparing them with corresponding frequencies for the full sample. The analysis of current teleworkers' characteristics has obvious significance for this study. The group of potential teleworkers is important due to the SP character of the study and their choices will play a significant role in estimation of a predictive model

	Full sample	Current teleworkers	Pre-ferrers		Full sample	Current teleworkers	Pre-ferrers
N	192	44	92	N	192	44	92
Category	%	%	%	Category	%	%	%
	Respondent's gender				**Commute cost including parking fee**		
Male	61.5	54.5	62	Up to £2	29.2	38.6	26.1
Female	38.5	45.5	38	Btw £ 2.1 - 5	28.6	20.5	33.7
	Respondents age			Btw £ 5.1 - 10	28.1	25	27.2
16--24	4.7	2.3	5.5	Btw £ 10.1 - 15	12.5	11.4	10.9
25--34	23.6	25	27.5	Btw £ 15.1 - 20	1.6	4.5	2.2
35--44	30.4	36.4	28.6		**Car availability ratio**		
45--54	26.7	25	25.3	Missing response	2.6	4.5	1.1
Above 55	14.7	11.4	13.2	Less than one car	15.6	4.5	20.7
	Living circumstance			One car	78.6	86.4	76.1
Married/cohabitating	84.4	86.4	80.4	More than one car	3.1	4.5	2.2
Single	15.6	13.6	19.6		**Escort duty**		
	Presence of children (<5year) in home			Yes	25.5	20.5	26.1
No	86.5	84.1	85.9	No	74.5	79.5	73.9
Yes	13.5	15.9	14.1	Category	**Respondent's education**		
	Presence of children (between 5-15)			Higher Degree	26.1	43.2	24.4
No	70.8	56.8	72.8	Degree	46.8	34.1	52.2
Yes	29.2	43.2	27.2	A-Level	12.8	18.2	15.6
	Care needs in the household			GCSE/Equivalent	12.2	2.3	6.7
Yes	18.8	25.6	18.7	No qualification	2.1	2.3	1.1
No	73.1	72.1	71.4		**Respondent's total household income**		
Sometimes	8.1	2.3	9.9	Less than £15k	1.1	0	2.3
	Return Commute journey time			Between £15--25K	7.5	4.5	8
Up to 20 Min	2.1	4.5	1.1	Between £26k--40k	19.3	11.4	30.7
Btw 21 - 40 Min	15.6	18.2	16.3	Between £41k--60k	29.4	29.5	29.5
Btw 41 - 60 Min	22.9	31.8	21.7	Above £60k	33.2	47.7	23.9
Btw 61 - 90 Min	28.6	20.5	28.3	Withheld	9.6	6.8	5.7
Btw 91 - 120 Min	19.8	13.6	20.7		**Respondent's job position**		
More than 120 Min	10.9	11.4	12	Senior management	12.6	22.7	6.6
	Space availability for TW at home			Middle management	35.8	47.7	34.1
No	15.2	4.5	11	Entry level/supervisor	20	13.6	23.1
Yes	84.8	95.5	89	Secretarial/Staff	24.2	9.1	26.4
				Others	7.4	6.8	9.9

Table 7-2: Distribution of DSEC variables among the samples of full sample, current teleworkers and telework preferrers

(next chapter). It was also intended to present in this table a third sub sample, comprising those who have not shown any interest in teleworking. However, it was found that there is not a sufficient number of such cases in the sample. From the RP data, it emerged that 62 respondents in the sample were neither current teleworkers nor showed preference for it. A closer scrutiny of these revealed that job unsuitability constraints were active for 41 respondents. However, Q13 on which this inference was based may not be a good indicator of job suitability. Among the remaining 21 respondents including one blank response, a further look at their SP responses revealed that 6 persons changed their mind in response to the SP experiment. Using this definition, only 14 respondents (about 7%) were uninterested in telework.

Table 7-2 shows the frequency distributions for each category of all the DSEC variables (questions 5-8, 26-29, 31-37 and 40) for the three samples. The full sample has been named as Sample one or S1, the current teleworkers are shown as Sample two (S2) while the Preferrers are categorised as Sample three or S3. Both S2 and S3 are mutually exclusive and are defined using responses to questions on practice and preference for teleworking (questions 14 and 16 respectively in the survey; see Appendix V at 13.5).

Table 7-2 shows the size of the three samples as absolute numbers in the second row and lists the DSEC characteristics as a percentage of the respective totals. The table lists a broader range of such variables than studied previously (section 2.8.1) and found to have an influence on teleworking adoption or preference.

	Mann-Whitney Test α	**Mann-Whitney Test α**	**Mann-Whitney Test α**	**Kruskal-Wallis Test α**
DSEC variables	S1 & S2	S1 & S3	S2 & S3	All Samples
Respondent's Gender	0.399	0.936	0.412	0.669
Respondents Age	0.749	0.482	0.814	0.769
Living circumstance	0.741	0.408	0.398	0.608
Presence of Small Children in Home	0.705	0.866	0.826	0.929
Presence of Young children in home	0.107	0.720	0.087	0.193
Care needs in the household	0.153	0.781	0.144	0.297
Commute time category	0.197	0.749	0.170	0.354
Commute cost category	0.589	0.962	0.579	0.844
Car availability ratio	0.066	0.276	**0.017**	0.057
Escorting needs in the household	0.482	0.919	0.475	0.752
Respondent's Education	0.054	0.677	0.121	0.146
Respondent's Income	0.159	**0.019**	**0.002**	**0.007**
Respondent's job position	**0.009**	0.155	**0.001**	**0.003**
Availability of Space for teleworking	0.061	0.341	0.219	0.138

Table 7-3: Alpha values for tests of sample independence for samples presented in table 7-2 (values in bold show a particular sample being independent from other(s) w.r..t that variable)

In the second step of the procedure a non parametric test for sample independence was performed on the data in

Table 7-2 and the results of the tests are presented in Table 7-3 which shows the significance differences among the samples in bold. Where the hypothesis for particular samples being independent from each other within a certain set of samples has been accepted at the usual 95% confidence interval, the returned alpha value has been highlighted in bold font in the table. Overall, the results show that the three samples are independent from each other only in terms of respondents' income and job positions among all the tested variables in the table. However, the above inference does not hold for certain sets of two samples. For example, S1 and S2 are not independent from each other with respect to income while they are with respect to job position. The S2 and S3 are also independent from each other in terms of car availability ratio. The main conclusion is that income and job position are the distinguishing variables among the three samples and the teleworkers differ from other populations by job position only.

7.2.2 Exploring the Employer's Influence on Teleworking

Table 7-4 presents frequencies from questions 13-18 and 37 in the survey on different aspects of teleworking explored in the survey and the context of the analysis is the employer's influence on teleworking characteristics. The purpose is to identify the significance of the employer's role in current and future take-up of teleworking due to its control over the teleworking supply options. The respondents in this survey belonged to different employers with different types of businesses. For this analysis, sample representativeness was an issue. Generally about 30 observations are considered sufficient to qualify them as a subsample. Six of the participating organisations, more or less, fulfil this criterion (ref. row 'N' in table 7-4) and can be included in this analysis.

Table 7-4 also shows how an employer based sample compares with the main sample in terms of teleworking characteristics of the respondents. Employer-based samples have not been analysed for DSEC characteristics other than job type because such an inter-organisational analysis would have added little value to what has already been achieved in the previous subsection. The omission of three employers with less than 25 observations explains the difference between the employers' total and the full sample total in the upper row. Current teleworkers in all the tables are exclusive of those with unsuitable jobs and who are not permitted by the employer while the preferrers exclude current teleworkers and those with unsuitable jobs. The employer based samples in

Table 7-4 were put through a non parametric test of sample independence in Table 7-5 where the hypotheses that employer based samples are part of the same sample have been accepted at 99% confidence interval for all the tested variables except for

	Full sample	Education Leeds	HSBC Bank	Park lane College	Pinsent Masons	University of Leeds	Yorkshire Forward
	%	%	%	%	%	%	%
	Respondent's job position						
N*	190	43	33	24	24	27	27
Senior management	12.6	11.6	6.1	4.2	20.8	14.8	0
Middle management	35.8	34.9	72.7	29.2	29.2	18.5	29.6
Entry level/supervisor	20	7	18.2	16.7	16.7	22.2	48.1
Secretarial/Staff	24.2	27.9	3	45.8	29.2	29.6	22.2
Others	7.4	18.6	0	4.2	4.2	14.8	0
	Availability of telework option						
N	188	43	33	24	24	27	26
Formally possible	23.4	46.5	24.2	0	4.2	3.7	53.8
Informally possible	28.7	20.9	30.3	21.7	29.2	44.4	19.2
Job unsuitable	26.1	20.9	42.4	26.1	25	18.5	23.1
Not permitted	21.8	11.6	3	52.2	41.7	33.3	3.8
	Current teleworker						
N	126	36	22	24	14	17	23
Yes	34.9	38.9	45.5	0	30	17.6	39.1
No	65.1	61.1	54.5	100	70	82.4	60.9
	Telework preference						
N	121	28	14	21	16	22	15
No	24	14.3	35.7	28.6	37.5	18.2	13.3
Yes	76	85.7	64.3	71.4	62.5	81.8	86.7
	Perception of daily cost of Telework						
N	124	29	19	13	13	21	21
Zero	7.3	10.3	10.5	0	15.4	0	4.8
Less than £1	12.1	10.3	5.3	15.4	7.7	9.5	19
Between £1.0-2.5	29	37.9	26.3	23.1	7.7	38.1	38.1
Between £2.5-5.0	27.4	34.5	10.5	23.1	46.2	33.3	28.6
Between £5-10	16.1	3.4	36.8	23.1	15.4	19	4.8
More than £10	8.1	3.4	10.5	15.4	7.7	0	4.8
	Who pays the teleworking cost						
N	123	33	18	13	13	19	20
Myself	60.2	69.7	44.4	46.2	84.6	52.6	70
Employer	26.8	18.2	38.9	38.5	15.4	21.1	20
Shared	13	12.1	16.7	15.4	0	26.3	10
	Telework Frequency (no. of days per month (%))						
N	37	11	9	0	2	3	9
0.5	5.1	18.2	0	0	0	0	0
1	25.6	18.2	33.3	0	50	33.3	33.3
2	43.6	54.5	33.3	0	0	0	55.6
3	2.6	0	0	0	0	0	11.1
4	15.4	9.1	22.2	0	0	66.7	0
6	2.6	0	0	0	0	0	0
8	5.1	0	11.1	0	50	0	0

Table 7-4: A comparison of the frequency distributions for employer based samples with the full sample (Note: * Rows with 'N' in left column indicate the number of respondents within a particular sample who answered the question about a particular variable. Other figures in each column are percentages relative to this figure)

telework availability and job position. The hypotheses that employer based samples are independent relative to the total sample or to each other with respect to shares of current or potential teleworkers have been rejected by big margins. This concludes that the employer based samples are different relative to the source and to each other only in terms of respondents' job positions and availability of option to telework

	Chi-Square	df	Kruskal-Wallis Test α
Availability of telework option	43.3058049	5	0.000000
Current teleworker	9.71930208	5	0.083591
Teleworking frequency	2.30447795	4	0.679954
Telework preference	5.72285004	5	0.334128
Perception of Telework cost	7.05545484	5	0.216549
Who pays the telework cost	8.62876739	5	0.124819
Respondent's job position	17.1899132	5	0.004153

Table 7-5: Alpha values for tests of sample independence for samples presented in table 7-4

To further examine the validity of the foregoing conclusion and to understand the connection between the job position and telework availability in the sample, the full sample was explored by dividing it into subsamples first on the basis of job positions and then on the basis of availability of teleworking option. The same statistical analysis procedure was followed and the results are shown in Table 7-6 and Table 7-7 for job position and in Table 7-8 and Table 7-9 for telework availability.

	Full Sample	Senior Manage-ment	Middle Manage-ment	Entry Level/ Supervisor	Secretarial/ Staff	Others
N	186	24	66	37	46	13
	Teleworking option availability					
Variable category	%	%	%	%	%	%
Formally possible	23.4	20.8	30.3	29.7	10.9	23.1
Informally possible	28.7	54.2	31.8	21.6	15.2	38.5
Job unsuitable	26.1	25.0	27.3	21.6	30.4	15.4
Not permitted	21.8	0.0	10.6	27.0	43.5	23.1
	Current Teleworker					
Yes	34.9	52.6	41.2	23.1	22.2	27.3
No	65.1	47.4	58.8	76.9	77.8	72.7
	Teleworking Preference					
Yes	76.0	60.0	83.8	77.8	72.7	75.0
No	24.0	40.0	16.2	22.2	27.3	25.0

Table 7-6: Distributions for main teleworking variables (Q13, 14 & 16) by job position (Q37)

The figures in Table 7-6 are of particular interest and show that the job unsuitability constraint is active for about 25% of all the job positions. Next comes the constraint of employer's permission which is especially active for positions in the lower hierarchy. Understandably, the respondents in senior management positions do not need permission to telework thus their distribution has been found as 0%. From a policy perspective perhaps the most interesting is the case of the respondents in secretarial and staff positions. Their perception of availability of the option (formally or informally) is considerably lower than the similar distributions for the full sample. Compared to 21.8% for the full sample, 43.5% of the respondents in Secretarial/Staff positions feel that they are not permitted by the employers to adopt teleworking. This can also be interpreted as the respondents in this job category with some or all of the job tasks suitable for teleworking feeling restrained by the employer.

Looking further down the same column in Table 7-6, 73% of the respondents in Secretarial/staff positions would prefer to telework. However, preference for teleworking is very strong in all the job positions though the practice is currently concentrated more in senior and middle management hierarchies. Three-quarters of the full sample would like to adopt telework given the option.

	Chi-Square	**df**	**α Value**
Availability of telework option	22.20998	4	0.000182
Current teleworker	6.584033	4	0.159572
Telework preference	2.880134	4	0.578081

Table 7-7: Kruskal-Wallis test of sample independence for Table 7-6

Table 7-8 (next page) which repeats the analytical procedure by telework availability shows that the respondents in the senior management positions understandably do not have any telework availability problem. The figures under teleworking preference columns are quite interesting for their significance. Two thirds of those who feel not permitted at present would prefer to telework given the option. Similarly, about a half of those who initially thought their jobs might not be suitable for teleworking changed their mind (as some of the job tasks might be teleworkable) when given the option.

When the subsamples in Table 7-7 and Table 7-9 (divided along the job position and telework availability criteria respectively) were examined through non parametric tests, it was found that subsamples based on job positions are independent from each other relative to the telework availability only while for the telework availability subsamples in Table 7-8 the hypotheses of independence for all the three variables were accepted at above 99% level. The foregoing conclusions were cross checked with a two-tailed Pearson correlation test and the results have been tabulated in Table 7-10 (next page) which shows that option availability (based on Q13) is correlated with all the three variables at the 99% level. On the other hand, the job position is only positively correlated with current teleworkers but is significant only at the 95% interval. This once again confirms the finding in section 7.2.1 though the correlation statistic does not indicate a very strong relationship.

	Formally possible	Informally possible	Job unsuitable	Not Permitted
N	44	54	48	40
	Respondent's Job Position			
Variable category	%	%	%	%
Senior management	11.4	24.1	12.5	0.0
Middle management	45.5	38.9	37.5	17.5
Entry level/supervisor	25.0	14.8	16.7	25.0
Secretarial/Staff	11.4	13.0	29.2	50.0
Others	6.8	9.3	4.2	7.5
	Current Teleworker			
Yes	50.0	40.7	0.0	0.0
No	50.0	59.3	100.0	100.0
	Teleworking Preference			
N	25	36	17*	39
Yes	96.0	86.1	47.1	66.7
No	4.0	13.9	52.9	33.3

Table 7-8: Distributions for teleworking variables (Q13, 14 & 16) by option availability (Q13) (* though this group were asked to skip Q on preference, 17 still responded)

	Chi-Square	df	α Value
Current teleworker	17.60992	3	0.000529
Telework preference	17.05557	3	0.000688
Respondent's job position	22.17081	3	0.0000601

Table 7-9: Kruskal-Wallis test of sample independence for Table 7-8

Correlated variables	Pearson correlation estimate
Option availability-Current teleworker	0.347891**
Option availability-Teleworking preference	-0.29911**
Option availability-Job position	0.27623**
Job position-Current teleworker	0.197648*
Job position-Teleworking preference	-0.01719
Current teleworker-Teleworking preference	-0.16125

Table 7-10: Tabulated Pearson Correlations (2-tailed) estimates among selected variables (** Correlation is significant at the 0.01 level, * Correlation is significant at the 0.05 level).

As expected, preference for teleworking is very strongly negatively correlated with option availability. In summary, option availability from the employer effectively explains the adoption and preference for teleworking, even better than the job position variable. However, the respondents in this sample do not appear to have a clear understanding of employer's policy on teleworking.

7.2.3 Analysing the Perceptions about Job (Un)suitability

In the context of the above analyses, it is also helpful to analyse the issue of job suitability for teleworking because when the data from the responses to SP situations (controlled conditions) were analysed relative to their RP (uncontrolled or free conditions) response, it revealed that respondents' perceptions regarding this issue and the dynamics of the choice behaviour varied quite significantly. Which perception of job suitability is correct: under free conditions or controlled conditions? Perhaps, there is no easy answer.

In an independent analysis for this purpose, 53 respondents, including four cases of blank responses, out of 192 considered their jobs unsuitable for teleworking under free (RP) conditions. Out of these 53, 11 chose to telework given the option (Q16). Of the rest (42), 12 changed their mind going through the experiment under the influence of policy and chose telework under one or more situations of the experiment. This leaves only 30 (15.6%) people in a sample of 192 who thought they were incapable of teleworking due to job unsuitability and did not choose the telework option under any of the given scenarios.

However, some of these 30 respondents may also have misunderstandings of telework. A closer look at these 30 cases reveals that two respondents have given blank responses to all the replications and the rest of them are equally divided (at 8% of the total sample) between those who chose from the non-teleworking choices (either change time or mode) and those who would continue car commute under all SP replications. It is, however, possible that the respondents in the latter category might be tied by circumstances, like escort duties. Thus, in the final analysis, in the absence of telework option, 28% considered their job unsuitable for telework. Given the option, this figure fell to 22%. But finally it was found that only 15.6% consider their job really unsuitable for telework.

7.2.4 ICT Availability in the Sample Households

This research was set into the context of diffusion of and access to ICT within households. To assess the relevance of this variable, questions 38, 39 and 39a were included in the survey. The finding from the sample shows that only ten respondents (5%) in the sample did not have a computer at home and 54% of the sample had access to between 2-4 computers at home(Q38). In only four cases where a computer was available at home, was internet access lacking at home(Q39) which also means that overall 94% of the households in this sample had internet access and 81% of them had broadband access (Q39a). These summary findings show that this variable does not have much explanatory power towards the practice and preference for teleworking and has lost its significance, highlighted in earlier studies, with the passage of time due to increased diffusion of ICT.

7.2.5 Characteristics of Current and Potential Teleworkers

The survey included questions on teleworking frequency, perceptions of teleworking cost in the sample and willingness to pay for it. This section presents an analysis of responses to these questions. Teleworking frequency is the foremost indicator of travel impacts of teleworking on overall travel demand in general and on the peak in particular; and is of primary interest in any study of telework. Generally this frequency has been found to be relatively low even among self-selected samples of current teleworkers (see discussion in section 2.8.2 also). This consideration motivated the selection of the time unit in the question which was applicable to current teleworkers in the survey. The question was: "How many full days per fortnight do you telework?"

To facilitate the comparisons with previous studies and use of the results from the survey at the forecasting stage, the distribution of responses obtained has also been adjusted to a weekly basis and is given in Table 7-11. N is 44 of whom 7 respondents gave blank responses to this question. Mode and median frequency is one day per fortnight and the frequency range is between quarter of a day and four days per fortnight. Compared to earlier studies quoted in section 2.8.2 which put the frequency between 1½ to three days per week, the overall teleworking frequency in this sample is on the low side. The fact that this was not a self selected sample, as they were in the majority of the studies referred to, might explain these low levels.

No. of Teleworkers	Days per week	Days per Fortnight	% of Total
2	0.125	0.25	5.41
10	0.25	0.5	27.03
15	0.5	1	40.54
1	0.75	1.5	2.70
6	1	2	16.22
1	1.5	3	2.70
2	2	4	5.41
Total 37			100

Table 7-11: Distribution of teleworking frequencies (Q15) among the current teleworkers

The responses to telework frequency were also cross checked for internal consistency with answers to QQ 1a, 1b and 1c in the survey. This analysis did not yield any meaningful result or interpretation for two reasons. First, item non response rate to Q1b was 50% (see table in Appendix VI at 13.6). Second, 34 teleworkers in the sample have a frequency less than or equal to half day per week, thus, incompatibility between the units of comparison/analysis. However, when the responses from the remaining 10 teleworkers were cross checked, it was found that only two of them gave consistent responses, three gave missing responses to Q1b while the remaining 5 either could not appreciate the purpose of this question or appeared to consider telework equivalent to travel. This might be the result of keeping the respondents unaware about the purpose of the survey at the start.

These low teleworking frequency figures, especially those less than or equal to half day teleworking per week, may also have implications for the decision to constrain the SP teleworking choices to between 1-4 days per week, an issue noted in 5.3.6. These low frequency teleworkers might have wanted to telework less under SP conditions as well but might have felt compelled to choose more telework in the SP design. This issue will be looked into at the SP data analysis stage (see 8.8.2).

7.2.6 Perceptions of Teleworking Costs

Section 3.4.3 has seen that determining the true cost of teleworking is a complex issue. Hence, the survey asked the respondents about their *perceptions* of teleworking cost per day and they were provided with a broad range to record their responses. The relevant question applied to both current and potential teleworkers and was phrased as: "If you were to telework how much would it cost you per day (include costs such as phone, internet, energy bills, etc.)?". The distribution of frequencies of responses to this question has been given in the second column from the full sample in table 7-4 and a graphic representation is shown in Figure 7.1.

To the knowledge of this author, no previous study has looked into this aspect of teleworking. The teleworking cost may be incurred on account of the provision of different facilities involved in making telework possible. A detailed discussion in this regard is given in section 3.4.3. In simple calculations, the cost of an internet connection is considered one of the main running expenditures these days. Currently, broadband type internet connection is used by most people. In most cases it is a fixed expense and considered a daily necessity. The contribution of other cost heads to total teleworking cost per day is often negligible.

From this perspective, for 25% of the sample to perceive teleworking cost more than £5 for a single day is a little surprising. This conclusion may also have a connection with the ranges of the cost categories which were defined rather broadly keeping in mind that perceptions of cost of an activity among people generally differ quite widely. The teleworking cost can also be contrasted with daily commute cost (including parking charge) figures in table 7-2 which for 58% of the sample is less than or equal to £5. Although the teleworking cost estimates from this sample may appear too high, there are suggestions that, depending on individual households' energy consumption (Banister et al 2007) in the face of rising cost energy, teleworking costs may actually exceed the travel costs, especially during the shorter winter days.

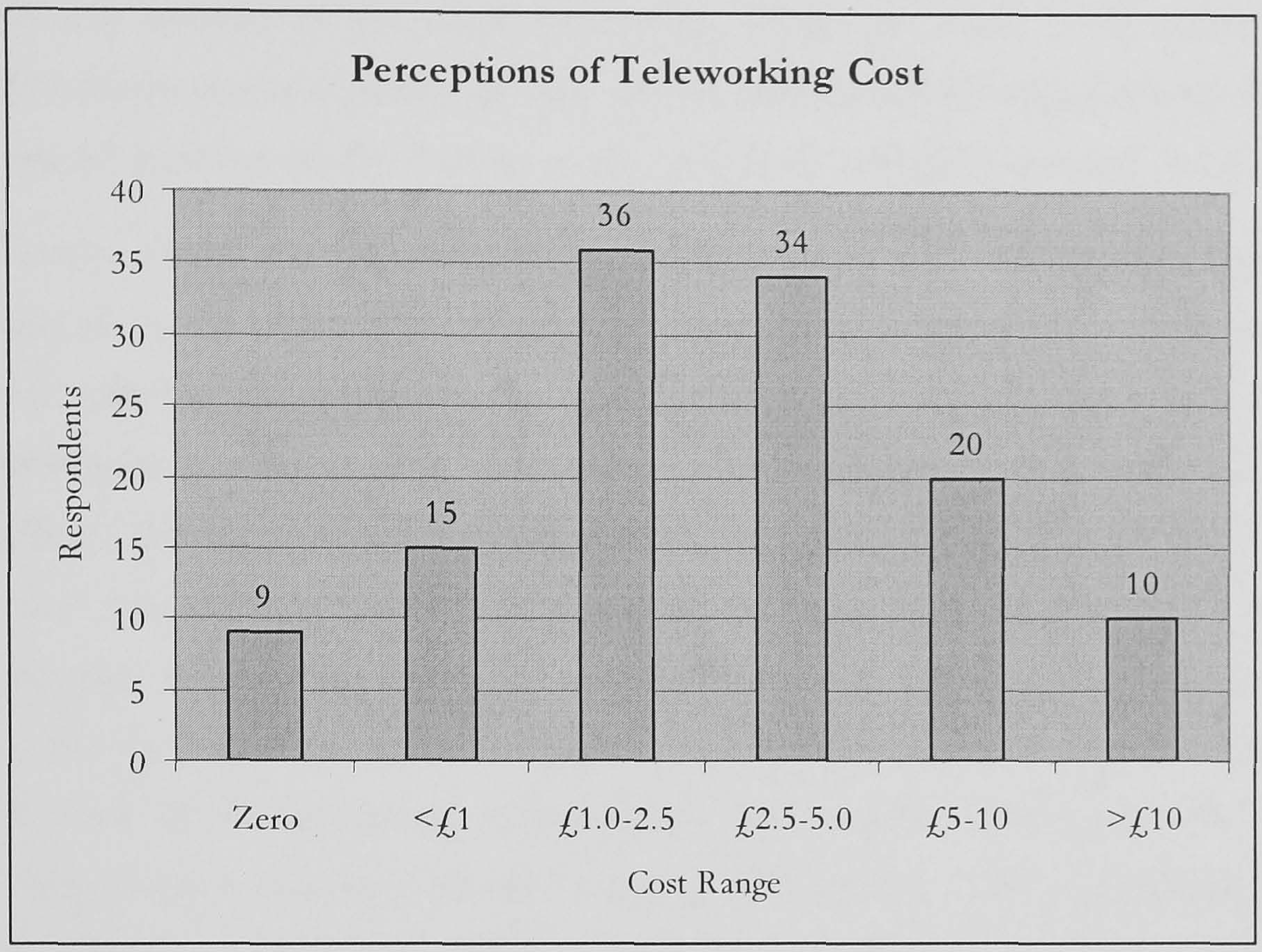

Figure 7.1: Graphical representation of responses on daily teleworking cost (Q17) (the figure on the top of a bar indicates the number of respondents choosing that particular category)

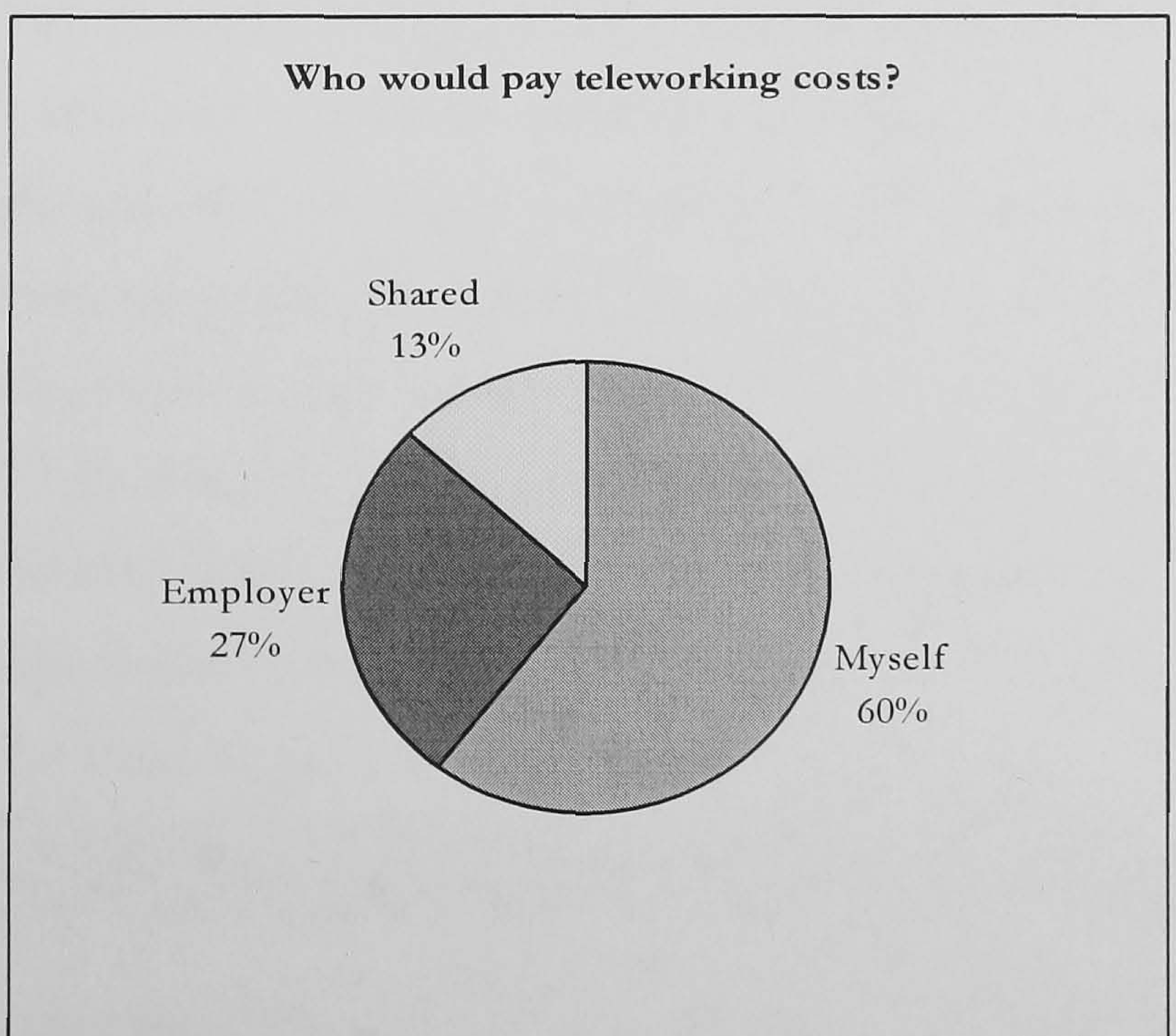

Figure 7.2: Distribution of responses to Q18: who would pay teleworking cost

When asked who they think would pay this cost, the result from the responses shows the pattern given in Figure 7.2. The distribution of these responses was not much different between those who currently practise and those who indicated a preference for teleworking. The finding suggests that despite their perception of higher teleworking cost, given the option the majority of the employees are resigned to having to pay for its running costs

7.2.7 Other Miscellaneous Analyses

The analyses in 7.2.1 through 7.2.6 have covered all the significant RP questions directly related to the study objectives. However, there were some relationships and distributions not covered in these tables which are investigated here. Before making the overall analysis on the dataset comprehensive, two factors need to be considered.

Firstly, there are skipping logics embedded in the instructions regarding the main questions on desirability of teleworking and on its impacts which significantly reduce the number of observations per variable of interest, especially related to impact questions. Secondly, low teleworking frequency among the teleworkers in this sample affects the meaningfulness, and thus desirability, of a deeper analysis especially through cross tabulations. Finally, some questions have a broad range of response categories and due to skipping logics the numbers of total responses they get are further reduced in the dataset. For example, Q17, Q20 and Q22 have six response categories each and in view of the foregoing observation, each response category on average would be likely to get a relatively smaller share of responses to these questions which when cross tabulated would yield little meaningful interpretation. With these caveats, some miscellaneous features of this data were further explored.

For example, it is possible to analyse travel behaviour by time of day in this sample and Table 7-12 shows the results. Excluding four respondents working shifts, it shows the distribution of travel behaviour of respondents with respect to both morning and evening peaks. However, any inference from this table needs to be qualified with the observation that the tabulation is based on departure time data and a journey started at 07:25 AM has been counted as 'before' peak but the travel would be done during the defined peak. The same observation applies to the data on return leg of the journey. The table shows that in this sample the spread in the morning peak is lop-sided while the evening peak has a relatively even spread.

	Morning Peak (0730-0930)		**Evening Peak (1700-1800)**	
	No. of Resp	% Relative to Total	No. of Resp	% Relative to Total
Before	58	30.9%	45	23.9%
During	128	68.1%	110	58.5%
After	1	0.5%	31	16.5%
Missing	1	0.5%	2	1.1%
Total	188		188	

Table 7-12: Travel behaviour of the sample by the time of day (QQ 2-3)

In addition to the cross tabulated analyses in 7.2.1, 7.2.2 and 7.3.2, the possibility for some further meaningful cross tabulations among the different features of teleworking in the survey was also explored. Table 7-13 presents the cross tabulation between the variable 'who would pay teleworking cost' (Q18) and 'whether the option to telework is available from the employer' (Q13) and shows that 66% of teleworkers are likely to pay for teleworking costs themselves if they are formally or informally allowed to telework. This result shows the attraction of this work arrangement and has welcome policy implications from an employers' perspective.

Telework availability response category	**Who would pay the teleworking cost**			
	Myself	Employer	Shared	Total
Formally possible	30	7	4	41
Informally possible	30	14	5	49
Job unsuitable	4	5	0	9
Not permitted	9	7	7	23
Total	73	33	16	122

Table 7-13: Relationship between telework availability and teleworking cost payee

Table 7-14 which cross tabulates 'frequency of teleworking' (Q15) with 'relocation decision' (Q25) clearly shows that there are not enough observations in each category to draw any meaningful inference. Responses to Q19, a partially open-ended question, were also analysed without detecting any significant pattern. The responses recorded in the case of an affirmative answer to it were largely in the forms of desires and suggestions, and mainly related to seeing improvements in PT, flexiweek or changing the job or location.

Relocation response category	**Teleworking frequency (days/week)**					
	0.125	0.25	0.5	1	1.5	Total
Already relocated	0	0	1	2	0	3
Would relocate	0	0	1	0	0	1
Think of relocating	0	1	0	1	0	2
Won't relocate	2	1	1	1	1	6
Total	2	2	3	4	1	12

Table 7-14: Relationship between teleworking frequency and relocation decision

7.3 Analyses of Attitudes towards Teleworking

Section four in the survey was devoted to exploring attitudes of the sample towards teleworking and contained eleven attitudinal statements. The majority of the statements (1-8) represented the perceived benefits and costs of teleworking in the literature. These statements were phrased to reflect a respondent's attitude toward a particular aspect of teleworking. Regardless of their content or character all the statements were phrased affirmatively and their evaluation was required on a bi-polar scale of 1-10 where 1 indicated a strong disagreement while 10 indicated a strong agreement. Their presentation in the survey was alternated by positive and negative statements. The following statements were used:

- Teleworking does/would provide me with more time for myself/family.
- I do/would lose on learning opportunities and social interaction at my workplace when/if I telework.
- Teleworking does/would provide me with increased flexibility in scheduling my day.
- Working from home does/would adversely affect my chances for career advancement or promotion.
- I do/would like the increased independence in doing my job afforded by telework.
- Teleworking does/would increase work-family conflicts.
- Teleworking does/would save me commuting costs and stress.
- Teleworking does/would develop a sense of isolation.
- Working from home does/would increase my job performance/make me more productive.
- Teleworking does/would help in catering to caring needs at home.
- My manager approves/ would approve of me working from home.

First a factor analysis has been performed on these statements. Doing so would ensure a check on the reliability and validity of the attitudinal responses in line with their design. After that the data on individual responses has been analysed.

To analyse whether the attitudes towards teleworking differ among the sample with respect to having a particular DSEC characteristic or being a current or potential teleworker, the ANOVA test was used. In an ANOVA, instead of Z or Chi square statistics used in non parametric tests above, the F-ratio is the statistic used to test the hypothesis that the effects are real: in other words, that the means of two or more groups within the sample are significantly different from one another. The F-ratio is thought of as a measure of how different the means are relative to the variability within each sample (Stockburger, 1996). The rest of the procedure and explanation for this test is the same as for Mann-Whitney U or Kruskal-Wallis tests. Similarly, SPSS software outputs the α value for ANOVA test also.

7.3.1 Analysis of Factors Underlying the Attitudinal Statements

Inclusion of attitudinal statements was motivated by two main reasons: to validate the choice data provided by different groups of respondents within the sample through cross check analysis and to explore the positive and negative psychological constructs about teleworking resulting in perceptions of teleworking cost and benefits. Therefore, it is useful to explore whether the factors underlying these statements are understood as intended across the sample and confirm their logic and design. For this purpose, an analytical technique called Factor Analysis is used. In this technique the main factors common to most of the variables being tested are extracted using a procedure called principal component analysis. These extracted factors, depending upon the purpose of the analysis, can be rotated to check the factor loadings on individual factors (Kline 1994).

There are certain requirements for the data to be suitable for this type of analysis. For example it is necessary: to check whether the dataset being used would afford meaningful analysis (which can be checked through the measure of sample adequacy); to avoid respondents' response bias creeping into the analysis (Brace et al, 2006); and that all the variables in the data being analysed are normally distributed (Tabachnick and Fidell, 2001). Measure of sampling adequacy was found at 0.8096 which is very good as the threshold value is 0.5. Checking the data properties assured that it meets these requirements. However, it was suspected that presence of four statements (No. 2, 4, 6 and 8) might create problem vis-à-vis the requirement of avoiding respondents' bias. These four statements were about negative perceptions of teleworking but were phrased affirmatively. The scores assigned to these statements were recoded in reverse order to avoid this problem, e.g. a score of 4 by a respondent to statement two was recoded as 6 on the given scale of 1-10. The results of the analysis are presented in Table 7-15.

	Exploratory analysis factors			Confirmatory analysis factors	
Attitude Variable	**1**	**2**	**3**	**1**	**2**
1-Increased Time availability		0.778			0.800
2-Loss of learning opportunities	0.807			0.771	
3-More Flexibility		0.782			0.811
4-Affects career	0.589		0.444	0.790	
5-Increase independence	0.356	0.621			0.580
6-Conflicts with family life	0.691			0.634	
7-Saves commuting stress & cost		0.649			0.661
8-Develop isolation	0.785			0.786	
9-Feel more productive	0.547	0.463	0.351	0.565	
10-Cater to care needs		0.581			0.654
11-Manager attitude			0.905	0.402	

Table 7-15: Factor loadings for different statements about teleworking

Table 7-15 shows factor loadings under two main columns of 'Exploratory Analysis' and 'Confirmatory Analysis' (while column sub-headings indicate the number of factors extracted under each procedure). The results for the former have been obtained using 'Varimax' (uncontrolled) rotation which has loaded all the statements (variables) on to three factors while the latter analysis uses 'Promax' (a procedure in which number of factors to be used for analysis is specified in advance) rotation and it has loaded all the statement variables on to two specified factors. The latter rotation is used for Confirmatory Factor Analysis where there is need to validate whether the responses to the questions/statements confirm the logic behind their design. In this case the results confirm the pre-conceived design as the first 8 statements have been clearly separated into positive (factor 2) and negative (factor 1) factors. All these statements have got very high loadings, more than 0.6 which is considered a high loading. Loadings with a value less than 0.3 are considered low or poor loadings.

However, it is interesting to note that statement 9 and 11 have been loaded on to the negative factor while the statement 10 has been assigned to the positive factor. The design logic had thought of these statements as neutral. However, as the number of factors (extraction condition) was pre-specified as two, so the analytical routine has to load them on to either of the factors. In this regard, the loadings of statements 10 and 11 to respective factors are plausible in view of the nature of their content. However, the loading of statement 9 on the negative factor with a rather satisfactory value is surprising. A possible explanation could be that rather than being a benefit of teleworking it may simply be an artefact of teleworking which is considered positive from the employer's perspective but may not be from an employee's perspective.

The factor loadings under Exploratory Analysis in Table 7-15 also make sense as they have been obtained without any restriction on the extraction process. There is a rather clear pattern to the loadings on factors 2 and 3 which may be named as 'personal autonomy' and 'job related factors' respectively. The statements 4 and 5 load on to two factors each though not with equal values but lower values for these are still satisfactory. The statement 9 loads on to all three factors though it has got the highest value for factor one which may be called 'concerns about teleworking'. The analysis of this statement indicates that the respondents are finding it hard to have a clear opinion or position with regard to this aspect of teleworking. Statement 11 has been loaded on to the 'job related factor' with the highest value for any statement under either of the analyses. This is in contrast to confirmatory analysis where it has to be loaded on either of the factors, and thus has been loaded on to the negative factor but with a value (0.402) just above the threshold. This confirms the argument about the neutrality of this statement.

7.3.2 Testing the Attitudes with ANOVA

To perform this analysis, a composite parameter, called attitude, was created taking the mean of the scores given to all the statements. For this purpose, transformed data on responses to four statements (No. 2, 4, 6 and 8) with negative perception of teleworking, as mentioned in the previous section, were used. Table 7-16 shows the α values obtained by analysing the sample with respect to various categories for different DSEC and other variables affecting teleworking adoption. The results in Table 7-16 show that the effects on attitudes of education, availability of the option for teleworking from the employer, preference for telework and the cost bearer are all significant at the 95% interval of confidence. For gender this hypothesis has been accepted at 93 % interval while for two ICT variables of degree of computer ownership and access to internet at home the same hypotheses have been accepted at the 90% confidence interval. Similarly, the attitudes vary significantly by employer and by the daily cost to telework at the 90% confidence interval. The hypotheses that attitudes towards teleworking vary with age and living circumstances have been rejected with big margins.

Variable Name	α value returned by ANOVA test
Gender	*0.066*
Age	0.256
Living circumstances	0.462
Presence of young children (between 5-15)	0.193
Presence of small children (under 5)	0.431
Household total	0.129
Care needs	0.626
Education	**0.029**
Income	0.606
Number of cars in the household	0.614
Escorting duty	0.195
Job position	0.485
Degree of computer ownership	*0.064*
Internet access	*0.095*
Type of access	0.636
Space availability	**0.000**
Travel time	0.416
Travel cost	0.108
By employer	*0.088*
Telework preference	**0.000**
Teleworking cost bearer	**0.012**
Teleworking cost perception	*0.073*
Teleworking option availability from the employer	**0.000**

Table 7-16: Results of ANOVA test showing if the attitudes towards teleworking differ among the categories of different variables (figures in bold show variables with significant differences)

Similarly, but surprisingly variations in travel time and cost incurred do not significantly influence attitudes towards teleworking. This means that the people with longer or costlier commutes do not have different attitudes towards teleworking from people with shorter or cheaper commutes. This observation also indirectly validates the earlier finding that commute time and cost are not significant in explaining telework adoption or preference for it (Table 7-3).

ANOVA only tells about the significance of differences among the categories of a variable at the desired level of confidence and has been used to identify the significant variables by which the attitudes differ. It does not indicate the nature or extent of the individual group differences within a particular variable. To find an answer to the magnitude of the differences (deviation) from the mean, Table 7-17 contrasts the sample attitudes (by mean statistic) with those held on the basis of gender while the scores (minus SD statistic) presented in Table 7-18 show the differences on the basis of telework availability to the respondents. In Table 7-19 attitudes of those who prefer to telework (Q16, yes sayers), who consider their job unsuitable (Q13) and who would not telework are compared (Q16, no sayers).

	Total sample		Male		Female	
Attitude Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Increased Time availability	6.64	2.98	6.65	2.85	6.62	3.20
Learning opportunities' loss	7.08	2.56	7.12	2.47	7.01	2.72
More Flexibility	7.04	2.76	6.86	2.71	7.33	2.83
Affects career	5.66	2.75	5.99	2.56	5.13	2.98
Increased independence	6.44	2.52	6.33	2.47	6.62	2.62
Conflicts with work family life	3.61	2.60	3.89	2.65	3.15	2.48
Saves commuting stress & cost	8.02	2.24	7.96	2.11	8.11	2.46
Develops a sense of isolation	6.61	2.57	6.57	2.45	6.68	2.76
Feel more productive	5.61	2.62	5.32	2.61	6.07	2.59
Caters to care needs	5.35	3.05	5.16	3.00	5.64	3.13
Manager attitude	4.95	2.78	4.57	2.55	5.55	3.02
N	185		114		71	

Table 7-17: Mean score for sample, male and female attitudes towards teleworking

The scores assigned to the attitudinal statements can also be taken as opinions about teleworking benefits and disbenefits. Looking at Table 7-17, the sample has rated, as expected, saving in commuting cost and stress as the greatest benefit of teleworking. In the second place is telework affording more flexibility in scheduling the respondent's day. After this comes increased time availability and feeling of increased independence due to teleworking. The biggest disbenefit of teleworking is loss of learning opportunities. The other significant disadvantage of teleworking is developing a sense of isolation. The sample is not particularly concerned about teleworking affecting career considerations. This may also be taken as an indication of changing perceptions of employment culture, increasing acceptability of teleworking by employers and the practice establishing itself as a work option. A more surprising finding from Table 7-17 is that respondents do not think that teleworking conflicts with family life while some of the earlier studies have speculated on this and some have even found empirical evidence to support it. On the rest of the attitudes, namely, being more productive while teleworking, for telework catering to care needs at home and manager's attitude towards teleworking; the sample has almost a neutral opinion. The finding on 'care need' here indirectly validates the conclusion drawn about this variable in Table 7-12 in section 7.2.1. The SD statistics for all the scores range between 2.5-3.0 points. Looking at the gender based differences in Table 7-17, females feel that their manager/supervisor is more likely to approve of their teleworking than males. Similarly, females more strongly disagree than males that telework conflicts with family life. Other notable differences between the sexes are with respect to teleworking affording more flexibility, affecting career, catering to care needs at home and being more productive.

Attitude Variable	Current TW	Job Unsuitable	Total sample	Not Permitted	Potential TW
	Mean	Mean	Mean	Mean	Mean
Increased Time availability	7.32	5.59	6.64	6.95	7.06
Learning opportunities' loss	6.11	7.89	7.08	7.45	6.84
More Flexibility	7.59	5.70	7.04	7.20	7.78
Affects career	5.00	6.26	5.66	6.10	5.62
Increased independence	7.45	5.13	6.44	6.21	7.21
Conflicts with work family life	3.00	4.41	3.61	3.75	3.20
Saves commuting stress & cost	7.91	7.85	8.02	8.10	8.36
Develops a sense of isolation	5.59	7.83	6.61	6.73	5.94
Feel more productive	6.73	4.39	5.61	4.93	6.25
Caters to care needs	5.23	4.85	5.35	5.85	5.86
Manager attitude	6.77	4.39	4.95	2.89	4.88
N	44	40	185	46	89

Table 7-18: A comparison of the mean attitudinal scores under differing conditions of option availability/possibilities for teleworking

Table 7-18 shows that those with unsuitable jobs are generally comparatively less positive about a perceived advantage and more negative about a perceived disadvantage of teleworking. This is also partially reflected in the scores current teleworkers have assigned to all the attitudinal statements. Generally, their assigned scores give an opposite picture of teleworking to that given by those with unsuitable jobs. Compared to the sample means, theirs have higher scores for the positive statements and lower scores for negative statements except for saving the commute cost and stress. On loss of learning opportunity they agree but not as strongly as the entire sample. This is significant as they are speaking from experience.

Similarly, those who would prefer to telework are more positive about the positive statements about telework and less negative about the negative statements compared to those who are not allowed to telework. The latter as a group have understandably given the lowest mean score to the statement on their manager's attitude compared to all the mean scores given to any of the other statements by any of the groups compared. Except for managerial attitude, overall their mean scores also are closer to the sample means than that of any other group.

Given the opportunity to telework, the starkest difference is between those who would like to telework (Interested) and those who do not prefer it. Table 7-19 shows this very clearly. Those in the middle column are genuinely 'Uninterested' (Q16, no sayers) in teleworking in contrast to those for whom any constraint, e.g. jobs unsuitability, is active. This group has given two highest scores to statements pointing to perceived costs of teleworking. The scores indicate a strong agreement that they would develop a sense of isolation and lose learning opportunities if they start teleworking. Conversely these people like the opportunities for learning and social interaction afforded at the conventional work place. What is surprising is the degree of their conviction in what they believe as a group indicated by related SD statistics for both these scores (refer to Table 7-19) which are among the lowest obtained in any of the analyses in this section.

	Prefer telework		**Un-interested**		**Job Unsuitable**
Attitude Variable	Mean	Std. D	Mean	SD	Mean
Increased Time availability	7.06	2.76	5.24	3.66	5.59
Loss of learning opportunities	6.84	2.49	8.41	2.06	7.89
More Flexibility	7.78	2.22	5.34	3.50	5.70
Affects career	5.62	2.64	6.38	3.20	6.26
Increase independence	7.21	1.97	4.11	2.81	5.13
Conflicts with work family life	3.20	2.29	4.66	3.14	4.41
Saves commuting stress & cost	8.36	2.04	7.07	2.55	7.85
Develops a sense of isolation	5.94	2.42	8.72	1.81	7.83
Feel more productive	6.25	2.39	3.07	1.98	4.39
Cater to care needs	5.86	3.07	4.71	2.79	4.85
Manager attitude	4.88	2.57	2.89	2.44	4.39
N	89		29		40

Table 7-19: A comparison of the means of attitudinal scores of three different groups

Those in the Uninterested group doubt that they will have increased independence in job performance while teleworking. Unintentionally, perhaps, they are in doubt about their own ability to work independently. They are also almost neutral about teleworking resulting in increased availability of free time and flexibility in scheduling their day. This is also supported by their low score on feeling more productive on teleworking days which is less than half of the score given to the same statement by those who are in the Interested group. However, an inexplicable finding here is the lowest score assigned to manager's attitude by the Uninterested group. The score is the same lowest score given to the same statement by those who are not permitted (Table 7-18). This may just be a coincidence as this similarity does not extend further. Nonetheless, the foregoing observations clearly establish that those uninterested in teleworking have markedly different perceptions.

The above analysis has established that there are two separate factors that influence a respondent's attitude towards teleworking. One factor is the DSE variables of gender and education and the other factor is a function of employee-employer relationship; i.e. whether the option to telework is available from the employer and whether a respondent's job is suitable for telework. This study has shown a clear evidence of correlation between job position and telework availability but not about the direction of causality. However, it may be assumed that for the majority of respondents the teleworking attitudes appear to be shaped by constraint(s) upon free choice regardless of whether this constraint emanates from lack of telework availability or job unsuitability. If so, this has clear implications for policy analysis of teleworking; an issue that will be addressed in Chapter 11.

7.4 Analysis of Teleworking Impacts

Section 2.10 hypothesised about the impacts of teleworking and section 4.2 short listed four responses to telework availability for study in this thesis. Questions on two of these responses were included in the survey instrument under a separate section (see section 5.4.3) and the results have been analysed here. SP experiments are also said to be characterised by respondent fatigue. This study could not observe direct evidence of any such fatigue from the responses to SP situations. However, the respondent fatigue in this study may be indirectly evident from the attempted responses to this section of the survey instrument. This section was applicable to only those respondents who were either current teleworkers or chose to be teleworkers in response to any of the SP situations presented to them.

Based on the eligibility criteria for answering, this section applied to 144 out of 192 respondents. However, 22% (31 out of 144) of these seem to have fallen victim to the fatigue which may be attributed to the cognitive rigour of the SP experiment as they chose to leave this section blank without any apparent reason. Therefore, the impact analysis is based on responses of a sample of 113 respondents comprising 41 current and 72 potential teleworkers. However, there were a few blank responses to some of the questions in this section which explains the difference in the numbers shown in the tables. This section combined both revealed and stated intention data which at times made it difficult to isolate the true impacts. It is suggested that these impacts should be studied as RP data.

7.4.1 Non-Work Travel Impacts

These impacts were studied through questions 20-22 which investigated the use of the car freed on a teleworking day. Q21 asked about the absolute change in weekly non-work travel trips due to increased availability of car to the respondents and their households, due to time saved from the given up commute trip. Q22 asked about the magnitude of the increase or decrease. Q20 asked about the purpose of the extra trip(s) and the respondents were allowed more than one choice.

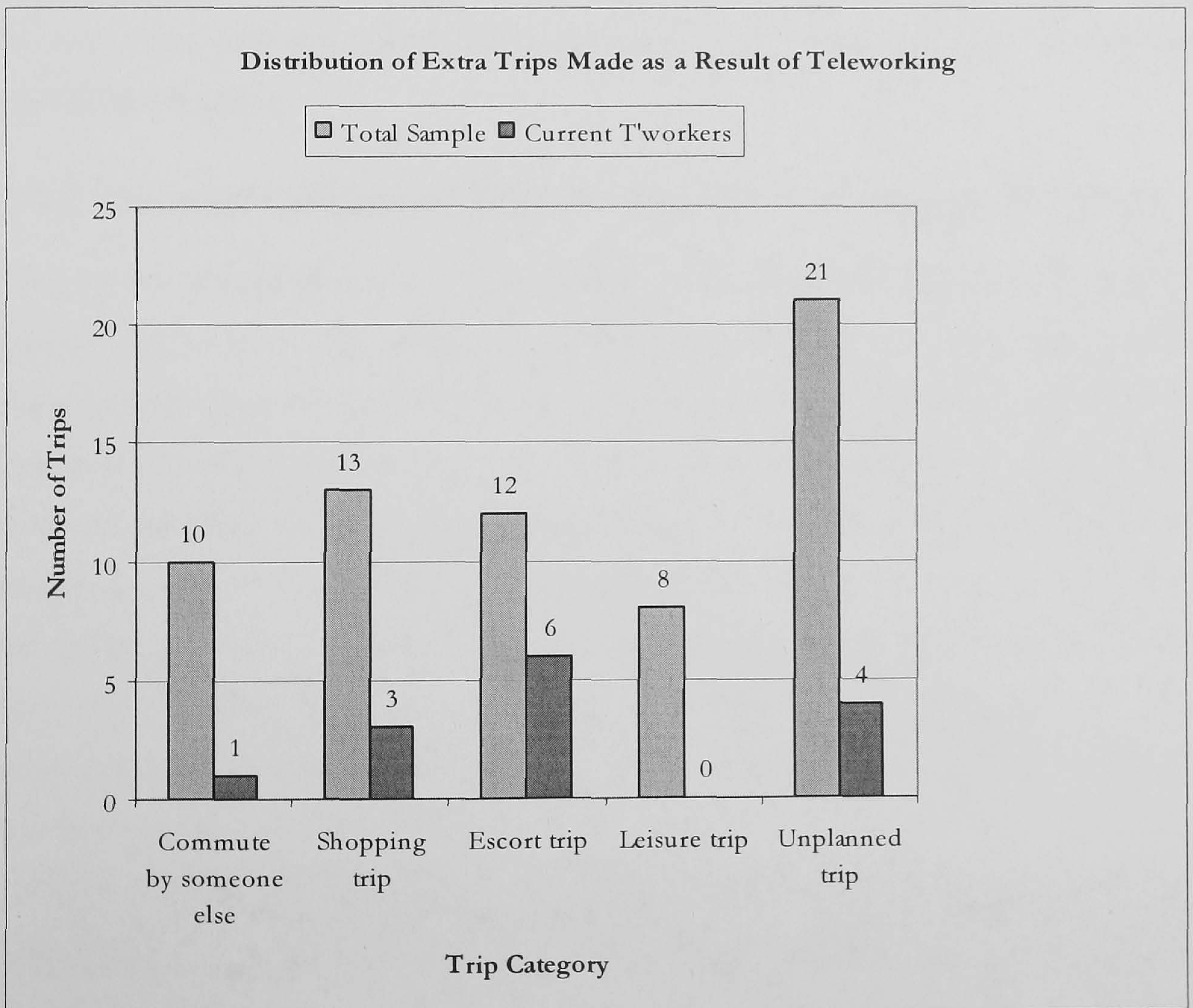

Figure 7.3: Distribution of extra trips made using the car released by teleworking (Q20)

Figure 7.3 plots the responses on trip purposes excluding those who said their car would not be used for any travel on a teleworking day (Q20). In response to Q21, 69% stated that there would be no change (no-sayers) in the non-work travel by their household as a result of their teleworking adoption. The corresponding figure for current teleworkers is 72%. The yes-sayers to Q21 were explored for the magnitude and direction of the change in Q22.

	combined sample	current teleworkers
1-3 trips more	17	6
4-6 trips more	8	3
More than 6 trips	2	0
1-2 trips less	6	1
3-4 trips less	1	0
Total	34	10

Table 7-20: Extent of teleworking impact on non work travel (Q22)

Q22 was asked relative to the average number of weekly trips made by the household of a teleworker. The response categories and the responses provided by both the samples are given in Table 7-20. For the combined sample, it points to the evidence that, besides the commute trips, non work trips would also fall for seven people between one to four trips per week while one current teleworker is already making one to two trips less per week for non commute purposes. This is potentially a very significant finding.

7.4.2 Interpretation and Discussion of Travel Impact Findings

The travel impact data show that perceptions about this impact are being commonly shared within both the samples, i.e. current teleworkers and combined sample which also includes potential teleworkers or preferrers. This finding is significant because it has implications for the sample size and interpretations based on it. However, there is a need to quantify the travel generation impact of teleworking in this sample. For this purpose, Table 7-21 determines the number of additional trips that are being or would be made by the combined sample. As noted above, this sample consists of 113 respondents. Out of these, 69 stated that their cars would not be used on their teleworking days during the week. For the remaining 34, their non work trip behaviour has been shown in Table 7-21.

Trip categories	No. of respondents in each category	Average weekly trips per category	Trips made by people in each category
1-3 trips more	17	2	34
4-6 trips more	8	5	40
> 6 trips	2	7	14
1-2 trips less	6	1.5	-9
3-4 trips less	1	3.5	-3.5
(Net) additional non work trips			75.5

Table 7-21: Calculation of non work trips from the data by combined sample

The first column from left lists the response categories in the survey. The second column provides the distributions of respondents in each response category. As the response categories consisted of ranges, the third column list the average of the range for a particular response category. Note that >6 is estimated as 7. The last column is the product of columns two and three. These calculations conclude that this sample would make 75.5 additional non work trips on their teleworking days per week which when distributed over 113 respondents gives a weekly travel generation impact of teleworking at 0.67 extra trip per teleworker which on a daily basis comes to 0.13 trips. These results are largely in line with the earlier literature (see section 2.10.2). For example Koenig et al (1996) and Henderson et al (1996) respectively found a daily increase of 0.5 and 0.3 trips in absolute numbers for non-commute trips.

The above finding can be put into perspective. For this purpose, the data in Table 8-14 can be used which clearly shows that a weekly teleworking frequency of two days is preferred by this sample. This means a savings of two commute trips per week. Thus, the net travel impacts of teleworking is a reduction of 1.33 trips per teleworker per week. However, in RP data this frequency is one day per week which means the net impact figure drops to 0.33 trips. Hence, it may be fair to say that the truth lies somewhere between 0.33 and 1.33. Determining the net impact in this way makes it sensitive to the changes in teleworking frequency. However, it is useful to note that travel generation impact is a function of increased availability of time to the teleworker and of car to the household of the teleworker. A reduced teleworking frequency would also effect a decrease in these two factors. Thus, there could be an inverse relationship between travel generation caused by teleworking and teleworking frequency which might not substantially affect the ratio between the save commute trip and extra non work trip determined above.

It may be pointed out that from the perspective of vehicle miles travelled, the impact is likely to be more pronounced as non work trips are usually shorter than a commute trip. Further, commute trips are overwhelmingly associated with peak periods while only a fraction of non commute trips may be made during this period. A deeper look into the data on individual trip categories further endorses these findings. For example, in the sample of current teleworkers, only one replacement commute trip by someone else is being made and the number of escort trips is also low when compared on a full sample basis. These findings are encouraging and lead to the conclusion that the net travel impact of teleworking adoption is quite beneficial.

7.4.3 Impacts on Location Behaviour

To investigate the link between teleworking and residence location/relocation, the respondents were asked for their perceptions. Here also three questions were asked to obtain responses on location preferences/behaviour of the combined sample, i.e. current and potential teleworkers. These questions were answered by 76% (out of 144) of respondents to whom this section applied. So, the analysis is this section is based on 110 responses. It was recognised that residence relocation is a household and medium to long term decision. Q23 (with four possible answers) asked about the perception that teleworking adoption has made or would make it convenient for the current or potential teleworkers to change their residential locations. The distribution of responses obtained is presented in Table 7-22 and commented upon in the next subsection.

	combined sample	Current teleworkers
Yes (presence of effect)	15	7
No (absence of effect)	18	7
Don't know	10	1
Happy with my location	67	25
Total	110	40

Table 7-22: Effects of teleworking choice on the location behaviour of the chooser (Q23)

Q24 was aimed at further exploring the ability of a household to relocate and the respondents were asked to consider all the circumstances associated with such a decision. The distribution of the responses has been shown in Table 7-23. The question was answered by 59 people including 20 current teleworkers. From the combined sample, 33% gave an affirmative response, i.e. it is or would be possible with telework adoption for their household to relocate. The corresponding figure for the current teleworkers in the same table is 30% (of 20).

	Combined sample	Current teleworkers
Yes	19	6
No	40	14
Total	59	20

Table 7-23: Do/would your household circumstances if you were to telework, allow you to relocate to your preferred location? (Q24)

Here it was thought interesting to explore whether the commute journey times have any effect on these choices. For this purpose first the continuous response data to QQ 4 and 5 were added to get consolidated travel times which were then converted into categorical choices which in turn were crosstabulated with response to Q24. Table 7-24 presents the results. The expection was that the respondents with longer commute journey might be more inclined to relocate. Again sample size limits any meaningful analysis. However, the number of observations available for the analysis in the table does suggest that seemingly the responses to Q24 are not influenced by the commute journey times.

Return commute journey time category (in minutes)	Do/would your household circumstances if you were to telework, allow you to relocate to your preferred location?		
	Yes	No	Total
Up to 20 Min	0	0	0
Between 21 - 40 Min	3	9	12
Between 41 - 60 Min	8	8	12
Between 61 - 90 Min	1	11	12
Between 91 - 120 Min	5	7	12
More than 120 Min	2	5	7
Total	19	40	59

Table 7-24: Relationship between relocation preference and commute journey times

The final question (Q25) on location behaviour in the survey was answered by 46 respondents, whereas given the skipping logics in the preceding question, only 19 respondents ought to have answered it. However, the question wording per se is very general and does not betray any particular context. The fact that only current or potential teleworkers have answered it makes the inferences drawn from the responses a valid reflection of the respondents' opinion. The respondents were asked to tick the choices given in Table 7-25 which also shows the distribution of responses within the two samples.

	Response distribution	
Choice description	Combined sample	Current teleworkers
I have already relocated	4	4
Yes, I would relocate	2	1
I am thinking/would think of relocating	14	3
No, I would not relocate	24	7
Total	44	15

Table 7-25: Distribution of responses from the sample data on the question: whether people would actually relocate if they chose to telework (Q25)

7.4.4 Interpretation and Discussion of the Findings

The presentation of the results in the previous subsection in general and in Table 7-25 in particular should be put in the context of three quite significant issues: first, just three questions cannot explore a complex and a long term decision making process resulting in location behaviour; secondly, two different groups of respondents, one with experience of teleworking (though the length is unknown) and the other without, would surely have different behavioural dynamics and should not be combined in the sample; and finally, when potential teleworkers are excluded the sample reduces to 15 respondents, thus, the sample cannot be deemed as representative. These observations should be further qualified with the fact that the respondents did not stick to the design logic for these particular questions. With these caveats some general inferences can be drawn from the analysis of the data presented in Table 7-22 through Table 7-25.

A clear majority in the sample is 'very happy with their current residence locations'. The actual figure for the combined sample is 61% while for current teleworkers this rises to 63% (ref. Table 7-22). As expected, telework alone does not weigh on the decision to change location as indicated by the responses of the rest. In the combined sample, for 66% household circumstances would not permit relocation to a preferred location even with teleworking while the corresponding figure for current teleworkers is 70% (refer Table 7-23). The implication here is that there are other factors involved for such a decision. Even if teleworking makes it convenient to relocate, 55% and 47% respectively from the combined sample and teleworkers would not relocate (Table 7-25). Out of these three sets of inferences, the set of inferences drawn from Table 7-23 is very significant for its implications in allaying any fears about further decentralisation of urban areas.

When looking for actual experience, four out of 15 current teleworkers who answered this question actually relocated. This appears a rather high number despite the fact that residence relocation is not an easy decision. However, the question wording did not make the connection between the location change decision and being a teleworker clear. This observation should qualify the finding. No prior evidence exists in the UK about this aspect of teleworking to validate the veracity of this finding.

In the context of the foregoing discussion, what can be defended safely is that there is some evidence of impact of teleworking on location decisions but what cannot be determined is the true magnitude and direction or causality of the impact. Following this it would be perilous to attempt any modelling of this response based on the results from this study.

7.5 Conclusions

Various procedures aimed at checking for inconsistencies and irregularities were performed to ensure good quality of the dataset which was at the base of analyses performed in this chapter. The response rate could not be established due to the practicalities of the survey administration process.

This dataset was analysed from at least four perspectives to detect the significance of association between DSEC characteristics as independent variables and teleworking choice and preference as dependent variables. Non parametric tests of sample independence established that only income and job position of a respondent are helpful in explaining the choice and preference for teleworking.

Exploring the dataset for employers' influence on the choice and preference for teleworking revealed that option availability from the employer effectively explains the adoption and preference for teleworking, even better than the job position variable. However, the respondents in this sample appear not to have a clear understanding of their employer's policy on telework which in part may be attributed to ambiguity in Q13. The study has found a strong positive correlation between a respondent's job position within an organisation and telework availability. It was also found that ultimate perception of job unsuitability is different under different conditions.

The respondents in senior and middle management positions are more likely to telework than are the respondents in other positions. This finding is further confirmed by the relatively low overall score given to manager's attitude in the sample when the attitudes of the respondents were analysed. This indicates a problem and potential space for policy intervention. This has clear implications for policy analysis of teleworking; an issue that will be addressed in Chapter 11.

The lack of significance for DSEC characteristics except for job position, which incidentally is an employment related variable, in explaining the telework choice and preference means that these variables are becoming increasingly less important in the face of increasing awareness about teleworking and the benefits associated with it. Given the option, the decision to adopt teleworking is likely to be independent of personal or household characteristics even more in future.

The analysis of attitudinal statements established that attitudes towards teleworking among respondents vary by only gender and education. Gender based differences in these attitudes were clearly evident though the nature of these differences were not very significant. Another factor influencing these attitudes was job related, i.e. whether the option to telework is available from the employer and whether a respondent's job is suitable for telework.

This study has shown a clear evidence of correlation between telework availability and job position but not about the direction of causality which may need further investigation. However, it seems reasonable to suggest that perception of one's job suitability for teleworking also affects the overall attitude towards teleworking and its perceived benefits and costs.

On the contrary the attitudes of those who are uninterested in teleworking even when it is available differ markedly from the rest of the sample. This group of people would have implications relative to the effectiveness of a policy aimed at encouragement of telework. Earlier, Factor Analysis confirmed the design logic underlying the attitudinal statements by clearly loading them on to two components of benefits and costs of teleworking and highlighted that the respondents tend to view managerial attitude towards their telework adoption negatively.

Descriptive frequencies and statistical tests identified the job position and telework availability as factors explaining the choice and preference for teleworking. Attitudinal analysis among other things helped in specifying the nature of employers' role relative to these factors by identifying the manager's attitude as a possible reason as shown by the low scores assigned to it. Thus, findings from both these analyses are complementary.

Regarding teleworking impacts, the analysis has established that teleworking has a travel generation impact. In this sample this impact has been determined at 0.67 trip per teleworker per week. The mode teleworking frequency as shown by the SP choice in the sample from is two days per week. Thus, the net beneficial teleworking impact on travel demand can be expected at to be a reduction of 1.33 trips per teleworker per week. However, from the RP data perspective this net impact figure drops to 0.33 trips. Hence, it may be fair to say that the truth lies somewhere between 0.33 and 1.33. These calculations are based on trip counting. A VMT perspective might reveal more beneficial impacts as the previous studies have shown.

When responses on location choices were analysed, it emerged that for 66% of those who were eligible to answer, household circumstances would not permit relocation to a preferred location even with teleworking while the corresponding figure for current teleworkers is 70%. In summary there is some evidence of impact of teleworking on location decisions but what could not be established given the small sample is the true magnitude and direction or causality of this impact. Therefore, the question whether teleworking contributes to urban dispersal is still awaiting an answer. In view of these findings, it is recommended that location behaviour of teleworkers should be studied separately from any other response and should be studied through RP data or SP data obtained from experienced teleworkers.

8 Analysis of SP Data and Model Estimation

8.1 Introduction

This chapter is devoted to the analysis of the SP data and the objective is to obtain predictive model(s) that could be used to develop estimates of the impacts of teleworking on travel. Section two starts by looking at the theoretical basis of SP analysis and the various techniques that may be used to estimate SP models and introduces the model estimation procedures. In the next section various aspects of the collected dataset are explored with respect to data quality issues and some internal evidence from the performance of survey instrument is examined. In view of the sophisticated nature of the design of the choice experiment, section four examines various critical issues about it. This helps in developing a sense of the dataset at the basis of the SP analysis. The preparation of the data file for model estimation software is described in section five.

Section six sets a model development framework by specifying a basic structure, listing model interpretation and validation procedures, and considering some specific issues about the model specification from this dataset. Examining key model specification issues, section seven obtains a range of model variants. Each variant represents a particular dimension of a key issue while combining relevant dimensions from the other issues. In this way some 15 variants are estimated and examined. Section eight assesses the estimated models in light of the applicable criteria and shortlists four variants as relatively valid models which may be used for forecasting. Finally, the chapter ends with a summary of the work reported here and some conclusions are also drawn.

8.2 Theoretical Foundations of SP Analysis

An SP experiment comprises hypothetical situations called replications which in most cases are characterised by trade-off decisions. The trade-offs relate to attributes of the alternatives in a choice set or their characteristics. Random utility theory (RUT) (Domencich and McFadden 1975) based on utility maximisation theory is well suited to study behavioural dynamics of such a compensatory decision making processes. RUT assumes that people when acting rationally choose an alternative with the highest utility from the competing options. The utility of each alternative represents the satisfaction or benefits to the person making the choice. However, it is impossible for the analyst to determine the precise utility of each alternative simply because of the fact that the random utility perception applied by the decision maker to measure the accruing benefits from the competing alternatives has both known and unknown components.

The known or measurable part of this utility is a function of known attributes of an alternative in the experiment and is commonly specified as a linear function. The unknown or random part reflects unobserved effects or dimensions and emanates from four distinct sources: unobserved attributes, unobserved taste variations, measurement error and model specification error (Ben-Akiva and Lerman 1985). The taste variation can be coped with through alternative specific constants (ASCs) and by segmentation analysis while the other errors are tackled through distribution functions for such errors among the population being studied as the exact size of the unobserved component is unknown simply because of uncertainty and complexity of human behaviour.

RUT has been operationalised by the use of logit model analysis (Ben-Akiva and Lerman 1985). The logit model analysis is well established in studying mode choice behaviour in the transport discipline. This thesis employs the logit model framework for the analysis of the data on choice responses. Section 4.3.1 has explained this framework. To cope with the error associated with unobserved attributes logit analysis uses the Gumbel distribution function which assumes this error to be independently and identically distributed (IID) in the population. Thus, only choice probability associated with an alternative is obtained. Another well-known property (or limitation) of a logit model is independence of irrelevant alternatives (IIA) which in simple terms means that the choice of an alternative by a respondent is not affected by the presence of any other alternative(s) in the choice set.

The estimation process of coefficients of the parameters within the utility functions of a logit model is based on the maximum likelihood function. These parameters can be interpreted as an estimate of the weights of all the observed attributes contributing to the utility obtainable from that alternative. As the parameters have associated standard error, an estimated coefficient is considered to be significantly different from zero at 95% confidence interval when its corresponding t-ratio (the ratio of the parameter mean to its standard error) has an absolute value greater than 1.96. However, if the sign of the estimated coefficient is correct and its magnitude seems plausible then t-ratio values as low as 1.6 are sometimes accepted representing the 90% confidence interval (Wardman, 2004).

The overall model goodness-of-fit is indicated by log likelihood ratio index of Rho Square, ρ^2. Its value lies between zero and one but a model having a value between 0.2 and 0.4 is considered to have an extremely good fit (Louviere et al 2000). For models estimated on SP data, Rho square values around 0.1 are typical (Wardman 2004). Overall detailed guidance on the principles described above and their application in SP analysis is available in Ben-Akiva and Lerman (1985), Ortuzar and Willumsen (2001), Louviere et al (2000) and DfT (2006). The analysis can be performed with the help of commercial software such as ALOGIT (Hague Consulting Group 1995) and GAUSS (Train et al 1999). This thesis has used ALOGIT software for model estimation. A brief summary of how it works is given in Appendix IV at 13.4.

8.2.1 Coping with the Sources of Error in the Analysis

Among the competing model forms, estimated employing RUT, the logit grew in acceptance and importance due to its simplicity. The deceptively simple structure of logit rests on two main assumptions that define its two properties (i.e. IID and IIA, the former leading to the latter), alternatively called its limitations or shortcomings. Depending upon the nature and scale of the data being used for logit analysis, these properties sometimes allow errors to creep in during the estimation process. Sections 5.2.2 and 7.1.2 discuss the various sources of random errors which may cause imperfections in the predictive capability of an SP model. In most cases, these errors can be attributed to not taking care of taste variations among respondents. This can happen both at category or group level and at individual level. The group level variations which may be called group heterogeneity may result from differences among various SEG and their respective decision attributes. But then individuals are different from each other even within the same group with regard to taste variations. This is called respondent heterogeneity and may be reflected through unobserved attributes denoted by the random component of the utility function. The presence of either or both of the heterogeneities causes the IID property of the logit model to be violated.

8.2.2 Analysis of Group Heterogeneity

Developments in the field of logit analysis can cope with taste variations among respondents and repeated measurement problems in the data. Segmentation analysis can handle the group heterogeneity with regard to observed attributes. Two variations of this technique can be used. In the first variation a separate model may be estimated for respondents belonging to a particular SEG or having a given set of trip characteristics (Preston and Wardman 1991). However, doing so may reduce the significance of coefficients (MVA et al 1987) probably due to the small number of observations available for each segment. A smaller number of available observations for each segment is apt to increase the standard error of the estimates.

The second variation is the use of incremental factors (MVA et al 1987) which allow different marginal utilities across segments of the sample. The estimation for this can be specified using Equation 5.4 (section 4.3.1). The variable which forms the basis of the segment analysis is specified as a dummy variable for each segment or category in the utility function arbitrarily choosing one of the segments as the base relative to which incremental effects are studied. The base segment is not specified in the function. The sign and size of the coefficients thus obtained can indicate any effect of that particular variable on the choice when compared with coefficients estimated from the basic logit model (Wardman et al 1997).

In order to test the fit among the models thus estimated, the likelihood ratio test is used given that the basic model is the special case of the segmented version. If required, interaction effects relative to main attributes (usually time and cost) among different (continuous) variables (or their levels in the case of categorical variables) can also be analysed using this technique.

8.2.3 Analysis of Respondent Heterogeneity

The sources of error resulting from respondent heterogeneity can be tackled through the logit based random parameter analysis technique as segmentation analysis is unable to cope with it. The model specification following this technique allows one or more coefficients of observed attributes as well as ASCs to vary randomly across the respondents rather than being fixed as in the basic logit model. The coefficients thus obtained are commonly assumed to be either normally or log normally distributed. Of all the literature, the paper by Hensher and Greene (2003) gives a very good exposition of this technique and summarises the developments in the field. However, this technique is under developed and the search for better applications is still going on. Besides, major research effort is directed at advancing the theory in the discipline. It may be pointed out that parameter coefficients obtained from logit analysis are often used in aggregate forecasting or in disaggregated studies that investigate the effects of SEG variables. These uses of the logit limit the practical value of random parameter analysis technique.

In SP experiments often multiple responses are obtained from each respondent. Sometimes this causes a problem which is referred to as the effects of repeated measurement in the SP literature and tends to grow as the number of observations obtained per respondent increases. Until recently the problem has usually been ignored in practice (Baste and Terzis 1997). To deal with this the literature proposes two methods. One involves correcting the t-ratios of the model parameters (Bradley and Daly 1993) while the other involves more sophisticated techniques like re-sampling and/or sub-sampling also called the Bootstrap or Jackknife method (Cirillo et al 1996). However, Ortuzar et al (1996) found neither of them reliable. Jaensirisak (2003) also examined this problem and concluded that it does not significantly affect the values of the coefficients in the logit model and only has a small effect in reducing their significance. Therefore, it is less likely to have considerable effects on the predicted results of the model.

Models walk on assumptions. If assumptions render inferences suspect, the quest for accuracy brings in undesired complexity. There seems no escape from this classical trade-off about the use of the logit form as well. The continuous and rigorous research effort to which simplicity of logit has been subjected over the years points that the majority of the choice modellers favour accuracy over assumptions. Now model forms within logit are available that can deal with discrete choice analysis by relaxing IID and IIA properties. An excellent paper by Koppelman and Sethi (2005) reports on the evolution of this research and integrates it into a model structure called

> *the Heterogeneous GNL model which extends our ability to represent the complex behavioural processes involved in choice decision-making.*

8.2.4 Model Estimation Procedures

The model estimation process was undertaken within the framework described in this section and involved a number of steps. The procedures employed include ensuring the quality of the SP data; processing the dataset, converting it into the required format and, sometimes, creating new variables to generate the data file; searching for the right specification, specifying the utility functions for each choice and estimating the model; and examining the output of the effort and making adjustments if required. Each procedure as it was used to estimate the model is described next.

8.3 SP Data Quality Issues

Quality management of the data file took two forms: validation of data on SP choices from internal evidence; and identification and exclusion of cases involving inconsistencies relative to experiment design logic. Both procedures are described next with the help of instances of internal evidence, identified inconsistencies and irregularities, and corrective measures taken. These procedures are likely to increase the degree of confidence in the SP choices data and the predictive ability of the model(s) estimated on this dataset. This thesis recognises the validation of the SP data and the SP model as two quite different processes. While guidance for the latter exists in the literature, no case of data validation particularly with respect to internal evidence was encountered during the brief literature review on the topic.

8.3.1 Validation of SP Data

The most often cited concern about models based on SP data is that they present validity problems. There are not enough measures to address these problems adequately and the recommended benchmark practice is to validate them against models estimated on RP data. However, in innovative applications of the SP method such as this study which are inherently void of RP data this is still a problem. In the case of the present study the problem stems from the composition of the choice set. Also, RP data on teleworking frequency choices are difficult to find. In such situations validating the SP data per se from some internal evidence could be a viable option. For this purpose some provision was made in the survey formulation. The results of this effort and other evidence to validate the collected SP data are discussed in the following subsection.

8.3.2 Evidence on the Effectiveness of SP Experiment

As indicated in section 5.4.3, one reason for inclusion of attitudinal statements in the survey design logic was to have provision for internal validation of the SP data. Out of the eleven statements used, four were positive in their character and four negative, and represented perceived benefits and costs of teleworking respectively. The rest of the statements were considered neutral (see section four of the survey in the Appendix V at 13.5). Regardless of their content or character all the statements were phrased affirmatively. They were to be evaluated on a bi-polar scale of 1-10 where 1 indicated a strong disagreement while 10 indicated a strong agreement. Since the scale applied to the statements about benefits in one order while to the statement about costs in the reverse order, this required a cognitive effort to correctly connect an affirmatively phrased statement, especially those about a negative aspect (indicating cost) of teleworking to the right response on this scale.

The analysis of responses to these statements (section 7.3) as indicated by mean scores assures that the respondents were giving their considered and measured opinion in the survey. The direction of their responses has been in line with the character of a particular statement and overwhelmingly in line with their likes and dislikes, with their preference and practice indicated before going through the SP experiment and with their attitudes as measured just after coming through the experiment.

Another piece of evidence on internal validation, especially about the effectiveness of the SP experiment in eliciting considered responses to the hypothetical situations, came to light accidentally when during the detailed scrutiny of responses to replications in each version of the survey it emerged that the random assignment of the replications to all the seven survey versions produced a survey version (S5, refer to Table 7-1) with two identical replications in it (Situation 3 and Situation 7). Although only eight people from the whole sample completed this survey version due to randomised distribution, the testimony it produced on the effectiveness of the SP design and experiment is useful. All but one of the respondents who completed this version of the survey gave identical responses to these two situations. Thus, the respondents had made measured choices.

8.3.3 Additional Data Vetting Procedures

To further improve the quality of the data file it was decided to scrutinise each and every response to the choice experiment by all the respondents for rationality. During this process, some 'irrational' responses to one or two replications by some respondents were identified. Six such cases were discovered. The choices made by another respondent gave the impression of being confused though the responses themselves were not illogical. All such choices were further excluded from model estimation procedures but not for other analyses.

8.3.4 Effects of current teleworkers' presence in the data file

The sample at the root of this dataset is exclusively of car commuters, some of whom already practise teleworking with varying degrees of frequency per week. The first choice in the choice set under the experiment was phrased as 'No Change' which, being relative to the base situation, for current teleworkers meant car commuting as well as teleworking at the current frequency. As time and cost parameters and choices were aggregated over the weekly scale, the described situation would introduce error in estimation of coefficients because the data file was not structured to allow for two simultaneous choices for a respondent. (Why two simultaneous choices were not allowed to a respondent in the experiment has been discussed in 5.3.6) Thus, current teleworkers' presence in the dataset represent a significant data quality issue with implications for the model estimates and this is examined further in 8.7.4.

8.4 Making Sense of the (Base and SP) Data

The SP data is based on a choice experiment which was rather sophisticated in its design. Exploring this design, this section develops a sense of the various dimensions of the dataset; particularly about the composition of the choice set, the questions used to deduce it, the issues that arose in the process and their implications for the model estimates. Therefore, before describing the generation of the data file, it is important to develop a sense and feel of the dataset on which the data file used to estimate the model is based.

8.4.1 Preferred Teleworking Frequency and its Potential Effects

It may be suggested that employees may be indifferent to the availability of teleworking beyond a certain amount. This SP dataset provides an opportunity to examine this aspect. This indifference toward teleworking might also have an effect on the model estimates. Table 8-1 presents the data extracted from SP responses on the choices the respondents made regarding teleworking. The table compares four samples. Except for the combined sample (which is an aggregation of current teleworkers and preferrers) all the samples have previously been used in tables in Chapter 7. The figures in the table cells are percentages of times the choice of each teleworking option has been made relative to the total number of opportunities available to each sample to make these choices. It may be recalled that each respondent was given nine opportunities to make these choices.

Samples	N	Total number of Opportunities available to make choices	Number of times (as %) TW1 was chosen	Number of times (as %) TW2 was chosen	Number of times (as %) TW3 was chosen	Number of times (as %) TW4 was chosen
Current TW	42	378	13.8	25.4	5.6	6.1
Preferrers	90	810	11.0	17.3	9.6	8.5
Combined sample	132	1188	11.9	19.9	8.3	7.7
Total Sample	186	1674	9.4	14.7	6.3	6.0

Table 8-1: Comparison of demand for teleworking frequency choices in four samples

Table 8-1 shows that the teleworking demand peaks for all the samples at two days per week. The sample of current teleworkers has a higher optimum demand for two days of teleworking than the rest. When current teleworkers and preferrers are aggregated into a combined sample, their choice behaviour more closely represents the choice behaviour of the total sample. Beyond two days per week the demand for teleworking decreases sharply. However, the preferrers show more demand for teleworking 3 and 4 days per week compared to the current teleworkers who are speaking from experience and should be given more weight in interpretation. These results suggest that under the experimental conditions the current or potential teleworkers are indifferent to teleworking supply beyond two days per week. It is possible that due to this indifference, a certain part of the utility derived from teleworking may convert itself into some disutility, especially for teleworking choice options which exceed two days per week.

8.4.2 The Nature of the Choices: Important Distinctions

The choice set in the SP experiment contained at least three distinctions regarding a commute trip. At the upper level the distinction was along the use of travel mode. Here the choice is between the car and the other modes but mainly motorised modes. (The users of non-motorised modes have been omitted for two considerations: firstly they were not sampled and secondly they are very small percentage of total commute demand.) At the next level the distinction is by time of day and choice is between travel by car during the peak or by car during off peak. The last level of distinction is whether to travel or telework. Following these distinctions, there can be two dimensions to each choice: activities and trips. From the perspective of this study, the users of the transport system fall into two main categories: the car users and the PT users. Further, sampled users sometimes make trips to access their work activity while at other times they may telework to pursue their work activity. Thus the number of days worked (activities) in a given week is the sum of the number of work trips made and the number of work trips which are replaced by teleworking.

The activity dimension is the parameter of focus during the sensitivity and robustness analyses in section 9.2.3 and 9.4. The trip dimension is the focus of the analysis of teleworking impacts on traffic levels and system performance in sections 9.5 and 9.6. This distinction between the weekly share of an activity and trips attributable to that activity brings into focus the distribution of teleworking activities choices in the sample. Determining their base share needed to calibrate the model is done next.

8.4.3 Frequency Distribution of Teleworking Activities

The survey for this study found current teleworkers to be 23% of the sampled population (ref table 7-2) with a wide range of frequency distribution (Table 7-11). Plausible estimates of teleworking frequency are a perennial problem given the dispersed nature of teleworking practice, sample accessibility and methodologies applied to the studies so far. This study tried to avoid some of the pitfalls encountered by the previous studies by improving upon the methodology. However, the other two factors, i.e. the dispersed nature of teleworking practice and sample accessibility were still a problem.

The RP and the SP distributions of teleworking frequencies do not match with each other in this dataset and there is a need to have base share estimates of these frequencies to calibrate the models for use in forecasting. For this purpose, concurring from different sources quoted in Cairns et al (2004) (and other literature which put the average teleworking frequency in the UK between 1.5 and 3.1 days per week) and based on the data on frequency from the survey (Table 7-11), this study assumes the distribution of theses frequencies as shown in Table 8-2. These figures have been obtained after ignoring the observations with teleworking frequency less than half day per week in Table 7-11 and rounding the rest to one day per week. As there are no current teleworkers with three or four days frequencies per week in the sample, these choices have zero share in the base.

Activity choices	TW 1 day	TW 2 days	TW 3 days	TW 4days
Distribution in the sample	13.62%	1.86%	0.00%	0.00%

Table 8-2: Frequency distribution of teleworking activity choices in the sample

8.4.4 Issues Regarding the Choice Availability

In SP choice experiments it is normal to expect that each choice is not available to all the respondents. In this regard, the wording of the questions which were used to deduce the choice set in the sample needs to be analysed because some limitations of this wording were identified which need to be discussed and qualified. The relevant questions in the survey are Q8, 10 and 13 and each of them is explored for its implications for model estimation next.

> *Q8: Would it be possible to save travel time by changing the time at which you depart to or from work?*

This question and the related sub-questions were used to define the choice of 'change departure time' for a respondent and its utility. The question wording did not mention travel cost saving because car users are unlikely to achieve substantial savings in cost by travelling off peak. Thus, the real savings which may affect the utility of this choice are likely to accrue from reduced travel time. Further, very few commuters are keen observers of small changes in fuel consumption resulting from small time savings. In the survey 12% of the respondents were unable to estimate their daily fuel cost (see the table in Appendix VI at 13.6). Hence, the effect of travel cost savings is likely to be small. This issue has been investigated in 8.7.5.

> *Q10: Would it be possible to save travel time by changing the means of travel you use to or from work?*

This question and the related sub-questions were used to define the choice of 'change means of travel' option for a respondent and utility. The absence of travel cost saving from the question wording is an error which crept in due to the use of copy/paste commands while drafting this survey as already noted in 5.4.3. An earlier version of the survey had the word 'cost' in this particular question. This is also evident from the fact that the related sub-questions under Q12 explore both the travel time and cost characteristics associated with the choice of this option. It is, however, recognised that in the absence of this error some respondents might have given different answers and that in reality this choice might have been available to a greater number of respondents. The effect of this issue on model parameters will be explored by experimenting with the availability of this choice during the model estimation process (see 8.7.5).

> *Q13: Is any type of Teleworking arrangement possible/permitted within your organisation? a) Formally possible (allowed as Firm's policy), b) Informally possible (allowed by my manager), c) Possible but job unsuitable, d) Not permitted*

It has been suggested that the response (c) to this question is ambiguous as it is not clear whether it refers to the respondent's assessment of unsuitability or that of the company. This issue was explored with the help of internal evidence from responses to other questions in the survey, e.g. responses to the attitudinal statements and the SP replications. From the analysis of the responses to attitudinal statements in Table 7-18 and Table 7-19 (see 7.3.2), it emerges that the respondents who chose response (c), i.e. possible but job unsuitable in reply to Q13, tended to answer in terms of their employer's assessment that their (respondents') jobs are unsuitable. This is also supported by the analysis of responses by these respondents as a group in 7.2.3. It was found that only 15.6% (in the total sample) consider their job unsuitable for telework against a 28% share who had originally chosen the response (c). The foregoing analysis ultimately formed the basis for defining the teleworking choice availability in the sample (see 8.7.1). However, it is accepted that some ambiguity is present.

8.4.5 Choice Characteristics of the Dataset

After identifying the implications in the previous subsection, this subsection tabulates the data from responses to Q8 to Q13, i.e. it provides a summary of the choice patterns in the base case and characteristics of travel choices. In this regard respondents were asked about the availability of a particular choice to them and, subject to that, additional information about the characteristics of the choice. Table 8-3 shows the choice patterns (for all the choices in the choice set). The table presents two cases for analysis: basic case is based on clear responses to the relevant question while the extended case also includes the missing/inappropriate/inconsistent responses.

Choice	Commute by car		Change departure time		Change to alternative mode		Teleworking	
Case	No. of Rspndt	% of Total	No. of Rspndt	% of Total	No. of Rspndt.	% of Total	No. of Rspndt	% of Total
Basic	192	100	91	47.4	21	10.94	98	51.04
Extended	192	100	100	52.08	60	31.25	103	53.65

Table 8-3: Choice patterns in the Base situation (choices are not mutually exclusive)

Time saving	Morning		Evening		Combined	
Case	Min	Max	Min	Max	Min	Max
Basic	0	45	0	45	10	75
Extended	0	45	0	45	5	75

Table 8-4: Ranges of Time savings by changing departure time

For teleworking choices, 98 respondents clearly indicated that telework was available to them while 5 respondents appeared undecided and gave blank responses. For the choice of changing departure time, 91 people provided clear answers while nine provided contradictory information because they gave additional information to subsequent questions while stating that changing departure time was not a choice for them in the first place. Table 8-4 shows the ranges of time saving available to the respondents who might be able to change departure time if required.

However, the case of mode change choice was a little different and deserves a rather extended comment. Twenty respondents indicated that it was possible for them to change to an alternative mode in the basic case. Sixty respondents reported that it was not a choice for them under RP conditions but still provided data on the alternative mode's characteristics. Notwithstanding the implications of the question wording discussed in the previous subsection, it was tempting to include them within the basic case due to the small number of clear responses. However, in view of the characteristics of this choice as summarised in Table 8-5, it was considered appropriate to count them among the extended case.

	Relative travel time difference (minutes)		**Relative travel cost difference (pence)**		**Walking time if any (minutes)**		**Waiting time if any (minutes)**	
Case	Min	Max	Min	Max	Min	Max	Min	Max
Basic	-30	30	-1000	300	-5	60	0	15
Extended	-30	130	-1000	1000	-10	120	0	40

Table 8-5: Ranges of time and cost characteristics by the alternative modes for a daily return commute journey

Table 8-5 presents the ranges of time and cost characteristics by all the alternative modes (train, bus and cycle) provided by those who might be able to switch mode if required. A look at the row labelled as 'Extended' reveals that some of the figures are at real extremes. These are ranges and do not characterise the journey of any one respondent. These extreme values help explain why many respondents thought the change of mode was not a realistic option in their response to Q10. Therefore, there was a case for constraining the mode choice for them during the model estimation process.

8.5 Preparing the Data File for Model Estimation

Section three of the survey instrument contained the SP experiment with nine replications. This produced nine choices or observations per respondent while the data for trip characteristics and other DSE variables were recorded only once. This required relating one common record of DSEC data to each of the nine choice responses. The attributes of travel time and cost in the experiment were presented relative to the current (base) trip characteristics. So even before relating the DSEC data to each choice, the responses from each of the seven survey versions (ref Table 7-1) needed to be collated as one dataset so that the correct amount of time or money is related (by addition or subtraction as the case may be) to the base and no mistakes are made by incorrect relations while calculating the travel time and cost (the data generation process) for each replication. A similar procedure was repeated for each survey version and in the end seven datasets were assembled in one data file. Once the foregoing procedure was completed, the technique of aggregate data estimation was used to generate a full dataset for logit analysis in which each case (data record) was recorded nine times to match the number of SP observations provided by each respondent in the experiment. A programme in Excel software was written for this purpose.

In view of the use of an unconventional choice set (which included four choices of teleworking) in this experiment, this study is essentially different from conventional travel mode choice studies. This is further reflected in the travel time and cost of each choice as will be seen shortly. The data on generalised cost of travel for each choice was generated next. The choice set consisted of seven choices and under the experiment the full set was available to all the respondents to choose from. However, some respondents were inherently unable to make certain choices. This required controlling the availability of such choices and setting up choice availability codes for all the choices except for car, which is the reference choice in the experiment, in the data file. These codes were generated based on analysis of responses to Q8, 10 and 13 (see 8.4.4) and all the relevant data tabulated in 8.4.5.

Travel time and cost are considered the main attributes in mode choice studies. Thus, time and cost data for each choice were calculated based on daily time and cost of a return commute journey based on the trip characteristics and travel mode involved. The teleworking choices were obtained on a weekly scale in the experiment. Further, on a teleworking day no travel costs are involved while travel time is saved and can be put to some other use. To take account of this and make the generalised cost of each choice comparable, time and cost data for all the choices were aggregated over the full workweek.

8.5.1 Calculating the Time and Cost Parameters for Each Choice

Section one of the survey contained questions on current commute journey characteristics which yielded the number of travel days per week, travel time, travel cost and parking charge data. Some respondents were unsure of their travel costs and gave blank responses. Such missing values were estimated based on the per minute travel cost over the sample and using the travel time data of the missing case. The daily parking charge was added to the travel cost of car users.

Section two of the survey provided the data on the use of alternatives in the choice set by the sample in the base case (RP data). In particular the data on travel cost and time (including walking and waiting times) if changing the travel mode were obtained. Similarly, the data on teleworking cost and frequency were also obtained and have been tabulated in

Table 7-4. Some brief comments were made regarding the seemingly high daily cost of teleworking while analysing these data. One reason for offering a broad range of choices in this regard was to treat this cost as a respondent's perception of both the tangible and intangible cost of teleworking. For discussion on the issue of teleworking costs refer to section 3.4.3 and for analysis of these data see section 7.2.6.

It would suffice here to say that the expectations of the respondents were that they would express their intangible concerns/costs also in monetary units as a response to the cost question. The underlying reason for this was to make the teleworking alternatives comparable to other travel choices which otherwise appear lopsided due to the advantages in time and cost savings. The treatment of the data on teleworking cost created considerable difficulties while estimating choice specific coefficients as their signs would not fall in line with the expectations generally held about, and by a mindset conditioned by, mode choice studies where travel time and cost, being disutilities must have negative signs. This issue has been taken up in detail later in the chapter (8.7.4).

The general principle of determining the travel time and cost of a choice was to add to or subtract from its base travel time and cost the time and cost of a particular policy replication in the SP experiment (hereafter called policy time or policy cost). This applied to the choice of commuting by car during the peak. However, when opting to change time of travel (off-peak), only the travel time component was adjusted by subtracting the time saved travelling off-peak if any and the cost element was taken as in the base without any addition or subtraction. This ensured that changes in policy time applied to travel during the peak as the experiment was controlled. The time and cost figures thus obtained were multiplied by the number of travel days per week for a particular respondent (for some respondents this figure was not always equal to 5 as their commuting routine varied). This is how time and cost values were generated for all the alternatives in the data file for model estimation. To illustrate the procedure mathematically, formulae for three alternatives are given in Equations (8.1) through (8.6) and a more specific example of calculations for a hypothetical situation is presented in section 8.6.1.

The travel time and cost of a time change choice is given by

$$T_{TC} = \{t_{car} - (t_m + t_e)\} \times D_{trvl} \quad (8.1) \qquad C_{TC} = c_{car} \times D_{trvl} \quad (8.2)$$

Where T_{TC} and C_{TC} are weekly total time and cost for the choice of changing time of departure; t_{car} and c_{car} represent the daily total time and cost taken by car commute in the base; t_m and t_e are the daily travel time saved by changing the departure time in the morning and the evening respectively (if any); and D_{trvl} is the number of travelling days per week.

The travel time and cost of a mode change choice is given by

$$T_{MC} = (t_{car} + \Delta t + t_{wk} + t_{wt}) \times D_{trvl} \quad (8.3) \qquad C_{MC} = (c_{car} + \Delta c) \times D_{trvl} \quad (8.4)$$

Where T_{MC} and C_{MC} are weekly total time in minutes and weekly total cost in pence for mode change choice respectively; Δt and Δc are the daily differences in total travel time and cost by the alternative mode when compared to the base daily total car travel time and cost; t_{wk} and t_{wt} are daily total walking and waiting times involved in using the alternative mode if any respectively; t_{car} and c_{car} represent the base daily total travel time and cost involved in car travel respectively; and D_{trvl} is the number of travelling days per week.

Travel time and cost for the choice of teleworking 3 days were calculated as follows:

$$T_{TW3} = (t_{car} + t_{policy}) \times 2 \qquad (8.5) \qquad\qquad C_{TW3} = 2(c_{car} + c_{policy}) + (c_{TW} \times 3) \qquad (8.6)$$

Where T_{TW3} and C_{TW3} are weekly total time and cost for the choice of teleworking three days; t_{car} and c_{car} represent the daily total time and cost taken by car commute in the base, and t_{policy} and c_{policy} are the total extra time and cost (if any) of peak car use imposed by the policy per day under the experiment; and c_{TW} represents the daily cost of teleworking. Similar calculations were made for other teleworking choices. It is useful to note that policy time and cost affect the time and cost of teleworking choices because there are associated car travel components during the peak with these choices, whereas policy time and cost changes do not affect mode change or off peak travel.

The resulting basic data file contained some 36 data arrays in one line and included codes for statements on teleworking policy. An extended data file was also prepared which along with the basic data also contained data on all the DSEC variables for segmentation analysis to test for the taste variations. Choice availability code and some additional data codes for variables to be entered in the utility of changing departure time were also generated.

8.6 Model Specification

Model specification is the fundamental procedure in the estimation process and involves definition and formation of a utility function for each choice in the experiment. It depicts the logic and structure of the basic model and ensures that the model conforms to the theoretical underpinnings of the situation it is supposed to depict and predict. There is no benchmark or set procedure as each situation has it own peculiarities. Which parameters to enter in the utility function(s) and in what fashion are often discretionary decisions and a function of specification searches. Ortuzar and Willumsen (2001) recommend a stepwise approach similar to multiple linear regression analysis

> *starting with a theoretically appealing specification. Then variations are tested at each step to check whether the variable under scrutiny adds explanatory power to the model.*

8.6.1 Basic Model Structure

Before proceeding on to sort out specification issues, it appears useful to define a basic model structure that is given in Table 8-6. The specification consisted of seven utility functions with six ASCs. Time and cost attributes were included in the utility functions of all the choices while teleworking policy being a categorical variable entered as a dummy variable and only in teleworking frequency choice functions. In transport applications of the SP method and logit model, travel time and cost are studied more often and they invariably enter as generic variables in travel mode choice studies. However, there may be exceptions to this convention as shall be seen in the case of this study which is not a mode choice study in the traditional sense.

$$U_{Car} = \beta_t * T_{car} + \beta_c * C_{car}$$

$$U_{t\Delta} = Const_{t\Delta} + \beta_t * T_{t\Delta} + \beta_c * C_{t\Delta}$$

$$U_{m\Delta} = Const_{m\Delta} + \beta_t * T_{m\Delta} + \beta_c * C_{m\Delta}$$

$$U_{TW1} = Const_{TW1} + \beta_t * T_{TW1} + \beta_c * C_{TW1} + \beta_{Pol1} * TW_{Pol1} + \beta_{Pol2} * TW_{Pol2} + \beta_{Pol3} * TW_{Pol3}$$

$$U_{TW2} = Const_{TW2} + \beta_t * T_{TW2} + \beta_c * C_{TW2} + \beta_{Pol1} * TW_{Pol1} + \beta_{Pol2} * TW_{Pol2} + \beta_{Pol3} * TW_{Pol3}$$

$$U_{TW3} = Const_{TW3} + \beta_t * T_{TW3} + \beta_c * C_{TW3} + \beta_{Pol1} * TW_{Pol1} + \beta_{Pol2} * TW_{Pol2} + \beta_{Pol3} * TW_{Pol3}$$

$$U_{TW4} = Const_{TW4} + \beta_t * T_{TW4} + \beta_c * C_{TW4} + \beta_{Pol1} * TW_{Pol1} + \beta_{Pol2} * TW_{Pol2} + \beta_{Pol3} * TW_{Pol3}$$

Table 8-6: Specification of utility functions in the basic model

U_{car}, $U_{t\Delta}$, $U_{m\Delta}$, U_{TW1}, U_{TW2}, U_{TW3} and U_{TW4} are the utilities of car commute, changing departure time, changing mode and teleworking choices 1-4 days per week respectively; $Const_{t\Delta}$, $Const_{m\Delta}$, $Const_{TW1}$, $Const_{TW2}$, $Const_{TW3}$ and $Const_{TW4}$ are ASCs entering the respective functions except for the car commute; T_{car}, $T_{t\Delta}$, $T_{m\Delta}$, T_{TW1}, T_{TW2}, T_{TW3} and T_{TW4} represent the total weekly travel times in minutes for both legs of the commute journey for all the choices respectively; C_{car}, $C_{t\Delta}$, $C_{m\Delta}$, C_{TW1}, C_{TW2}, C_{TW3} and C_{TW4} represent the total weekly travel costs in pence for both legs of the commute journey for all the choices respectively; TW_{Pol1}, TW_{Pol2} and TW_{Pol3} are the parameters for employer's policy on teleworking (for policy statements one, two and three respectively) which enter as categorical variables in the utility function and take on dummy values relative to teleworking policy statement four; and β_t, β_c, β_{Pol1}, β_{Pol2}, and β_{Pol3} are coefficients to be estimated respectively for travel time, travel cost, telework policies one, two and three. Note that the teleworking policy variable enters only in the utility functions for teleworking choices and enter as a dummy variable – an issue to be addressed later on. Thus, the coefficients for this variable are to be estimated for these four utility functions only.

8.6.2 Model Interpretation and Validation Procedures

The important tasks of the model interpretation and validity checks need to be performed on estimations obtained from a particular specification. Interpreting the model results means checking for: the significance of the variables included in the specification stage, correlations among the parameters and the appropriateness of the signs of the estimated parameters. A brief reference to the benchmark validation procedures described in the literature is made here.

Most commonly models are estimated using the maximum likelihood method and the result is a rho squared ρ^2 value which measures the goodness of fit of the estimated model (Ben-Akiva and Lerman 1985 and Louviere et al 2000). The prevalence of any (near) collinearity between variables may affect the sign and/or significance of parameter estimates. Such dependency can be investigated through estimating models with restricted sets of variables, and examining the behaviour of the model as variables are added or removed (Ortuzar and Willumsen 2001). As the parameters in the utility function are scaled relative to the variance of unobserved factors, larger variance in ASCs will lead to smaller beta values. The rest of this section draws on the guidance available from DfT (2006) on the topic.

When it comes to interpretation, ratios of parameters are more meaningful than absolutes, since the scale factor μ, as defined in equation 4.1, cancels out. In linear in parameter functions these ratios can also be interpreted as 'marginal rates of substitution', e.g. calculating a value of time (VOT) ratio. The next step is of validating the model with regard to its predictive capabilities. DfT (2006) recommends that the properties of the estimated model should be validated against benchmark empirical evidence. The validity of the estimated model should be further tested in implementation. The estimated model should be applied to forecasting and the ability of the model to replicate observed market shares assessed.

Validation procedures for the estimation output from a nested logit model are also given in the literature. The inferential and diagnostic analysis in this regard is essentially the same as for simple logit, although one primary test is required first in order to check the internal consistency of the nested logit structure. When testing a nesting structure, a value of theta greater than one indicates that the structure is not valid. A practical difficulty when specifying a nested model is that the most appropriate structure may not always be obvious. It may, therefore, take some effort to identify a definitive structure and the judgements in this regard should be based on internal consistency, relative explanatory power and other properties of the model such as implied valuation and elasticity.

8.6.2.1 Expected Signs for the Model Coefficients

Using the above criteria, it is now possible to identify the expected signs for the coefficients of the model to be estimated as a primary test of model interpretation. For time and cost parameters for all the choices in the estimated models, the expectations are that both coefficients should have negative signs because of the disutility associated with increasing time and cost of travel. For teleworking policy parameters (statements given in section 8.7.4), the coefficients for policy one and two should have positive signs while for policy three and four the sign should be negative due to the character of these policy statements.

8.6.2.2 Acceptable Significance Level of t-Values

As an additional measure of a primary test, the lowest acceptable t-ratio value for a coefficient to be considered significant has been set at 1.6 as discussed in section 8.2.

8.6.3 A Worked Example

In view of the relative complexity in specifying the utility functions for the choices in this SP experiment, an example is provided. Besides illustrating the point about some of the specification issues, this elaboration will also help understand the mathematical logic behind the model estimation in general. For example, for a respondent in the sample it takes 25 minutes in each direction to commute and costs £3 for a return trip plus £5 for parking charge and the respondent commutes only 4 days per week. The base travel time and cost per week are (25+25)*4 = 200 minutes and (3+5)*4*100 = 3200 pence. This respondent is able to save 5 minutes in the morning and 10 minutes during the evening commute when travelling off-peak. She is presented with a replication in the experiment in which total travel time during the peak has gone up by a half and cost of the return journey has also gone up by £4 in the peak. Her weekly replication time and cost (TimeR and CostR respectively) by car come to (25+25)*4*1.5 =300 minutes and (5+3+4)*4*100 =4800 pence per week respectively.

Now suppose she has only two choices (in reality she may have all the choices in the experiment available to her): to continue the car commute during the peak or to change her travel time to off-peak. For the first choice, her time and cost by car (Time1 and Cost1 respectively) are same as for replication (TimeR and CostR). For her second choice, however, the situation is different. Time and cost (denoted as Time2 and Cost2) for choice two would become {(25+25)-(5+10)}*4 =140 minutes and (5+3)*4*100 =3200 pence.

8.6.4 Issues in Model Specification

The model specification process was confronted with a host of issues which can be separated into minor and major ones. Minor issues included: whether it is possible to obtain a model without specifying ASCs; whether elaborate specification of the utility of changing departure time gives a better model; and finally whether the specification of time and cost parameters as differential parameter values (as differences between time and cost of the replication and the chosen option) rather than absolute parameter values (which is the norm) improves the model estimation process.

In view of their significance, the major issues required a fuller treatment and are discussed in section 8.7. In the rest of this subsection, the minor issues are addressed. The comments that follow are based on experience from running the software and estimating the model tests described in the previous section. The detailed presentation of the models is excluded for want of space.

Tests were conducted of models without ASCs. Without the inclusion of ASCs in the utility functions for the choices, overall model fit was very poor. The ASCs represent the effects of the unobserved factors or some other unmeasured effects in the experiment. It is impossible to control all the dimensions of an experiment and obtain data about all the aspects of a particular choice. This issue has added significance in this experiment due to the unconventional and broad choice set. In a generic specification, the ASCs also indicate preference of one alternative over the competing ones. Highly significant ASCs with negative sign mean that such alternatives are not attractive to the respondents.

For the choice of changing departure time alternative, the survey obtained elaborate information. It asked some additional questions about whether the respondents would save time by departing early or later. The responses showed that some people are indifferent to early or later departure on both legs of the journey. This generated 12 additional variables: six on the options of when to change time and six on how much time would be saved. All these variables in addition to the main attributes were entered in the utility function for changing travel time. The detailed specification of the utility of changing the time of travel refines the model and gives a better overall fit. However, it was realised that these additional variables would have little or no role in forecasting as it would actually amount to segmenting the group of off peak commuters into 12 categories. Also, parameters returned for some of them have insignificant t-ratios and it was not always easy to interpret the signs and magnitude of the coefficients.

The issue of the model specification using differential parameter values can be explained with the help of the example in section 8.6.3. In 'absolute parameter value' specification the utility of car commute is P1*Time1+P2*Cost1 (in terms of actual values from the example it is P1*300+ P2*4800) where 'P' is the coefficient of the parameter to be estimated while utility of changing travel time is P1*Time2+P2*Cost2 (in terms of actual values from the example it is P1*140+ P2*3200). In the 'differential parameter value' specification, the first choice, i.e. car commute, was specified as P1*(TimeR-Time1) +P2*(CostR-Cost1) and for choice of changing departure time it was specified as P1*(TimeR-Time2) +P2*(CostR-Cost2). With differentiated parameter values the utility of car commute which is a reference utility is always zero in this specification while utility of changing departure time in this example is P1*(300-140) + P2*(4800-3200). A model with zero coefficients for car commuting choice is of little use for the policy analysis objective of this study. Further, the fit of the model estimated was not significantly different from the model estimated using absolute value.

8.6.5 Testing for Group Heterogeneity in the Choice Data

The test of group heterogeneity in the SP data was also attempted using the segmentation analysis technique during the model estimation process. For this purpose some DSEC variables were entered into the relevant utility functions and the outputs of the segmented logit model were examined (estimates of one such attempt are available in Appendix VII). This partial analysis indicated the significance of some DSEC variables. However, it was not possible to readily interpret the estimates of this model as many of the returned parameter signs were counter-intuitive. Besides, there were other issues which cast doubts on the validity of the obtained estimates.

First is the unusually large number of such variables in the dataset which makes it virtually impractical to include all of them in all the utility functions. Secondly, most of these variables are categorical in nature and almost all of them have more than two categories each. Testing all the combinations by relating each category of a variable with all the categories of all the variables was virtually impossible.

Thirdly, testing of categorical variables in logit analysis is done through dummy specifications where n-1 categories of a particular variable are entered in a utility function arbitrarily choosing the non-specified category as the base. Choosing different categories of the same variable (especially where a variable is non binary in character or has non binary data, sometime extending to six categories in this dataset) as a base produces markedly different estimates and evidence on the causes remains inconclusive. Hence, there are obvious difficulties in model interpretation (similar problem was encountered in the case of estimation with choice specific specification later in 8.7.2). This is a very well known shortcoming of dummy specification.

Fourthly, there is the issue of distinguishing between the main effects and interaction effects of the variables in a utility function, especially when they are specified as dummies. The main effects are present when a variable exerts influence on the utility of a function independently. The interaction effects result when a categorical (DSEC) variable interacts with any or all of the main attribute(s) in the utility function and as a result the performance or influence of the utility function improves. For example, the income variable interacts with travel cost of a particular choice, and as a result influences the overall utility of the entire function for that choice.

Fifthly, the investigation of the significance of DSEC variable(s) is meant to explain, and influence, the choice of dependent variable(s). The choice set of dependent variables in this study is broad and includes travel and non travel choices. This aspect is also a complicating factor for the estimation of a segmented model.

Sixthly, SP datasets are characterised by repeated measurements where each respondent typically makes 9-12 choices. This phenomenon results in a general problem wherein the t-ratios returned by the logit analysis due to additional variables in the utility functions for the segmented model are over-estimated. There is, though, a procedure to correct this situation by dividing the t-ratios by the square root of the number of observations. However, correcting t-ratios in this way just to examine the output of a software run, when a large number of runs were being made on the analytical software, was not considered a judicious use of time, especially considering the difficulties of transferring the output of estimates to a spreadsheet after each run for calculation of adjusted t-ratios due to incompatible output format.

Perhaps, there was still an option of using the results of analyses from 7.2.1 and 7.2.2 and estimating a segmented model relative to job position and option availability variables. The final analysis in this regard, however, saw that the latter variable overrides the former and was used to control the availability of teleworking choices for the basic model. For all these reasons, the segment analysis using logit application was not attempted any further.

8.7 The Process of Model(s) Development: Key Issues

The search for an optimal model specification is basically an iterative process mainly guided by intuition but within the theoretical reasoning of the situation being modelled. An examination of the output from each combination of the attributes characterising a choice informs this process by suggesting appropriate adjustments for the subsequent attempt. Koppelman and Sethi (2005) remark that

> *an important issue in model development is the order in which the increments of model refinement are undertaken and presented. Since changes in later increments could impact the decisions made in earlier stages, it would be appropriate to revisit these decisions.*

Primarily, it was within this context that the development of the preferred model was undertaken and the significant issues surrounding it were investigated. Model estimation output for each specification effort was subjected to intense scrutiny at every stage and constantly traced back to the data file which produced it. The key issues identified were:

- The treatment of telework policy 4 as the base;
- Whether to use generic or option-specific coefficients;
- Whether models should be nested;
- How to treat the presence of current teleworkers and depicting teleworking with a frequency of ½ day per week in the data file; and
- Whether choices expressed in the SP should be constrained by choice sets deduced from the RP questions (8, 10, and 13).

8.7.1 The Nature of the Key Specification Issues

From the perspective of model estimation procedure using logit analysis, the first issue in the above list is really not a key issue, rather it is procedural issue or requirement of model estimation process involving categorical attributes. When a categorical attribute is employed in a choice study, it enters as a dummy variable in the model specification scheme (as in the basic model structure in 8.6.1) and has to have a base. Thus, specifying a dummy is not a matter of choice, rather it is a procedural necessity. For example, it was not possible to circumvent this through an approach which suggests the omission of all the current teleworkers from the analysis.

However, from the perspective of this study this issue might be a significant one because it employs four policy statements about the desirability of teleworking which are quite different from each other in their effects on respondents. As the model estimation process is relative to all the parameters within a function and to all the utility functions within a model, arbitrarily choosing the effects of (any) one statement as a base might affect the estimates of the parameters in the specified model. This implies that the base for the dummy variables should be defined and chosen with care. The SP experiment tested the following four categorical statements:

- 1-Employer willing to permit telework by those with needs
- 2-Employer allows everyone who wishes to telework
- 3-Promotion linked to employee attending usual workplace
- 4-Employer permits telework but does not like it

From the phrasing of the policy statements above, it is clear that statements 2 and 3 are the most positive and the most negative respectively. Statement 1 while mildly positive and possibly true for some employers still does not reflect the current overall employer attitudes towards teleworking as documented in this and various other studies (see 2.6.7 and 7.5). Statement 4 is more in line with the mildly negative attitude of the majority of employers suggested by the analysis of attitudinal statements in section 7.3.2. Further, the models were tested treating each policy statement in turn as a base with three options for control over choice availability, as defined below, including the option of full control over choice availability which excludes those who say telework not currently permitted. In all cases as would be expected, the models had identical rho squared values and only differed in their coefficients for policy statements tested in each of the variants. Since the models were otherwise identical and policy statement 4 was considered the closest to the current situation, it was used as the base for the purpose of dummy specification.

The rest of the issues in the above list overlap and this overlapping through different combinations produced 15 model variants. The first of the remaining issues has two variants: choice specific and generic. The issue of model nesting also forced testing for at least four alternative structures described later in 8.7.3. The presence of current teleworkers in the data file spawned three variants. This issue was managed by preparing three different data files with corresponding reduction in the number of data arrays in the data file. The resulting data files were defined as:

- Full data file (includes all teleworkers);
- Restricted data file (exclusive of observations/responses by current teleworkers who currently telework more than half a day per week in the sample); and
- Limited data file (excluding all teleworkers regardless of their weekly teleworking frequency).

The discussion of the implications of question wording in 8.4.4 raised the issue of choice availability. There is a feature within the estimation software which helped manage this issue. To address those implications satisfactorily, this issue was explored for its effects on model estimation process from the following dimensions:

- Uncontrolled choice availability (all the choices were available to all the respondents during the estimation process regardless of their answers to Q8, 10 and 13);
- Restricted control over choice availability (the choice availability for all the choices was controlled *except* for mode change choice); and
- Full control over choice availability (choice availability for all the choices in the choice set was controlled which meant that a particular choice was available to only those respondents during the estimation process who indicated in their answers to Q8, 10 and 13 that they were able to choose it).

The above variations of the data file and the choice set themes combined with variations of specification and nesting option themes to be discussed in the next two subsections produced 15 model variants. Table 8-7 on the next page presents defined specifications of these variants. The subsections from 8.7.2 to 8.7.5 investigate them in a logical way and detail the results.

8.7.2 The Case of Choice Specific Specification

In studies where the choice set consists of alternative travel modes, two approaches to coefficients' specification are more common. They are: generic specification and choice specific (CS) specification. In generic specification, the attribute parameter(s) remain constant over the range of utility functions, i.e. each attribute has one common coefficient for all the choices in the model. Under CS specification, each choice in the choice set has its own individual coefficient for each attribute parameter entering in its utility function. For this study which has a rather diversified choice set, theoretically the CS specification appeared more appealing and the search for a preferred basic model started with this specification.

	Specification Theme			
Model Variant	Specification	Structure	Data File	Choice set
M1	CS	Simple	Full	Fully constrained
M2	CS	Simple	Full	Partially constrained
M3	CS	Simple	Restricted	Fully constrained
M4	CS	Nesting option 1	Full	Fully constrained
M5	Generic	Nesting option 1	Full	Fully constrained
M6	Generic	Nesting option 2	Full	Fully constrained
M7	Generic	Nesting option 3	Full	Fully constrained
M8	Generic	Nesting option 4	Full	Fully constrained
M9	Generic	Simple	Full	Unconstrained
M10	Generic	Simple	Restricted	Unconstrained
M11	Generic	Simple	Limited	Unconstrained
M12	Generic	Simple	Limited	Partially constrained
M13	Generic	Simple	Limited	Fully constrained
M14	Generic	Simple	Restricted	Partially constrained
M15	Generic	Simple	Restricted	Fully constrained

Table 8-7: Defined specifications of all the model variants under key themes

The theoretical reasoning for CS specification of time and cost coefficients rests on the fact that variations in time and cost have quite different dynamics for the sets of teleworking and non teleworking choices and for some choices, e.g. teleworking choices, they vary quite significantly. It is also helpful to remember that the travel time and cost by car during the peak for a particular replication always served as the reference (referent choice/utility) when evaluating an alternative choice (in the choice set).

The CS specification used the same basic model structure for all the utility functions as shown in Table 8-6. The only difference was that instead of having the same coefficient for travel time and cost for all the functions, all seven utility functions were assigned individual time and cost coefficients. For example, in the CS model time coefficient β_t would become β_{t1}, β_{t2}, β_{t3}, β_{t4},β_{t5}, β_{t6} and β_{t7} for all the functions listed in Table 8-6 respectively. Similarly, cost coefficient β_c would become as β_{c1}, β_{c2}, β_{c3}, β_{c4}, β_{c5}, β_{c6} and β_{c7} respectively for all the functions in the same table. All these coefficients were estimated individually by the estimation software. Table 8-8 shows the estimates for the model variants under this specification which are defined as:

- M1: CS specification + full data file + uncontrolled choice availability
- M2: CS specification + full data file + restricted control over choice availability
- M3 CS specification + restricted data file + full control over choice availability.

Model variants	**M1**		**M2**		**M3**	
Variable Name	β	t	β	t	β	t
Constant for Changing Time	-1.989	-10.9	-1.898	-7.3	-1.778	-6.1
Constant for Changing Mode	-1.904	-8.4	-1.929	-8.4	-0.516	-1.4
Constant for Telework 1 Day	-3.344	-12.6	-3.295	-11	-3.354	-10.6
Constant for Telework 2 Day	-3.053	-12.9	-3.025	-11.2	-3.247	-11
Constant for Telework 3 Day	-3.121	-10.9	-3.039	-9.2	-2.954	-8
Constant for Telework 4 Day	-3.989	-13.7	-4.152	-11.5	-4.220	-10.8
Time for Car	-0.001993	-5.3	-0.001346	-3.3	-0.001365	-2.5
Cost for Car	-4.411E-05	-1.2	-0.0001148	-2.9	-0.00014	-3
Time if Departure Time Change	-0.0007418	-1.3	*0.001079*	1.2	*0.00002076*	0
Cost if Departure Time Changed	*0.00004414*	0.9	-0.00006309	-1.1	-0.0001041	-1.5
Time if Mode Changed	-0.001497	-2.8	-0.001013	-1.9	-0.004173	-4.9
Cost if Mode Changed	-3.024E-05	-0.5	-0.0001083	-1.8	*0.0002688*	3
Time if Teleworked 1 Day	-0.0008905	-1.5	*0.00003017*	0	*0.000323*	0.4
Cost if Teleworked 1 Day	*0.0001726*	3	*0.0001498*	2.4	*0.000132*	1.9
Time if Teleworked 2 Day	-0.0004042	-0.6	*0.00138*	1.8	*0.001784*	1.8
Cost if Teleworked 2 Day	*0.0001837*	3	*0.0001155*	1.7	*0.0001343*	1.8
Time if Teleworked 3 Day	-0.001053	-0.8	*0.00155*	1.1	*0.001094*	0.6
Cost if Teleworked 3 Day	-2.877E-05	-0.3	-0.0001537	-1.5	-0.0002548	-2.1
Time if Teleworked 4 Day	*0.007405*	3.3	*0.01391*	5	*0.0149*	4.5
Cost if Teleworked 4 Day	-0.0001859	-1.9	-0.0003323	-2.8	-0.0004175	-3
Telework Policy Statement 1	0.7219	4.7	0.6698	3.8	0.8484	4.3
Telework Policy Statement 2	1.349	9.2	1.449	8.2	1.547	8
Telework Policy Statement 3	-0.2379	-1.5	-0.2094	-1.1	-0.2185	-1.1
Rho-Squared w.r.t. Constants	0.0502		0.0788		0.0965	
Iterations taken to Converge	4		3		4	
No. of Observations	1662		1514		1200	

Table 8-8: Estimates of model variants using CS specification

The results show that there are deviations from the expected signs in all the model variants above which have been *italicised* for a quick reference. All of them relate to time and cost coefficients for all the choices except for the reference choice. Similarly, there are many coefficients with insignificant t-ratios including ASC for mode change choice in M3. The possible reasons for deviant signs in these variants may lie in the role of teleworking cost which has been noted at many places in this thesis. Owing to this role, the respondents may simply become indifferent toward teleworking beyond a certain (saturation) teleworking choice as alluded to in section 8.4.1. This creates a conflict in the model. While teleworking is clearly advantageous on account of time saved from not commuting, tangible and intangible cost concerns associated with telework may work against the time advantage. This might have caused the choice process to vary from choice to choice. Thus, applying the primary tests for model interpretations described in 8.2, especially the sign test, all the model variants of this specification are clearly invalid as indicated by negative coefficient signs and t-ratios.

8.7.3 Estimation of Nested Logit Models

The issue of whether the models should be nested which means testing for any violation of IIA property among the alternatives in the choice set, was forced by two main aspects of the choice set. First was the fact that teleworking choices stem from a more common base than the non teleworking choices. (The nesting option investigating this aspect may be called teleworking versus non teleworking structure.) The second aspect was that time and mode change choices in addition to teleworking choices were *relative* to current car travel conditions during the peak which was represented as 'no change' in the choice set. This common fact among the alternative choices, i.e. change from the current conditions, may also have caused a violation of IIA property. (The nesting option representing this aspect can be called 'no-change' versus 'change' structure).

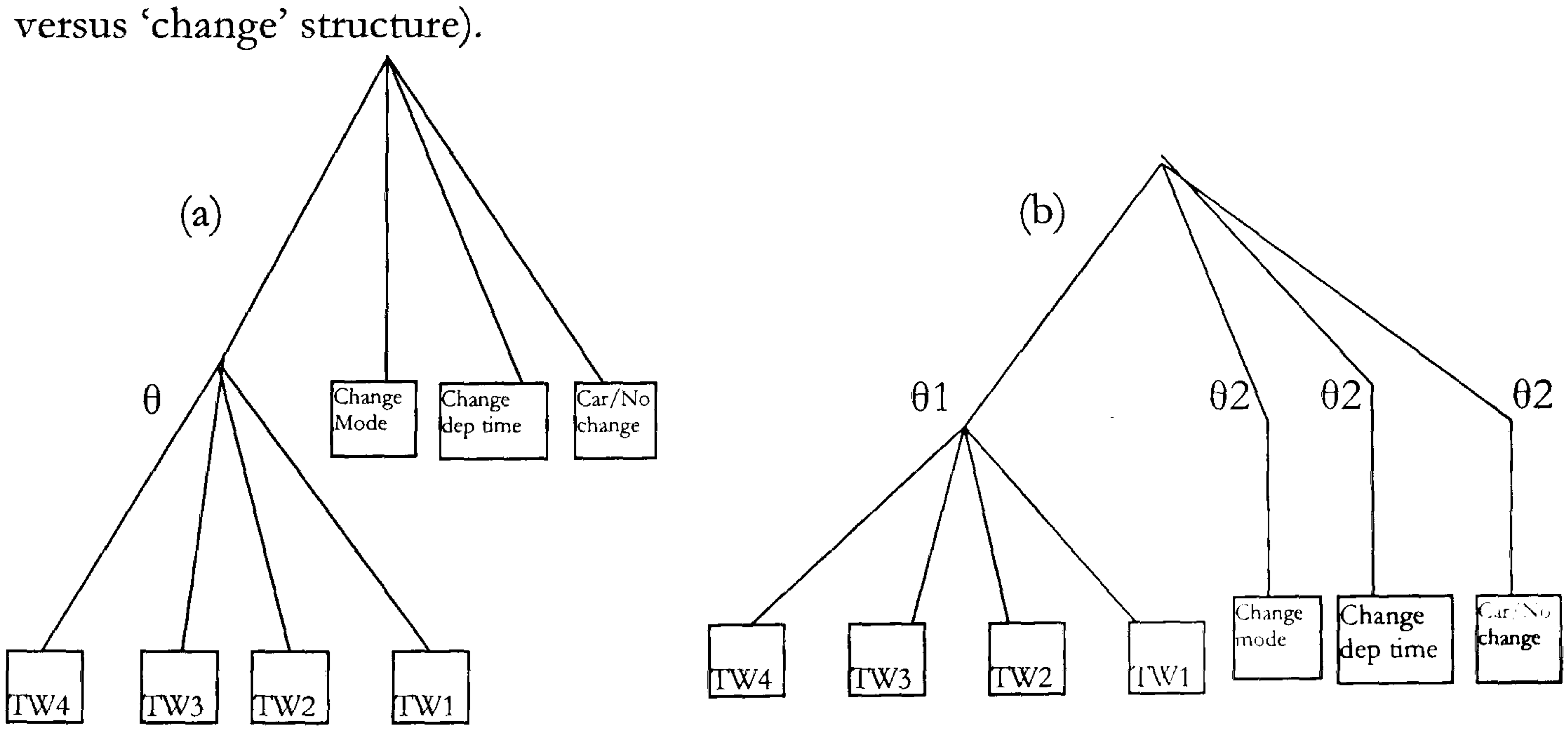

Figure 8.1: Nesting option one showing structure for teleworking versus non teleworking choices

However, a practical difficulty when specifying a nested strutures is that the most appropriate structure may not always be obvious. Therefore, it must be noted that besides the two foregoing nesting options, many other nesting structures were also tested while investigating this issue. As all such attempts failed due to one or the other reason, therefore, they were not reported here for reason of practicality.

Figure 8.1 shows nesting structure for teleworking versus non teleworking choices while Figure 8.2 shows nesting structure for 'no-change' versus 'change' choices. Each of these options has two further variants, forced by theoretical considerations noted later, represented by figures 'a' and 'b' within each figure. Version 'a' in each figure specifies the logsum (θ) for the nested choices only while version 'b' of each figure specifies one common theta for choice(s) outside the nest also, thus treating them as separate nest(s).

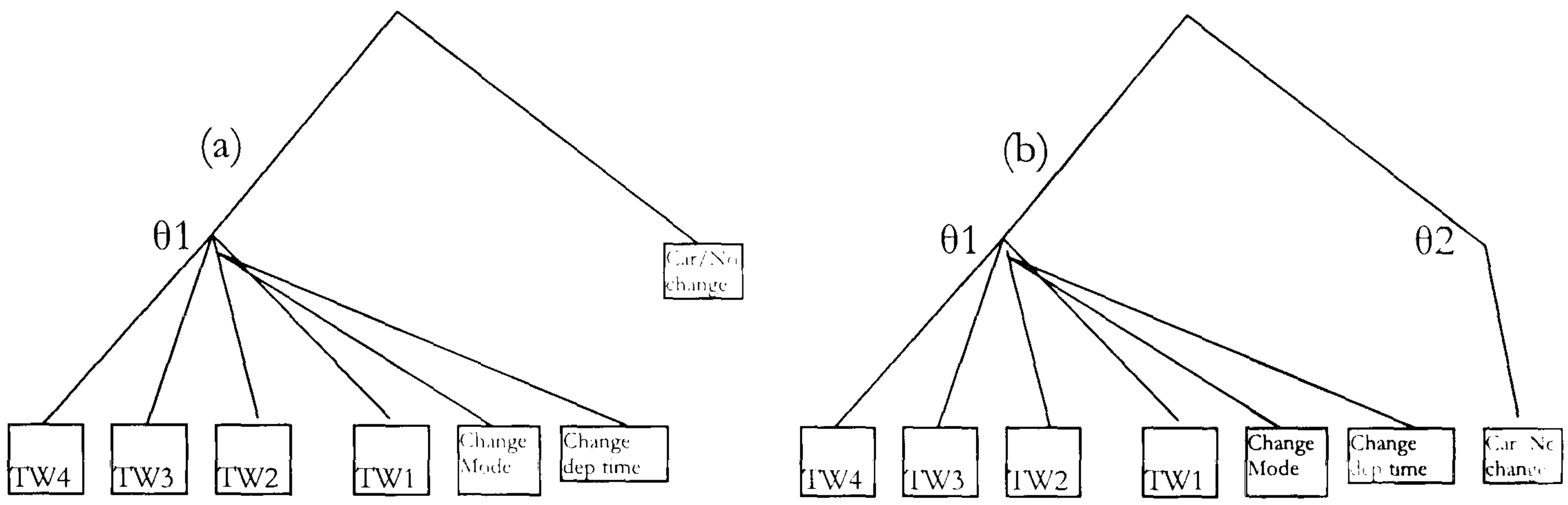

Figure 8.2: Nesting option one showing structure for 'no-change' versus 'change' choices

For simplicity the full nesting options in the above figures can be conveniently defined as follows:

- Nesting option 1: teleworking versus non teleworking choices with one theta
- Nesting option 2: teleworking vs non teleworking choices with separate theta
- Nesting option 3: 'no-change' versus 'change' choices with one theta
- Nesting option 4: 'no-change' versus 'change' choices with separate thetas

The above four nesting alternatives were used to define and specify model variants under this theme. There was sufficient evidence from the previous round of estimations not to try the CS specification any further. However, for the sake of thoroughness it was decided to combine it with one alternative from the nesting theme. The rest of the variant in this round were specified using the generic approach. Thus, in total five variants were defined as follows:

- M4: CS + nesting option 1 + full data file + full control over choices
- M5: generic + nesting option 1 + full data file + full control over choices
- M6: generic + nesting option 2 + full data file + full control over choices
- M7: generic + nesting option 3 + full data file + full control over choices
- M8: generic + nesting option 4 + full data file + full control over choices

Estimates for M4 showed the same pattern for the coefficients' signs as in the previous efforts in 8.7.2. Further, the model did not converge after trying 6 iterations though the theta value was 0.6036 with a t-ratio of 2.7. These un-converged model estimates were based on 1329 observations. To be useful, the model must converge.

Model variants	M5		M7		M8	
Variable name	β	t	β	t	β	t
Constant for Changing Time	-0.599	-1.8	-1.685	-7	-1.976	-11.1
Constant for Changing Mode	-0.3521	-1.8	-1.032	-4.4	-2.367	-12
Constant for Telework 1 Day	-1.544	-11	-2.126	-8.3	-2.694	-12.1
Constant for Telework 2 Day	-1.241	-6	-2.009	-7.6	-2.396	-11.4
Constant for Telework 3 Day	-2.283	-7.5	-3.262	-11	-3.36	-15
Constant for Telework 4 Day	-2.575	-6.4	-3.791	-11.6	-3.597	-15.4
Travel Time	-1.24E-03	-1.7	-2.91E-03	-7.8	-1.12E-03	-3.3
Travel Cost	-6.29E-05	-2	-1.08E-04	-2.9	-4.62E-05	-2.6
Telework Policy Statement 1	0.2359	*1.6*	0.6431	3.2	0.6175	4.2
Telework Policy Statement 2	0.5235	1.8	1.44	6.9	1.196	6.8
Telework Policy Statement 3	-0.7564	*-0.9*	-0.1989	-1	-0.2489	-1.6
Theta1	2.474	1.8	0.841	10.2	2.327	4.5
Theta2	N/A		N/A		1.182	5.3
Rho-Squared	0.0575		0.0569		0.0410	
Iterations taken to Converge	20		8		17	
No. of Observations	1329		1329		1329	

Table 8-9: Estimates of model variants M5, M7 and M8 with nested structures

For M6, estimation software did not accept the given specification and reported that at least one coefficient estimate, i.e. ASC for TW 4 day choice, would become infinity, so the estimation process was automatically terminated by the software and there were no model estimates to report. The model results for other three variants are shown in Table 8-9. Nesting structures in figures 8.1a and 8.2a, respectively defined as M5 and M7 above, are theretically inappropriate as discussed in the relevant literature, see e.g. Koppelman and Wen (1998, Fig. 1) and the references contained therein. To be comparable with the choices in the nest(s), a logsum for choice(s) outside the nest should also be specified as was done in the case of structures shown in figures 8.1b and 8.2b, respectively defined as M6 and M8 above.

As already noted in section 8.6.2, when testing a nesting structure, a value of theta greater than one indicates that the structure is not valid. A scrutiny of θ values of model estimates in Table 8-9 shows that only M7 which was specified with one theta passed this test while theta values for M5 (with one theta) and M8 (with two thetas) are clearly more than one. Thus, both M5 and M8 are not appropriate models. To further investigate this, a variant of M8 was specified in which θ1 and θ2 were forced to take same theta value during estimation. This variant produced a theta value of 1.483. Thus all the tested nesting structures have proved unsuccessful. In the absence of any other a priori justified nesting structure, it was decided to revert to an MNL structure. As a result, both the themes, i.e. choice specific and nesting the models, were excluded from estimation of further variants which were estimated using generic specification and un-nested simple MNL structure.

8.7.4 Examining the Effects of Different Data Files

This issue arose from the presence of current teleworkers in the sample and data from their responses. There were 44 cases of current teleworkers in the sample. Out of these 34 have a weekly teleworking frequency of less than or equal to half day and three out of these have chosen 'no change' as a response to all the nine replications presented to them. The current frequency of these 34 cases being very low was considered to have negligible effect on their choice behaviour relative to the SP experiment. Besides, 31 of them have made non-teleworking choices as well in the experiment. For the rest, in one case the frequency is 0.75 days per week while in nine cases, the frequency is equal to or more than one day per week. Out of these nine, two people telework two days per week and two out of these nine have chosen 'no change' in all of the situations of the experiment. The case of one respondent is particularly interesting. Her current frequency is two days per week but under the experiment she has chosen 'change time' in five (out of nine) situations.

This brief analysis indicates that the choices of all the current teleworkers are complex and it is very difficult to find a pattern. To tackle this situation, three data files were defined as described in 8.7.1. The logic behind their creation is that presence of current teleworkers with significant (non-negligible) teleworking frequency, i.e. full data file might introduce distortions as discussed previously. On the other hand, excluding all the current teleworkers from the analysis would reduce the number of observations substantially as in the limited data file, thus leaving fewer observations for model estimation. A compromise was sought in the restricted data file which excluded only those current teleworkers whose frequency is more that half a day per week. Table 8-10 presents the estimates for models from this round of analysis which are defined as:

- M9: full data file + uncontrolled choice
- M10: restricted data file + uncontrolled choice
- M11: limited data file + uncontrolled choice

In this set of models, all the models have expected coefficient signs for all the parameters. However, the magnitudes of time and cost coefficients are very small for all the models. Further, M11 has insignificant ratios for travel cost and telework policy 3 parameters though it has a slightly better rho squared value compared to M9 and M10 which have almost the same rho squared value. The reason for these estimates of M11 seems to lie with considerably reduced number of observations at the base of analysis. Due to its very low t-values for two main parameters, M11 was considered not sufficiently sensitive to reveal the effects of policy testing related to these parameters and only M9 and M10 were carried forward for further evaluation though both have somewhat insignificant t-values for cost coefficients below the threshold of acceptability of 1.6 as set above.

Model variants	M9		M10		M11	
Variable name	β	t	β	t	β	t
Constant for Changing Time	-1.647	-15.3	-1.547	-15.1	-1.363	-12.8
Constant for Changing Mode	-1.722	-16.2	-1.684	-15.3	-1.465	-12.9
Constant for Telework 1 Day	-2.103	-16.1	-2.031	-15.1	-2.405	-15
Constant for Telework 2 Day	-1.921	-14.4	-1.847	-13.4	-2.279	-13.9
Constant for Telework 3 Day	-3.014	-17.8	-3.074	-17	-3.063	-15.5
Constant for Telework 4 Day	-3.398	-17.1	-3.323	-16	-3.443	-15.1
Travel Time	-0.002469	-8	-0.002269	-7.1	-0.00242	-7.2
Travel Cost	-4.95E-05	*-1.5*	-5.11E-05	*-1.5*	-5.141E-5	*-0.4*
Telework Policy Statement 1	0.5853	3.9	0.6019	3.9	0.7849	4.4
Telework Policy Statement 2	1.243	8.7	1.249	8.4	1.514	8.9
Telework Policy Statement 3	-0.2849	-1.8	-0.3746	-2.2	-0.09109	*-0.5*
Rho-Squared	0.0353		0.0356		0.0391	
Iterations taken to Converge	4		4		5	
No. of Observations	1662		1528		1321	

Table 8-10: Model variants showing the effects of current teleworkers presence on the estimates (M9, M10 & M11)

8.7.5 Controlling the availability of choices

Before putting the respondents through the SP experiment, it was thought reasonable to prime them about the potential choices available to them. Table 8-3 indicates that all choices are not available to all the respondents in the base case. However, when the SP experiment imposed certain conditions and limitations on the respondents, their before-experiment equilibrium became disturbed (discussed in detail in section 7.1.4) and they started thinking even about those alternatives which they considered infeasible under the free conditions. On the other hand, letting them choose an alternative which they are incapable of practising for any reason may introduce errors in the model estimation process.

Controlling the choice availability was meant to take care of issues like job unsuitability and inability to change departure time or mode. However, the respondents who said they are not permitted to telework were allowed in the model as possible changes in the employer's policy on telework were made explicit in the SP experiment. A further dimension was added to this analysis when the implications of the question wording were analysed in 8.4.4. These combined considerations defined the dimensions of this issue, listed in 8.7.1. Thus, in contrast to the previous round the focus in this round of estimation was on managing the availability of the choices to the respondents during the estimation process. Table 8-11 and Table 8-12 show the parameter estimates for the model variants explored in this round which are defined under each table.

Model variants	**M12**		M13	
Variable name	β	t	β	t
Constant for Changing Time	-1.276	-9.0	-1.349	-9.4
Constant for Changing Mode	-1.567	-13.1	-0.4624	-2.6
Constant for Telework 1 Day	-2.057	-11.2	-2.084	-11.2
Constant for Telework 2 Day	-1.952	-10.3	-2.024	-10.6
Constant for Telework 3 Day	-2.821	-12.6	-2.945	-13
Constant for Telework 4 Day	-3.301	-12.7	-3.487	-13.1
Travel Time	-0.00223	-5.7	-0.00308	-7
Travel Cost	-1.4E-05	-1.3	*-1.2E-05*	*-0.3*
Telework Policy Statement 1	0.6996	3.4	0.7519	3.5
Telework Policy Statement 2	1.642	7.8	1.627	7.6
Telework Policy Statement 3	*0.0215*	*0.1*	-0.09132	*-0.4*
Rho-Squared	0.0593		0.0633	
Iterations taken to Converge	4		4	
No. of Observations	1181		996	

Table 8-11: Model variants showing the effects of control over choices

Model variants	**M14**		M15	
Variable name	β	t	β	t
Constant for Changing Time	-1.52	-10.9	-1.5990	-11.2
Constant for Changing Mode	-1.796	-15.5	-0.7280	-4.3
Constant for Telework 1 Day	-1.65	-11	-1.7060	-11.3
Constant for Telework 2 Day	-1.492	-9.6	-1.5950	-10.2
Constant for Telework 3 Day	-2.864	-14.1	-3.0220	-14.7
Constant for Telework 4 Day	-3.191	-13.6	-3.4120	-14.2
Travel Time	-2.20E-03	-5.8	-2.99E-03	-7.2
Travel Cost	-1.27E-04	-3.1	-8.93E-05	-2.1
Telework Policy Statement 1	0.5053	2.8	0.6055	3.3
Telework Policy Statement 2	1.304	7.3	1.3100	7.2
Telework Policy Statement 3	-0.3699	-2	-0.2964	*-1.5*
Rho-Squared	0.0592		0.0609	
Iterations taken to Converge	4		3	
No. of Observations	1380		1200	

Table 8-12: Model variants showing the effects of control over choices

- M12: limited data file + restricted control over choices
- M13: limited data file + full control over choices
- M14: restricted data file + restricted control over choices
- M15: restricted data file + full control over choices

M12 has an extremely low t-ratio and counter intuitive sign for its policy statement 3 parameter. M13 has low t-raitos for two important parameters. Thus, both models were considered unsatisfactory. Both M14 and M15 pass the sign test and have relatively good rho squared values. They also pass t-value test for all the parameters except for policy 3 in the case of M15 which like M9 and M10 has a value of 1.5, below the acceptability threshold. The coefficient for policy statement 3 also has a lower magnitude compared to the coefficients of the other two statements tested. The ready interpretation of this is that such a policy would affect teleworking choice and frequency negatively as the phrasing of the statement indicates but the effect on the relative choices in the sample is not significant. The better rho squared for both these variants points to the fact that control over choice availability directly affects the model fit in this study.

8.7.6 Valid Model Variants

The analysis in the last four subsections has produced four variants which can be considered valid with certain qualifications and have been selected for use in forecasting subject to further testing in the next chapter. These four variants which all have generic and un-nested specifications are:

- M9: full data file + uncontrolled choice availability
- M10: restricted data file + uncontrolled choice availability
- M14: restricted data file + restricted control over choice availability
- M15: restricted data file + full control over choice availability

Here some general comments on these variants seem in order. A notable feature of the selected models is that the magnitude of the time and cost coefficients (investigated in detail in 8.8.2) is significantly smaller than other parameter estimates. In this regard the role of ASCs which represent the effects of unobserved factors in a model is important. This is evident from t-values for all the ASCs in these models which are highly significant, especially in M9 and M10 indicating the large influence of unobserved factors on these estimates. This is further endorsed by the relatively low rho square values for these two variants. Further, the ASCs for two teleworking choices (3 and 4 days) are relatively large in all the model variants. This may be explained by the point made earlier in 8.4.1 about the desirability of teleworking beyond two days per week which might have created conflict in the estimation process as was evident from the estimates obtained for CS variants. Overall, all the selected variants have low rho squared values. However, these values for M14 and M15 are almost double those obtained by M9 and M10. In a sense, M9 can also be considered a base model (because it contains all current teleworkers and choices are unconstrained in it) relative to which the performance of the other three variants can be judged.

The analysis in the last five subsections has also settled three of the five key issues listed in 8.7. That is, model estimation process in this study has to have a base with regard to the categorical attribute of teleworking policy and policy statement 4 is the most appropriate base. The analysis has further shown that choice specific and nested specifications are inappropriate for estimation of models from the SP experiment used in this study. Further, excluding teleworkers with smaller frequencies (< or = ½ day per week) from the data is clearly not wise. Since they travel on five days a week, their utilities will be similar to those who do not telework. However, their absence does affect the estimation significantly by reducing the base for analysis. The two remaining issues will be further investigated in the next chapter.

8.8 Model Evaluation and Validation Procedure

The model variants shortlisted in the previous section were further evaluated, interpreted and validated using the following criteria:

- Value of time (VOT) test
- Validation of coefficients' magnitudes
- Model validation with RP data

8.8.1 VOT test

Some considerations need to be taken into account regarding the application of the VOT test. First, travel cost included parking charges which had large variations in the sample. Another point of concern was the daily cost of teleworking which for high frequency teleworking choices worked in the opposite direction to that of the travel time factor. Therefore, the VOT test and its valuation(s) obtained from conventional mode choice studies, mainly based on 'in-vehicle-time-and-cost', may not be applicable to this study. Further, the sets of time and cost coefficients in these variants represent the composite effects of sample averages for travel time and cost for both travelling and teleworking choices. Therefore, the VOT test may not be relevant here and cannot be applied to these models in the same way as to other conventional mode choice studies. With these caveats, Table 8-13 presents VOT figures (pence per minute) for the model variants.

Model	M9	M10	M14	M15
VOT	49.8	44.4	17.2	33.5

Table 8-13: VOT figures for selected model variants

For overall commuting by different modes in Britain this figure is around 8 pence per minute (Wardman, 1998). Therefore, all the figures in the table are clearly out of line on this criterion. A partial explanation for the big difference may be sought in the fact that the sample is white collar workers/managers, often highly educated, who travel to the city centre and usually place a higher value on their time. Further, this VOT is affected by the cost of teleworking choices, especially choices for 3 and 4 days which in many cases outbalance the cost of travel. However, M14 is clearly preferable on this criterion.

8.8.2 Validating the Magnitude of the Coefficients

The discussion above pointed to a notable feature of these models that the magnitudes of the time and cost coefficients are very small compared to the size of the ASCs for all the choices or the magnitudes of the policy coefficients. When interpreted, this means that variations in travel time and cost have little or very little effect on this sample in explaining the behavioural logic underlying the distribution of these choices. The ASCs and teleworking policy attribute would control the estimates forecast using these models which ultimately mean little influence of cost and time changes on the utilities of all the choices. The ASCs represent the effects of unexplained/unobserved factors which could be anything not studied. From a policy analysis perspective (in the next chapter) this feature of these models has implications for the forecast estimates and may be a cause of concern. Thus, the reasons underlying these smaller coefficients need to be investigated.

Some of the causes for this are quite obvious. For example, the sample is of car commuters who are assumed to be generally happy with their current travel means. Further, 23% of them already practise some teleworking and given the option, a further 48% of the sample would prefer to telework without any policy intervention. Moreover, two of the policy statements tested in the SP experiment are teleworking friendly. These facts leave little room for the influence of variations in travel time and cost to impact upon the choice process. A look at Table 8-14 provides further empirical evidence in this regard.

	N	TW1	TW2	TW3	TW4
Current TW	42	52	96	21	23
Preferrers	90	89	140	78	69
Combined sample	132	141	236	99	92
Total Sample	186	157	246	106	100
Diff. (Row 4 - 3)	54	16	10	7	8

Table 8-14: Shares of teleworking choices (in absolute numbers) made by different groups of respondents under SP experiment

The figures in the table cells are absolute numbers and should be read as the number of times the respondents in a particular sample have made a particular teleworking choice out of the seven choices including four teleworking choices. A rather subtle aspect of this table is the bottom row which shows the difference between rows 4 and 3 in the table and represents those who are neither current teleworkers nor preferrers. The figures in this row provide the evidence that the respondents in this particular group changed their minds and, *ceteris paribus*, explain the real effect of travel time and cost changes and change in employers' policy under the experiment. As the numbers of their choices are quite small in proportion to the numbers of the choices made by the other samples in the table and as they are only 29% of the sample (54 out of 186), this 'real effect' by implication results in smaller magnitudes for the coefficients for time and cost. Thus, these attributes will have little influence on the overall utilities of all the choices. This evidence is also in line with the argument about perception of job unsuitability in 7.2.3.

Here it is also possible to settle the issue (raised in 5.3.6 and further elaborated in 7.2.5) of whether by constraining the SP responses to telework frequencies of 1, 2, 3 or 4 days per week, important data on less than weekly teleworking were lost. Table 8-14 suggests that, under the time, cost and policy scenarios tested, the preferred telework frequency among the sample is 2 days per week, not 1 day per week. Most of the SP responses in this table bunch around this frequency. Therefore, it is reasonable to conclude that looking at the study objective the survey did not lose important data on less than weekly teleworking. Had this been an RP study there might have been reason to believe that the design and survey have missed on important data on less than weekly teleworking but not in this case.

8.8.3 Model validation with the RP Data

The general rule for validation of SP models is to compare them in performance with RP models from similar studies, or to use similar data pooled both from RP and SP sources to estimate such models, or to use RP data to replicate the base shares of choices through the application of estimated model. The primary motivation for the use of SP data for this study was the absence of similar RP data as discussed in section 5.2. This and other limitations mentioned there are still active. Another alternative was to estimate an RP model from the RP data obtained in this study. But the dynamics of RP and SP datasets and choice availability under both situations are entirely different in this study. Further, the RP dataset did not contain enough observations to estimate a model.

The last option was to apply the model to RP data to replicate the base shares. This is done using a technique called sample enumeration. In this technique, using RP data, each respondent in the sample is enumerated through the model and their individual probabilities relative to all the choices in the choice set are determined and then averaged over the entire sample. The estimates thus obtained can be further improved by checking the ranges of probabilities for individual choices and identifying the outliers. When these procedures were applied to the dataset that produced these models, it emerged that due to the differences in the availability of choices under the RP and the SP conditions the sample enumeration cannot be truly achieved.

In final assessment it is recognised that VOT could not be applied to these model estimates which also could not be validated with respect to any external (RP) source. These limitations have mainly resulted from the novelty of this study in which the base and hypothetical situations have entirely different logics and dynamics. However, it was possible to validate the SP data (8.3.1)which produced them and the magnitude of their coefficients estimates (8.8.2). The foregoing observations mean that in novel situations only indirect validation methods may be used and the indirect validation diagnostics employed prove that the model parameters are reasonable estimates of the sample behaviour relative to the choice set. These limitations have some implications for predictive use of these models and for developing forecasts of teleworking impacts which is the focus of the next chapter.

8.9 Summary and Conclusions

Employing the discrete choice modelling framework based on random utility theory, SP data collected from a non random sample have been analysed and the logit model form has been used to specify and estimate the model relationships.

In addition to the quality control processes described in section 7.1, a number of data vetting procedures were employed to ensure the quality of the SP data and to prepare the data file for model estimation. During this process some key issues were identified with potential consequences for model estimation procedures. The following issues were specifically considered during the model estimation process:

- Whether to use generic or option-specific coefficients;
- Whether models should be nested;
- How to treat the presence of current teleworkers in the data file; and
- Whether choices expressed in the SP should be constrained by choice set deduced from the RP questions (8, 10, and 13).

Taking into account various combinations of the above issues, a total of 15 model variants were estimated. The choice specific (CS) model variants failed on the sign and significance of coefficients criteria and consequently were considered invalid for use in forecasting. However, their estimates do suggest the importance of considering extensions of model specification to allow for complex covariance between the main attributes of time and cost, especially for teleworking choices as their presence appears to substantially influence model goodness-of-fit and change model forecasts.

The test for the violation of IIA property in model estimation through nested variants found that the tested nested structures were inappropriate and the use of a simple, un-nested structure may not violate the IIA property among the alternatives in the choice set. For this purpose a range of nested structures were investigated. However, all the variants thus estimated turned out to be inappropriate for a variety of reasons.

Experimenting with different versions of the data file to take account of the presence of current teleworkers led to conclusions that on the one hand it improves the fit of model estimates as indicated by rho square value, while on the other hand, the reduced number of observations impacts upon significance of some coefficients. From this round two variants (M9, M10) were selected for further evaluation. The investigation of the critical issue of choice availability produced two more variants (M14, M15) that were considered fit for further diagnosis. The principal lesson from the investigation was that incrementally increasing the control over choice availability tends to improve the overall model fit.

Overall, the analysis of the five key specification issues showed that the model estimation process in this study has to have a base with regard to the categorical attribute of teleworking policy and policy statement 4 is the most appropriate base, and that choice specific and nested specifications are inappropriate for estimation of models from the SP experiment used in this study. The two remaining issues of data files' effects and control over choice availability will be further investigated in the next chapter.

The preliminary diagnostics showed that the parameters of the shortlisted models are good estimates of the sample behaviour relative to the choice set. The models have the coefficients with the correct signs and significance except for one parameter each for M9, M10 and M15. Generally, it was found that the data on teleworking costs and how the time attribute was determined for the teleworking choices played a significant role in the estimation of model coefficients, particularly for the CS model variants. A deeper analysis of the SP data on teleworking choices revealed that the demand for teleworking beyond two days per week decreases significantly. This coupled with the relative estimation by the logit function most probably complicated the estimation process for the CS model. With a larger dataset with less noise in it, a valid and theoretically more appealing CS model may be estimated.

9 Forecasting the Impacts of Teleworking

9.1 Introduction

One of the objectives of the study is to develop estimates of the impacts of teleworking on travel demand, the peak and congestion. This type of work has partially been done in the past in different time periods, in different spatial settings and following different methodologies. Details of such work have been extensively reviewed in chapter two. While the previous work has made worthwhile contributions of varying nature to the topic, no known previous work has explored the effect of policy scenarios on the adoption and frequency of teleworking. Thus, one of the main contributions of this study lies in the methodology used for analysis and forecasting. The details of this methodology have been discussed in chapters four, five, six and nine which developed the individual elements of the methodology.

This chapter integrates the individual pieces of the employed methodology and attempts to forecast the teleworking impacts on transport. The use of this methodology entails two different approaches to the forecasting exercise which have been used from a transport planner's perspective. The first approach which may be called demand forecasting provides estimates of the impact on total commuting demand, commuting demand by car and during the peak within the study area under varying policy interventions. The second approach analyses the impacts of teleworking take up on performance of the network in terms of congestion during the peak and may be called systems forecasting. Both approaches work within the same (comprehensive) framework but with slightly different requirements in terms of modelling capability and contextual data, and yield different outputs. In fact, the second approach is an extension of the first approach and takes into account the effect of changes in congestion on demand for car use.

The chapter has been organised as follows. The next section performs sensitivity analysis for the shortlisted models and looks at model calibration issues. Section three looks at various model transferability issues including the nature and characteristics of the data used, and the forecasting context which led to the development of appropriate assumptions. In section four, the robustness of the transferred models has been evaluated and some observations regarding the performances of the models vis-à-vis estimation issues of chapter eight have also been made. Sections five and six are devoted to demand and system forecasting respectively. For this purpose, first policy tests and performance indicators have been defined and then an array of tests were administered followed by discussion and analysis of the test results to identify the most effective policy measure(s) relative to the study objectives. The chapter ends with a summary of the results and conclusions from the policy analysis.

9.2 Sensitivity Analysis

Four model variants were considered acceptable for use in forecasting at the end of the previous chapter. They are M9, M10, M14 and M15. The investigation of key estimation issues (ref 8.7) in subsection 8.7.2 through 8.7.5 proved that choice specific coefficient specification and nesting the models were not appropriate and thus did not affect the model estimation process. Therefore, the shortlisted variants were specified using generic specification and an un-nested MNL structure. In addition to this, all have two additional features which are:

- M9: full data file + uncontrolled choice availability
- M10: restricted data file + uncontrolled choice availability
- M14: restricted data file + restricted control over choice availability
- M15: restricted data file + full control over choice availability

In these model definitions the full data file consists of all valid observations including all teleworkers while the restricted data file is exclusive of current teleworkers who currently telework > ½ day per week in the sample. Restricted control over choice availability means that the availability for all the choices was controlled *except* for mode change choice (to account for inadvertent error in the wording of Q10) while full control over choice availability meant that a particular choice was available to only those respondents during the estimation process who were able to choose it as a result of their answers to Q8, 10 and 13. Why these issues arose and what is their nature have been discussed in 8.4.4 and 8.7.1 respectively.

The models' parameters and performances are given in Table 8-10 and Table 8-12. Out of these variants, no variant was without a minor flaw except M14 and all have rho squared values which are considerably lower than the lower limit of 0.2 (section 8.2) for a relatively reliable predictive choice model. After the sensitivity analysis, a comparison between the performances of M9 and M10 may give some insight into the influence of different data files on the model estimates because with regard to other dimensions they are exactly the same. Comparing the performances of M10, M14 and M15 which all have common dimensions except differing degrees of control over choice availability may highlight the role of the choice availability issue.

Before analysis of forecasts to be produced by the model variants, all variants required calibration within a framework which reflects the base conditions in the study area. The following subsection describes the calibration procedure followed by a decision on the base shares for model calibration. After that the results of sensitivity testing are presented and some observations are made regarding whether the predictions are reasonable and reliable.

9.2.1 The Calibration Procedures

During the calibration process, the ASCs of an originally estimated model are adjusted to replicate the base shares of the choices it is supposed to predict. The process has a theoretical basis (DfT, 2006). The ASCs account for the unobserved effects of known or unknown variables. It is possible that the model estimation process did not account for those effects. Two methods can be employed to adjust the ASCs, either using the following formula or to do it through trial and error:

$$NASC_i = ASC_i - \log_e \frac{s_i}{S_i} \qquad (9.1)$$

Where $NASC_i$ and ASC_i are the new and the originally estimated ASC for alternative i respectively, s_i is the forecast share of alternative i, S_i is the population share of alternative i. During the model estimation process, the constant for one alternative is not specified and that alternative is treated as dummy or reference alternative. In ASC adjustment using the formula method, the reference constant must also be amended. However, this method can only be used if everyone in the sample has all the alternatives available, otherwise this method would adjust constants for the choices which have no representation in the base to such a large magnitude that the magnitudes of those constants would override the effects of other parameters in forecasting as has been experienced in this study. In the end a combined approach, i.e. using the above formula and refining the obtained estimates of ASCs through trial and error, was used in this study to the adjust the ASCs. This approach proved more efficient because it was found that the formula approach is helpful in providing the near-estimates of ASCs which can be further refined through the trial-and-error approach.

9.2.2 Deciding on the Base Shares

Table 9-1 shows the distribution of activities in the base which has been obtained by the following reasoning. This sample consists entirely of car commuters travelling during the peak, therefore, mode change activity has zero share in the base. The time change activity is also assumed to have zero share in the targeted sample. The distribution for teleworking activities was obtained in Table 8-2 which means that after excluding the distribution in Table 8-2, the rest of the sample consists of five day car commuters. Using the distinction between activity and trips made in 8.4.2 and reducing the teleworking activities proportionately for not travelling on a given day produced the figures in Table 9-1 that can be 'attributed' to each choice in the base case. In this table four choices have zero shares. During the actual model calibration exercise, it was base shares for model calibration. After that the results of sensitivity testing are presented and some observations are made regarding whether the predictions are reasonable and reliable.

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Choice	Car	Time Chang	Mode Chang	TW 1 Day	TW 2 Day	TW 3 Day	TW 4 Day	No travel
Activities	84.52%	0.0%	0.0%	13.62%	1.86%	0.0%	0.0%	0.0%
Trips	84.52%	0.0%	0.0%	10.9%	1.12%	0.00%	0.0%	4.27%

Table 9-1 Distribution of activities and trips attributable to each choice on a typical day in the base case

On the other hand, it is not difficult to imagine that a small number of respondents in the sample despite being car commuters may make these choices occasionally under different circumstances. In this regard changing departure time (off peak travel) is more attractive than changing to an alternative mode as evident from Table 8-3 to Table 8-5. Thus, to avoid the above procedural difficulty and following the foregoing argument, all the choices with zero shares were arbitrarily allowed some nominal share in line with the degree of their relative attractiveness in the base case. The share for activity choices for teleworking one day and two days were also adjusted as shown in Table 9-2. This issue of base shares for model calibration gets a fuller treatment in 9.3.5. Here, it would suffice to note that at this stage this issue is not very significant for a variety of reasons which include that the model variants are to be used in sensitivity analysis, calibrated on the same base shares and minor variations in allocations would not affect the models' performances.

	Activities						
	Car	Time change	Mode change	Tw 1 day	Tw 2 days	Tw 3 days	Tw 4 days
Shares	84.5%	2.0%	0.5%	10.0%	2.0%	0.5%	0.5%

Table 9-2: The base shares for all the activity choices in the sampled workforce (only car commuters) after allowing nominal shares for choices with zero shares (Scenario 1)

Thus, the ASCs of all model variants were calibrated on the *activity* shares as shown in Table 9-2 which may be regarded as 'scenario one'. Under activities in this table, Tw stands for telework. The model was calibrated around the shares figures in the table which means the exact adjustment of ASCs was almost impossible beyond four decimal points. For example an activity choice with a 0.5% share may have been calibrated as 0.0049 or 0.0051 in the base. However, it may be noted that the probability determined by the logit function for each choice is a relative estimate and relative estimation beyond four decimal places is not likely to affect the end results and analysis significantly. Thus, this lack of precision in model calibration can be ignored.

9.2.3 Analysis and Assessment

Before putting the models to diagnostic and sensitivity testing, in addition to the adjustment of the ASCs they were also calibrated on sample average data on travel times and costs for all the activity choices (mentioned in 8.5.1). The calibrated models were used to perform some what-if tests to evaluate their performances and the validity of the forecast estimates. Three policy tests were selected for this purpose:

- Cost increases by 100%;
- Time increases by 100%; and
- Testing the effects of policy statement two.

	M9	M10	M14	M15
Choice	Travel Cost increases by 100%			
Car	-1.0%	-1.0%	-2.6%	-1.8%
Time change	13.0%	13.4%	36.8%	24.6%
Mode change	13.0%	13.4%	36.8%	24.6%
Tw 1 day	2.5%	2.6%	6.5%	4.6%
Tw 2 days	6.1%	6.3%	16.2%	11.2%
Tw 3 days	9.0%	9.3%	24.7%	16.8%
Tw 4 days	11.4%	11.7%	31.7%	21.3%
	Travel time increases by 100%			
Car	-7.0%	-6.3%	-6.1%	-9.0%
Time change	138.1%	122.3%	116.9%	184.1%
Mode change	138.1%	122.3%	116.9%	184.1%
Tw 1 day	9.2%	8.6%	8.4%	10.5%
Tw 2 days	32.7%	29.9%	28.9%	40.0%
Tw 3 days	61.2%	55.4%	53.3%	77.2%
Tw 4 days	95.9%	85.9%	82.4%	124.4%
	Effects of Teleworking policy 2			
Car	-24.6%	-24.7%	-26.2%	-26.3%
Time change	-24.6%	-24.7%	-26.2%	-26.3%
Mode change	-24.6%	-24.7%	-26.2%	-26.3%
Tw 1 day	161.3%	162.4%	171.9%	173.0%
Tw 2 days	161.3%	162.4%	171.9%	173.0%
Tw 3 days	161.3%	162.4%	171.9%	173.0%
Tw 4 days	161.3%	162.4%	171.9%	173.0%

Table 9-3: The results of the sensitivity analysis of four model variants (Scenario 1) (%s in the cells are changes from the base and the definitions of the models can be found on page 200)

The cost and time in these tests refer to cost of or time for travelling by car during the peak only. The magnitude of the tests was deliberately kept large so as to test the sensitivity and realism of the model, especially in view of the small coefficients for travel cost and time in these models. Table 9-3 shows the results and the figures in the cells are percent increases or decreases relative to base percent activity shares for the respective choices as shown in Table 9-2.

All the models are behaving sensibly in response to increases in travel cost or time. When time or cost of car travel goes up, full car commuting loses share to all the other choices in the results from all model variants; more so for time changes and less so for cost changes. This confirms the speculation made in 8.7.5, that the models seem more sensitive to travel time change than to change in travel cost.

For increases in travel time and cost by car during the peak, the choices of time change and mode change gain most because the utilities of teleworking choices are also affected by car time and cost increases in the peak. The increases for teleworking choices are larger the more days of teleworking, as would be expected given the smaller impact of car use. These choices, i.e. time change and mode change, increase by the same amount because they are not affected by changes in travel time and cost under the test.

Similarly, telework policy 2 which is the most positive of all the telework policies has a significantly positive effect on teleworking choices and negative effects on the travelling choices. This policy results in constant positive effects for teleworking choices and constant negative effects for non teleworking choices because policy statements have entered into the models as categorical, non-interactive attribute. The model predictions are in line with the character of the policy statement (see section 8.7.4), thus plausible.

9.2.3.1 The Role of Estimation Issues

Here it is possible to make a partial assessment whether the two remaining key issues, i.e. 1) presence of current teleworkers in the dataset and 2) controlling the choice availability have any bearing on the predictions made by these models. As noted above in section 9.2, an assessment on the first of these issues can be made from a comparison of performances between M9 and M10. M9 is relatively more sensitive to time change and very slightly less sensitive to cost change and to the effects of teleworking policy 2. However, the differences are sufficiently small to suggest that the two models are not significantly different from each other. Thus, exclusion of current teleworkers with > ½ half day weekly frequency from the data file has no significant effect on the estimates of the model's parameters.

The assessment regarding the second issue, i.e. control over choice availability, can be made from comparing the performances of M10, M14 and M15 because they all have common features except differing degrees of control over choice availability. For this comparison M10 can be considered as base model among the three variants as it has uncontrolled choice availability. M14 which constrains choice availability except for mode change is much more sensitive to cost change, slightly less sensitive to time change and more sensitive to policy 2 than M10. M15 which constrains choice availability for mode change also, is more sensitive to cost change, more sensitive to time change and much more sensitive to policy 2 than M10. The greater sensitivity of M15 is due to its being calibrated only on people with a choice. Therefore, it is bound to be more sensitive. Given that M10 and M15 give very different results for time and cost policies, the choice between them is important if one wishes to explore policy effects.

9.2.3.2 Preliminary Assessment

The analysis in this section has helped in judging the relative sensitivities of all the model variants. It has also helped in drawing some preliminary inferences with regard to the effects of the two remaining estimation issues. An investigation of the role of current teleworkers' presence in the data file reveal that excluding the teleworkers with > ½ day weekly frequency makes little difference to the performance of the model. On the other hand, control over choice availability gives more sensitive models with better rho squared vallues. Whether the predictions from these variants are robust and whether the inferences drawn about the role of key estimation issues in a model's performance hold across populations, however, remain to be seen. Given that, all variants were retained for further investigations which were done by transferring them to full population of the study area, i.e. Leeds City Centre and access routes to the centre, in contrast to the sampled population.

9.3 Setting the Context for the Models' Transfer and Forecasting

This section looks at various aspects of transferring the model variants to the full population. It also sets the context for model transfer, robustness testing and demand forecasting by using the forecasting framework developed in section 4.3. The database used for this purpose related to different geographical dimensions of the area in terms of access to locations of economic activities. It consisted of both primary and secondary data, though the role of secondary data was more prominent in calibration of the models and development of assumptions.

9.3.1 A Theoretical Perspective on Model Transfer

DfT (2006) suggest the following considerations before a decision on model transfer:

- There is a relevant model to transfer, with appropriate segmentation and behavioural responses;

- The quality of the model considered for transfer is high (based on analysis of the significance of model coefficients, results of validation tests, etc.);
- The age of the model considered for transfer;
- The areas and zone systems are broadly similar;
- Local, preferably disaggregate data, is available (or could be collected) and is compatible with the original model;
- The network descriptions between the original model and area of transfer are broadly similar;
- The mode shares and trip lengths between the original model and area of transfer are generally compatible.

The estimated models score favourably on almost all of these criteria. The significant aspects of these models for transfer are that they are relevant, recent, estimated and calibrated on data from the same area. However, there are some concerns. The foremost among them is that the quality of the models might not be very high. Further, the data were collected from commuters who mainly use car as their usual means of travel to work. It is well known that different user classes (car and PT, especially bus users) are not equally distributed over all the SEGs. Similarly, it is also possible that they may have different distributions of TW frequency choices rooted in differences of SEGs and for the same reason may also have different propensities to adopt teleworking. These issues raise concerns regarding the model transferability.

However, despite these concerns there still exists a case for model transfer. The case rests on the facts that: the model transfer would increase the generalisibility of the forecast; the constraint regarding the availability of teleworking choice was removed by the assumption in the survey; the respondents were given the choice of switching to an alternative travel mode and they did record their experiences with PT in their responses and comments; the teleworking policy statements used in the SP experiment were equally applicable to all user classes; and in their responses the respondents showed willingness for mode switches.

Regarding the issue of job unsuitability, two points need to be made. The sample despite its focus on 'suitable' jobs included 26% of the respondents with unsuitable jobs for teleworking (Table 7-8) whose choices were analysed in section 7.2.3 given the option to telework. The issue has also partly been dealt with while discussing the study area economic characteristics in section 9.3.3. Here it is also helpful to mention that one third of PT users accessing the study area are rail commuters and might not have the same SEG based differences towards teleworking as may be the case with bus commuters. The job unsuitability has been another overriding concern as the sampling strategy was aimed at netting only the 'suitable' jobs. Therefore, overall this model transfer has its merits. However, at the same time it is also important to note that the population to which the models are to be applied should have the same degree of choice as was determined for the estimated models. From this perspective a caveat should qualify the transfer of M14 and M15 which have been estimated on constrained choices.

9.3.2 The Assumptions and the Database

An important distinction regarding the nature of the choices being modelled and about the forecasts being developed was made in section 8.4.2. In view of this peculiar aspect of the study, purpose-specific data are not available in many instances. To overcome this limitation, some assumptions had to be formulated regarding how the data obtained from Leeds City Council and other sources were handled and required information was extracted. The full database used to develop those assumptions and to model the impacts consisted of the following items:

- Averages of travel cost and time data for all the activity choices from the sample (discussed in 8.5.1)
- Availability of different activity choices to the population in the sample (Table 8-3)
- The distribution of teleworking frequency in the sampled population (Table 7-11)
- Estimates of shares of jobs in different sectors of the economy (external source)
- Estimate of number of current teleworkers in the UK using sources quoted in 2.8
- Traffic data from Leeds City Council
- Data on average trip length, free flow speed, peak period speed and free flow link time from the MARS model of Leeds.

The data items about the study area listed above need to be put in context with regard to their characteristics and relevance which is done next.

9.3.3 The Leeds Data: Characteristics of the Activities and the Trips

The data in Table 9-4 show the distribution of different types of jobs within broad industry sectors at the UK level. The two sectors at the bottom of the table accounted for 50.7% of the total jobs in the year 2007 and are projected to increase to 52.2% in the year 2012. A great majority of the jobs in these sectors are appropriate for teleworking.

Shares of Jobs (%)	1982	1992	2002	2007	2012
Primary & utilities	5.2	3.5	2.2	2	1.8
Manufacturing	22.7	16.6	13.2	11.7	10.5
Construction	6.7	7	6.3	6.1	5.9
Distribution, transport, etc.	28.3	29	29.6	29.5	29.6
Business & other services.	16.5	21.1	25.6	26.9	28.6
Non-marketed services	20.6	22.7	23.1	23.8	23.6
Total	100	100	100	100	100

Table 9-4: Estimates and projections about the share of jobs in different sectors of UK economy. Source: adapted from Working futures (Wilson et al, Dec. 2004)

Further details in the source document for Table 9-4 reveal that these sectors include industry/service groups in Banking & finance, Insurance, Professional services, Computing services, Other business services, Public administration & defence, Education, Health & social work. Leeds city is the second biggest centre of financial services after London in England. A great majority of them are located within the study area, Leeds City Centre. There are other white-collar/office jobs which employ information workers and the majority of the large educational institutions are also located in or around this area. Besides a major establishment of City Council offices and facilities, the main health facility for the city is also located in the area. There is also a significant presence of retail businesses usually associated with the character of a city centre. Industrial manufacturing activity and other blue-collar jobs are almost non-existent within the boundaries of Leeds city centre.

Assuming that the sectoral definitions and respective share allocations in Table 9-4 are applicable to the Leeds economy, all the service groups mentioned in the first paragraph of this subsection except the health services were covered in the survey (see sample description in 6.7.2). Thus, based on the sample composition it can be assumed that the survey was able to reach about 80-90% of the employment within the two sectors mentioned just above the 'Total' row of Table 9-4. Further, based on the characteristics of the study area described in the second paragraph of this subsection, all the trips to this area during the morning peak have been assumed as commute trips either for employment or for education with a ratio of about 80:20 respectively.

Two conclusions can be based on the assumptions in the preceding paragraph that: the overall share of employment commute trips to the area during the peak (80%) to access sampled employment (90% of the employment in the area) is 72% of the total commute trips (for employment and education) during this time and to this area; and the estimates developed from the forecasting exercise in this chapter may be applicable to 45% (90% of the 50% in the last two sectors of Table 9-4) of the total Leeds employment in the year 2007. Here it is also helpful to distinguish between the sampled and the non sampled types of population. The non sampled population includes:

- All non commuting population;
- Commuting but with jobs in sectors considered not teleworking friendly; and
- Commuting for job types suitable for teleworking but by non motorised modes and public transport.

The composition of this population is a significant issue for model transferability and has been taken up again later in the chapter. The sampled population comprised the rest, i.e. job types thought suitable for teleworking and accessed by car.

9.3.4 The Leeds Data: the Trip Modal Shares

However, another significant issue to decide is to determine modal shares that could be allocated to the set of activity choices. It has been observed in section 8.4.2 that the activities in the choice set are not uniform with regard to the travel mode and the time of day. Determining the size of the demand within one period of the day and/or by conventional modes is easy from the available dataset. It was, however, quite a tricky issue to estimate the share of commute trips that could be attributed to car commuters who currently travel during a relatively less congested period. Both 'off peak' and 'mode' terms are misnomers here. The referred time period cannot be called exactly off peak; rather it is on either shoulder of the peak. Similarly, the term mode refers to the means of travel not to time of travel. However, to avoid further confusion about the terms being used in this thesis 'time change' is referred to as 'off peak' and may also have connotation of a travel mode about it in the discussion and analysis in this chapter.

The above elucidation of the issue provides the context to the use of the data on traffic flows and modal shares in the study area which were formally obtained from Policy Planning Wing of Leeds City Council. A main dataset consisted of daily counts of in- and outbound cars crossing the Leeds Inner Cordon for an entire week during May 2006 for every 15 minute interval. A smaller set of data consisted of counts of passengers using all modes in the morning peak period from 07:30 to 09:30 hours for every 30 minutes interval within the same area. So, in a sense the two datasets are complementary. With the help of the latter dataset, it was possible to interpolate or extrapolate modal shares for other time periods. After performing these procedures the required data were assembled in one place and is shown are Table 9-5.

Time	Walk	Cycle	M/cycle	Car	Bus	Rail	Total
0700-0730				14867			
0730-0800	618	162	179	18544	7313	3741	30556
0800-0830	1151	187	163	18949	9084	4648	34181
0830-0900	1497	208	176	17409	8783	4494	32567
0900-0930	754	120	95	13757	6530	3341	24596
0930-1000				13080			
Total	4020	676	612	96605	31709	16224	121900

Table 9-5: The Leeds traffic data showing travel demand by different modes during morning peak.

To estimate the share for off peak car commuters from this dataset required some careful thinking and allied assumptions. The foremost among them was to define the peak period. As a first step it was decided to apply the analysis to the morning peak only and define it. After due diligence in which two competing suggestions were considered, it was decided to assume peak traffic activity period spanning three hours in the morning from 07:00 to 10:00 hours. This period was further thought of as having a core peak from 07:30 to 09:30 hours and a half hour of shoulder on either side of it. Thus, the final assumption is that the peak period for this study is between 07:30 and 09:30 hours. Two considerations motivated this assumption: first, the peak has been spreading over the years and the conventional peak between 08:00 and 09:00 hours has become irrelevant; and secondly the survey conducted in this study did not provide a specific definition of the peak and left it to the discretion of the respondents. Therefore, a rather broad definition of peak was considered more appropriate.

It was evident from the responses in the survey that car commuters who would change time to avoid congestion would do so by travelling either early or late but adjacent to their usual departing time and it was assumed that a great majority of them would adjust their changed departure time within a 30 minute interval. Therefore, it was further assumed that a half hour period on either side of the peak is the relevant period for travel demand estimation from those who changed time to off peak. Linked to this assumption is the consideration of the purpose of the trips during both these half-hour periods. Considering the time dimension for the trips other than for commute purpose, all the trips between 07:00 and 09:30 was assumed to be for commute purposes while 20% of the trips in the second peak shoulder were assumed to be for non commute purposes. This figure in the foregoing assumption is a rough estimate without any particular basis.

To qualify the foregoing assumptions further, the modal shares for non-motorised modes and motorcycle from the dataset in Table 9-5 were ignored for the reasons mentioned in section 8.4.2 and modal share for PT in the shoulders was also ignored because it was not covered in the survey. Hence, the analysis and forecasting have been based on the travel demand shown by the borderlines in Table 9-5 which when manipulated gives the trips' shares for the three activity choices as in Table 9-6:

Activity/mode	car	off peak	Bus	Rail	PT Combined
Share	47.50%	19.34%	21.94%	11.22%	33.16%

Table 9-6: Estimates of trips shares, for activities requiring travel, in the base demand

9.3.5 Travel Demand Affected by Teleworking Activities

However, the picture about the size of the travel demand affected by all the activity choices is not complete yet, as only demand for trips from activities requiring travel has been accounted for. There is a need to account for the travel demand avoided through participation in teleworking activities. The travel or commute trips by teleworkers on a non-teleworking day are implicit in the travel demand shown in Table 9-5 and there is a need to estimate the trip shares that could be allocated to them. This has to be based on the frequency distribution of teleworking activities within the commuting workforce. For the sampled population the frequency distribution for these activities was noted in Table 8-2.

The corresponding distribution for the non sampled/general or total population along with the estimates of current teleworkers in both populations is shown in Table 9-7 and how it was obtained is discussed below. The left half of Table 9-7 presents the shares of teleworkers in both populations. The survey for this study found teleworkers to be 23% of the sampled population (ref table 7-2). The same table also presents the comparable figure for the UK workforce which has been obtained through extrapolation of the data from section 2.8.

Workforce	Current Teleworkers			Frequency Share	
Sampled	22.91% (Ref table 8.3)		Activity choices	Sampled	Total
Total	13.63% (Ref Sec. 2.8)		TW 1 day	13.62%	10.00%
			TW 2 days	1.86%	2.00%
			TW 3 days	0.00%	0.50%
			TW 4days	0.00%	0.50%

Table 9-7: Estimates of current teleworkers and frequency shares of teleworking activity choices in the two commuting workforces

In 2001, ONS estimated the number of teleworkers at 7.4% of the workforce and Cairns et al (2004) estimated an annual average increase of 13% between 1997 and 2001. This latter estimate is also supported by another source (at 11.7%) mentioned in section 2.8. Thus, assuming the year 2001 as base and an annual increase of 13% provides an estimate of 13.63% of the workforce as teleworkers in the UK at the end of 2006. This figure has been assumed to be true for that part of the Leeds workforce which was not sampled.

The frequency distribution for teleworking activity choices for the sampled workforce as determined in Table 8-2, also shown in Table 9-7, show that a great majority of teleworkers telework one day per week and the rest telework two day per week with no representation for the other two activity choices. Similar distribution has been assumed to be true for the general population. Assuming 13% teleworkers in the general population as determined above, their distribution among the four activity choices has been shown in Table 9-7. The allocations to teleworking three and four days choices which have zero share in the sampled population have been made to remove a procedural difficulty about the model calibration process as discussed in section 9.2.2.

Overall the figures in Table 9-7, especially for non sampled population, represent a conservative estimate for teleworking activity choices of one day and two days because they are based on estimates of 48.7% of information workers in 2002 (two economy sectors at the bottom in Table 9-4) and do not take into account the predicted 2% shift in their number by 2007, when the share of workers in these sectors is projected to reach 50.7% of the total workforce (ref Table 9-4).

9.3.6 Estimates of the Base Shares

The first step in transferring the model is to have a plausible and accurate estimate of the base shares. Based on a number of assumptions developed about the study area, the modal shares of the commuting populations and the shares of teleworking activity choices in section 9.3, Table 9-6 and Table 9-7 were obtained. Table 9-6 depicts the total trips to which the selected model is applicable after its transfer while Table 9-7 presents the frequency distribution for the teleworking choices. As the model is now being applied to the combined population, the distribution for the total population in Table 9-7 is applicable for the base estimation. Both these items of data from Table 9-6 and Table 9-7 combined provide the base share for model calibration.

However, due to the presence of teleworking activity choices or teleworkers the total demand for work-based activity is underrepresented by Table 9-6, since it omits those who work from home on a given day. By implication, the trip shares for the non teleworking (or travelling) activity choices are overrepresented. This difference has been shown in Table 9-8 under 'Not Travelling' column. Table 9-8 adopting the distributions for teleworking choices by activity from Table 9-7 shows the trip dimension of these choices and reduces the number of trips by a reduction factor which is the proportion of the days on which commute trips are made.

Choice	% of person-days worked	% of working days involving travel	% person days involving travel	Not travelling
TW1	10.00%	80	8.00%	2.0%
TW2	2.00%	60	1.20%	0.8%
TW3	0.50%	40	0.20%	0.3%
TW4	0.50%	20	0.10%	0.4%
Total	13.00%	N/A	9.50%	3.50%

Table 9-8: Shares of teleworking choices along activity and trip dimensions in the base

From Table 9-8 it is clear that for every 100 people, only 96.5 people are making trips on a given work day. Therefore, the share distribution in Table 9-6 needs to be adjusted by this factor. At the model transfer stage it was not known how many current PT and off peak users telework, hence the assumption is that the users of car during peak, of PT and car during off peak have similar proportionate shares of current teleworkers who make these choices and the distributions for teleworking frequencies choices are also the same as has been assumed for car users. Therefore, the adjusted shares for the three travelling choices further need to accommodate the distributions of 9.5% trips by teleworkers proportionately.

After going through the above procedures, finally it was possible to have estimates of base shares and Table 9-9 lists them for all the choices along both dimensions, i.e. activity and trips. The figures in table cells are percentages. The difference in the sums of the rows in this table is the same as calculated in Table 9-8 under the 'Not travelling' column and indicates the impact of teleworking on commute trips on a given day in the base case with current shares of teleworking frequencies.

Share	Car	Off peak	PT	TW1	TW2	TW3	TW4	Trips forgone	Total
Activity	41.33	16.82	28.85	10.00	2.00	0.50	0.50	N/A	100
Trips	41.33	16.82	28.85	8.00	1.20	0.20	0.10	3.50	100

Table 9-9: Estimates of the base shares for choices along both the activity and the trip dimensions for the entire commuting workforce in the study area

9.4 Testing the Models' Robustness

The analysis in this section tests all the model variants for robustness. This is done by transferring the models to the full population of the study area as contrasted with the sampled population. For this purpose theoretical aspects of model transferability were looked at and a case was made in 9.3.1. The analysis also required calibrating the models on the (new) base shares which were obtained in Table 9-9. Before the analysis an important assumption under which the models were applied to full population and its implications for the results needs to be mentioned.

9.4.1 An Important Assumption about Model Transfer

The sensitivity analysis in 9.2.2 did not bother about the distribution of teleworking choices among the PT users because of a small assumed share for this travel choice in the base. For robustness analysis under changed travel conditions (full population) in which PT users have significant share in the base, this cannot be ignored. This issue can be addressed by looking at the economic activity profile of the study area. The discussion in 9.3.3 highlighted that the composition of the jobs in the full population is not significantly different from that of sample population. Therefore, it is reasonable to assume that the distribution of teleworking choices among the PT users is also the same as it is for the car users in the sampled population.

By implication, the foregoing assumption means two things. First, 10% activity share for TW1 choice in Table 9-9 is proportionately shared by the three user classes (i.e. car, off peak and PT) under changed (transferred) travel conditions. This applies to all the teleworking choices. Secondly, the activity of a teleworker within a particular user class on a given day is shared by both dimensions (i.e. activity and trip). The respective shares are in proportion to her weekly teleworking frequency. This applies to all the user classes.

However, as noted earlier some caveats regarding the transfer of M15 must be recognised. M15 was calibrated on a constrained choices and on the assumption that teleworking involves car use only. When applied to a population which has no constraints, and among whom teleworking might well involve use of PT, rising costs of car will cause an exaggerated shift from teleworkers to other modes. This means that the interpretation of predictions from M15 must be done with great caution.

9.4.2 Analysis and Assessment

All model variants (M9, M10, M14 and M15) were recalibrated on the activity share distribution for the study area population as shown in Table 9-9 (called scenario two). The models were put through the same set of tests as were performed under scenario one.

	M9			M10		
	S1	S2	S2/S1	S1	S2	S2/S1
	Travel cost increases by 100%					
Car	-1.0%	-6.5%	6.71	-1.0%	-6.8%	6.80
Time change	13.0%	6.7%	0.51	13.4%	6.8%	0.51
Mode change	13.0%	6.7%	0.51	13.4%	6.8%	0.51
Tw 1 day	2.5%	-3.2%	-1.26	2.6%	-3.4%	-1.31
Tw 2 days	6.1%	0.1%	0.02	6.3%	0.0%	0.00
Tw 3 days	9.0%	2.9%	0.32	9.3%	2.9%	0.31
Tw 4 days	11.4%	5.1%	0.45	11.7%	5.2%	0.44
	Travel time increases by 100%					
Car	-7.0%	-42.6%	6.04	-6.3%	-39.8%	6.32
Time change	138.1%	47.1%	0.34	122.3%	42.9%	0.35
Mode change	138.1%	47.1%	0.34	122.3%	42.9%	0.35
Tw 1 day	9.2%	-32.5%	-3.55	8.6%	-30.2%	-3.51
Tw 2 days	32.7%	-18.0%	-0.55	29.9%	-16.5%	-0.55
Tw 3 days	61.2%	-0.4%	-0.01	55.4%	-0.1%	0.00
Tw 4 days	95.9%	21.1%	0.22	85.9%	19.5%	0.23
	Effects of Teleworking policy 2					
Car	-24.6%	-24.6%	1.00	-24.7%	-24.5%	0.99
Time change	-24.6%	-24.6%	1.00	-24.7%	-24.5%	0.99
Mode change	-24.6%	-24.6%	1.00	-24.7%	-24.5%	0.99
Tw 1 day	161.3%	161.3%	1.00	162.4%	163.3%	1.01
Tw 2 days	161.3%	161.3%	1.00	162.4%	163.3%	1.01
Tw 3 days	161.3%	161.3%	1.00	162.4%	163.3%	1.01
Tw 4 days	161.3%	161.3%	1.00	162.4%	163.3%	1.01

Table 9-10: A comparison of the performances of M9 and M10 under both scenarios using a common set of tests

The results for M9 and M10 are given in Table 9-10 while those for M14 and M15 are in Table 9-11. Both tables also repeat the results from scenario one (Table 9-3) for these models and the figures in the table cells once again are percent changes relative to the respective base percent shares under each scenario. Scenario one, two and the ratio of their effects appear as S1, S2 and S2/S1 respectively in these tables. The analysis has three parts. The first part tries to understand whether the models' results are plausible under scenario 2 also. After that each model's robustness is evaluated. The final part investigates whether it is possible to identify the precise nature of the effects of the model estimation issues as discussed in 9.2.3.1.

9.4.2.1 Whether the Results are Plausible?

Overall, the combined effect of time sensitivity of these models and changes in base shares for full travel choices under scenario two explains the much larger decrease in the share for car (commute full workweek), when travel time is doubled, from -7.0%, -6.3%, -6.1% and -9% under scenario one to -42.6%, -39.8%, -38.3% and -50% under scenario two respectively for M9, M10, M14 and M15. The telework choices which have associated car trips to a greater degree exhibit the same pattern. When time or cost is increased, these associated trips incur a proportionate decrease in utility. As already noted in 9.2.3, the increases for teleworking choices are larger the more days of teleworking. In scenario 2 choice of TW1 and in some cases TW2 and TW3 actually falls. The reductions for some teleworking choices are probably due to the transferability problem as noted earlier since teleworking involving substantial cas use becomes less attractive. It did not happen under scenario 1 because the car choice monopolised the travel conditions in the base under that scenario and all models were applied to the population on which they were estimated.

The presentation of these results as relative percent changes also sometimes creates difficulties in interpretation because the absolute magnitude of an effect remains hidden. However, this way of presentation was preferred because some choices have very small base shares under both scenarios and an absolute or net change in the share of such a choice resulting from the effecs of a particular policy test was also very small, e.g. in M9 the PT share as a result of a 100% increase in cost of travel by car during peak changed from 0.43% to 0.49% in absolute terms while in relative terms this was a 13% change.

The test of policy 2 affects only teleworking choices. The specified base shares for these choices also remain the same under both scenarios. Therefore, the magnitude of the test effects also remains almost same under both scenarios with only negligible adjustments in the shares of all the activity choices which is the working of relative estimation of probabilities by the logit function. Thus, the results of policy 2 test are also plausible.

	M14			M15		
	S1	S2	S2/S1	S1	S2	S2/S1
	Travel cost increases by 100%					
Car	-2.6%	-16.6%	6.31	-1.8%	-11.7%	6.52
Time change	36.8%	17.2%	0.47	24.6%	12.0%	0.49
Mode change	36.8%	17.2%	0.47	24.6%	12.0%	0.49
Tw 1 day	6.5%	-8.7%	-1.34	4.6%	-6.0%	-1.30
Tw 2 days	16.2%	-0.4%	-0.03	11.2%	-0.1%	-0.01
Tw 3 days	24.7%	6.8%	0.28	16.8%	5.0%	0.30
Tw 4 days	31.7%	12.8%	0.40	21.3%	9.1%	0.43
	Travel time increases by 100%					
Car	-6.1%	-38.3%	6.32	-9.0%	-50.0%	5.55
Time change	116.9%	42.5%	0.36	184.1%	56.0%	0.30
Mode change	116.9%	42.5%	0.36	184.1%	56.0%	0.30
Tw 1 day	8.4%	-28.8%	-3.43	10.5%	-39.3%	-3.73
Tw 2 days	28.9%	-15.3%	-0.53	40.0%	-23.2%	-0.58
Tw 3 days	53.3%	0.7%	0.01	77.2%	-2.7%	-0.03
Tw 4 days	82.4%	19.8%	0.24	124.4%	23.2%	0.19
	Effects of Teleworking policy 2					
Car	-26.2%	-26.3%	1.01	-26.3%	-26.4%	1.00
Time change	-26.2%	-26.3%	1.01	-26.3%	-26.4%	1.00
Mode change	-26.2%	-26.3%	1.01	-26.3%	-26.4%	1.00
Tw 1 day	171.9%	171.4%	1.00	173.0%	172.8%	1.00
Tw 2 days	171.9%	171.4%	1.00	173.0%	172.8%	1.00
Tw 3 days	171.9%	171.4%	1.00	173.0%	172.8%	1.00
Tw 4 days	171.9%	171.4%	1.00	173.0%	172.8%	1.00

Table 9-11: A comparison of the performances of M14 and M15 under both scenarios using a common set of tests

The results from all the models under this scenario show that the relative impacts of increase in travel cost and time, and policy 2 are similar to those under scenario 1. They are most sensitive to time change, moderately sensitive to policy 2 and least sensitive to cost change. These effects, as explained earlier for scenario 1, are plausible.

9.4.2.2 Whether the Models are Robust?

The above analysis shows that the models are predicting in the expected direction and their results are plausible under different travel conditions. However, it did not establish whether the models' performances are robust also. This can be established through a combined inter-scenario and inter-model comparison. Before that it is useful to note that: all models were calibrated to the same sets of base shares under each scenario; the calibration technique used was the same; and the share distribution for teleworking choices remained unchanged under both scenarios. These three conditions can help define two criteria for testing model robustness: 1) that the ratios of change in effects (S2/S1) when changes in travel cost and time are tested should be the same or similar without any significant variations in inter-model comparison; and 2) that the ratio of effects for the policy 2 test between the two scenarios should always be one.

On the defined criteria, all the models appear to be robust as their ratio values, relative to each other, vary within small ranges for each choice for cost and time change tests. For example, the ratios for full car commuting choice in response to change in travel cost range from 6.31 to 6.80 and to travel time change from 5.55 to 6.32. This also shows that collectively the models have retained their characteristic sensitivities between the scenarios. There is a smaller changes in travel cost and a broader range for changes in travel time. For the relative stable policy 2 test (stable because it is a categorical variable and the distribution of share for teleworking activity choices remains the same under both scenarios) the ratio values for M10 and M14 are almost one while M9 and M15 have perfect unit ratios for all the choices. These ratio values incidentally also vouch for the veracity of the calibration process.

Finally, it has to be recognised that the assessment of a model's robustness in this section is relative. There is no independent or absolute way to do this in the available conditions and this caveat should qualify the above opinion about the models' robustness.

9.4.2.3 Whether Estimation Issues Affect Models' Predictions?

After the sensitivity analysis some observations were made regarding the influence of estimations issues on the models' performances in 9.2.3.1. The inter-scenario comparison of the models' performances in the previous two subsections has confirmed that no model has changed its scenario 1 character under scenario 2. By implication this also confirms the veracity of the observations made regarding the influence of the estimation issues in 9.2.3.1. Overall, M9 and M10 are more similar in their results than any other pair of models. This confirms the conclusion that inclusion of those teleworking < ½ day a week does not affect the models' performance significantly. Hence, either of the models can be used for policy analysis as their simultaneous use would add little value to the forecasts. Thus, M9 was dropped at this stage due to having a relatively lower rho squared value.

On the second issue it was observed under both scenarios that: allowing everyone in the sample to travel by alternative mode regardless of whether that choice is available to them or not, which is the only difference between M14 and M15, makes the model much more sensitive to travel cost in M14; and when mode availability is also controlled as in M15, this offsets some of the model sensitivity toward cost changes with a little more sensitivity towards time changes. On the basis of these observations, it was not possible to choose between M14 and M15 and both were retained for policy testing to give a range of forecasts, especially to evaluate the effects of inadvertent error in the wording of Q10 of the employees' survey on the forecasts.

However, logically a complete control over choice availability in the estimation process is desirable because it not only allows a particular choice only to those whom it is actually available but also gives a better model as indicated by a higher rho squared value. Along with the two estimation issues was a third consideration of whether to transfer the models to the full population in developing the forecasts of teleworking uptake. The argument developed in the previous section and the results of the analyses in this section have demonstrated that the models can, with caution, be transferred to the full population. This would increase the generalisibility of the forecasts.

The forecasts from the finally selected variants relative to each attribute can represent a range. Within that range, their sensitivity rankings are as follows. For cost change, M14 and M10 are most and least sensitive respectively. For time change, M15 and M14 are most and least sensitive with no significant difference between M14 and M10 here. Inclusion of M9 would not have affected these rankings on these two attributes. Towards policy 2, M15 and M10 are respectively most and least sensitive with very minute difference between M15 and M14. Inclusion of M9 would have ranked it as the least sensitive in place of M10, however, the difference of magnitude between the effects from the two models is very small.

9.5 Impact of Teleworking Policies on Travel Demand

Within the context set in section 9.3 and using the framework developed in 4.3, this section analyses the effects of teleworking policies on the entire commuting population in Leeds city centre area subject to the assumptions formulated in previous sections. For this purpose, the three model variants M10, M14 and M15 which proved robust during analyses in the previous section are used. To avoid unnecessary complications early on, the model evaluation analyses in 9.2.3 have so far focused only on the activity dimension of the choices. The purpose of analysis in this section is to forecast impacts of teleworking on travel demand under different policies. This requires policy performance evaluation on the *trip* dimension, defining policy tests and indicator(s) of teleworking impacts.

Policy tests were categorised into two categories: individual policies and combined policies. For individual policies following tests were defined:

- Travel cost by car during peak increases by 25% (denoted as Cc25)
- Travel time by car during peak increases by 25% (denoted as Ct25)
- Travel time by PT during peak decreases by 25% (denoted as PTt-25)
- Introducing the effects of teleworking policy 1 (denoted as P1)
- Introducing the effects of teleworking policy 2 (denoted as P2)
- Introducing the effects of teleworking policy 3 (denoted as P3)

Tests of combined policies included the followings:

- Telework policy 2 + 25% increase in car cost during peak (P2+Cc25)
- Telework policy 2 + 25% increase in car time during peak (P2+Ct25)
- Telework policy 2 + 25% decrease in PT time during peak (P2+PTt-25)
- Telework policy 2 + 25% increase in car time during peak + 25% decrease in PT time during peak (P2+Ct25+PTt-25)

To measure the performance of these policies, three performance indicators were selected. One of these indicators entered as the 'Not travelling' in the discussions and analysis in the previous section (Table 9-8). It is the overall difference between the activity and trip dimensions and, by implication, the impact on total daily demand for work based travel. The other two indicators are changes in overall levels of car commuting and car commuting during the peak as a result of teleworking. Specifically, they have been defined as

the percent of all person-working days for which a journey is not made. This is the teleworking impact on total demand for work based travel denoted as Not Travelling;

the percent of all person-working days for which a journey is made by car regardless of the time of day. This also reflects teleworking impacts on car commuting and is denoted as Level of Car Use; and

the percent of all person-working days for which a journey is made by car during the peak. This also reflects teleworking impact on car commuting during peak and is denoted as Level of Peak Car Use.

These indicators when compared with the base figures for them show the decrease (or increase) resulting from a policy test and, by implication, show the performance of the particular policies. All the indicators can also be calculated as percent change or net decrease (or increase) relative to the base. However, a simple decrease or increase in the relevant indicator appears more meaningful. The figures in the other tables appearing in this section are percent changes relative to the base *trips* for a particular activity as presented previously in 9.2.3.

9.5.1 Individual Measures: Analysis and Estimates

In the first step individual measures were tested. The models were calibrated with the *activity* shares for all the choices given in Table 9-9. As the calibration was 'around' these shares and imperfect (as explained at the end of section 9.2.2), this resulted in a small positive bias for all the models over the base figure of 3.5% for persons 'Not Travelling' as determined in Table 9-9. As argued earlier, due to the relative estimation of shares by the logit model, this bias is unlikely to affect the overall veracity of the effects of the policy tests significantly. Table 9-12 and Table 9-13 present the results of the performance of the tests defined above on the selected indicators.

Models	Indicator	Base	Cc25	Ct25	PTt-25
M10	Not Travelling	3.53%	3.52%	3.39%	3.17%
	Level of Car Use	64.3%	63.8%	61.2%	57.2%
	Level of Peak Car Use	45.7%	44.9%	40.6%	40.7%
M14	Not Travelling	3.58%	3.56%	3.45%	3.24%
	Level of Car Use	64.7%	63.4%	61.6%	57.8%
	Level of Peak Car Use	46.4%	44.3%	41.4%	41.5%
M15	Not Travelling	3.56%	3.55%	3.38%	3.09%
	Level of Car Use	64.7%	63.8%	60.5%	55.3%
	Level of Peak Car Use	46.3%	44.9%	39.6%	39.6%

Table 9-12: Performance of individual cost and time measures on the defined indicators

The results in Table 9-12 show that individual travel cost and time measures do not have much influence on overall travel demand and the percent of people not travelling actually falls. However, this decrease in "not travelling" (due to a reduction in teleworking) as revealed for the car cost tests in this and all the relevant subsequent tables may be artificial reflecting the problem with the model transfer noted above.

Models	Indicator	Base	P1	P2	P3
M10	Not Travelling	3.53%	5.81%	9.28%	2.53%
	Level of Car Use	64.3%	62.8%	60.5%	65.0%
	Level of Peak Car Use	45.7%	44.7%	43.0%	46.2%
M14	Not Travelling	3.58%	5.45%	9.71%	2.58%
	Level of Car Use	64.7%	63.4%	60.6%	65.4%
	Level of Peak Car Use	46.4%	45.5%	43.4%	46.9%
M15	Not Travelling	3.56%	5.88%	9.73%	2.74%
	Level of Car Use	64.7%	63.2%	60.6%	65.3%
	Level of Peak Car Use	46.3%	45.2%	43.4%	46.7%

Table 9-13: Performance of teleworking policy on the defined indicators

Both time measures are comparatively more effective in this regard. Among the three models M15's forecasts are most sensitive to travel time changes. Here it also needs to be pointed out that the different results for the base achieved in M10, M14 and M15 show that the models are not equally well adjusted. Expressed as % changes from the respective bases, the predictions by M10 and M15 of the extent of "not travelling" for Cc25 (and for Ct25) are also very different. On the other hand, teleworking policies are more effective in reducing the overall demand for travel as Table 9-13 shows though policy 3 in line with its character has a negative impact in this regard. Inter-model comparison of forecasts reveals that there is not much difference in the models' performances and the effects of the best performing policy (telework policy 2) range from 9.28% (M10) to 9.73% (M15) for all the models, as compared with a base share of 3.5% for people not travelling on any given day. The negative effects of policy 3 range from 2.74% for M15 to 2.53% for M10 on the same base for the same indicator. These small variations within the forecasts ranges produced by all the model variants confirm that the results from teleworking policy tests are very robust in arresting overall demand for travel. For the indicators of reduction in car use, all models give identical performance for teleworking policy tests which are less effective than the policies of travel time change.

In the above analysis, the model comparison was based on performance indicators which showed that the differences between the models were not great. Therefore, the actual *trip shares* for the choices are shown only for M15 (which incidentally is the best model on rho squared value criterion) in Table 9-14.

		% Change in base level					
Choices	Base	Cc25	Ct25	PTt-25	P1	P2	P3
Car	41.68%	-2.9%	-13.6%	-13.3%	-9.9%	-26.4%	3.5%
Off peak	16.54%	3.0%	14.8%	-13.3%	-9.9%	-26.4%	3.5%
PT	28.53%	3.0%	14.8%	33.3%	-9.9%	-26.4%	3.5%
TW 1	8.17%	-1.4%	-9.3%	-13.3%	65.0%	172.8%	-23.0%
TW 2	1.21%	0.1%	-3.8%	-13.3%	65.0%	172.8%	-23.0%
TW 3	0.20%	1.4%	2.0%	-13.3%	65.0%	172.8%	-23.0%
TW 4	0.11%	2.3%	8.2%	-13.3%	65.0%	172.8%	-23.0%
No Travel	3.56%	-0.4%	-5.1%	-13.3%	65.0%	172.8%	-23.0%

Table 9-14: Results from M15: effects of individual policy measures on the trip shares

Overall, the tested travel time changes are most effective at reducing car commuting during the peak. Teleworking policy 2 is the next most effective for impact on the peak. Compared to policy 2, policy 1 has lower impact because it is less attractive and policy 3 has a negative impact as it has been perceived as detrimental to telework. The results clearly indicate that overall the teleworking policy 2 is the most effective among the three teleworking policies in increasing teleworking adoption.

These conclusions have policy implications. For example, the results suggest that making teleworking widely available might be a more effective means of reducing peak period car use than increasing peak period car costs by 25% (as might be achieved by introducing a road charge of around £1.50 per day). Further the capacity freed from reduced travel as a result of teleworking can be reallocated in line with the priorities of an urban sustainability objective. For example, travel by PT can become faster.

9.5.2 Effects of the Combined Policies

In the next step travel cost and time measures were combined with the most effective telework policy and the policies' performances on the defined indicators for all three models are shown in Table 9-15 while Table 9-16 presents the *trip shares* attributable to each activity choices when the combined policies were tested in M15.

Models	**Indicators**	**Base**	P2+Cc25	P2+Ct 25	P2+PTt-25	**P2+Ct25 +PTt-25**
M10	Not Travelling	3.53%	9.27%	9.05%	8.56%	8.27%
	Level of Car Use	64.3%	60.0%	57.6%	54.0%	50.9%
	Level of Peak Car Use	45.7%	42.2%	38.3%	38.4%	33.8%
M14	Not Travelling	3.58%	9.69%	9.49%	9.01%	8.72%
	Level of Car Use	64.7%	59.4%	57.7%	54.4%	51.3%
	Level of Peak Car Use	46.4%	41.5%	38.8%	39.0%	34.5%
M15	Not Travelling	3.56%	9.71%	9.41%	8.74%	8.31%
	Level of Car Use	64.7%	59.7%	56.8%	52.0%	47.8%
	Level of Peak Car Use	46.3%	42.0%	37.2%	37.3%	31.3%

Table 9-15: Performance of 2-way and 3-way measures on the defined indictors

Table 9-15 shows that among all the combined measures, the combined policy measure of P2+Cc25 (telework policy 2 when combined with a car cost increase of 25%) is the most effective combination for an increase in persons Not Travelling. For overall level of car use and car use level during peak, the most effective policy is a three way combination of P2+Ct25-PTt25 (policy 2 combined with car travel time increase of 25% and PT travel time decrease of 25%). These results are true for all three models. The least effective combined measure for not travelling is the three way test of P2+Ct25-PTt25, while the least effective for overall car use level and car use during peak is a two way measure of P2+Cc25.

As regards the model performance, M15 produces the largest impact with regard to policy effectiveness on the three indicators. Its best result for not travelling is at 9.71%, for level of car use is at 47.8% and for level of car use during peak is at 31.3%. At the lowest end of the range with regard to policy effectiveness for these indicators are models M10 (at 9.27%), M14 (at 51.3%) and again M14 (at 34.5%) respectively. These observations again confirm that the models' forecasts regarding teleworking are very robust.

Overall, all the combined measures are slightly less effective than telework policy 2 alone on the 'Not Travelling' indicator. However, if the objective is to reduce the Level of Car Use then the effect of all combined measures is greater than the single measure of policy 2 and the most effective policy on this indicator and for Levels of Peak Car Use is the three-way policy.

		% Change in base level			
	Base	P2+Cc25	P2+Ct25	P2+PTt-25	P2+Ct25+PTt-25
Car	41.68%	-28.4%	-35.2%	-33.9%	-42.7%
Off peak	16.54%	-24.0%	-13.8%	-33.9%	-23.9%
PT	28.53%	-24.0%	-13.8%	1.7%	17.1%
TW 1	8.17%	169.6%	152.3%	145.1%	122.8%
TW 2	1.21%	173.8%	167.6%	145.1%	136.3%
TW 3	0.20%	177.2%	183.8%	145.1%	150.7%
TW 4	0.11%	179.8%	201.1%	145.1%	165.9%
No travel	3.56%	172.4%	164.1%	145.1%	133.3%

Table 9-16: Results from M15: effects of combined policy measures on the trip shares

The most interesting result on shares distribution for individual choices (Table 9-16) is a two way policy of P2-PTt25. The shares for PT and teleworking choices still increase and, by implication, teleworking policy 2 has no effect on PT users if PT times are reduced simultaneously which is plausible. Overall, this also means that reduction in PT times and teleworking policy pull in opposite directions between themselves but both gain at the expense of car travel. This has welcome implications for policy formulation towards greater encouragement of teleworking as the competing choices in this case clearly are travel by PT and telework and the question arises whether to travel at all. Travel by PT is clearly preferable than car travel in light of the overall objective and its policy implications pointed to at the end of section 9.5.1 because PT use is also associated with lower energy use, congestion, related externalities and other social costs. By the same token, assuming that teleworkers consume less extra energy at home than they would if they travelled to work by public transport, teleworking is preferable over commuting by PT.

9.6 Systems Impact of Teleworking Policies

The demand forecasting in the previous section has explored the first order or direct effects of teleworking. The purpose of impact forecasting is to represent the second order or final impacts of congestion on mode choice, particularly on car commuting during the peak. The framework used for forecasting the impacts remains the same as in the previous section (depicted in 4.3.3). This section only extends the demand forecasting analysis to system wide impact analysis. The aim of this analysis is to observe the system wide effects of the selected policies, particularly telework policy 2 which is aimed at greater encouragement of teleworking. This takes the form of observing the changes in the network conditions and a single link model (SLM) described in 4.3.2 for this purpose. For this analysis only one model has been used. M15 was the preferred model because of its high rho square value and credible coefficients (although it is recognised that M10, because it is applicable to a population whose choice sets are unconstrained, would, theoretically, have been a more defendable choice).

Here it also needs to be acknowledged that models M10 and M15 were calibrated on different choice sets, unconstrained in the case of M10 but constrained in the case of M15. Thus, after transfer, M15's results are bound to show an inflated degree of response, especially for travel cost and time changes. The magnitude of this inflation can be assessed from the fact that the base figure for 'Level of peak car use' indicator for M15 is 46.3% compared to 45.7% for M10. This caveat applies to all the analyses in the previous section and the rest of this chapter.

9.6.1 Assumptions for the Analysis

The framework designed in 4.3.3 depicted the network in sufficient details. It is capable of analysing car and PT modes, and demand by time of day and of incorporating the (non work) travel generation impact of teleworking (section 8.4.2). It has a provision for three SLMs: two peak SLMs for two main modes and one SLM for combined off peak demand. A fuller version of this study was supposed to use all the three SLMs for forecasting the travel impacts of teleworking. Such a study required detailed depiction of the framework through software development and corresponding data. However, the limitations of time resource forced some more simplifications to that depiction. In the end, only the SLM for car commuting during the peak was modelled. This simplification needed adaptation of the BPR function given in equation (4.6) and finally the function used for car peak SLM was formulated as:

$$t = t_0 + \{\alpha \times (P_{car} \times V_{total})\} \qquad (9.2)$$

Where t is peak travel time, t_0 is free flow travel time, α represents the slope of the time-flow curve on the link which has been assumed as constant and linear, P_{car} is the mode share or the probability of car commuting during the peak and V_{total} is the total demand for work related travel along the activity dimension. It is useful to note here that this SLM function has been constructed as a change in capacity which affects the slope of the SLM. This in turn would dampen the effect of those policy measures which test system response to travel time changes.

A further set of simplifying assumptions has been formulated for forecasting system impacts through this simplified depiction. The entire road network of the study area was imagined as a typical single link with an aggregate travel demand between a pair of origin-destination (OD) zones to represent the commuting journey to Leeds City Centre. Thus, it does not represent any one physical link in the system. Further, the travel-time/flow relationship on this link has been assumed to be linear which means when flow on the link increases the link travel time increases in direct proportion.

Particular inputs required for the function in (9.2) include free flow time on the depicted link, peak link flow and peak travel time on the link. For these inputs, the relevant data was transferred from the MARS model of Leeds (Shepherd et al, 2007). This model runs on average data for times, flows and speeds for typical OD pairs which have been assumed to be applicable to the single link that is being modelled.

The average travel distance on the link was taken as 8 km. Free flow speed was set at 35 km/hour which gave the free flow time for a journey on the link equal to 13.71 minutes while the peak time of 38.09 minutes per single journey was used from the survey data (sample average for respondents' travel time by car during the morning peak) which incidentally was very close to the comparable average time of 34 minutes in the MARS model. The number of cars on the link for a 15 minute interval during morning peak was deduced from the dataset obtained from Leeds City Council as described in section 9.3.4 (and shown in Table 9-5) and was set at 9500 people by car per 15 minute on the implicit assumption that there is only one person per car.

9.6.2 Operating the Model

A spreadsheet in MS Excel was developed as software to specify the relationships for the SLM depicted in the flow diagram for the framework (Figure 4.1). The system was calibrated for the base conditions. Whenever a policy effect is introduced in the system it affects the utilities of the relevant choices which, when fed into the MNL function, in turn determine the relative probabilities for all the choices. For the first iteration the function which determines the flow on the link takes demand from the base condition and multiplies it with the sum of the probabilities of the activity choices that affect the demand for commuting by car. This means feeding the proportionate fraction of car trips made by teleworkers with different frequencies back into the link flow function. In this case the term P_{car} in Equation (9.2) would consist of

$$P_{car} = p_{car5} + \{(p_{TW1} \times 0.8) + (p_{TW2} \times 0.6) + (p_{TW3} \times 0.4) + (p_{TW4} \times 0.2)\} \times f \quad (9.3)$$

Where p_{car5}, p_{TW1}, p_{TW2}, p_{TW3} and p_{TW4} are probabilities of activity choices car commuting five days, telework one, two, three and four days respectively and f is the factor which under the assumption of all the travelling choices having proportionate shares of teleworkers adjusts the car trips by teleworkers during the peak and proportionately reduces them with the trips made during off peak and/or using PT. However, it needs to be clarified that V_{total} do not represents only cars (which in this case are 9500) but also encompasses all work-related travel on the network on other links for off-peak and PT as shown in Figure 4.1. The new flow is fed into the SLM function which then calculates the link time for the next iteration and feeds it into the utility functions of all the choices. The system continues to iterate until it converges to an equilibrium flow on the link (see Figure 4.1).

9.6.3 Tests and Results

This subsection presents the results from the application of the SLM function, illustrated in the previous subsections, to car commuting during the peak. For this analysis three single and one combined tests were selected for the study of their impact on the system performance. The tests are:

- Travel cost by car during peak increases by 25% (denoted as Cc25)
- Travel time by car during peak increases by 25% (denoted as Ct25)
- Introducing the effects of teleworking policy 2 (denoted as P2)
- Telework policy 2 + 25% increase in car cost during peak (P2+Cc25)

The measures of system performance (indicators) are link flow (in number of cars as well as percent share of the total work-related travel), link speed (Km/h) and link travel time (minutes). Table 9-17 shows the results for the first indicator. The results for the other two indicators are presented in Table 9-18.

Policy tests	Cc25	Ct25	P2	P2+Cc25
	As % of all work-related travel into Leeds			
Base	46.34%	46.34%	46.34%	46.34%
Direct effect	44.91%	39.64%	43.38%	42.04%
Final effect	45.31%	41.96%	44.19%	43.22%
	Link Flow (No. of Cars)			
Base	9500	9500	9500	9500
Direct effect	9208	8127	8893	8620
Final effect	9290	8600	9060	8860
Direct (relative change)	-3.07%	-14.45%	-6.39%	-9.26%
Final (relative change)	-2.21%	-9.47%	-4.63%	-6.74%

Table 9-17: Results of the impact of different policies including teleworking on the system performance – Link Flow

The MNL model provides the output on direct effects which when fed into the SLM results in the final effect. The SLM represents the congestion response. In the upper half of Table 9-17, the results of policy effects have been presented as the share of cars as percent of total flow. This is to facilitate the comparison with the corresponding tests in the previous section. By definition, the figures in 'Direct effect' row are identical to the figures obtained for these tests in Table 9-12, Table 9-13 and Table 9-15 for the Level of Peak Car Use indicator.

In the lower half of Table 9-17, both effects are shown as absolute figures as well as relative percentage changes. It is clear from these results that an increase in travel time is the most effective in reducing the flow on the link. The least effective policy is the increase in travel cost. The combined measure of cost increase and telework policy 2 has the second best impact on system performance.

Policy test	**Cc25**	Ct25	P2	P2+Cc25
	Link Speed (Km/h)			
Base	12.6	12.6	12.6	12.6
Direct effect	12.9	10.1	13.2	13.5
Final effect	12.9	10.8	13.1	13.2
Direct (relative change)	2.38%	-19.46%	4.92%	7.43%
Final (relative change)	2.08%	-13.89%	4.14%	5.00%
	Link Time (minutes)			
Base values	38.1	38.1	38.1	38.1
Direct effect	37.21	47.3	36.31	35.46
Final effect	37.32	44.24	36.58	36.28
Direct (relative change)	-2.32%	24.16%	-4.69%	-6.92%
Final (relative change)	-2.03%	16.13%	-3.98%	-4.76%

Table 9-18: Results of the impact of different policies including teleworking on the system performance – Link speed and travel times

The results in Table 9-18 show that the combined measure of telework policy 2 and a 25% increase in cost (P2+Cc25) is the best policy when judged on the indicators of link speed and travel time. However, it is only slightly better than telework policy 2 (P2) alone. A 25% increase in time is the least effective in improving the link speed.

9.6.4 Analysis and Discussion

Here it is useful to note that introduction of congestion response through the SLM has dampened the effect of all the policies tested. However the SLM response for the increase in time is greater than for other policies. As mentioned earlier, this is due to the fact that the Time policy was implemented as a change in capacity which affects the slope of the SLM and hence the second oreder response.

From the perspective of system performance, no policy test can be singled out as the best on all the indicators as they measure different things. Further, the character of the policy measures tested is also different relative to the SLM function. Therefore, any judgement about the effectiveness or desirability of a particular policy cannot be based solely on its performance relative to congestion response represented by the SLM. The congestion response of a policy is just one of the criteria that have been used to evaluate the effectiveness of teleworking policies in comparison to the other measures.

The results for link flow indicators clearly show that Ct25, i.e. increase in time for car travel reduces the absolute number of cars on the link most. However, as noted above this policy also increases the travel time the most.

The results in both tables above also indicate that the final effects of telework policy 2 on link flow and speed are more than double the effects of the cost increase. This conclusion once again supports the view presented in the previous section that a telework policy can be a potentially better alternative to road pricing.

On the link speed indicator, P2+Cc25 (i.e. telework policy 2 and increase in travel cost) gives the best performance but only slightly better than P2 (i.e. telework policy 2 alone). However, being a single measure, telework policy 2 (P2) may be preferable as cost increases may not be acceptable to the car users.

The analysis in this section has evaluated the policies relative to travel during the peak and the results even after the congestion response is taken into account of all the policies tested are consistent with their respective performance on the Level of Peak Car Use indicator. Thus, the results and the analysis reinforce the conclusions drawn in the previous section. Finally, it is a matter for the decision-maker's perspective and policy objective to decide on the appropriate performance indicator(s) out of the three indicators used for the evaluation of (telework) policies.

9.7 Summary and Conclusions

Employing the modelling framework developed in the early stages of this study and using the predictive models estimated from SP data, this chapter has produced estimates of the impacts of teleworking through demand forecasting and system forecasting approaches.

Before the forecasting exercise the shortlisted demand models were put through diagnostic and sensitivity analyses. During the sensitivity testing, called scenario 1, the results from all model variants were plausible. It was found that between M9 and M10, the former was relatively more sensitive to time change and very slightly less sensitive to cost change and to the effects of teleworking policy 2. However, the differences were sufficiently small to suggest that the two models are not significantly different from each other. Similarly, comparisons among M10, M14 and M15 revealed that M14 which constrains choice availability except for mode change is much more sensitive to cost change, slightly less sensitive to time change and more sensitive to policy 2 than M10. M15 which constrains choice availability for mode change also, is more sensitive to cost change, more sensitive to time change and much more sensitive to policy 2 than M10.

After the sensitivity analysis, the models were transferred to the full population to judge their robustness under different travel conditions. Different aspects of model transfer including the characteristics of the dataset used and the study area were then explored: to set the context for model transfer to full population and impact forecasting; to formulate the required assumptions; and develop the estimates of the new base shares (called scenario 2).

Under scenario 2, the four models again produced plausible results. In inter-scenario comparison of the models' performances it was confirmed that no model changed its scenario 1 character under scenario 2. Overall, M9 and M10 were more similar in their results than any other pair of models. This confirmed that inclusion of those teleworking < ½ day a week does not affect the models' performance significantly and M10 having a slightly higher rho squared value was retained for policy analysis from this comparison.

It was observed under both scenarios that: allowing everyone in the sample to travel by alternative mode regardless of whether that choice is available to them or not, which is the only difference between M14 and M15, makes the model much more sensitive to travel cost measure as does M14; and when mode availability is also controlled as in M15, this offsets some of the model sensitivity toward cost changes with a little more sensitivity towards time changes. Hence, it was not possible to choose among M10, M14 and M15 and all three were retained for policy testing to give a range of forecasts.

The argument developed in 9.3 and the results of the analyses in 9.4 demonstrated that the models can, with caution, be transferred to the full population. This would increase the generalisibility of the forecasts. The sensitivity ranking of the finally selected variants was as follows. For cost change, M14 and M10 are most and least sensitive respectively. For time change, M15 and M14 are most and least sensitive with no significant difference between M14 and M10. Towards policy 2, M15 and M10 are respectively most and least sensitive with very minute difference between M15 and M14.

M15 was the preferred model because of its high rho square value and credible coefficients (although it is recognised that M10, because it is applicable to a population whose choice sets are unconstrained, would, theoretically, have been a more defendable choice and that M15's results were bound to show an inflated degree of response, especially for travel cost and time changes).

For demand forecasting, three performance indicators were defined as Not Travelling, Level of Car Use and Level of Peak Car Use (see 9.5 for definitions). The performance of teleworking policies used as an attribute in the SP experiment along with travel time and cost measures was evaluated against these indicators. In the first round which tested single policy measures, overall the tested travel time changes were found most effective in reducing the car commuting during peak. Teleworking policy 2 was the next most effective for impact on the peak. Compared to policy 2, policy 1 had lower impact because it was less attractive and policy 3 had a negative impact as it was perceived as detrimental to telework. The results clearly indicate that overall the teleworking policy 2 is the most effective among the three teleworking policies in increasing teleworking adoption.

Inter-model comparison of forecasts reveals that there is not much difference in the models' performances and the effects of the best performing policy (telework policy 2) range from 9.28% (M10) to 9.73% (M15) for all the models, as compared with a base share of 3.5% for people not travelling on any given day. The negative effects of policy 3 range from 2.74% for M15 to 2.53% for M10 on the same base for the same indicator. These small variations within the forecasts produced by all the model variants confirm that the results from teleworking policy tests are very robust in arresting overall demand for travel. Among the three models used for the policy analysis, M15 was considered the best because it has the highest rho squared value. Hence the results from only M15 were analysed and presented in details.

Looking at the results produced by M15, a two-way combination of telework policy 2 and an increase in travel cost by car during the peak was slightly less effective than telework policy 2 alone for Not Travelling but more effective in reducing overall level of car use and during the peak. Similarly, a three-way combination of telework policy 2, a 25% increase in travel time for car during the peak and a 25% decrease in travel time by PT was the most effective for both Levels of Car Use and Levels of Peak Car Use, simultaneously reducing both indicators from 64.7% and 46.3% respectively to 47.8% and 31.3% respectively.

The policy analysis by different models proved that no estimation issue had any *significant* effect on coefficient estimates for teleworking policy statements which were the focus of this study. In this regard, all the models showed results of almost the same magnitude with insignificant variations when the impacts of teleworking policy statements on travel were tested. Thus, greater confidence can be placed in the forecasts developed by this study

In the second part of the impact analysis only M15 was used and the analytical framework consisted of an MNL model and an SLM function. Two indicators of system performance (link flow and link speed) were set. A subset of policies was tested for their system wide impacts. The differences between the direct and final effects of all the policies varied across the policies; however, they showed consistent results relative to the appropriate (Level of Peak Car Use) indicator under both forecasting approaches.

The SLM represented the congestion response. When the direct effects of policies were introduced to the SLM, the effects of all policies were dampened. Despite its simplified representation the SLM was able to capture congestion in the system successfully. However, the SLM results cannot be used as the sole criterion to judge the performance of a particular policy. The decision about the appropriate performance indicator(s) for the evaluating the (telework) policies should be base on the planner's perspective and policy objective.

However, when telework policy 2 was introduced into the system for its congestion response, on a base of 9500 cars on the link and a link speed of 12.6 km/h, it reduced the flow by 4.63% while the speed on the link increased by 4.14%.

The conclusions from the analyses in this chapter have clearly made a case for introducing telework policies as TDM measures for a variety of objectives. This has clear implications for the future of transport planning practice, particularly at the local level and in the urban setting. The implications mainly pertain to policy planning, formulation and implementation and have been discussed in the next chapter.

10 Policy Planning Context

10.1 Introduction

The analyses in the previous chapter have established that teleworking policies can be used as an effective means of TDM. The current chapter briefly reviews the present transport planning context and looks into those aspects that may be helpful in guiding the policy formulation on teleworking. Given the paucity of examples in this regard, it draws on examples and evidence taken from cognate fields and looks into powers and methods of persuasion open to government and local authorities which they might use to influence firms' policy on teleworking. Section two outlines the current legislation and guidelines regarding teleworking policy from different sources. Section three looks at the working examples of any such policies and examples from the cognate fields which might be relevant. Section four summarises the results of a brief survey that was conducted among the employers whose employees participated in the survey for the main study. Finally, the chapter ends by assessing the applicability and likely success of the various approaches in the light of evidence and draws some conclusions.

10.2 Current Legislation and Guidelines

The policy debate on telework is maturing, especially in the US where specific legislation exists on the topic. In this regard, the present context has two aspects: direct legislation/guidance on teleworking and employment legislation that indirectly supports teleworking. Both are discussed here.

10.2.1 Direct Methods

As noted in section 2.6.2, the National Telecommuting and Air Quality Act of 1999 in the US is the only example[7] of legislation that directly supports teleworking. It has helped in establishment of The Congestion Mitigation and Air Quality (CMAQ) Improvement Programme which provides a flexible funding source for state and local governments to help meet the requirements of the Clean Air Act (CAA) and its

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[7] *The following weblink lists and updates all the US legislation and current debate on the topic: http://www.ivc.ca/governments/usa/federal/index.htm*

amendments, and to fund eligible transportation projects and programmes. Eligible activities include introducing teleworking options also. The federal share for most CMAQ-eligible projects is 80 percent. Further, this legislation has also helped introduce a market-based incentive programme to encourage teleworking. Its pollution-credit programme allows businesses with teleworkers to gain pollution credits that can be sold to other businesses. The USDOT policy guidelines also recommend making it part of a larger employee trip reduction plan, development of transportation management plans, and plans for establishment of "auto-free zones".

Recognising the growing significance of teleworking, the EU launched its 'Framework Agreement on Telework' in consultation with relevant social partners in July 2002 (EC, 2002). This framework is a non-binding agreement developed at the European level by employer and employee organisations as part of the Social Dialogue process. The nature and scope of this framework is advisory and the purpose is to provide guidance on how the member states can find a way to meet the telework needs of employers and employees. Subsequent work on the implementation of this framework agreement is in progress. This framework has been adopted in the UK and the Department of Trade and Industry has issued "Telework Guidance" (DTI, 2003) agreed by the relevant social partners in the UK which mainly explains the EU framework on the topic in the UK context.

On employment conditions, DTI guidance makes no distinction between teleworkers and comparable workers at the employer's premises. Both benefit from the same rights, guaranteed by applicable legislation and collective agreements. However, in order to take into account the particularities of telework, the guidance suggests consideration of some additional issues when entering into a formal contract on teleworking. Those issues pertain to place of work (e.g. employer ensures that it conforms to health and safety standards), hours of work, extra responsibilities, expenses policies like claiming for teleworking cost, benefits like provision of work equipment and workplace insurance cover.

Before the 2003 UK Budget, employer's contribution towards incidental cost of teleworking paid to a teleworker was considered a benefit and thus liable for tax. After that it was not only converted into an expense but payments up to £2 per week (£104 per year) were also exempted from supporting evidence. Beyond this amount, the exemption will still be available but subject to supporting evidence. These provisions ensure employers meet some or all of the incidental costs incurred by teleworkers without it giving rise to a tax charge.

Potentially three elements of this guidance are significant for their implications for encouragement of teleworking: guaranteed same rights for teleworkers, extra provision for considering telework specific circumstances in employment contract when starting teleworking and taxation benefits regarding incidental costs of teleworking. However, the critical aspect of this guidance is that it is non-binding.

10.2.2 Indirect Methods

The UK has no legislation that specifically governs teleworking practice and teleworker is also not defined in the law. It, however, has some legislation that indirectly supports teleworking. In this regard, Telework Guidance (DTI, 2003) mentions the following:

> *Under UK law, from April 2003, parents with disabled children or children under six have the right to request flexible working, including to telework if they so wish..... Employers will be under a duty to give serious consideration to such requests. However, it should be noted that teleworking cannot be guaranteed under the right. There are a number of business grounds on which an employer may refuse a request.*

workSMART, a web resource run by the TUC - the umbrella organisation for Britain's unions[8], lists the following advice on the topic:

> *Laws governing teleworking are complex and incomplete. In many areas, a teleworker has the same rights, under the same legislation, as an office-based worker. The European voluntary agreement on teleworking is currently not enforceable in law, and has not been implemented in the UK. Instead it currently acts mainly as a good practice guide for employers and employees........From April 2007, employees who care for adults (for e.g. those who are elderly or sick) also have this right.*

10.2.3 Assessment and Implications

It is clear from the above review that there is no law either in the US or the UK that gives an employee the right to be a teleworker. This is perhaps understandable in view of evolving nature of teleworking and a government's sensitivity towards employers' sentiments in this regard. The US legislation which is more direct in nature helps in acceptability and spreading of teleworking with financial support from federal government to state and local authorities. Conversely the relevant UK legislation supports teleworking only indirectly which has implications for greater encouragement of teleworking.

The DTI guidance makes it clear that teleworking cannot be guaranteed and an employer can refuse a request for teleworking for any reason. It is essentially the employer's discretion in this regard that is decisive. The complexity of the laws thought to be governing teleworking referred to above is also a source of hindrance rather than help. Therefore, while the trigger that allows an employee to be a teleworker remains

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[8] *http://www.worksmart.org.uk/rights/viewquestion.php?eny=625 Viewed on 11-4-2007*

weak, the helpful provisions regarding the same employment conditions for teleworkers and tax benefits noted above will be of little practical use.

10.3 A Review of Examples of Existing Methods

This section reviews the performance of the programmes and legislation which offer direct and indirect methods to encourage teleworking.

10.3.1 Teleworking Programmes

The US legislation on teleworking noted above initiated a 5-city pilot programme to encourage teleworking for emissions reduction purposes (USDOT 2007) which was launched in Denver, Washington, DC, Houston, Los Angeles, and Philadelphia. In each city, a local planning organisation took the lead in promoting the programme to businesses that would sign up and then in turn, enrol their employees. The programme commenced in June 2001 and by March 2004, 49 companies with 535 employees had participated (Nelson et al, 2007). The goal of the programme was to evaluate whether it is possible to increase the level of teleworking by linking it to an emissions credit mechanism.

The designs of the individual city programmes are of interest as they explored different dimensions regarding how to encourage teleworking among the employers. For example, in Philadelphia, the local authority explored the potential for tradable credits and other incentives to motivate employers to develop teleworking programmes. It initiated its pilot programme tailored to meet the city's business market and needs. Houston local authority designed a programme to provide incentives for businesses to implement telework programmes. The programme allowed a tax deduction to companies and their employees who reduce VMT through teleworking in exchange for the emission reductions. In another case, Washington Metropolitan Regional Authority provided consulting services to help employers start or expand teleworking programmes in exchange for using the sites as case studies. The selected sites were required to have top-level support, a teleworking team, and a designated coordinator, as well as equipment and communications services.

Nelson et al (2007) consider that such programmes have an obvious advantage compared to explicit financial incentives – tax credits, subsidies, and so forth – because government does not need to allocate funds to reward employers who encourage teleworking. On the other hand, Nelson et al question the environmental integrity of tradeable credits and tax rebates resulting from difficulties in designing sufficiently rigorous quantification protocols to accurately measure the emissions reductions from teleworking. This is not to imply that efforts to encourage teleworking should be abandoned because it is not just about emission reduction. It is also a congestion mitigating measure and the study by Nelson et al (2007) does not say anything about this aspect of teleworking. Overall the establishment of these teleworking programmes suggests that the use of financial support for state and local authorities by the federal government appears to be indirectly effective in encouraging teleworking.

In the UK, no such programmes for businesses with government or local councils' financial involvement exist. Cairns et al (2004) in their study on Smarter Choices list the following instances where local councils were involved with the pilot projects that have either specifically focused on teleworking or considered it. Hertfordshire's Trading Standards department introduced 'flexible working' for 65 plus staff by introducing localised workstations to reduce the number of journeys made to headquarters. It reduced work mileage by 7%. Sefton Metropolitan Borough Council undertook a pilot with 19 employees over a twelve-month period and employees kept travelogues detailing their travel patterns and how they were affected by teleworking. Almost 22,000 km of car travel was saved. Since the successful pilot, the personnel department has appointed a senior manager to continue developing and promoting teleworking as an integral part of the Council's approach to flexible working.

In 1997 Surrey County Council launched a five-year programme aimed at 3500 staff. The key motivation was to save office space. Initiatives include hot desking, teleworking, development of ICT infrastructure and intensive staff training in ICT skills. There is no information available about the effects of the strategy. Wakefield Metropolitan District Council, as part of the EU 'Target' project, began a pilot project in 1999 with 23 volunteers teleworking once a week. There is no information about the effects of the pilot initiative. There were plans to extend the initiative to 9,500 staff within the authority. York City Council also ran a trial of teleworking with its own staff. Nottinghamshire County Council and Buckinghamshire County Council have both developed remote tele-centres both for their own staff, and for use by others in the local areas where the centres are established.

It is useful to note that all these projects were started or in existence before DTI guidance was launched. The projects specifically focusing on telework were typically small scale and all such projects covered only a particular council's own employees. Their transferability to and acceptability by businesses at large have not yet been tested.

10.3.2 Use of Legislation Supporting Telework

A recent DTI policy review (Fitzpatrick and Grainger, 2007) states that the UK legislation is

> *available from 6 April 2003 via regulations under Employment Relations Act 2002 aimed at working parents with young children [and] introduced an employee right to*

request flexible working arrangements, and a duty on employers to consider requests seriously.

This review was done by two politicians involved in policy making and the selection of words reveals a mindset that is over-sensitive to the interests of employers. It is odd to note that an employee needs a law to 'make a request'. The same document lists that the main aims of the policy behind this law is are:

help achieve a cultural shift in attitudes by both employers and employees towards flexible working and work-life balance; encourage employers to make flexible working arrangements more widely available; encourage an increase in the rate of employee requests for flexible working, and reduce the level of unmet employee demand; and ensure employer support by legislating in a light touch and phased way, that does not add unduly to the costs to business.

The authors claim that only 7% of the workforce say no form of flexible working is available while 56% have a flexible working pattern now or in the past year. However, it was not clear on what basis they attributed these figures to 'the right to request' as the methodology and the data source are unmentioned in the document. They conclude that right to request appears to have led to an acceleration in the provision and availability of flexible working arrangements, and flexible working is increasingly likely to be handled informally by employers. On the list of their concerns are: awareness of the detail of the right is quite low, even among those employees who considered it very important to them; men in private sector jobs are much more likely to have their request to work flexibly declined than other employees; and the decline rate for requests has risen since 2005.

Three elements of the above review are significant: sensitivity towards the additional costs to businesses; advocacy of an informal approach; and claims of a cultural shift in British workplaces. The last in the list is perhaps the most significant for its implications, since the authors of the review suggest that, despite a recent rise in the decline rate for requests, flexible working is now the norm rather than the exception.

10.3.3 Evidence from Cognate Fields

The DfT in the UK commissioned a study aimed at exploring the options for sustainable and energy efficient travel behaviour. The study was named 'Smarter Choices: Changing the way we Travel' (Cairns et al, 2004) and drew on options and measures from different areas of activity. These are the measures which local authorities do not usually get involved with. Some of the measures were specifically targeted at businesses, which included encouragement of teleworking. Cairns et al suggest that 'smarter choices' could achieve a reduction in peak period urban traffic of about 21 % and that the measures targeting the journey to work (company travel plans (CTP), car sharing schemes and telework) could deliver about half this potential overall traffic reduction. The intent of this section is to review evidence on establishing CTP and car sharing schems as to whether there are lessons to be learnt when formulating policies on the encouragement of teleworking.

10.3.3.1 Review of Applicability of Company Travel Plans

A CTP sets out steps to encourage staff to travel to work by public transport, on foot, by bike or by car share. Such travel plans could cover a single site or a cluster of businesses. Measures vary depending on the number of employees, but might include: giving all staff public transport information; offering personalised journey plans to staff; interest-free season ticket loans; special deals to reduce the cost of bus and rail travel for employees; secure cycle parking; business cycle mileage allowance; parking 'cash out' (paying employees a small sum on days they do not drive); car parking restricted to essential users; and publicity such as newsletters, prize draws etc, linked to special car-free days. Local authorities can also offer grants to businesses – especially small and medium enterprises – to encourage them to develop a CTP. In Bristol, companies receive grants of up to £5,000 to fund up to 40 to 50 per cent of the cost of their CTP initiatives (DfT, 2005).

Cairns et al (2004) conclude that a typical CTP can reduce car use by between 10 per cent and 25 per cent and taken together, a well-developed programme of CTPs across a large number of employers might be expected to reduce car commuting by an average of about 18 per cent. The impact of a CTP can increase over time, as more measures are put in place. However, it can also go down, e.g. if a key champion leaves a company. So it is important to keep supporting a company once it has got its CTP up and running.

DfT (2005) guidance suggests that local authorities can promote CTPs by: employing a dedicated team of several CTP officers to promote travel planning to businesses; getting the development control section to review all planning applications and require CTPs to be built into all large or strategically significant developments (e.g. any development that will employ more than 50 people might be required to draw up a travel plan in order to get planning permission). Further, such initiatives should concentrate on larger employers and those with congested site access. In this way about 30 per cent of the workforce can be targeted in an urban area. Setting up commuter planner clubs to encourage travel co-ordinators in different companies to share information and work together is another option. Sometimes it is also useful to set up business clusters – e.g. bringing together employers in the same sector (such as educational institutions) or employers based in the same area.

10.3.3.2 Review of Applicability of Car Charing Schemes

There are two types of car sharing schemes (DfT, 2005). Firstly, the schemes operated by some local authorities, businesses and schools to promote car sharing for regular trips to work or school. People who register with the scheme are matched with one or more people who make the same trip. Secondly, there are schemes which help people find someone to share a one-off car journey. It is the first type that is applicable to the present case because they are targeted at the daily commute. Such schemes may operate within a single company or across a number of different employers in the same area. The rest of the material in this subsection is synthesised conclusions from work by Cairns et al (2004). National Travel Survey for 2003 data indicates that 82 cars are used for every 100 people travelling to work by car. Of these 100 people, 69 drive alone, 13 are drivers with at least one passenger, and 18 are passengers. In other words, 31% of those travelling to work by car are sharing a vehicle, and average car occupancy amongst commuters who already car share is 2.4 people per vehicle.

Bonsall (2002, cited in Cairns et al) highlighted that the amount of informal sharing was always likely to be greater than that of organised sharing, and reiterated the concern from the conclusions of his earlier studies on the topic that formal schemes may abstract revenue from conventional public transport. Employer-led car sharing schemes represent only a small subset of car sharing schemes. However, there has been considerable interest and development of such initiatives in the UK, with impressive levels of resulting increases in car sharing being reported. Cairns et al identified factors like priority parking, financial incentives, on-road priority; publicity, a critcial mass, a committed organisation and scheme identity as important for the success of a scheme.

The principal reason for targeting car sharing as a policy measure is that it helps in cutting parking and petrol costs for the individual with attached system benefits. Data about the effectiveness of car share schemes is often relatively limited. Formal car sharing schemes differ substantially in terms of the numbers of members they attract. This is partly because some schemes simply offer a web based matching facility, which does not enable the operator to identify whether matches result or not. Car share schemes are often seen as an explicit part of workplace travel plans, and are starting to become an explicit component of school travel plans also. Sharing seems to be most common for work journeys, although there is also some evidence of its being used for occasional trips or non work travel. Available evidence suggests that overall a 3% reduction in travel can be achieved through car sharing schemes.

10.3.4 Assessment of the Applicability of the Schemes

From an operational perspective, a CTP scheme is likely to be aimed at the entire staff while a similar scheme for encouraging teleworking should target only a subset of staff due to job suitability considerations. Both schemes can operate at organisational and individual levels. Despite the difference in the target groups, all the strategies and tactics for motivation of a CTP scheme at respective levels should be transferable to adoption of teleworking. At the organisational level, measures like control over planning permission, awareness creation compaigns and finding a key champion at a higher level of hierarchy in a company by offering financial support and expert advice can be especially effective. As car commuting teleworkers would be the common target of teleworking and CTP schemes, there is a possibility for integration of measures from both schemes and realising synergies in efforts most obviously by expanding a CTP to include teleworking. Though there is evidence that there is no problem with the acceptability of teleworking at the individual level, eligible but reluctant staff can be targeted by imposing parking restrictions, offering incentive payments and contributions towards the incidental costs of teleworking.

Implementing a car sharing scheme has potentially four dimensions: organisational involvement, operational aspects, interaction among the sharers and individuals' acceptance of the scheme. Only the first and the last of these dimensions are transferable to teleworking encouragement, which reduces the scope for application of the lessons from this measure. The strategies and tactics at both organisational and individual levels are similar to those for a CTP scheme. Cairns et al stressed two key issues that could potentially affect scaling up of car sharing: 'a stronger steer from government that this is an important area of policy interest and a national advertising scheme' which could be equally true for teleworking encouragement.

10.4 Results from the Employers' Survey

The review and discussions in the foregoing sections form an interesting background to analyse and interpret the results from a brief employers' survey. The main objectives of this survey were to add context to the predictions based on the SP questions in 9.5, to inform the policy debate in 10.2 and to strengthen the conclusions and recommendations in chapter 11. The other important aims were to complement some aspects of the results from the employees' survey in chapter 7 and to map the differences in perceptions on teleworking in 7.3.2, especially the future take-up levels.

The survey instrument, whose contents are explained below, went through various rounds of revision regarding the number and wording of the questions. It was pilot tested with the Institute's human resource manager and appropriate adjustments were made. The final version is given in Appendix V at 13.5. It was sent in June 2007 to all nine employers who participated in the main study and same methodology for its administration was followed as described in 6.7.3. The letter accompanying the survey to the head of the organisation from Prof May is given in Appendix III at 13.3. The responses from five employers were received within two weeks. After waiting for another week, the coordinators who helped in the main study from two of the non responding employers were contacted for follow-up. The remaining two employers (Bank of England and St. James Securities) being very small in size (see 6.7.2 for sample description), and thus having little significance for the results, were not followed up. When the two employers still did not respond, they were sent reminders and contacted over phone but without any success. After waiting further for a week it was decided to proceed with the analysis of the existing responses. The employers' profiles are given in 6.7.2 while Table 7-1 presents their response characteristics to the employees' survey.

The survey included 13 questions in total of which six questions at the end were on factual information. Of the remaining questions, given below, Q1 was about an organisation's knowledge of the UK government's teleworking policy, Q2 focused on discovering each firm's policy on teleworking with four possible responses (the same as in Q13 of the employees' survey), Q3 was to bridge the time gap between this and employees' survey, Q4 was to estimate current levels of teleworking, Q5 and Q7 were to investigate perceptions of employees' aspirations and likely uptake of teleworking; and Q6 about circumstances in which each firm would contemplate being more accommodating towards teleworking:

Q1: Do you think the government has a policy on teleworking?

Q2: How would you describe your organisation's policy on teleworking?

Q3: Has there been a change to this policy over the last one year?

Q4: Please provide an approximate figure on the current estimate of the number of your staff (as % of total employment in your organisation in Leeds) who telework at least one full day a fortnight ___%

Q5: Approximately what percentage of your staff would telework at least one full day a fortnight now if everyone who wished to do so was enabled to do so? ___%

Q6: Please consider the statements below and indicate for each how strongly each would influence your organisation's ability to support higher levels of teleworking by assigning a score between 0-5 (where 5 is very strongly; 1 is very little and 0 is no influence at all)

Q7: If the factors which you identify as most supportive in question 6 were introduced/active now, approximately what % of total employment in your organisation in Leeds, do you think, would opt to telework at least one full day a fortnight? ___%

As noted in 7.1.7, the initial efforts to ascertain the indicative response rate by asking questions about the share of car commuters in an organisation's total staff revealed that the employers had poor knowledge of the commute mode choice of their employees. For this reason and to avoid cognitive difficulties in first estimating the share of car commuters in their organisation and then basing on those estimates the estimated share of teleworkers at present, the employers were asked to base their estimates of teleworkers in response to these three questions on the total staff numbers.

Table 10-1 tabulates responses to Q1-Q5, Q7, Q9 and Q11. Overall employers in this sample, which have been named as E1 through E5 for confidentiality reasons, have mixed knowledge of goverment's current policy on teleworking. Excluding the two employers who admitted their ignorance about the policy, the remaining three are divided. One of them believed that there is a policy on teleworking. This clearly indicates ambiguous perceptions of DTI guidance and current legislation noted earlier. Similarly, the employees' perception of teleworking policy as evident from data in table 7-4 is also very different from their employers' (Q2 in Table 10-1). Table 7-4 tabulated data on employees' responses and indicates that some employees from the same set of employers think that teleworking is available to them in a formal way. Tempting though it is to extend such comparisons between Table 10-1 and table 7-4, there are differences between the populations these tables are based on.

Employer	E1	E2	E3	E4	E5
Q1	Don't know	No	Don't know	No	Yes
Q2	Informal	Not permitted	Informal	Informal	Informal
Q3	*	*	*	No	No
Q4	1	**	5	0	1
Q5	1	Don't know	10	10	3
Q7	5	No idea	15	25	3+
Total staff	325	865	7600	100	1100
Who responded	Managing Partner	HR Director	Transport Coordinator	Managing Director	Chief Executive

Table 10-1: Employers' policy knowledge and perception of teleworking take up levels (* indicates missing data, ** indicates question not applicable)

The employees' survey was aimed only at car commuters while the employers' estimates are based on total staff numbers. This difference explains the quite visible differences in perceptions about current (Q4) and projected (Q5) levels of teleworking adoption between the surveys, thus the respective estimates in both tables are actually incomparable. Four employers responded to questions on estimates of future take up levels under both scenarios (Q5 and Q7). The remaining one was contacted over phone to discuss his non response to this and other questions. But he could not add much value to the already provided data. E1 and E4 considered the studied factors (noted in Table 10-2) to have substantial influence under the second scenario.

Overall, the employers' survey has revealed poor estimates of current levels of take up and it does not compare well with employees' estimates or even estimates from national census data. This confirms of a wide gap between the employers' perceptions and the wider reality about teleworking. A possible explanation could be that in the majority of the surveyed organisations, teleworking is allowed on an informal basis which means that formal records are not kept and hence there is little knowledge behind these responses.

Table 10-2 presents mean scores assigned by the employers to ten factor statements in Q6 above. In light of the hypotheses studied in the employees' survey, the issue of job suitability and the review in 10.2 and 10.3, these factors were considered to be potentially instrumental in making a firm more accommodating towards teleworking. These results cannot be taken as representative of employers' perceptions and attitudes towards teleworking due to the sample being very small. However, they do provide some insights on certain factors which might influence teleworking take up in future. Legislation with a mean score of 4.2 understandably has been considered of utmost influence. This again confirms that the current legislation is not being viewed as specific to teleworking as noted in 10.2.2. Perhaps most interesting is the case of the 'industry norm' factor which has been given a score of 3.8. This indicates the influence of business culture and pressure to conform. Data security concerns and job redesign have been found next joint most influential with a mean score of 3.6.

factor	Mean score
If there is legislation requiring the introduction of telework	4.2
If employer relieved of the responsibility for health and safety issues through legislation	2.4
If concerns on data transmission speed and security addressed	3.6
If tax credits/incentives for teleworking programmes	2.8
If government or local council provide support for TW	2.6
If TW becomes industry norm in employer's line of business	3.8
If commute times increase significantly	2.6
If commuting costs increase significantly	2.6
If employers are not required to bear home office expenses	1.8
If there is legislation requiring job redesign for teleworkers wherever possible	3.6

Table 10-2: Employers' perceptions of factors influencing their ability to support telework

Surprisingly, the factors related to council help and offer of incentives from government to define and introduce teleworking programmes did not elicit as much interest among this small sample. This sample of employers also did not consider increases in commute cost and/or time particularly important for teleworking take up. In comparative terms, this speaks volumes of differences between the perceptions of an urban planner and a business manager about teleworking's role. The former would tend to think that costlier and more stressful commute journeys would make people work from home. On the other hand, a business manager is less concerned with commute conditions and would like to evaluate how teleworking fits into overall business strategy.

Employers considered the factors related to health and safety issues, and home office expenses least influential on their ability to make telework available with scores of 2.4 and 1.8 respectively. Note that as per the wording of Q6, all factors with a score of >0 are influential and a factor with a higher score is relatively more influential. For an overall effect of these factors on employers' projections of future levels of teleworking, only a partial assessment can be made because, as noted in the analysis of the data in Table 10-1, one employer could not respond to Q5 and Q7 while another, E5, did not respond clearly. In case of E3, these factors are likely to cause a relative increase of 50%. The remaining two employers considered these factors to have substantial impact on their projections. For E4, these factor would result in a relative increase of 250% in teleworking uptake while for E1 the relative increase would be 400%.

Overall, certain aspects of this survey are not comparable to the results from the employees' survey. However, where the data from two surveys are relatively comparable, the responses show clear gaps between the perceptions of employers and employees, and especially on employers' understanding of the DTI guidance. Thus, there is no surprise that the conclusion from the employees' survey about not having a clear understanding of their employers' policy on teleworking has been confirmed. Generally the studied factors can significantly and positively influence teleworking uptake. For this purpose the results found the factor of specific legislation requiring employers to introduce teleworking as most effective. Creating a culture where teleworking is readily accepted as a work arrangement can be another potentially fruitful strategy to help achieve the objective of higher uptake levels as indicated by the influence of factor of 'industry standard'.

10.5 Assessment and Conclusions

It is clear from the review of the relevant literature that there is no law either in the US or in the UK that gives an employee the right to be a teleworker. The relevant US legislation advocates acceptability and spreading of teleworking with financial support from federal government to state and local authorities. The teleworking programmes established as a result of this legislation were promotional in their nature, aimed primarily at emission reduction and appear to have been indirectly effective in encouraging teleworking. No study was done to measure the extent of their acceptability by the businesses at large. Neither is anything known about the particular features which were considered attractive and motivated the businesses to participate in these programmes. The characteristics of participating businesses are also unknown. Thus, their effectiveness and transferability remain unknown.

In the UK, DTI launched its teleworking guidance in 2003 which has three useful elements for encouragement of teleworking: guaranteed rights for teleworkers, extra provision for considering telework-specific circumstances in employment contracts and taxation benefits regarding the incidental costs of teleworking. However, the critical aspect of this guidance is that it is non-binding. The complexity of the UK laws thought to be governing teleworking is also a source of hindrance rather than help. There is a need to make this guidance binding on employers where applicable and convert the 'right to request flexible working' into a 'right to telework' for eligible employees. In this regard, it would be more appropriate to define teleworkability of a job instead of teleworker in the law to reduce an employer's discretion while deciding on a request for the right to telework.

In the UK's case, small scale council teleworking pilot projects for their own employees were in existence before the DTI guidance was launched. A review of the legislation, cited in this guidance as indirectly supporting teleworking, found it sensitive towards the additional costs to businesses and advocating an informal approach towards the encouragement of flexible working. The review also claimed that British workplaces were experiencing a cultural shift in which flexible working was the norm rather than the exception. This potentially provides a fertile ground to launch teleworking initiatives with a more aggressive strategy.

Reviewing the evidence from the other cognate fields it was found that despite the difference in the target groups, the strategies and tactics for implementing a Company Travel Plan should be transferable to teleworking encouragement. In this regard, measures like requiring a teleworking programme in new planning permissions for businesses, awareness creation campaigns, finding a key champion at a higher level of the hierarchy in a company, and offering financial support and expert advice are likely to be especially effective in encouraging firms to participate. By incorporating teleworking encouragement into a CTP, a CTP scheme may work more effectively as there might be a possibility for realising synergies by integrating both measures. Similarly, the review also identified some transferable elements from CTP and car sharing initiatives to teleworking encouragement at the individual level.

The government also has an important role to play in encouragement of teleworking and shaping policy on it. The government can initiate a robust debate which can also be linked to its strategy on climate change. In this regard, a stronger steer from government that teleworking is also an important area of policy interest and a national publicity scheme would be helpful.

In the above context when the results of a brief survey on a small sample of employers were interpreted, they confirmed that perceptions of government policy on teleworking are ambiguous. By singling out legislation as the most influential factor on their willingness to accommodate teleworking, the employers indirectly confirm that they do not consider the current legislation on 'right to request flexible working' sufficient. A theme that resonates through all the strands of research reviewed in this chapter is the need to create a culture in which teleworking is considered the norm rather than the exception. The employers' survey also confirmed the importance of this theme by ranking the 'industry norm' factor as the second most influential on their willingness to pursue teleworking. However, too much should not be read from the survey results due to the very small sample.

This chapter has reviewed the available evidence on the effectiveness of teleworking legislation and of policy initiatives on telework and related fields. All these fields are relatively un-explored territories; therefore the paucity of literature is understandable. This paucity limits any fruitful debate on the most appropriate means of encouraging the main actor who matters in this debate, i.e. the employers. The results from a small survey point to the influence of legislation, which as a by product is also likely to produce a shift in employers' attitudes towards acceptability of teleworking. In this regard, however, government is likely to be sensitive to the wider economic implications of any such legislation. This calls for purpose-specific research on how a teleworking policy that is also sensitive to the employment and business management implications of teleworking should be defined, so that hard evidence could inform the policy debate about the acceptability of initiatives to promote teleworking on its own or as part of a CTP.

11 Conclusions and Recommendations

This chapter consolidates the findings and conclusions from this study in section one. In section two various issues that arose in the course of study are highlighted. Finally, the thesis ends with some policy recommendations and how they might be pursued and implemented.

11.1 Policy Findings from the Study

This section identifies the policy relevant findings from the study, puts them into a policy perspective, discusses their implications and assesses how they might support the transport policy objective.

11.1.1 Literature Review

The nature of information and communication technologies (ICT) impacts on urban space and travel makes it a potentially significant avenue for search for solutions to urban transport problems. ICT have four types of relationships with transport: travel substitution, travel enhancement and generation, efficiency in resource use, and medium to long-term consequences for land use and transport. All of these except the 'efficiency in resource use' have implications for Travel Demand Management (TDM). Various types of tele-interventions are possible. However, this study focused on teleworking since it is more amenable to planner's control.

The studies of teleworking were started during the 1980s in the US where the majority of the work has been done. However, the practice has also attracted interest in Europe and the UK during the last decade and its potential as a TDM measure is being recognised. There is no all-purpose definition of the term and its use mainly depends upon the user's perspective which poses measurement problems across study disciplines. This has implications for data collection and impact determination. A practical definition of teleworking was formulated that focuses on its impacts on the Land Use and Transport Interaction (LUTI) system and reads as

> *A person is a teleworker if a policy decision by her employer results in full or partial relocation of work, facilitated by ICT-use, to her home.*

Available evidence on teleworking take-up from both supply and demand perspectives suggets that teleworking in the UK is growing steadily though the estimates from the former are more conservative. ONS figures suggest that teleworkers are growing at an annual rate of 13% in the UK and their overall share in the workforce is around 13%. However, ONS' definition of teleworking raises questions.

An analysis of the available UK data from 2001 indicates that seven out of ten teleworkers (69%) are men but adoption rate among women is also increasing, over a quarter of all teleworkers (27%) work in the business services sectors with another 25% in the public and voluntary sectors. Most teleworkers (68%) are in senior jobs, they are more likely to be graduates, married and in mid-career (in their thirties or forties). The fastest-expanding teleworking occupation is management, with an annual increase of 25% in managers working from home. The growth has been especially strong in the financial services sector.

The benefits of teleworking are tied to average frequency of teleworking. The figures available on frequency from different sources vary greatly. Plausible estimates of adoption levels and frequency are important for impact assessment.

The review showed that there were clear benefits for all the stakeholders in making teleworking a feasible alternative to conventional work arrangements. The employees among other things can save on general cost of commuting and have flexibility and control over their time management. The employers can cut the cost of business and realise increases in productivity and decreases in absenteeism. Indirectly, they can also benefits from cost savings due to reduced congestion. The transportation system and society would benefit from reduction in energy use, reduced demand for additional infrastructure through the release of existing network capacity, reduced social costs and decrease in demand for office space particularly in congestion-hit urban areas.

The review of employee and employer attitudes towards teleworking suggests both are convinced of its advantages and resulting impact on different aspects of life. However, they do have some differences of perception, especially regarding issues of employee productivity and managerial control. A successful teleworking programme would require some degree of job redesign and should address career concerns of teleworkers. Creating awareness about teleworking among all the stakeholders is likely to allay most of their respective concerns. Care and creativity in designing teleworking programmes are also likely to contribute to their success.

Another significant finding from the review was that although the potential of teleworking as a TDM measure had been speculated upon, no known attempt had been made to systematically study, model and quantify its impact as a policy instrument. This is what differentiates this study from the similar efforts in the field.

To expose the gaps in our current understanding of the teleworking impacts and inform the study design, a theoretical framework was developed that captured the significant responses to telework adoption and interaction among the main actors and markets. The interplay of these responses underlies the impacts on transport and land use systems.

The framework made it possible to study and model the impact of teleworking adoption on travel. For this purpose, a survey was carried out to develop estimates of teleworking adoption and frequency, their impacts and the factors influencing them including a choice experiment which formed the basis for conclusions on telework activity which are presented next.

11.1.2 Teleworking Adoption and Frequency

The results of this study are based on the fresh data which were needed due primarily to the nature and the objective of the study and required telework to be modelled as an instrument of transport policy. For this purpose a choice experiment was designed. Along with the stated preference (SP) responses to this experiment, some revealed preferences (RP) on contextual variables and on alternatives in the choice set and data on attitudes towards teleworking were also collected. Thus, the survey instrument used the RP, the SP and Attitudinal approaches to data collection, and was targeted on the employees who were commuting by car and belonged to the organisations located in Leeds City Centre and area around it. The respondents were approached through their employers using a business based sampling strategy. A short survey of the employers in the same sample was also conducted to complement some aspects of the main study.

The surveys focused only on those industry sectors which were thought to have jobs suitable for teleworking in greater numbers. The result of the employees' survey confirmed the appropriateness of the sampling strategy by yielding a share of 71% for respondents who currently telework or would do so given the option (table 7-2). The share of current teleworkers in the employee sample was found at 23% which is approximately twice the share of teleworkers in the general workforce as might be expected. Current teleworking frequency in the employees' survey varied between a quarter of a day and two days per week.

In the employees' survey no demographic, socio-economic and commute (DSEC) variable except for job position and income emerged as significant in explaining adoption of teleworking. This partly supports the contention that DSEC characteristics of an individual are becoming less relevant in explaining the propensity to adopt telework. However, when the dataset was explored from other angles, job position proved more robust as a determinant of telework adoption. It was also found that the respondents in senior and middle management positions are more likely to telework than the respondents in other positions.

Conversely, the perception of whether teleworking is available to them is the most important factor in determining its uptake by the individuals in job positions below middle management. Senior managers have a zero frequency for this response while the respondents in secretarial/staff positions indicate that 43.5% do not have the option to telework. By contrast, 72.7% of these respondents preferred to telework when given the opportunity to telework. This clearly indicates that provision of a telework option by the employer is an important policy variable.

In the employees' study, information regarding telework availability varies significantly among the respondents from the same organisation. This implies that the respondents often do not have a clear understanding of their employer's policy on telework. The results from the employers' survey revealed that the employers' understanding of whether government has a policy on telework was also unclear. This indicates that a telework policy whether from government or an employer needs to be explicit and well-communicated.

25% of respondents in the sample considered that their job was unsuitable under free choice. However, the ultimate perception of job unsuitability is different under different conditions. When the respondents' freedom of choice was constrained under different policy scenarios in the experiment, it was found that only 15.6% considered their job really unsuitable for telework. The employers' survey found the need for legislation requiring job redesign among the top three factors that would influence an employer's ability to be supportive of teleworking. Thus, this issue also needs to be addressed in policy discussions.

The literature reviewed regarding the factors influencing teleworking frequency was inconclusive. However, it suggested that generalised cost (GC) of commute, employer attitude and nature of job may have a role. The first two of these were explored as attributes through the choice experiment. The SP responses suggested that they definitely have a role in influencing the frequency and indicate opportunities for policy intervention and it appears difficult to achieve a frequency of more than two days a week. Other individual factors e.g. presence of care needs in the home and desire for increased autonomy operating independent of policy may also have a role in influencing the frequency.

11.1.3 Attitudes Towards Teleworking

Attitudes were sought towards eleven aspects of teleworking. The sample mean score indicated that respondents on average were just about neutral that their manager would approve of their teleworking. However, the factor analysis highlighted that the respondents tended to view managerial attitude towards their telework adoption negatively. Among individual groups of respondents, current teleworkers were understandably more positive about their managers' attitudes to teleworking. However, those who were not permitted to and those who were not interested in telework assigned the lowest score to the statement the manager's attitude among all the scores given to any attitudinal statement. Combined, both groups are 39% of the sample. This is where the space for policy intervention lies.

Overall the significant conclusion from this analysis was that the employment conditions i.e. whether the option to telework is available from the employer and whether a respondent's job is suitable for telework, do not influence the teleworking attitudes directly. Rather they are a significant determinant of teleworking choice which indirectly shapes a respondent's attitude. This implies that, for the majority of respondents, the (mostly negative) teleworking attitudes are shaped by constraints upon free choice regardless of whether these constraints emanate from lack of telework availability or job unsuitability. If the constraints regarding both these factors are removed, this is likely to result in a positive change in attitude towards teleworking.

11.1.4 Impacts of Teleworking

The notion that teleworking might generate non-work travel is based on increases in time available for other household activities and in car availability to all household members as a result of teleworking. The travel generation impact of teleworking in this study has been found at 0.67 extra non work trips per teleworker per week. Viewed in the context of teleworking frequencies from both the RP and the SP data in this study, the net impact of teleworking, i.e. net reduction in travel lies somewhere between 0.33 and 1.33 trips per teleworker per week.

Evidence on teleworking impacts on the location decisions by teleworkers was completely lacking in the UK and remains so even after this study due mainly to the sample size and the methodological problems. The study found that for 70% of current teleworkers, teleworking adoption would not allow them to change residence to a preferred location. Some evidence of the impact of teleworking on location decisions has been found, i.e. some teleworkers may relocate; however, the magnitude and direction or causality of this impact is still unclear.

However, teleworking impacts are not limited to these two areas. As noted in Figure 2.1, they exhibit themselves in a relatively broader field of human activity and have not yet been quantified fully, though efforts are increasing with the passage of time. Beneficial impacts of teleworking also need to be balanced against not just its transport cost but all of its conceivable costs. A broader set of such costs was noted in section 3.4.3. A true assessment of teleworking impacts, therefore, would involve a wider analysis of its costs and benefits to all the stakeholders and thus would take some time to emerge.

11.1.5 Policy Analysis

The policy analysis required an analytical tool. For this purpose, four model variants were obtained after taking care of a series of data and estimation issues. The models were put to sensitivity and robustness tests after calibration with the relevant data and the analyses proved that all the models not only produced plausible results but they are also robust under different travelling conditions. It was found that: inclusion of those teleworking < ½ day a week in the estimation did not affect the models' performance significantly; and that the models can be transferred to the full population thus increasing the generalisibility of the forecasts. After settling these issues, M9 was not used for forecasting due to being very similar to M10 and having the lowest rho squared value. The remaing three models which were used for the policy analysis aimed at modelling teleworking impacts produced a narrow range of forecasts. On balance, M15 was considered the best among those three models and was used for detailed analysis and system forecasting.

Three performance indicators were defined as Not Travelling, Level of Car Use and Level of Peak Car Use. The policies tested individually and in combination were an increase of 25% in travel time and cost by car, a decrease of 25% in PT travel time and all teleworking policy statements 1, 2 and 3; all tested during the peak. When individual policies were tested, telework policy 2 which reads as '*Employer allows everyone who wishes to telework*' emerged as the most effective policy measure in increasing the number of people Not Travelling which overall is a better indicator from an urban sustainability perspective. On the other hand, policies to increase travel cost and time actually reduced the percentage of people Not Travelling.

Telework policy 2 increased the reduction in work based travel from 3.56% in the base to 9.73%. On the other two indicators, i.e. Levels of Car Use and Levels of Peak Car Use, a three-way combination of telework policy 2, a 25% increase in travel time for car during the peak and a 25% decrease in travel time by PT was the most effective in simultaneously reducing the Levels of Car Use from 64.7% in the base to 47.8% and the Level of Peak Car Use from 46.3% in the base to 31.3%. These results from M15 indicate that depending upon the policy objective, telework policy 2 or a similar telework policy can be used flexibly and effectively, individually or as part of an integrated strategy.

For the second part of the impact analysis, the framework for analysis was extended to include a Single Link Model function and two indicators of system performance, link flow and link speed, were set. A subset of policies was tested for their system wide impacts. The differences between the direct and final effects of all the policies varied across the policies; however, they showed consistent results relative to the appropriate (Level of Peak Car Use) indicator under both forecasting approaches. Telework policy 2 reduced the flow by 4.63% while the speed on the link increased by 4.14%. Thus, policy analysis has clearly shown that depending upon transport policy objective telework policies can be used as TDM measures and may be more effective than policies influencing time and cost of travel.

11.1.6 Current Policy Environment

The review of available evidence on desirability and effectiveness of relevant legislation and policy initiatives on telework and in cognate fields showed that all these fields are relatively un-explored territories, thus the paucity of literature is plausible. This paucity limits any fruitful debate on the acceptability of teleworking by the employers. DTI's guidance on telework is also non-binding in character.

A common theme resonating in telework policy debate was about creating awareness/a culture in which teleworking is considered as a norm rather than exception. A review of current legislation indirectly supporting teleworking claimed a cultural shift at British workplaces where flexible working had become the norm rather than the exception. This potentially provides a fertile ground to launch the above recommended awareness campaign and new teleworking initiatives with a more aggressive strategy. The employers' survey also confirmed the importance of this theme by ranking 'industry norm' factor as the second most influential on their ability.

The transferable lessons from the cognate fields suggest that additional measures like tying the new planning permissions for businesses to telework availability and making teleworking encouragement as part of Company Travel Plan schemes can be effective at the organisational level. At the individual level, measures like imposing parking restrictions, payment of an outright incentive in lieu of foregoing a parking space and contribution towards the incidental costs of teleworking can be aimed at eligible but reluctant staff.

Primarily teleworking specific legislation is needed. However, there are other challenges also. They are: to design teleworking programmes in such a way that increases their acceptability by the employers and to make sure that such programmes are owned at the top level. A way forward could be differentiated teleworking programmes tailored to the requirements of businesses in a particular area, e.g. financial or IT sector.

11.1.7 The Case for Policy Intervention: a Summary of Conclusions

It is not possible to conclude on the desirability of teleworking without full knowledge of all its costs and benefits to society. The policy findings in this study, subject to certain caveats, have made a case for policy intervention for encouring teleworking adoption among the eligible employers and increasing its adoption and frequency among the eligible employees. The main message from these findings can be summarised as follows:

- Despite its beneficial impacts on commute travel, teleworking has not been used as a measure of transport policy;
- The issue whether any DSEC variable is significant in explaining propensity to telework has become irrelevant from a policy perspective;

- There is a nexus between higher job positions and telework availability;
- For other job positions particularly at lower level of organisational hierarchy; there is an issue of job suitability as perceived by the respondents, which reflects a lack of trust on the part of managers;
- There is a need to tackle both these issues by making telework freely available;
- Current regulatory framework for teleworking support for employees is inadequate and non-binding and there is a need for clear teleworking specific legislation; and
- When a policy which *allows everyone who wishes to telework* was tested on a sample of car commuters, it produced significantly beneficial results from an urban sustainability perspective.

11.2 Methodological Issues in the Study of Teleworking Impact

One of the innovative aspects of this study has been the use of a particular modelling methodology. This novelty was bound to raise issues regarding the different aspects of the methodology. Those issues are discussed in the light of the lessons learnt. Taking care of these issues can significantly enhance the reliability/acceptability of the results of future studies on similar themes.

11.2.1 Issues of Teleworkability and Managerial Attitudes

There has been a nagging issue of job suitability for teleworking. There is also confusion regarding the use of the term, i.e. whether it is suitability or unsuitability of a job for teleworking which can be removed by adopting the concept of 'teleworkability' used by Lake et al. (1997) who thought of it in terms of 'location-independent' tasks of a job, although this is still a very broad term. The concept of teleworkability can be further developed and made more specific to cater to definition of jobs suitable for teleworking.

The teleworkability of a job can be thought of as the degree or extent of a job to which the tasks encompassed by that particular job are suitable for teleworking. This thesis defines it as:

> *All those jobs or job tasks that do not require: face-to-face interaction with and/or supervision over or by other person(s); heavy and immovable equipment; and bulky material(s) for the duration of one full working day at a particular place(s) should be considered teleworkable.*

The delivery of the tasks using means other than face to face interaction, if required, is implicit in this formulation. A significant number of such job tasks has always existed. The advent, affordability and diffusion of ICT have only added to this number by extending the possibilities for remote but effective communication and making the remote delivery of task possible.

In this perspective, the issue of teleworkability is a job design or redesign issue, lies within employer's domain of action/initiative and should also be a target of the overall issue of policy on telework availability. The more flexible is the work design under which the employees work, the greater their willingness to telework Brewer and Hensher, 2000). A definition like the above should guide the job design process and the aim should be to make job more compatible with teleworking from the employee's perspective.

11.2.2 Travel and Location Issues

This was a trip based study due to its travel demand modelling character. For true impact assessment, a vehicle perspective is more appropriate; assessment should be based on log entries about the vehicle normally used by the teleworker and all members of the household who use that vehicle should maintain that log. For log entries, there should be clear guidance regarding the routine use and any extraordinary use by the entire household.

Changes in location patterns in response to adoption are perhaps not yet ripe for study of *actual* impacts due to their long term nature. Their impacts may be more evident in five to ten years' time. At this stage, perhaps it is more appropriate to study their likely implications for urban sustainability and planning. There is no denial that this response can be significant. However, it should be explored from a perspective independent of teleworking through an SP method where telework and its variations should be among the main attributes of the design experiment. This is likely to provide very useful insights into the likely location choice behaviour as a function of teleworking adoption and can inform the urban decentralisation issue and planning exercise.

11.2.3 Data Collection Issues

For policy analysis, an SP method is perhaps the best among the available options and policy analysis should focus one issue/aspect at a time. Further a stratified sampling method should be used for each group within the population of interest. Different groups may have different behavioural dynamics and propensities. From an employee perspective, two main stratifications should be based on modal use and teleworkability of job. Further, the respondents should be screened based on their realistic expectations from their employers regarding telework availability.

This study included a wide range of DSEC variables in the analysis and has concluded that they are no longer as important in explaining teleworking adoption as they used to be during the initial years of the practice. Studies of adoption should avoid a general singular focus on them in future unless required by some particular feature of an individual study. For the study of frequency, however, the study of some of these variables may still be important or of interest. In such cases, their number in the survey should be kept to a minimum. This would result in an overall good effect on the survey activity and better quality of the data to be collected.

It is also recommended that detailed exploration of more than one response should not be combined in one study, especially when a paper based survey instrument is used. An SP study should employ a staging process in the design of a choice experiment and for instrument formulation, and be able to use CAPI for survey administration.

11.2.4 Modelling Issues

The original intention of the project was to incorporate the full range of user responses to teleworking into existing strategic transport and land use models. Unfortunately, this proved not to be feasible. Instead a standalone teleworking demand model was developed, and linked with a simple peak only single link model. Inevitably this simpler approach limits the conclusions which can be drawn on modelling methodology.

One of the options considered in this study for modelling commute travel demand affected by teleworking was to model teleworking as a (non travel) mode. This would mean evaluation of teleworking choice in comparison to the travel mode choices. For this purpose, the role of teleworking frequency and cost is very significant. Both need to be considered with care and relatively good precision. For predictive use this study employed three different model variants using a *generic* multinomial logit (MNL) framework, given the problems in calibrating a choice-specific (CS) model. However, a CS specification is theoretically more appealing for the study of a non-uniform choice set. Successful calibration of such a model would require a fuller dataset than was obtained in this study and such a dataset may have provided a better model fit for CS model.

The standalone model of telework adoption detailed in section 3.4.4 can be linked to a travel demand modelling tool at trip generation stage and that it can be used to reflect responses at a disaggregate level. The output on telework adoption levels then can be fed into an MNL model of teleworking frequency. At a disaggregate level, this can potentially be done by determining the travel/teleworking demand in each category through segmented MNL models for respective categories. The successful use of an MNL model within the modelling framework of this study reinforces this confidence.

Another positive aspect of this study is the use of an SLM for congestion analysis and system performance in the face of resource availability. Despite its simplified representation, the SLM technique has shown that it is capable of producing plausible estimates of system performance, consistent with the demand analysis. However, the model used needs to be extended to the public transport modes and off peak travel. It also needs to represent the build-up of congestion more effectively; this requires a non linear relationship between travel time and flow.

Modelling non-work travel is a matter of preference about level of analysis, trip categories and data available for this purpose. Following a trip based approach, this analysis can be incorporated within all the non commute travel categories handled within a particular model. However, it would not be easy to model trip ends. Distribution of such travel across categories for different purposes is another complicating factor. A simpler approach could be to factor the trip ends for different purposes in the trip distribution matrix.

The analysis of location response of the teleworkers in this study has been disappointing, given the limited information obtained in the survey responses. A general lesson from this study is that it is more appropriate to model teleworking adoption and resulting accessibility needs and location responses within a land use model with the exception of the frequency response. To do this in an appropriate manner, the land use model should be able to separate the job supply from the location of employment activities along the industry sectors.

The entire modelling effect for this purpose would need to be incorporated in two parts: travel demand creation and accommodation of the effects of travel demand on (re)location through changes in accessibility fed back by the transport model. The first part appears less complicated and may be handled without much regard to the design and construction of individual land use models. The second part is relatively difficult as it has to deal with the relocation tendencies/characteristics of teleworkers which would influence the utilities of their location choices that would need to be incorporated in the location choice mechanism of the model. Similarly, the location response by the employers would need a corresponding but separate location choice process. In this case the model process which matches the land use supply with the demand for different purposes would also need to be strengthened to accommodate changes in land use patterns as a result of employers offering telework.

11.2.5 The Applicability of the Study

A few caveats need to be borne in mind before considering the interpretation and applicability of the results of this study to the teleworking population or commuting workforce at large. Well known limitations are that all the estimates are from a non random sample and the propensities indicated by the results are those of car commuters. When considering the applicability of these results to other geographic areas, differences in system and area characteristics would need to be taken into account. In this regard the results from model transfer are only indicative of the propensity of different user classes and consequent impact on the travel demand and the transportation system.

Some economy sectors were ignored in this study for reason of having a greater number of jobs with low teleworkability. They are also likely to yield some teleworkers. The survey showed that the sectors with more jobs with high teleworkability are likely to yield around 75% current and potential teleworkers (the actual share in the sample was 71%). If a reverse percent share (i.e. 25%) were assumed for the ignored sectors then the current and potential teleworking population in the entire workforce can be put at 50% in 2007. This means that the results are applicable to 50% of the population though this share is projected to increase further in the next five years as the same table indicates. Further, the results are also applicable across the sampled job sectors in other areas/populations.

11.3 Recommendations

The importance of teleworking as a TDM measure has long been recognised. Since its advent as a work arrangement it has continued to attract the attention of policy makers and planners. The discussion of the study findings in the previous sections has seen that it is the supply side of the teleworking market in which the main issues need to be addressed, potentially through governmental legislation. This section presents some recommendations regarding the use of telework as a policy instrument to address part of the foregoing issues.

11.3.1 On Specific Policy Measures

The policies analysed in this study and the results they showed assume added importance and the role of telework policy 2, under which 'employers allow everyone who wishes to telework', is particularly significant. The analysis found that transport policies alone may affect car use to some extent however, they mean nothing for telework adoption unless it is available as an option. When telework policy 2 was introduced in the analysis, it proved most effective in reducing the work based travel and the effect was a 9.73% reduction in travel. The results further show that in combination with travel time and cost measures this teleworking policy is even more effective towards the overarching objective of urban sustainability by reducing car use.

With better planning and effective use, more sophisticated travel time and cost measures are also likely to encourage telework and increase teleworking frequency. The conclusion from these results indicates that teleworking can and should be used as a policy measure. To achieve the best result relative to the objective of urban sustainability, the policy should be aimed at encouraging telework adoption as well as increasing teleworking frequency. The measures to increase adoption rates should include:

- increasing telework availability for eligible employees;
- increasing teleworkability of jobs through job redesign; and
- making the policy well-communicated within the organisation.

The measures to increase the frequency should focus on

- increasing the teleworkability of jobs;
- fighting negative managerial attitudes towards teleworking by making firms' policy on it more explicit; and
- combining telework availability with effective travel time and cost measures for each travel mode.

The adoption and enforcement of these measures lie within different domains which are discussed next.

11.3.2 On Creating an Environment for Adoption

All the stakeholders concerned with urban sustainability have a role to play. A collective concerted effort, especially by firms located in the CBD of an urban area, would benefit all players, due to reduced congestion and improved environment quality of the area. The fact that government and the firms have so far proved to be reluctant in making telework available calls for a greater role for the planning agencies. This means that the role of the planning agencies operating in collaboration with the firms is even more important. The range of measures listed above also implies this.

The findings in the previous chapter have seen that the firms will not act until or unless there is a profit motive, it is an industry standard or there is some kind of legislation. They are especially resistant to change when it involves additional cost outlay for them. They are more receptive to advice when they have to do something in response to business competition. The planners need to take these factors into account when defining their role.

In this context, the sustainability planner should provide: the initiatives, the designs of viable teleworking programmes, the blueprints of a feasible teleworking programme and all the necessary guidance and support needed to make a successful transition and adjustment. After successful trials and an initial period of voluntary adoption programmes, there should be a provision for some policy enforcement reward mechanism, perhaps based on the polluter pays principle. The firms may also need support regarding job (re)design, employment contracts and employer's responsibility regarding occupational health and safety issues. Thus, a resource bank should be set up for these purposes.

The role of the firm should be aimed at incorporating the required changes in corporate management cultures and include: showing a commitment at the top to a well-defined teleworking programme; making it a part of the firm's policy on social responsibility and possibly fitting it into the firm's business strategy; using telework as an incentive where possible; establishing the job redesign processes and changing the corresponding control regimes; and designing regimes to compensate teleworkers for the perceived or real costs. While designing such regimes, care must be taken not to disadvantage those whose jobs have low or zero teleworkability.

Employers' policy should be made explicit. This provision would discourage negative managerial attitudes and change the overall organisational culture towards the acceptability of teleworking. It is better that the businesses are alert and proactive to this need now than being reactive in 20 years' time when it might prove more painful a process.

11.3.3 On Need for Legislation

Currently there is no teleworking-specific clear legislation anywhere in the world. Instead of defining a teleworker, the teleworkability of jobs should be defined in the law. Government appears to be reluctant due to the wider contractual and economic implications of any such legislation for businesses. In this context when the results of a brief survey on a small sample of employers were interpreted, they confirmed that perceptions about government's policy on teleworking are ambiguous. By singling out legislation as the most influential factor on their ability to accommodate teleworking, the employers indirectly confirm that they do not consider the current legislation on 'right to request flexible working' relevant to teleworking.

Hence, the main challenge is to overcome government's reluctance in introducing clear legislation and to convince the employers of the desirability of such legislation and teleworking programmes. This can be done by initiating a publicity campaign about the benefits of teleworking to all and a robust policy debate focusing on it as an important policy area. Some of the lessons from Company Travel Plans are transferable to teleworking initiatives.

Current DTI guidance on teleworking has some useful elements in it and the 'right to request flexible working' in it needs to be converted into 'right to telework' for eligible employees. The useful elements of this guidance, e.g. guaranteed same rights for teleworkers, extra provision for considering telework specific circumstances in employment contract when starting teleworking and taxation benefits regarding incidental costs of teleworking to both employee and employers, can still serve as an important plank of an awareness creation campaign aimed at both parties in a teleworking contract, especially among employees.

11.3.4 On Measurement and Enforcement Regimes

Teleworking measurement difficulties have been highlighted at various places in this thesis. This is an important area which requires the attention of ONS. It should revise its teleworking definition and strategy to gather data on teleworkers. The effort on revision should focus on regular employees and include the issue of frequency. The statistics should be gathered and compiled keeping in view the requirements of different study disciplines, e.g. commute characteristics, overall time use and travel behaviour from a transport perspective, occupational health and psychology, location patterns/preferences, and skills' bank/availability from a human resource management perspective.

The discourse on teleworking and the debate on its use for policy objectives are relatively advanced in the US. The efforts on creating teleworking programmes and enforcement regimes can be benchmarked against the practice there. However, there are implications attached to all such enforcement regimes. From a regulatory perspective, there are difficulties in establishing sufficiently rigorous quantification protocols to accurately measure the impacts, e.g. the emission reductions from teleworking. There are also quite significant cost implications to the regulator for establishing these kinds of regimes which are likely to result in relatively high transaction costs. So far, there are few success stories about carbon emission trading and the emissions reductions from a single teleworker are likely to be extremely small.

Following the polluter pays principle, an indigenous new approach could be to introduce some sort of transport related Environmental and Social Impact Factor (ESIF) for those firms whose businesses are suitable for teleworking by the city councils. Determining and publishing a firm's annual ESIF per vehicle used by the firm or a composite ESIF relative to the size of the firm in a directory can be considered as an option. At the moment it is just an idea. However, it can possibly be related to three contributing factors:

- number and engine specifications of the vehicles used by an organisation's employees for commuting to its main location(s)
- parking space requirement for those vehicles and its opportunity cost
- employees' opinions about un-necessary commuting and effects it might have on their overall health and well-being

Further, the firms may be rewarded or disciplined on the basis of their ESIF scores by the council. The firms with an adverse ESIF could be encouraged to introduce teleworking programme on priority and given the needed support. Also, a composite firm-wide ESIF may be a more viable option in view of the abovementioned implications of enforcing telework programmes as the transactional cost in this case would need to be balanced against the entire range of benefits not just the environmental benefits.

11.3.5 On Regulator's Responsibility and the Need to Act

This thesis has dealt with a fast evolving phenomenon in terms both of advances in ICT and of its diffusion. Their use by the society is hastening the traditional processes of social and technological change, and unleashing new ones whose dynamics are still unknown. In parallel to these there is a process of demographic changes in the business, industry and workforce. Viewing these processes through a coherent approach to analysis, travel patterns and workplace culture are likely to change to a great extent in next 10-15 years. Younger generations with more favourable attitudes towards ICT application in every day life will have entered the ranks of decision makers and affect teleworking adoption and policy. Looking at the challenge from this perspective can provide a glimpse of the shape of the things to come and consequent tumultuous adjustments in the travel behaviour.

The discussion in the above paragraph points to the need to act without delay and the government as the ultimate regulator of the new markets has also a role to play. This role touches a number of domains and enacting required legislation is only one of them. A large-scale increase in teleworking could contribute towards its strategy on climate change and also produce welcome emissions benefits for many highly polluted areas. Eliminating regulatory obstacles to teleworking and approaches that minimise transaction costs for establishment of enforcement regimes are other areas which need attention.

Difficulties in establishing enforcement regimes should not be taken as an excuse for not promoting teleworking. Efforts to this end can also benefit carbon emission trading regimes. What is needed is more research on aspects like these and the government and its funding bodies have also responsibilities towards this. Moreover, as major employers, both the government and the public sector have a major opportunity to influence the work and business travel of their own employees.

11.3.6 On Directions for Future Research

Owing to its stated limitations and the indicative nature of the study results, a similar study but on a much wider scale which also takes care of all the methodological issues on measurement, data collection and modelling would benefit the debate about teleworking as an instrument of transport policy. In such a study teleworking choices should not be tied with the non teleworking choices in the choice set because of the complicated nature of the analysis.

It would also be interesting to further explore the role of teleworking cost and study telework as a mode. Such a perspective can combine travelling and non travelling choices but the choice set should be simple and the role of teleworking cost should be carefully planned.

This study could not link the accessibility output from the modelling framework to a land use model as suggested in 4.3. This could be another potentially fruitful direction for further work, especially as an extension of the modelling methodology as was the original idea behind this study. It would be quite interesting to explore the ways to accommodate the accessibilities of teleworkers resulting from this study within a land use model and model their effects to study the changes in location behaviour of teleworkers under the model logic and changes in the location patterns depicted in the land use model.

From a policy perspective, determining the true impact of teleworking on location choice is quite important because it has implications for travel generation and use of different modes which can be either beneficial or harmful. It can be argued that the location choice and decision would not be influenced by adoption only, but also by teleworking frequency. In this regard, there are many complicating factors and dynamics involved which make this dimension of teleworking a potentially very significant area of reseach. Following specific issues need investigation:

- 1 – what is the share of teleworkers who have changed location
- 2 – how many in (1) can really attribute their decision to their being teleworkers
- 3 – what is the impact on individual commute distances of the decision by those in (2)
- 4 – what is the teleworking frequency of those in (2)
- 5 – how different are non-commute travel patterns at the new location for those in (2)

A mirror study to this one but from the employer's perspective in which attributes like regulatory interventions, problems in making telework available and business processing cost can also be recommended. This study can also take a LUTI modelling perspective and be made more comprehensive with the inclusion of the study location preferences and needs. The sample may consist of the firms which have active teleworking policies and substantial numbers of teleworkers and the LUTI model could analyse travel demand from a trip attraction perspective. There may be a need to develop purpose-specific models and a new modelling framework and the suggestions and guidance available in chapter three and particularly the framework in Figure 2.1 can be useful for this purpose in future.

Another related but useful research theme from an urban sustainability planner's perspective could be to investigate specific ways and approaches to policy interventions and to encourage employers to participate in teleworking programmes. Another dimension of the same theme can be to research the features of teleworking legislation and programmes that increases their acceptability of by employers and/or how a teleworking policy that is also sensitive to the employment practice and business management implications of teleworking should be defined.

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13 Appendices

13.1 Appendix I: A Copy of the Letter to Employers by Prof May

Addressed to someone high in the organizational hierarchy

Company name

Leeds

LS1 ---

Subject: Request for Assistance on a Transport Policy Related Research Project

Dear Sir,

At the suggestion of Martin Dean of the Leeds Initiative, I am writing to you to request your firm's support and assistance for a research project on the potential of Teleworking to reduce congestion in Leeds which I am leading here at Institute for Transport Studies, University of Leeds. We have approached your company due to its location and size and hope that given your participation in the Leeds Initiative, you would find it of interest. It is not essential that you have a policy on the acceptability of Teleworking.

This research investigates the possibility of reducing the demand for travel by car during the peak hours by offering commuters various choices, particularly the choice of working from home (Teleworking) if the nature of their job allows. For this we want to collect some data on commuters' preferences when faced with congestion on their journey to-and-from work through a short paper-based, anonymous questionnaire that would take only 15-20 minutes to complete.

Filling in the survey is voluntary and the only criterion for participation is the use of the car as their usual means of travel to work. We are interested in obtaining responses from the full range of employees across the genders, job types and hierarchical levels. Individuals' responses would be kept confidential. However, we would be happy to provide a summary of results for your company and to discuss the overall results of the study with you.

The assistance we are seeking is to allow eligible employees of your firm to participate in this study and to help us to distribute this short survey among them. We would take particular care to keep the person-hours required from your firm to complete this activity to the minimum. If you are agreeable to this request please let me know and I will arrange for my research student, Nasir Rana, to contact you or a nominated colleague to discuss arrangements for the survey. It would be helpful to have reply by Friday, May 12th.

I hope you will be willing to help us and the University with this important research. If you have any queries I would be happy to answer them.

Yours sincerely,

Tony May

Professor of Transport Engineering

Institute for Transport Studies

University of Leeds,Leeds - LS2 9JT

13.2 Appendix II: Copies of Messages Used for Follow-up

A: Copy of the Follow-up letter

Dear Ms/Mr (Name)

Thank you for agreeing to help us with the survey in response to Professor May's letter.

May name is Nasir and I shall be carrying out the survey activity. For this we need help with survey distribution and response collection within your organization.

Depending upon your preference, the survey can be distributed either in electronic or in paper formats. If distributed electronically it would need to be printed (4 A-4 size pages) by the respondent as we need responses on paper.

(Given the choice we would prefer distribution of the electronic version. In our view it would increase response rate and avoid unnecessary wastage. However, we are open to suggestions regarding distribution and collection.)

For response collection we may need a collection point (a contact person) within your organization where the respondents would be requested to return the survey by a certain timeline. Looking at the coordination needs of this activity, you may wish to nominate a coordinator at your end for this purpose.

As a first step it would be helpful to know about your preferred alternative for survey distribution. In your preferred alternative is a paper-based distribution then it would be further helpful to know an estimated number of eligible participants (who use car as a commuting means) from your organization.

I look forward to hearing from you (or a coordinator on your behalf) very soon.

Yours sincerely,

Nasir Rana, Doctoral Candidate, University of Leeds

B: Copy of Message that Accompanied the Survey

Dear Ms/Mr. (Name)

Thanks for replying.

As desired I am sending you the survey in electronic format. However, there is a slight problem with using electronic distribution.

We have three different versions (normal MS WORD files) of the survey with some subtle variations in them and want to randomise their distribution so that the responses we get are not biased. This would have worked fine with distribution paper-based format.

However, to circumvent this problem I propose two solutions. Usually there are separate distribution lists within an organisation. If you also have this arrangement then there should not be any problem. The sender can at random attach one version of the survey with each distribution list. However, if you have only one distribution/circulation list then we have to circulate all the versions with the email and request the recipient to download and print at random only one version.

For response collection we can request the respondents to return the survey after filling either to a contact point within your Organization or directly mail to my University address by an appropriate timeline (say, within a week or ten days. If not enough people respond by this date, we may need to send a reminder giving one more week. Once most of the people would have returned the survey to you then I can come to collect them. I suggest the following 'covering message' (it is open to appropriate editing) for circulation in the email containing the survey:

"Dear Colleagues

The University of Leeds has sought help from Yorkshire-Forward for an important research project. The Management would like to encourage **all those who travel to work by car** to participate in a short paper based survey that takes about 15-20 minutes to fill in.

Please download, print the attached survey (4 pages) and mark your responses clearly.

(alternatively if all the versions are circulated to one distribution list: In attachment are three different versions of this survey with some subtle variations. As the researchers want to randomise the distribution so that the responses they get are not biased, therefore, please **download only one version at random**, print and mark your responses clearly.)

The University would prefer your responses on paper. However, if you choose to respond to the survey electronically, please make sure that its layout is not disturbed and preferably use a different font colour when you insert you responses in it (please don't forget to save once you have completed it). It would be helpful if your responses are received back by 28th of June.

The survey is self-explanatory. However, if you have any questions you are welcome to contact the researcher concerned direct on 07952 343366 or at nrana@its.leeds.ac.uk. Please return the completed survey to .... or direct to Nasir Rana, Transport Studies, University of Leeds, LS2 9JT.

Thank you very much for your time and help."

Please put my address in the cc field when you circulate it. I have put the response due date thinking that the survey is circulated today. For a later occasion please amend this date accordingly.

If anything is unclear, please feel free to call me or drop a line. I would be grateful if I get to know the progress on the activity at intervals you deem appropriate.

Kind regards

Nasir Rana

13.3 Appendix III: Letter Accompanying the Employers' Survey

Dear Sir

You might remember that I requested your help with a survey regarding an academic research project on incidence of teleworking among the employees of your organisation last year. I gratefully acknowledge and appreciate the help we received in conducting that survey which provided us with valuable data on your employees' perspective on the issue.

To complement the picture we have developed, we are now seeking information on employers' perspectives on some aspects of the study. For this purpose we have a few brief questions to ask which can be completed in the accompanied survey in about **five** minutes. Any answers which you gave will be treated in strict confidence.

I hope you will be able to answer these questions yourself as they relate to organisational policy. However, if you feel that another person in your organisation can provide more appropriate answers then please forward them to her him with the request to mail the completed survey back to my research student Nasir Rana as soon as it is convenient.

Nasir is available at 07952 843366 or nrana@its.leeds.ac.uk if you have any questions on this request. The address for hardcopy mail back is Nasir Rana, Transport Studies, University of Leeds, Leeds, LS2 9JT. I very much hope that you will be able to assist us in this way.

Yours sincerely

Professor Tony May

13.4 Appendix IV: Description of the Software used for Model Estimation

ALOGIT requires a data file (in test format) as input in which values of all the variables related to a given observation are arranged on one line and separated by a space or comma. The next step is the specification of a control file in which all the modelling logic is defined using different commands and required formats. This is a very detailed process and perhaps an area where the modeller is prone to making most mistakes, not only of specification but also of getting the logic in the utility functions right.

The third step is to run the estimated model and examine the output mainly from two files. In this step, the data is input from the base data file(s) to PREPARE command. It may then be amended by transformations specified by the user. The transformed data is then checked to ensure its suitability for logit modelling and written out in a special compressed format to a temporary file for use by ESTIMATE command. One of the output files contains the estimated coefficients and their t-ratios with the overall model fit also listed. The other file contains the required statistics and report of any errors encountered. ALOGIT uses the maximum log likelihood as the measure of model fit which can be used through statistical tests to improve the overall model fit if required.

In the next step the estimated model's validity is tested in relation to the observed choices. At this stage, another set of data and control file mainly based on the output from ESTIMATE step needs to be programmed as input. This is also very detailed process, quite similar to its counterpart above but with one difference. Instead of coefficient specifications, model dimension controls are specified to see how its predictions vary across different groups of individuals. The second part of the model validity test is to examine the output after the model run on the above specification. Two types of output files are produced: log and scenario files. The log file contains demand elasticities for all the choices for a change in the specified coefficient while the scenario files, their number corresponding to numbers of dimensions controlled, report predictions for different bands/categories within a variable.

13.5 Appendix V: The Survey Instruments

Survey on Responses to Congestion on Work Journeys

Institute for Transport Studies

Dear Respondent

Thank you for agreeing to answer this short questionnaire about your responses to congestion on your journeys to and from work. It should be filled in by one employed adult who travels to work **by car**. This survey is being undertaken by the Institute for Transport Studies at the University of Leeds for an academic research project. The information you provide will be treated as confidential and only used for the purpose for which it is being sought.

ABOUT YOUR JOURNEY TO WORK

Q1 **In a normal week how many days do you work?** ______ **How many days do you travel to work?** ______

If you travel fewer days than you work, please specify why: ______________________________

Q2 **At what time do you normally set off from home to work?** ______ am or pm (please delete as appropriate)

Q3 **At what time do you normally leave work for home?** ______ am or pm (please delete as appropriate)

Q4 **How long does it normally take from your home to reach work (in minutes)?** ....

Q5 **How long does it normally take you to get home from work (in minutes)?** ....

Q6 **What is the approximate daily petrol cost of your return journey? £**______

Q7 **About how much per day does it cost you to park at work? £**______

ABOUT YOUR ALTERNATIVES

People react to uncertain congestion and delays on their journey to work in different ways. Among them are:

Changing Departure Time (if *allowed* they could depart for work or leave for home *significantly* earlier or later than their usual time to avoid delays or save time.)
Changing Means of travel (if they are *able,* they could switch to a different means of travel to avoid delays or save time.)
Adopting Teleworking (If nature of the job and employer *allow*, instead of travelling to work they could work from home at least one full day using information and communication technology.)

Please keep in mind the above and answer questions below by ticking (✓) the circle as appropriate.

Q8 **Would it be possible to save travel time by changing the time at which you depart to or from work?**
Yes.........O No / already departing at optimum time.........O (Please go to **Q10**)

Q9 **If you were to change departure time to save travel time, compared to your usual time about how much**

A) Earlier/later would you **set off for work?** __________ Min. earlier/later (*please delete as appropriate*) and
B) About how much time would you be able to save? _______Min

C) Earlier/later would you **return to home?** __________Min. earlier/later (*please delete as appropriate*) and
D) About how much time would you be able to save? _______Min

Q10 **Would it be possible to save travel time by changing the means of travel you use to or from work?**
Yes...............O No (not feasible/already using best means)......O (Please go to **Q13**)

Q11 **If you were to change means of travel, which means would you use?** Bus...O Train...O Cycle...O
Other (please specify) ________

Q12 If you were to use the means of travel you indicated in Q11 in both directions for your work journey, *compare to your usual means* **about how much more or less:**

A) **Travel time** would it take? ______ Min. more/less (*Please delete as appropriate*)
B) Would it **cost** you? £______ more/less (*Please delete as appropriate*)
C) **Walking** time (if any) would it involve? ______ Min. more/less (*Please delete as appropriate*)
D) **Waiting** time (if any) would it involve? ______ Min. more/less (*Please delete as appropriate*)

Q13 **Is any type of Teleworking arrangement possible/permitted within your organisation?**
Formally possible (allowed as Firm's policy) .....O Informally possible (allowed by my manager)......O
Possible but job unsuitable......O(Please go to Q19) Not permitted...O (Please go to Q16)

Q14 **Do you currently telework?** Yes ......O No.....O (Please go to Q16)

Q15 **If yes, how many full days per fortnight do you telework?** _____ (Please skip next Question)

Q16 **Suppose that teleworking is permitted, would you consider teleworking?**
No...............O (Please go to Q19) Yes...............O

Q17 **If you were to telework how much would it cost you per day (include costs such as phone, internet, energy bills, etc.)?**
Zero.....................O Less than £1.0.................O Between £1.0—2.5........O
Between £2.5—5.0......O Between £5—10..............O Above £10...................O

Q18 **Who would pay this cost?** Myself......O Employer......O Shared......O

Q19 Is there **any other alternative** you would consider to avoid congestion or save time on your journey to and from work and/or save time? No.....O Yes ......O (Please specify________________________)

ABOUT YOUR CHOICES

We would now like you to react by making a choice in the hypothetical situations presented below about your journey to-and-from work. *If you choose to Telework, then please also indicate how many days per week*.

The situations are described in terms of your daily journey-to-and-from-work cost and time during the peak traffic period, and your employer's policies on Teleworking. Reasons for changes in cost or time could be changes in government policy, new investments or simply more cars on the existing roads. Please assume that time spent travelling off-peak and also by other means does not change.

Now please consider the situation in each row carefully and make your choices.

If	**Total** journey **Cost** to-and-from work **during Peak** plus Parking	**Total** journey **Time** to-and-from work **during Peak**	**Employer's Policy on Teleworking**	**My Choice would be** (*Please make only one choice by considering the changes in the boxes on the left and ticking (✓) the most appropriate circle*)
Situation 1	**Stays same**	**Goes up by A HALF**	**Promotion linked to employee attending usual workplace**	No change.............O Change Departure Time.........O Change Means of Travel......O Telework: 1-day..........O 2-days.............O 3-days........ O 4-days.............O
Situation 2	**Goes Up by £6**	**Goes up by A QUARTER**	**Willing to permit those with needs**	No change.............O Change Departure Time.........O Change Means of Travel......O Telework: 1-day..........O 2-days.............O 3-days........ O 4-days.............O
Situation 3	**Goes Up by £2**	**Goes up by A HALF**	**Employer permits but does not like it**	No change.............O Change Departure Time.........O Change Means of Travel......O Telework: 1-day..........O 2-days.............O 3-days........ O 4-days.............O
Situation 4	**Goes Up by £2**	**Goes up by A HALF**	**Allows everyone who wishes to telework**	No change.............O Change Departure Time.........O Change Means of Travel......O Telework: 1-day..........O 2-days.............O 3-days........ O 4-days.............O

Situation 5	Stays same	Stays same	Willing to permit those with needs	No change..............O Change Departure Time.........O Change Means of Travel......O Telework: 1-day..........O 2-days.............O 3-days........ O 4-days.............O
Situation 6	Stays same	Goes up by A HALF	Employer permits but does not like it	No change..............O Change Departure Time.........O Change Means of Travel......O Telework: 1-day..........O 2-days.............O 3-days........ O 4-days.............O
Situation 7	Goes Up by £6	Goes down by A QUARTER	Allows everyone who wishes to telework	No change..............O Change Departure Time.........O Change Means of Travel......O Telework: 1-day..........O 2-days.............O 3-days........ O 4-days.............O
Situation 8	Goes Up by £4	Goes up by A QUARTER	Willing to permit those with needs	No change..............O Change Departure Time.........O Change Means of Travel......O Telework: 1-day..........O 2-days.............O 3-days........ O 4-days.............O
Situation 9	Goes Up by £2	Goes up by A QUARTER	Promotion linked to employee attending usual workplace	No change..............O Change Departure Time.........O Change Means of Travel......O Telework: 1-day..........O 2-days.............O 3-days........ O 4-days.............O

ABOUT YOUR ATTITUDES TO TELEWORKING

In recent years increasing numbers of people have started working from home instead of travelling to work, enabled by the widespread availability and use of information technology. This form of work, often called teleworking, has both pros and cons. Please think about teleworking and mark each of the following statements on a scale of 1-10 where 10 indicates a ***STRONG AGREEMENT*** *while 1 indicates a* ***STRONG DISAGREEMENT****.*

Statement	Score
Teleworking does/would provide me with more time for myself/family.	____
I do/would lose on learning opportunities and social interaction at my workplace when/if I telework.	____
Teleworking does/would provide me with increased flexibility in scheduling my day.	____
Working from home does/would adversely affect my chances for career advancement or promotion.	____
I do/would like the increased independence in doing my job afforded by telework.	____
Teleworking does/would increase work-family conflicts.	____
Teleworking does/would save me commuting costs and stress.	____
Teleworking does/would develop a sense of isolation.	____
Working from home does/would increase my job performance/make me more productive.	____
Teleworking does/would help in catering to caring needs at home.	____
My manager approves/ would approve of me working from home.	____

ABOUT IMPACTS OF TELEWORKING

Please answer Q 20 to 25 below only if you are already teleworking or if you chose to telework in any of Situations 1-9 above. *If neither applies then please skip this section and go to Q26.*

Q20 **Is/would the car no longer used by you for travelling on a teleworking day (be) used by you or another member in the household to make** (tick as many as apply)?

Journey to Work by someone else......O Shopping trip............O School/escort trip...........O
Additional leisure trip...........O Any other unplanned trip........O Would not be used.........O

Q21 As a result of your answer to Q20, do you think the number of non-work trips by car per week made by your household on average would/do change? Yes.........O No.........O (skip next Q)

Q22 If yes, then how much is/would be the change per week? 1-3 trips more ....O 4-6 trips more........O Above 6 trips.......O 1-2 trips less ....O 3-4 trips less.........O Below 4 trips........O

Q23 Does/would your adoption of Telework make it convenient for you to move house to a preferred location? Yes......O No............................O Don't Know......O Very happy with my current location............O(Please go to next section)

Q24 Does/would your *household circumstances* if you were to telework, allow you to relocate to your preferred location? Yes......O No......O (Please go to next section)

Q25 Now please ✓ one of the following choices: I have already relocated......O Yes, I would relocate......O I am thinking/would think of relocating...........O No, I would not relocate...O

ABOUT YOU AND YOUR HOUSEHOLD

Q26 Are you: male.......O female...........O?

Q27 Age: 16--24....O 25--34....O 35--44....O 45--54....O 55 and over....O

Q28 Your living situation/Marital status: Married/Cohabitating.......O Single.......O

Q29 How many persons are there in your household excluding yourself:
Adults_____ Children aged 5-15_____ Children under 5_____

Q30 How many of them are in a full-time occupation (employment/education): ____

Q31 Are there small children or elderly people in your household who need care by you or your partner during week days? Yes......O No......O Sometimes......O

Q32 What is your educational level: Higher Degree..........O Degree.........O A level........O GCSE or equivalent........O No qualifications....O

Q33 What is the annual income of your household before the deduction of tax?
Less than £15k .... O £26k-£40k.................... O over £60k.......................... O
£15k-£25k .... O £41k-£60k.................... O Withheld .... O

Q34 How many cars are there in the household? ____

Q35 How many driving licence holders? _____

Q36 Do you escort children to school or partner to work on your way to your workplace?
Yes..........O No...........O Not applicable........O

Q37 Which of the following broad categories best describes your position within your firm?
Senior Management......O Middle Management ......O Entry level Management/Supervisor..........O
Staff (secretarial, ancillary/technical, clerical, etc.) ....O Other......O (please specify_______________)

Q38 How many computers are accessible at home (including laptop owned or provided by employer): _____

Q39 Is access to the internet available at home: No...........O Yes...........O
If yes, type of connection: dial-up.........O broadband.........O Others.........O

Q40 Do you have space or a spare room in your house that could be or is used as a workplace?
No.........O Yes.........O

If you would like to add any comments about this survey, please do so here:

Survey of Employers on Incidence of Telework

Thank you for agreeing to help us. Please try to provide the required information as accurately as possible.

1 Do you think the government has a policy on teleworking? Yes....O No....O Don't Know....O

2 How would you describe your organisation's policy on teleworking? (Please tick one statement)
O....We have a formal telework policy whereby eligible workers are encouraged/allowed to telework
O....We do not have a formal telework policy but eligible workers can seek informal arrangement on teleworking with their managers/supervisors
O....We do not have a formal telework policy, and do not encourage employees to consider it
O....Employees are not permitted to telework in our organisation (Please skip Q4)

3 Has there been a change to this policy over the last one year? No....O Yes....O (please specify the nature of the change ______________________________)

4 Please provide an approximate figure on **the current estimate** of the number of your staff (as % of total employment in your organisation in Leeds) who telework **at least one full day a fortnight** ______ %

5 Approximately what percentage of your staff would telework at least one full day a fortnight now **if everyone who wished to do so was enabled to do so**? ______ %

6 Please consider the statements below and indicate for each how strongly each would influence your organisation's ability to support higher levels of teleworking by assigning a score between 0-5 (where 5 is very strongly; 1 is very little and 0 is no influence at all)

If there is legislation requiring the introduction of telework ______
If employer is relieved of the responsibility for health and safety issues related to teleworking through legislation ______
If concerns about data transmission speed and security are addressed satisfactorily ______
If there are tax credits/incentives for introducing the teleworking programmes ______
If the government or local council provide support and advice for such programmes ______
If it becomes industry norm in your line of business ______
If commute times increase significantly ______
If commuting cost increase significantly ______
If employers are not required to make any contribution to home office expenses ______
If employers are required by legislation to redesign jobs for aspiring teleworkers wherever possible ______

7 If the factors which you identify as most supportive in question 6 were introduced/active now, approximately what % of total employment in your organisation in Leeds, do you think, would opt to telework at least one full day a fortnight? ________ %

8 Name of your organisation: ______________________

9 Number of total staff in Leeds ______

10 How many of them commute by car (approx) _____%

11 Your position in the organisation: ______________________

12 The extent of your responsibility for teleworking policy in your organisation ______________________

13 Would you be willing to have a short meeting to discuss these issues further if your responses are of particular interest to us? Yes....O No....O

Appendix VI: The Table of Item Non Response Rates

Q No	Variable name	Applicable to	No of Missing Responses	Non Response Rate	Q No	Variable name	Applicable to	No of Missing Responses	Non Response Rate
Section 1	Current Journey characteristics					S3	192	4	2.1%
1	WorkDays	192	0	0.0%		S4	192	6	3.1%
1a	TrvlDys	192	0	0.0%		S5	192	6	3.1%
1b	WkTvlDif	30	15	50.0%		S6	192	5	2.6%
2	DeprTime	192	0	0.0%		S7	192	6	3.1%
3	RetuTime	192	0	0.0%		S8	192	7	3.6%
4	ToTvlTim	192	0	0.0%		S9	192	6	3.1%
5	FrmTvlTm	192	0	0.0%	Section 5	Teleworking Impacts			
6	FuelCost	192	23	12.0%		Section 5	144	31	21.5%
7	ParkCost	192	1	0.5%	20	CarOnTwD	113	0	0.0%
Section 2	Characteristics of the Alternatives				21	TripChng	113	3	2.7%
8	ChTmPosi	192	1	0.5%	22	IfYHwMch	32	0	0.0%
9a	ChngToT	91	6	6.6%	23	LocHppy	113	3	2.7%
9b	ToTmSvng	91	8	8.8%	24	TwHhConvn	43	0	0.0%
9c	ChngReTm	91	4	4.4%	25	IfYsOptn	3	0	0.0%
9d	ReTmSvng	91	5	5.5%	Section 6	Household Data			
10	ChgMdPsb	192	0	0.0%	26	Gender	192	0	0.0%
11	WichMode	21	1	4.8%	27	Age	192	1	0.5%
12a	ChgMTrTm	21	1	4.8%	28	Marital	192	0	0.0%
12b	ChgMdTrC	21	3	14.3%	29a	AdltInHh	192	0	0.0%
12c	ChgMWlkT	21	3	14.3%	29b	ChlUnd15	192	0	0.0%
12d	ChgMWtT	21	2	9.5%	29c	ChldUnd5	192	0	0.0%
13	TwOptAvl	192	4	2.1%	30	NoOcuHh	192	0	0.0%
14	CurntTw	192	0	0.0%	31	CareNeed	192	5	2.6%
15	CurTwFqy	44	2	4.5%	32	Edu	192	2	1.0%
16	TwPrfrnc	93	3	3.2%	33	Income	192	5	2.6%
17	TwCost	143	9	6.3%	34	CarsInHh	192	1	0.5%
18	TwCstPye	143	9	6.3%	35	LicsInHh	192	5	2.6%
19	OthAltnv	192	22	11.5%	36	Escort	192	0	0.0%
19a	IfYsWich	48	21	43.8%	37	Job	192	1	0.5%
Section 3	SP Replications -- Not Relevant				38	Computer	192	1	0.5%
Section 4	Attitudinal statements				39a	IntAccss	190	0	0.0%
	S1	192	5	2.6%	39b	IfYsType	180	7	3.9%
	S2	192	4	2.1%	40	TwSpace	192	0	0.0%

Appendix VII: Estimates of a Segmented Model

Variable description	Beta	t-ratio	Variable description	Beta	t-ratio
Constant for Changing Time	-2.562	-2.9	Time saved by late evening departure	-2.397	3.1
Constant for Changing Mode	-0.2325	-0.5	Time saved by being indifferent to evening departure	-0.0175	-1.3
Constant for Telework 1 Day	-19.35	-0.1	Time saved by being indifferent to morning departure	-0.0082	-1.4
Constant for Telework 2 Day	-19.38	-0.1	Telework Policy Statement 1	1.268	4.3
Constant for Telework 3 Day	-18.64	-0.1	Telework Policy Statement 2	2.62	8.7
Constant for Telework 4 Day	-20.23	-0.1	Telework Policy Statement 4 (dummy, policy 3)	0.0687	0.3
Time for Car	-0.0018	-2.5	If respondent is male (dummy, female)	1.729	7.1
Cost for Car	-0.0004	-6.3	If respondent is singly (dummy cohabitation)	1.286	3.2
Time if Departure Time Changed	-0.0004	-0.3	If respondent has age between 16-24	-1.69	-2.4
Cost if Departure Time Changed	-0.0003	-3.4	If respondent has age between 25-34	0.1549	0.4
Time if Mode Changed	-0.0091	-6.7	If respondent has age between 35-44	-0.7786	-1.9
Cost if Mode Changed	0.0006	4.2	If respondent has age between 45-54 (dummy > 55)	1.073	2.4
Time if Teleworked 1 Day	0.0012	1.1	If respondent has a Higher Degree	15.09	0
Cost if Teleworked 1 Day	0	0.6	If respondent has a Degree	14.33	0
Time if Teleworked 2 Day	0.0032	2.2	If respondent has education up to A-level	14.15	0
Cost if Teleworked 2 Day	0	0.2	If respondent has education up to GCSE or equivalent (dummy, No Qualification)	13.72	0
Time if Teleworked 3 Day	0.0027	1.1	Presence of care needs in the household	-1.187	-2.2
Cost if Teleworked 3 Day	-0.0005	-3.3	Absence of care needs in the household (dummy, occasionally)	-1.861	-3.4
Time if Teleworked 4 Day	0.0188	4.1	If household income is < £15000	-2.913	-1.9
Cost if Teleworked 4 Day	-0.0006	-3.6	If household income is between £15k-25k	-2.375	-4
Early morning departure	1.122	1.5	If household income is between £26k-40k	-1.086	-2.2
Early evening departure	-0.3989	-0.7	If household income is between £41k-60k	0.0742	0.2
Late morning departure	5.64	4	If household income is above £60000 (dummy, income withheld)	0.3789	0.7
Late evening departure	-2.402	-3.6	If respondent is in sr. management position	-0.2185	-0.4
Indifferent to the morning departure	2.759	1.8	If respondent is in middle management position	0	0.2
Indifferent to the evening departure	0.5205	0.4	If respondent is in entry level/supervisor position	-0.4985	-1
Time saved by early morning departure	-0.0007	-0.3	If respondent is in support staff position (dummy, all other job positions)	-1.061	-2.1
Time saved by early evening departure	0.0014	0.9	Rho-Squared	0.2364	
Time saved by late morning departure	-0.0254	-4.5	Final Log Likelihood	-1104.2	