TRANSPORT IMPACTS ON LAND USE: TOWARDS A PRACTICAL UNDERSTANDING FOR URBAN POLICY MAKING

by

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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.

ABSTRACT

The premise of this study was that transport impacts on land use are rarely given formal or adequate consideration in the strategic planning system in the UK. Therefore, this research examined current attitudes to transport impacts on land use, amongst a wide range of relevant planners, academics and consultants. It was found that there was little familiarity with either research into these relationships, or the methods that can be used to forecast impacts. However, there was acknowledgement that incorporating this relationship into planning processes is necessary in order to integrate fully land use and transport planning.

The research therefore focused upon determining the necessary attributes of practical methods to examine transport impacts on land use. Three contrasting methods were applied to a single case study area (Lothian region). These were (1); a novel application of the Delphi technique, (2); an updated implementation of an existing static land use response model, and (3); a newly developed complex dynamic land use transport model. Each was used to examine the land use response from hypothetical road pricing and light rail transit schemes. These methods and their forecasts were then assessed using the views of planners in a further round of more complex in-depth interviews.

From this several conclusions were reached. If transport impacts on land use are to be more commonly and formally assessed, then it is necessary to generate indicators that are directly relevant to the planners' needs. Examples of such indicators are discussed. Secondly, any method must be able to explain the forecasts in terms that are acceptable to the planners, in order to foster confidence in the method. The requirements for increasing confidence are examined, and comprise both technical and qualitative issues. Neither of these issues specifically requires new methods but rather, better targeting of, and education in, the existing available techniques.

It was found that the planners favoured the more complex approaches, not for any increased accuracy that may be possible, but for the better interpretation of results that such methods allow. However, this complexity also requires a much greater understanding of the assumptions and processes in the model, in order to avoid drawing spurious conclusions from the results. Conclusions are drawn regarding the balance between confidence and complexity, and hence the practical value of these methods to strategic planning.

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LIST OF ABBREVIATIONS

ACC	Association of County Councils
BART	Bay Area Rapid Transit
BHPS	British Household Panel Survey
CAAA	(US Federal) Clean Air Act Amendment
CATS	Chicago Area Transportation Study
CBD	Central Business District
CEC	City of Edinburgh Council (Unitary Authority)
DBOS	Memory management software for SALFORD complied programs
DELTA	Generic name for a land use transport model, denoting the major submodels 'Development, Employment, Location, Transition and Area quality'
DoE	UK Department of the Environment
DoT	UK Department of Transport
DRAM	Residential Land use model developed by Putman (1995)
DSC	David Simmonds Consultancy
DSCMOD	David Simmonds Consultancy Model: a generic version of the static LUCI model
EFM	External Forecasting Model (the trip generation element of START)
EMPAL	Employment model developed by Putman
ERM	Environmental Resources Management
GIS	Geographic Information Systems
GMAP	GIS Consultancy from University of Leeds Department of Geography.
GRO(S)	General Registrar's Office (Scotland)
HOV	High Occupancy Vehicle lane
IMREL	Static land use model developed by Anderstig and Mattsson (1992)
IRPUD	Dynamic land use transport model for the Dortmund area
ISGLUTI	International Study Group on Land Use and Transport Interactions
ISTEA	US Federal Intermodal Surface Transport Efficiency Act
ITLUP	Integrated Transport Land Use Policy model (from which DRAM and EMPAL were submodels)
IVHS	Intelligent Vehicle-Highway Systems
JATES	The Joint Authorities Transport and Environmental Study. Name for the Lothian strategic transport study, and also strategic model used in this study (which was precursor to START).
JAVELIN	Name for spreadsheet/database financial planning software, used as a data preparation tool for START
JIF	JATES into Fife; study of the potential and impacts of a Second Forth road bridge, and name for the START model of Lothian and Fife.
LASER	MEPLAN model of London and South East
LILT	Leeds Integrated Land use Transport model
LPAC	London Planning Advisory Committee
LRC	Lothian Regional Council: strategic authority for Lothian until April 1996
LRT	Light Rapid Transit
LUCI	Land Use Change Indicator model

MARTA	Metropolitan Area Rapid Transit Authority (LRT system in Atlanta, Georgia).
ME&P	Marcial Echenique and Partners: transport and land use consultants
MEPLAN	Dynamic land use transport model developed by ME&P (Hunt and Simmonds, 1994)
METROSIM	Land use transport model developed by Anas (1994)
MPO	Metropolitan Planning Organisation (for US urban areas)
MVA	The MVA Consultancy (formerly Martin Vorhees Associates)
NECTAR	Network of European Communications and Transport Activities Research
NEIPC	North East Illinois Planning Commission (an MPO)
NHB	Non home based (trip purpose)
NOMIS	National Online Manpower Information System
NTS	National Travel Survey
OST	Office of Science and Technology: UK Central Government department
PPG	Planning Policy Guidance
RUT	Random Utility Theory
SACTRA	Standing Acting Committee on Trunk Road Appraisal
SASINES	Register of housing transactions for Scotland
SEG	Socio Economic Group
SEPTA	Urban rail system run by Philadelphia Transit Authority
SIC	Standard Industrial Classification: employment divisions
SO	Scottish Office
SOFTER	South Fife to Edinburgh Rail study
START	Strategic transport model developed by The MVA Consultancy
TDM	Transport Demand Management
TRANUS	Dynamic land use transport model developed by de la Barra (1989)
TRICS	Trip Rate Information Computer System
UDP	Unitary Development Plan (for UK urban areas)
VOC	Volatile Organic Compounds
WLC	West Lothian (District) Council
WTP	Willingness To Pay

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CHAPTER 1
INTRODUCTION

1.1 Background and rationale

This thesis argues that transport systems have a significant impact on the evolution of urban space over time, but that this relationship, important though it is, is largely overlooked by the current strategic land use and transport planning system. That transport, especially during periods of innovation, shapes urban development is evident from urban morphology and is not in question. However, within these long term trends, the impacts of individual transport improvements are not easily isolated. They comprise a host of subtle factors, concerning the influence of accessibility and transport related environmental variables on activity patterns. As altered land uses affect the distribution of transport demand, so a complex urban land use transport interaction develops.

This interaction is generally ignored in current transport forecasting. Feedbacks of the type outlined above are rarely investigated, and instead the impact that transport planning has upon future land use and transport patterns is dealt with in an *ad hoc* manner. The results of poor consideration of these impacts can lead to mismatches of transport supply and demand, and unexpected changes in distribution of urban growth or decline. Moreover, spatially disaggregate forecasting into the future may be more prone to inaccuracy, as distributions of activities and their associated trip generation patterns change over time, but are not accounted for. Land use transport models exist, but with one or two exceptions, are confined to use in academic research rather than planning practice.

In recent years the links between transport and land use have come to prominence in planning as a potential means to reduce some of the adverse environmental consequences of the continuing rise in private motor vehicle use. For the first time, urban land use planning is being used explicitly as an instrument to control and alter transport demand. However, there is little heed paid in recent planning guidance to the impacts that transport has upon land use.

This increasing prominence creates a necessity for strategic planning to reconsider the treatment of how transport affects land use. From a research viewpoint, there is a real need to identify the methods that can practically be applied, and the information that planners require, in order to tailor the methods to meet these needs. This study therefore falls into the category of 'meta-analysis', concerned with the appropriateness of the methods, and the attitudes of planners towards both the relationship and the methods. It is not chiefly concerned with new ways of examining the land use transport relationship, although novel and innovative methods are applied.

1.2 Objectives and methodology

This thesis focuses upon the urban scale, where transport problems in the UK are most acute, and aims to examine the views of planners concerning the importance and relevance of land use response to transport policy in strategic planning. More specifically, this can be subdivided into four main aims:

1. to examine the kinds of impacts that transport can have upon land use;
2. to assess the current treatment of transport impacts on land use in the UK structure planning system, and the attitudes of planners towards the importance of such impacts;
3. to determine the potential value of a range of formal methods for forecasting transport impacts on land use, and isolate the key features required of these methods in order to meet the planners' needs;
4. to identify the potential relevance and significance of assessing transport impacts on land use in strategic planning.

The first objective was initially examined via a literature review. Following this, the main methodology used to meet the second objective was the interviewing of a sample of planners in the UK and USA. A wide selection of consultants, academics and planners involved in strategic planning were selected and interviewed regarding their current views on the importance of, and practice of, assessing transport impacts on land use. These were termed the 'Phase 1' interviews. On the basis of these interviews it was found that there was little familiarity with either the details of the relationship, or the methods to assess and forecast impacts. To provide an international perspective, additional interview research work was undertaken in the USA and in Germany.

In order to meet the third and fourth objectives, more detailed information and reasoned judgements were required from the planners. Original research into transport impacts on land use was undertaken for a study area (Edinburgh and its surrounding region) using three different methodologies. The first involved the use of a formal expert opinion survey (the 'Delphi technique'), the second, the use of a simple 'land use change indicator' (LUCI) model of land use response, and the third, a complex dynamic model of land use and transport interaction. The application of several methods in a single area allowed a comparison of the different techniques, and conclusions to be drawn about how transport can affect urban evolution.

These methods and their results on land use response were then presented in a more rigorous set of interviews to a subset of the Phase 1 interviewees (comprising those planners from the study area). These are termed the 'Phase 2' interviews and assessed the following issues:

- the relevance of the results to strategic planning, and what types of output would be of most use to the planners, (in other words, how 'useful' are the results, regardless of the methods used to produce them);
- the 'validity' of the methods, in terms of planners' confidence in the techniques, and the necessary level of understanding of the methods that is required by the planners;
- the 'plausibility' of the results, determined by asking the planners which of the various results accorded with their own views, or gave results which they felt were probable in the study area;

These findings from the planners allowed conclusions to be drawn on the potential and significance of transport impacts on land use in strategic planning, to meet the fourth objective.

This research thus uses a qualitative method for assessing the opinions of the samples of planners, and quantitative research for examining transport impacts on land use. A central argument of this thesis is that quantitative methods for forecasting land use and transport interaction must be targeted with the aims of the planners in mind. To research this in detail requires a qualitative approach, utilising and formalising the opinions of the people that need to use these methods in the real world.

1.3 Structure of the thesis

The thesis is divided into three broad sections. Chapters 2 to 4 comprise **Part 1** of the study. Chapter 2 examines theoretical approaches to understanding land use and transport, and how these have been developed into model representations. Chapter 3 examines empirical research into the impacts that transport has upon land use in the urban arena. Chapter 4 presents the results from the 'Phase 1' interviews with planners and experts in land use transport interaction.

Part 2 of the thesis (Chapters 5 to 8) describes the methods that were undertaken, and the results. Chapter 5 introduces the study area, and the research methodology applied. Chapter 6 describes the first technique, the opinion survey 'Delphi' method. Chapter 7 discusses the simple land use change indicator (LUCI) model that can be 'bolted on' to an existing transport forecasting model. Chapter 8 outlines the dynamic land use transport model, which builds upon the theoretical concepts in the LUCI model, but is a more complex dynamic land use transport model. Each method was tested with two strategies that are currently under consideration by the study area local authorities. These are a light rapid transit (LRT) system, and a city centre road use charge (commonly termed 'road pricing').

Finally **Part 3** draws together the results from parts 1 and 2. Chapter 9 compares the three methods and then compares the results to empirical and other evidence of land use response. Chapter 10 describes the final ('Phase 2') round of interviews with the sample of study area planners, to determine the potential role of these methods to strategic planning, and the required features of them. Chapter 11 then draws together the final conclusions to the study, and the implications of the results.

1.4 Role of the CASE sponsors

This research was supported and partly funded by The MVA Consultancy and David Simmonds Consultancy. Close co-operation between the author and the consultancies occurred for the development and implementation of the static and dynamic land use transport models (presented in Chapters 7 and 8). The land use models were designed and programmed by David Simmonds Consultancy, with The MVA Consultancy making the necessary changes to the existing strategic transport model of the study area to allow interaction with the land use model. The author collaborated in the implementation of the dynamic model, and then undertook the strategy tests. Thus the design and specification of the model are not the subject of this thesis. The author was given full freedom to discuss the validity of the model in the Phase 2 interviews, and report the findings.

CHAPTER 2

TRANSPORT IMPACTS ON LAND USE: THEORY AND MODELLING

2.1 Introduction

The aim of this chapter is to summarise the theory concerning the ways in which transport is perceived to influence land use, and to examine the application of this theory in operational land use transport modelling. The basis of how land use can respond to transport is outlined, along with the basic theories of how this can be represented. The incorporation of these theories into operational models is then discussed, along with a summary of the features of the models. Finally, a framework is proposed to categorise the level of understanding that is required to use and interpret the results of land use transport models.

2.2 How transport can affect activity and land use patterns

It is well understood that transport can have a profound impact on the pattern of activities and morphology of an urban area over the long term, and this has been illustrated in the qualitative historical works of several authors, for example Giannopoulos and Curdes (1992). However, in the short term (the time scales under which even strategic planning decisions must be taken), the influence of any one particular transport scheme on urban evolution is difficult to isolate, especially in mature urban areas where accessibility is already very high.

Clearly, the nature of the urban environment (quality, opportunities for further development, redevelopment or refurbishment), and the activities[1] in the area (in turn dependant upon economic, social and political considerations) will determine what impacts occur. However, the specifications of the transport policy will also have an influence on the impacts. The two particular policies that this research focuses upon are LRT (light rapid transit) schemes and road pricing. Dealing with each in turn, it could be hypothesised that the impacts of LRT will depend upon:

- the network of the system, in other words how it fits into pre-existing patterns of demand;
- the level of service of the system, for example its frequency, travel time, and the quality of the service, i.e. the image of LRT compared to existing rail or bus;
- the size of the accessibility benefit offered, which may not be great if the service is replacing or competing with existing bus services.

The impacts of a road pricing cordon charge may depend upon:

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[1] Activities refers to households, employment/firms and other users of land.

- the level of the charge;
- policy decisions such as exemptions, e.g. for residents living within the cordon, or off-peak deliveries.

In both cases, the perception of success of the policy may have an influence on its ultimate land use impacts. For example, impacts may be greater if the city centre is perceived as a more pleasant place to live as a result of road pricing, or if increased LRT patronage creates greater retail opportunities. Also in these examples, the impacts intended as part of a policy objective hinge critically upon whether they are expected and encouraged by policy makers, and if so, whether there is a supporting package of complementary land use and fiscal policies. These important issues are discussed further in the next chapter.

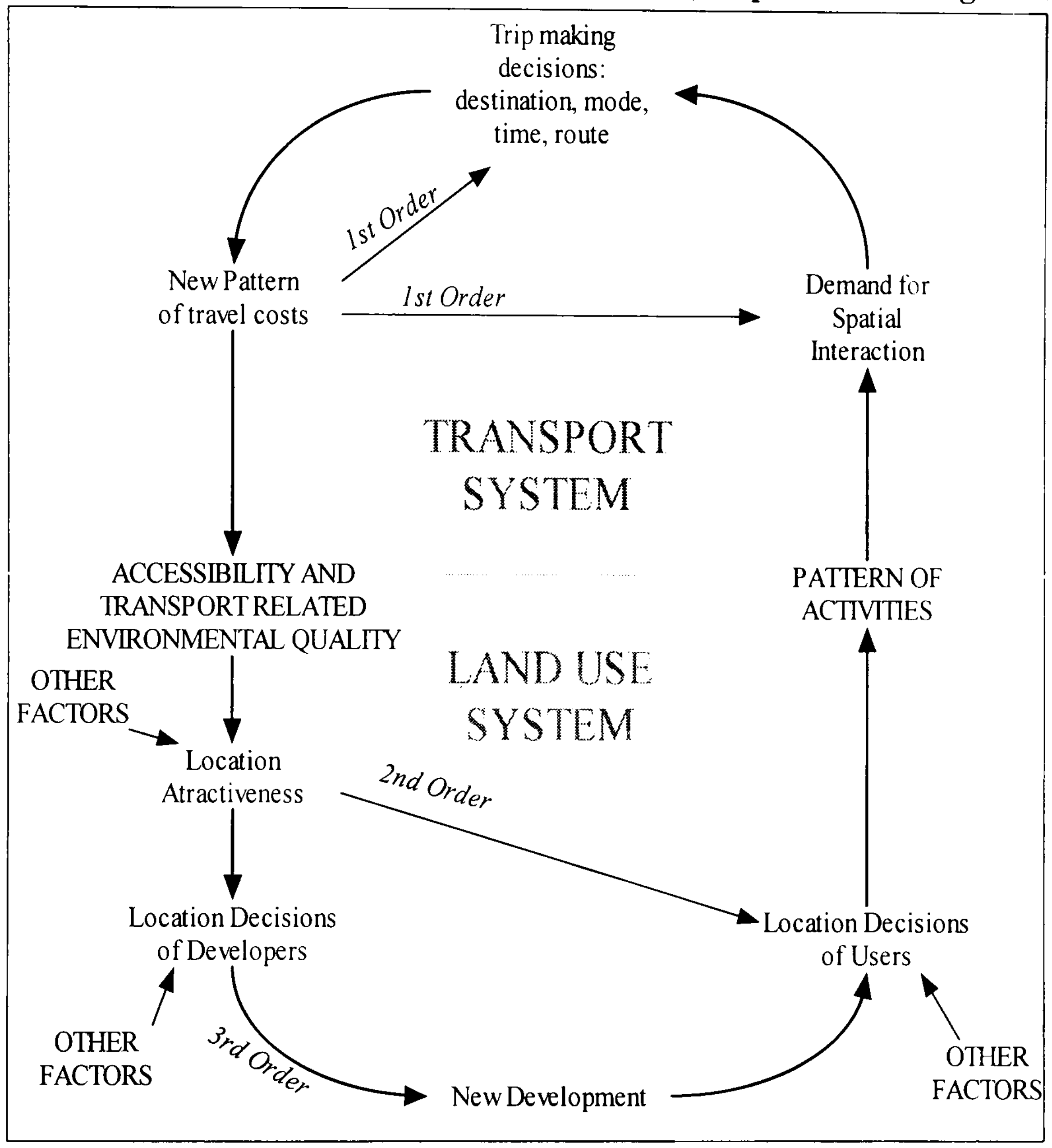
Activities in the land use system can respond to changes in the transport system in a number of ways. Mackett (1994) identifies three 'orders' of response. First order responses are those contained within the use of the transport system itself, such as switching mode, travel time, or route. These are the responses traditionally captured within a transport 'four-stage' modelling framework. The second order of response involves the relocation of activities within the existing stock to take advantage of the new accessibility, or environmental improvements. Living in the city centre to avoid a road pricing charge would be an example of such a response. Third order responses involve the construction of new floorspace, responding (usually) to the demand from second order responses. This creates a wider option set for second order responses, which may over time affect activities not initially influenced by the original change in accessibility.

This is a complex process, and is reflected in other indicators such as property rents and values, densities, and the quality of the urban fabric. It is also cyclical, as represented in figure 2.1, which shows the dynamism of the three orders of land use response. This figure illustrates that the spatial pattern creates the demand for movement. The resulting trip patterns and travel costs create the pattern of accessibility, which in turn influences future location decisions (although location choice is determined by many other exogenous factors as well). Furthermore, changes in accessibility can be negative as well as positive (as is possible from road pricing, or other traffic management policies). It should also be remembered that the perception of the policy and the associated impact is as important as the 'real' impact, as it is the perception that guides a location choice.

2.3 Basic theories

Defining a unified theory of these processes of cause and effect is difficult, and theories for examining these relationships vary from simple to complex depending upon how much of the interaction they incorporate. Basic theories involve describing how activities respond to the transport system in making their location choices. Three main theories exist: the first based upon micro-economic theory, the second based upon spatial-interaction/entropy modelling, and the third a fusion of these two incorporating random utility theory. These are discussed in turn. However, initially it is important to discuss the concept of accessibility.

Figure 2.1: Land use and transport interaction (adapted from Wegener, 1994)



2.3.1 Defining accessibility

Accessibility is perhaps the most obvious, although not the only, indicator that links the transport system to the decisions of locating activities (such as households or firms). It is an abstract concept that can take a variety of forms. However, the fundamental feature of accessibility is that it is a measure of the ease of reaching a location at which an activity can be undertaken. In other words it explicitly links the activity and transport impedance of getting there. Accessibility is important to this thesis because it is the main link between land use and transport in operational models. However, it is also important because potentially it can be used as an indicator of 'system performance' in its own right, for example, as has been attempted in London for access to public transport (Kerrigan and Bull, 1992).

Measures of accessibility have been summarised by Jones (1981), and Pooler (1995). The simplest is the 'isochronic definition', which is the number of opportunities obtainable within certain travel time thresholds. As such it can be presented as isochrones on a map from one origin, or cumulatively as a zonal index. Such a measure was used in the 'Joint Authorities Transport and Environmental Study', or JATES (The MVA Consultancy, 1991). Its main problem is the 'boundary effect', in that a travel contour is somewhat arbitrary, so travel impedance is treated discretely rather than continuously.

Isochronic indicators are generally used for presentational purposes rather than within a modelling framework. Far more popular for land use transport modelling is the 'weighted opportunities' index, often called a 'Hansen Index' after Hansen (1959). This has the following basic form:

$$A_i = \Sigma_j \; W_j \, exp(-\beta \, c_{ij}) \qquad \text{(Eqn. 2.1)}$$

Where A_i is the accessibility of a given zone i, W_j is the measure of opportunities at destination zone j, and c_{ij} is the cost between zones i and j. The parameter β controls the 'dispersion', i.e. the relative weight between the importance of the activities and travel cost. It is important as this parameter should change depending upon the opportunity (i.e. travel purpose). For example it may be expected that the parameter for access to primary schools (where proximity is important) may increase the importance of travel costs compared to higher education (where people are prepared to travel further).

This kind of weighted opportunity function is the basis of the accessibility indices used in the models in this thesis. Its main theoretical drawback is that it considers accessibility to all locations, rather than just to the activities that a given location seeker may consider important. Raji (1987) has criticised this (and more economic based measures), as being empirically inaccurate, as in reality, individuals are more likely to be 'satisficers' rather than 'maximisers'. Furthermore, being an aggregate measure it implies that all activities perceive accessibility in the same way. Finally, used in traditional zonal models, it can be biased by zone sizes, and the arbitrary nature of zones.

Despite these drawbacks the weighted opportunities measure is widely used within modelling. However, increasingly common is the use of the same functional form but derived from random utility theory (Jones, 1981), hence providing a behavioural underpinning for the index, (discussed further on page 14 in the context of location models). Accessibility functions based upon such measures of 'composite utility' can also be interpreted as measures of consumer surplus (de la Barra, 1989), with potential applications in economic evaluation. Martinez (1991) developed such an index that merges the consumer surplus benefits to the traveller, with the 'capitalisation' benefits of land rents to the land owner, and hence allows both to be represented within a single index.

A central issue for this thesis is how comfortable strategic planners are with these concepts of accessibility, and whether they see value in an accessibility index as an explicit performance measure, or simply an internal index for forecasting models. Koenig (1980) points out that 'planners'[2] rarely use accessibility indicators in strategic planning, as they do not fully understand what the indicators reflect, especially if the indicator lacks an underlying theory. However, he then comments that the 'gravity-type' indicator functions as a good proxy of the more behavioural approaches, and is more easily understood by planners. Measures based upon more complex behavioural theory are understandable by only a small number of technical experts, and do not necessarily produce different results from the simpler methods. This is an important point, and represents the balance between a workable model or an elegant theory. This issue will be examined in the discussions with planners in later chapters.

Finally, it should be noted that accessibility is not the only measure from a transport policy that can influence location choice, as image and transport related environmental impacts may also figure. This leads to the related question of whether forecasts of transport impacts on land use can be made without using an explicit accessibility measure at all, as will be seen in the Delphi survey in Chapter 6.

2.3.2 Urban economic theory

There is a long legacy of theories that attempt to explain the distribution of land uses via transport costs. This includes the work of Von Thunen (1826: translation 1966), on agricultural land uses, and Christaller (1933: translation 1966) on urban spheres of influence. The main intra urban work however is that of Alsonso (1964) and Wingo (1961). The economics of these theories have been outlined in more detail in Anas (1982), and de la Barra (1989). However, it is useful to outline the basic processes, which are fundamental to the land use transport models discussed in this thesis.

The basic theory makes a number of simplifying assumptions about the structure of the city, most important being that the city is circular, with all the employment in the central business district (CBD), and workers living around it. Transport cost to work is uniform around the city, but rises as distance from the CBD increases. The theory aims to predict the rents and distribution of land uses for competing socio-economic groups or land uses within the city. The basic process is that activities trade their desire for space (which has positive utility), against transport costs to the city centre (which has negative utility). If no other goods are

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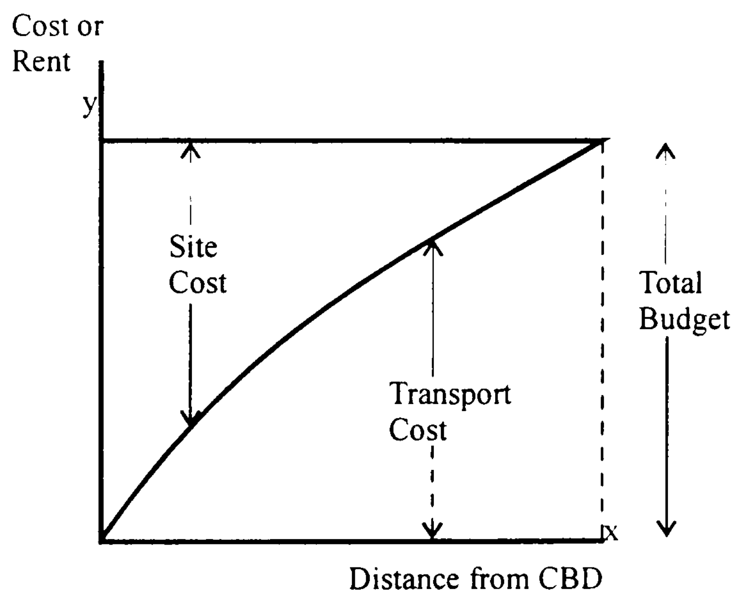
[2] Koenig is likely to mean planners in general by this sweeping term.

consumed then the sum of rents and transport costs must be constant across the city (leading to figure 2.2a), called 'complementarity' (Wingo, 1961). However, the usual case is to include another category of expenditure; 'all other goods and services'. Households are assumed to act to maximise their consumption and hence overall utility of these two goods, and minimise their consumption of transport, subject to a budget constraint.

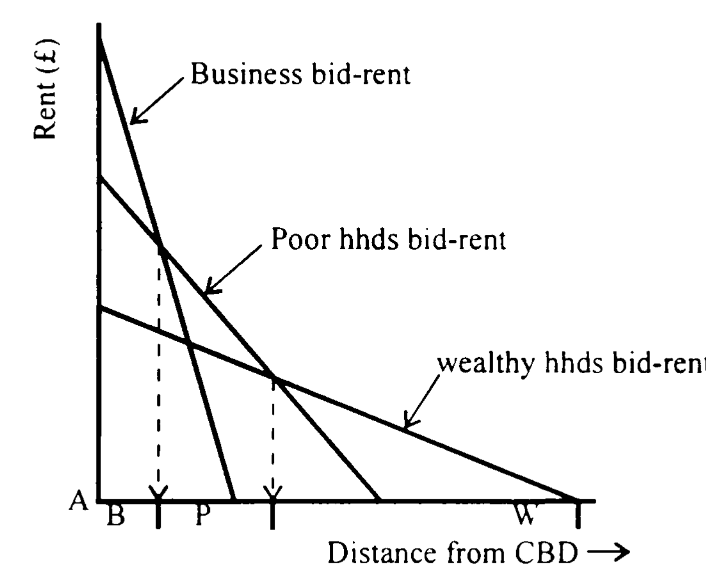
Figure 2.2 (b) shows the typical pattern of land use that emerges from locators maximising their utility, and landowners maximising their profit from this 'bid auction' behaviour. It can be seen that this pattern will lead to a concentric pattern of land uses. Business (B) has outbid residential uses close to the core. However, poor households (P) have outbid richer households (W) by being prepared to live at higher densities to reduce transport costs.

Figure 2.2: Graphs showing basics of urban economic theory (adapted from Button, 1993).



Note that whatever the cost of transport and rent, the auction process will mean that a fixed amount is spent upon them.

Figure 2.2(a): Graph showing 'Complementarity'.



The land use pattern has business (B) closest to the centre, then lower income hhds (P), with the suburbs consisting of wealthy hhds (W).

(A) is the agricultural value of land

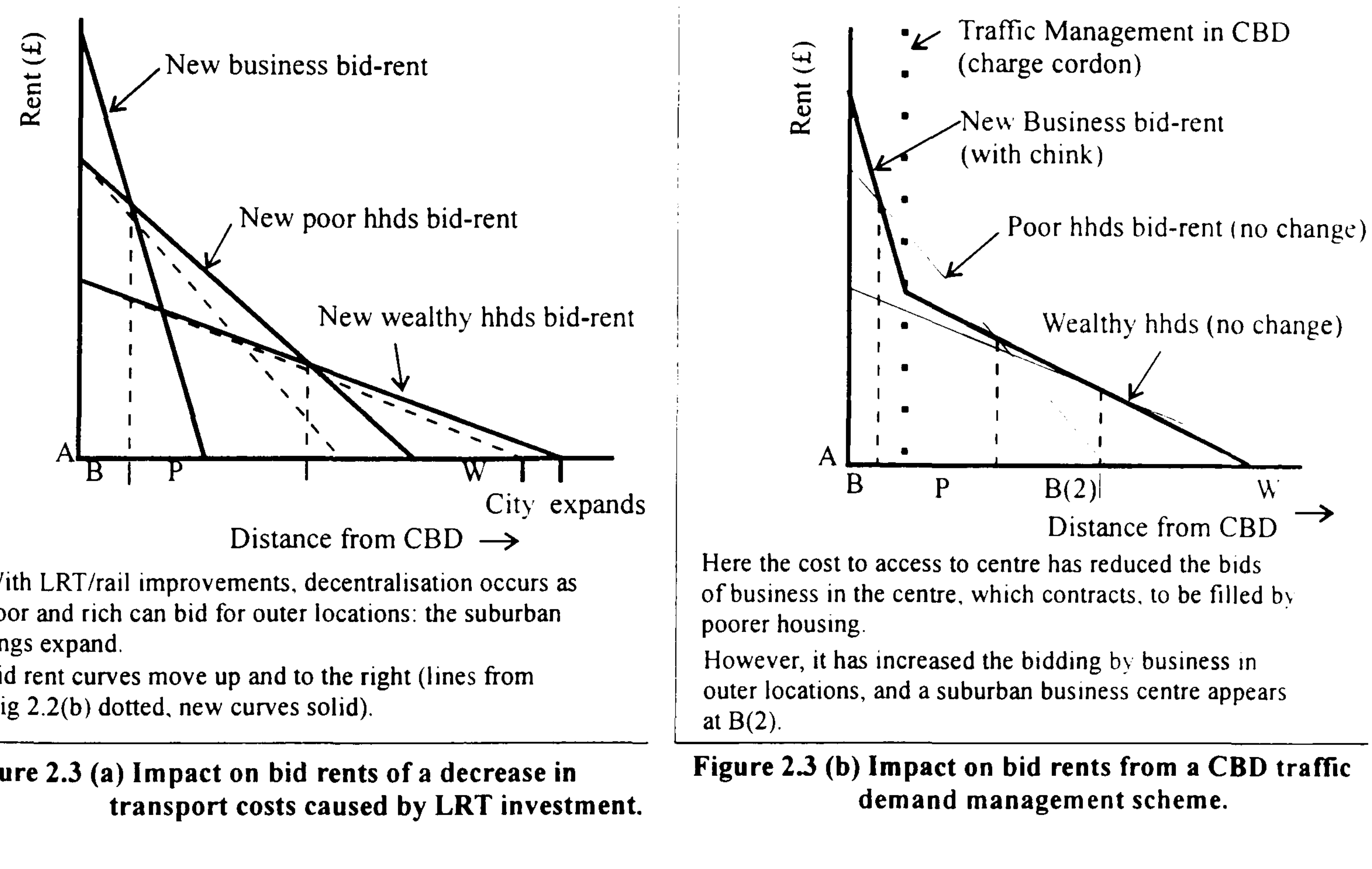
Figure 2.2(b) Bid-rent curves forming concentric land uses

The theory can be used to illustrate the impact that transport has on land use. At the margin any savings in transport costs will be transferred to land as rent (as the bids for land can increase). A decrease in transport costs (for example from a widespread rail or LRT improvement programme) will decrease the overall transport component in individual budgets, and allow more money to be spent on land and/or travelling further. The result is shown in figure 2.3 (a). All the 'bid rent' curves move up and to the right, and hence the city expands (which can be seen as a mechanism of decentralisation).

Figure 2.3 (b) shows the impact of a demand management policy that discourages travel into the CBD. Clearly the impact of this would depend upon the form of its implementation. In a simple case for example, a rise in costs for all travel in and out of the central area could be predicted to reduce business bidding for the central site. While households bid for small sites in the city centre to off set their rise in travel costs, the displaced industry establishes a suburban business district 'ring' at B(2).

Urban economic theories can be used to illustrate the impacts of transport costs on land use, and present a broad explanation of how economic and spatial systems operate and evolve. Given the bid-price preferences of individuals, and transport costs, they will calculate the distribution of land uses, and the rents that lead to such a distribution. The model is optimising, in that it predicts the equilibrium, normative outcome of households maximising their utilities under budget constraints. The theory focuses upon market mechanisms, land prices and behaviour, and the role of accessibility, all of which were identified as important at the start of this chapter.

Figure 2.3: Graphs showing the impacts of transport improvements and management schemes (adapted from Button, 1993)



With LRT/rail improvements, decentralisation occurs as poor and rich can bid for outer locations: the suburban rings expand.
Bid rent curves move up and to the right (lines from Fig 2.2(b) dotted, new curves solid).

Figure 2.3 (a) Impact on bid rents of a decrease in transport costs caused by LRT investment.

Here the cost to access to centre has reduced the bids of business in the centre, which contracts, to be filled by poorer housing.
However, it has increased the bidding by business in outer locations, and a suburban business centre appears at B(2).

Figure 2.3 (b) Impact on bid rents from a CBD traffic demand management scheme.

However, there are several drawbacks to applying urban economic theory to solve planning problems. Firstly, the many simplifying assumptions are very restrictive. In particular, the treatment of space as a uniform variable is unrealistic, and leads to a severe limitation in representing any spatial policy. Secondly, transport is given a pivotal role in being a key determinant of land value. However, this ignores the other complex interactions of social, environmental and political influences. Thirdly, the model represents individual behaviour. This would quickly become difficult in large urban systems, as demand curves cannot simply be aggregated, since this would assume that all individuals have identical preferences. Finally, the equilibrium nature of the models is open to question. Evans (1973) comments that given the barriers to moving location, and the distortions in the land market, equilibrium is unlikely ever to occur.

De la Barra (1989) has commented upon the lack of 'operational models' to be developed following this theory, as once economists have established their theoretical framework, they then tend to use linear econometric models for their empirical work, for example establishing relationships between density and distance from the city centre. It is very difficult to use the theory to represent actual cities due to the limiting assumptions discussed above.

2.3.3 Spatial interaction models

The second approach to the examination of how transport impacts on land use is via the use of spatial interaction models. The term 'model' is used, rather than theory, as there is no explicit theory that relates to the phenomenon being studied, rather it is a statistical interpretation of system organisation. These models are characterised by their treatment of space, where space is divided into discrete zones. Activities locate in each zone, and the zones interact via linkages between them, traditionally with interactions declining with increasing distance as in a 'weighted opportunities' accessibility function.

Although gravity theory was the first to be applied to a description of the urban system, the more common derivation of the models was the use of 'entropy maximisation' (Wilson 1970)[3]. The derivation of the models is not required for this study, the important issue being that the model finds the most 'probable' final state (entropy is the degree of likelihood of the final state of the system). There are several models in this 'family', depending on whether the pattern of trip generation is constrained at the origin, destination, or both. It is the 'singly constrained' versions that can function as a location choice model based upon transport costs. A typical example is shown below for an 'origin constrained model', where the origins are known, but not the destinations;

$$T_{ij} = O_i \ A_i \ W_j \ exp(-\beta \ c_{ij}) \qquad \text{(Eqn. 2.2)}$$

Where O_i are the trip origins for zone i, W_j is the attractiveness of destination zone j (usually some measure of floorspace or employment), and

$$A_i = [\Sigma_j \ W_j \ exp(-\beta \ c_{ij}) \ ]^{-1} \qquad \text{(Eqn. 2.3)}$$

This ensures that $O_i = \Sigma_j \ T_{ij}$, i.e. that the sum of the columns in matrix T_{ij} equals the origins to balance the matrix.

[3]The spatial interaction model form is very similar to a gravity formulation, only specifying a negative exponential cost function.

T_{ij} represents the interaction taking place between origin zone i and destination zone j. For an employment location model, once all the T_{ij} flows had been generated for the origin constrained model, they would be summed with respect to the destination to give the total employment (E) in each zone:

$$E_j = \Sigma_i T_{ij} \qquad \text{(Eqn. 2.4)}$$

A similar basis was used for the population location model developed by Hansen (1959):

$$dP_i = dP^t \frac{L_i(\sum_j W_j \exp(-\beta c_{ij}))}{\sum_i L_i(\sum_j W_j \exp(-\beta c_{ij}))} \qquad \text{(Eqn. 2.5)}$$

In this dP_i is an increment in population, allocated as a function of the 'potential' of the zones. L_i is the vacant land per zone, and dP' is the total population. Thus if there is no vacant land, no population is allocated.

It should be noted that in using these location models, the influence of transport is solely determined by the β 'dispersion' parameter, which operates in the same way as in the accessibility function from section 2.3.1. The closer β is to zero, the less the deterrence effect of transport will be on accessing opportunities.

The importance of transport costs to location is determined in the calibration of this parameter. Calibration is usually undertaken cross sectionally, for the base year (Foot, 1982). The relationship is then assumed to hold for future year predictions. It is in calibration that the jump is made from a theory or basic model, to an 'operational' model, actually representing an urban area. Calibration itself is not an exact science. Although techniques such as linear regression and maximum likelihood estimation can be applied, there is often a certain amount of *ad hoc* 'fine tuning' involved, which both implies that the modeller has prior expectations of the model outputs, and that the modeller has a detailed understanding of the workings of the model. This is discussed further in Section 2.5, and Chapter 8.

The most well known model to utilise spatial interaction modelling is the Lowry model (Lowry, 1964). Here an economic base mechanism supplies exogenous employment. Population is a function of total employment and service employment is in turn a function of population. Two singly constrained models allocate households (via accessibility to employment) and service employment (via accessibility to households *and* previously allocated employment). The process iterates until no more additional employment can be supported.

In summary, entropy maximising models can be seen to make the least prejudiced statements about the system being modelled, as they are essentially a process of 'statistical aggregation' (i.e. make very few assumptions about the behaviour of activities or processes in the systems). Hence the models are descriptive rather than causal, '*as the fundamental sources of variability are not subject to a causal interpretation*' (Williams, 1977, quoted in de la Barra, 1989 p. 64). De la Barra also emphasises the discrete nature of spatial interaction models. This has the advantage of using algorithms which can provide a better 'fit' to the data, rather than relying upon known continuous functions, as in micro economic modelling.

However, there are clearly some drawbacks. The lack of a behavioural framework means that no causal relationships can be established, and the lack of an economic framework means that the role of markets is ignored, which clearly misses some of the main mechanisms by which transport influences land use, as discussed in Section 2.2. As with any method which divides space into discrete zones, the size and division of zones needs careful selection as it determines the catchment for the 'weights', and the generalised costs. There is a fine (and often arbitrary) balance between data limitations and the desire for small zones, due to the danger of 'losing' much of the spatial interaction in larger zones.

2.3.4 Random utility theory (RUT)

The use of this theory in location choice modelling is very much the current state of the art (Wegener, 1994), and is used in most of the models discussed later in this chapter, as well as in Chapters 7 and 8. In fact, RUT is a merging of utility maximisation and spatial interaction modelling, hence providing a behavioural base for zonal location choices. The result is a 'discrete choice model' that works on the basis that the

> '*probability of* (activities) *choosing a given option is a function of their socio-economic characteristics and relative attractiveness of the option*' (Ortúzar and Willumsen 1994, p. 207).

The central concept is that individual perceptions of utility (represented as utility functions), can be aggregated under the assumption that group utility will vary around a mean value, reflecting the variability of the population. The aggregated utility function for a population thus appears as:

$$u^{gk} = U^g (X^k, \varepsilon) \qquad \text{(Eqn. 2.6)}$$

where u^{gk} is the utility group g obtains from choice k, U^g is the utility function for the group appertaining for all options of this kind, X^k represents the measurable attributes of option k and ε is the random variation in the utility function. The utility function represents all options in the choice set. A distribution function is used to represent the random variation. If a Weibull distribution (S-shaped plot) is applied, then the logit model can be derived. This is shown below, where P^{gk} is the probability that group g will select option k:

$$P^{gk} = \frac{\exp(\beta^g V^k)}{\sum_k \exp(\beta^g V^k)} \qquad \text{(Eqn. 2.7)}$$

Where V^k is the deterministic attribute of choice k, and β^g is the parameter (by group g) in the exponential function. This parameter is negative when representing costs (such as distance). Its calibrated value is related to the dispersion of the utilities. Note that this model appears very similar to the spatial interaction model in equation 2.5, and indeed the spatial interaction model can be reinterpreted using random utility theory (de la Barra, 1989).

Given its derivation, it is not surprising that RUT in its logit model form suffers from weaknesses already discussed in relation to the other methods. Perhaps most obvious is the concept of 'utility' which cannot be directly measured (being that which a locator seeks to maximise). Another issue is that while the Weibull distribution produces a conveniently simple model, there is not a great deal of empirical evidence to suggest that real distributions of stochastic terms are of this form. Bell (1994) argues that this is a case of convenience (of having a working, reliable model) outweighing theoretical elegance.

A recent theoretical advance has been the interpretation by Martinez (1991) of urban economic theory with a focus on the concept of consumer surplus. The willingness of a consumer to locate in a given zone is given by the willingness to pay minus the rent/price. This becomes the deterministic element V^k in the logit model. The central problem is then the derivation of the 'willingness to pay functions'. Ortúzar and Willumsen (1994) comment that this is a '*powerful and flexible*' model, but as will be discussed below, are still critical of its application in planning.

2.4 Operational models

2.4.1 Available models

The preceding section has outlined the basic building blocks by which location choices can be modelled taking transport into consideration. In fact, as Wegener (1994) argues, both the entropy and RUT models, at equal levels of aggregation, are directly equivalent, and are used in most models, although usually in a more complex form than has been discussed here.

All the models use the concept of accessibility to link land use choices, which usually means interpreting a change in the transport system as a measure of generalised cost. Hence other attributes, such as the image of an LRT system or concerns over road pricing, are ignored. Transport related environmental indicators are also ignored, unless they are included as a separate element in the utility function. Although generalised cost changes have been used as the sole influence of transport on travel behaviour (e.g. Bates, Brewer, Hanson, MacDonald and Simmonds, 1991), for location decisions factors such as environmental conditions and image intuitively appear important.

The operational models that incorporate these basic processes are summarised in table 2.1. This categorises the models by their treatment of time, their 'approach' to modelling land use, and the subsystems that they represent. The basic split is in the treatment of time. 'Static models' calculate changes to the land use system as a result of differing sets of accessibilities, without any explicit time component. Thus these models produce an 'instant' change to the city. Dynamic models incorporate a time component, and iterate between the land use and transport system over successive time periods. These models therefore generate their own forecasts of the future, whereas static models are of more use in 'scenario' testing (where one or more exogenous forecasts of future likely land use and activity patterns are developed and the transport implications of each examined).

For example the LUCI model (Simmonds, 1991) takes a set of output generalised costs (or accessibilities) from an existing transport model, and models the land use implications of the change in accessibility from the base to horizon year, or between two transport strategies predictions for the horizon year. IMREL[4] (Anderstig and Mattsson, 1992), usually linked to the 'Emme/2' transportation modelling package, calculates the future land use for use in subsequent transportation modelling. Simmonds (1995) comments that both models take relatively little effort to implement, and can simply be 'bolted on' to an existing transport study, with little change in the standard transport modelling methodology.

Dynamic models are altogether more complex, as they have to model the interactions between subsystems over time. As a result while static models can be almost as simple as equation 2.5, dynamic models must link demographic and employment evolution to urban development, transport policy and location choice. Dynamic models can be further categorised four ways by their treatment of the interrelations between the major subsystems. These are sequential submodels, unified approaches, micro simulation models and optimising approaches, as shown in table 2.1.

The 'Lowry-type' models were derived from entropy principles and Lowry (1964). LILT[5] (Mackett, 1991) is essentially a 4 stage transport model with a Lowry model, and in addition models changing jobs and housing. DRAM/EMPAL[6] are the remaining elements of a more comprehensive model; ITLUP[7]. DRAM represents residential location choice considering

[4] Integrated model of Residential and Employment Location (Anderstig and Mattsson, 1992)
[5] Leeds Integrated Land use Transport model (Mackett, 1991)
[6] DRAM: Dynamic residential allocation model, EMPAL: Employment Allocation model (Putman, 1995)
[7] Integrated Transportation and Land Use Package (Putman, 1995)

land and accessibility, EMPAL represents employment location on a similar basis, although it does not have the random utility rationale that has been applied to DRAM (Putman, 1995).

Table 2.1: Classification of operational models (adapted from Wegener, 1994)

Treatment of Time	Model / Approach	Systems Modelled	Main Mechanisms	Policies Modelled
Static (incremental)	LUCI (composite)	Population/hhd location Employment location	Random utility in location choice, market clearing with endogenous price changes	Land use policy related to space constraints
Static	IMREL (composite)	Population/hhd location Employment location	utility optimising function for location choice.	Unknown
Dynamic (5 yr. steps)	LILT (Lowry)	All subsystems	Initially entropy based, Lowry formulation. Land use equilibrium, no modelling of markets.	Land use policies Travel cost changes Infrastructure changes
Dynamic (5 yr. steps)	DRAM/ EMPAL (Lowry)	Employment Population Land Uses	Random utility underpinning of DRAM.	Land use regulations via zoning only
Dynamic (5 yr. steps)	MEPLAN/ TRANUS (unified)	All subsystems	Random utility for location choice, input / output model and economic base model. Simultaneous solutions	Land use policy Travel cost changes Infrastructure changes
Static or Dynamic (yearly)	METROSIM (unified)	All subsystems	Random utility for location choice, economic underpinning of all relationships.	Land use regulations focusing upon economic cost/benefit
1991 version static, new version dynamic	5-LUT[8] (unified)	Population Housing Transport network and travel representation	Random utility for location choice, hybrid with micro economic underpinning of all relationships.	Infrastructure changes focusing upon economic cost/benefits
Dynamic (2 yr. steps)	IRPUD (microsim)	All subsystems	Random utility with land use equilibrium. Activity based household changes with microsimulation	Land use policies Travel cost changes. Infrastructure changes
Dynamic (period unknown)	MASTER (microsim)	Employment Population location Housing Transport choices	Micro simulation of choices using Monte Carlo simulation	Unknown
Dynamic	POLIS[9]: (optimising)	Employment Population Housing Land Use	Random utility Locational surplus	Land use policies Infrastructure changes

Notes:
- composite: refers to an approach based on discrete autonomous submodels.
- 'All subsystems' refers to modelling transport networks and travel, employment, population, housing, workplaces, and land uses.

The second category involves a much more unified approach to the land use transport system, treating it as a series of markets. TRANUS and MEPLAN are very similar, and have been subject to much review (e.g. Simmonds, 1994, Hunt and Simmonds, 1993). The economic system is represented via an input-output model, a bid-rent Alonso type function

[8] 5-stage Land Use Transport Model (Martinez, 1991)
[9] Projective Optimisation Land Use Information System (Prastacos, 1986)

and a random utility model of location choice. All three elements are solved simultaneously for each period for which the model is run (Hunt and Simmonds, 1993). Finally, METROSIM is very new, and builds upon the strong economic foundations of Anas' previous location models (e.g. Anas, 1994).

The third category includes less economic theory, and attempts to model urban processes more explicitly as activities changing over time. Both IRPUD and MASTER (Mackett, 1990) use Monte Carlo simulation to locate residents. This process is random and determined by probabilities. IRPUD uses cohort survival to model demographic change over time, and takes economic change as external to the model (Wegener, 1994).

The final type are 'optimising models', of which the POLIS is a good example (Prastacos, 1986). These models are, as their name implies, fully normative and used for setting policy objectives within a unified modelling framework, as opposed to being able to examine transport impacts on land use.

Note that in addition to these 'operational' models are several packages that have been developed and used as training tools to illustrate the links between land use and transport. Two examples are the HLFM (Highways and Land use Forecasting Model), which is essentially a four stage transport model with a Garin-Lowry model (Horowitz, 1994), and PLUTO (Planning, Land Use and Transport Options). PLUTO represents land use and transport in a hypothetical circular 'city', and allows land use to respond to transport given an average transport cost function, development control policies, available space, fiscal policy and economic buoyancy (Bonsall, 1993). Both models are quick and simple to use (PLUTO especially so), and show the potential that simple models can have for illustrating the importance of transport impacts on land use to planners.

2.4.2 Model applications

Table 2.1 contains references to 11 models. Although this reveals a keen interest in examining the relationship between land use and transport, most models have been confined to academic interest, as opposed to entering mainstream planning use (Wegener, 1994, Southworth, 1995 p.59). Similarly, interview research undertaken in the USA, Germany and UK for this thesis revealed that very few applications have been undertaken that have had a direct policy commission (see Chapter 4).

In the USA, by far the most common application is that of DRAM/EMPAL, which has been used by USA Metropolitan Planning Agencies to conform to recent transport environmental impact legislation (see Chapter 4). The forerunners to METROSIM have also been used for private sector applications in New York (Anas, 1995), and POLIS was developed specifically for the Bay Area of governments in California.

Outside the USA, the MEPLAN model has been used in studies in Europe, and LILT has been used for examination of the impacts of the Channel Tunnel. The LUCI model has been applied to, among others, Edinburgh and Dublin, and IMREL was developed in connection with the Stockholm regional authority. However, the fact that the models incorporate land use and transport interactions does not mean that the planning study is explicitly interested in the impacts of transport on land use, as will be seen in Chapter 4.

Several of these models (MEPLAN, LILT and IRPUD) were also used in the 'International Study Group on Land Use and Transport Interaction' (ISGLUTI). This important study compared seven models and their 'calibrated' cities, and was reported in Webster, Bly and Paulley (1988). The key findings of this study regarding transport impacts on land use are discussed in the next chapter. The second phase of the study involved applying various models to the same city (e.g. Mackett, 1991, Wegener, Mackett and Simmonds, 1991), and one model to various cities (e.g. Echenique, Flowerdew, Hunt, Mayo, and Simmonds, 1990). The summary of this lengthy study revealed the following points concerning the operational use of these models:

- In general there was an "encouraging" amount of agreement when several models were applied to a single dataset (city). However, agreement concerning impacts declined as knowledge, especially of certain behavioural aspects, decreased. Agreement also declined as the number of variables involved increased, e.g. as in the relocation of population.
- It was found that;

  'because the initial transport impacts of a policy may be modified drastically by the subsequent land use effects, it is important to establish the correct links between the transport and land use components of the model' (Webster *et al*, 1988, p.215).

  This led the team to consider whether the more factors other than just accessibility should be considered in the models. However, the main alternative factor felt to be significant was available land, which was also incorporated in several models. Alternatively, other location influences (such as environmental quality) may be under represented, a point raised earlier in this chapter.
- There was some evidence to suggest that the feedbacks from transport affecting location choice in the models were too influential. This means that while the models may forecast changes in the expected direction, more work is required to gain confidence in the magnitudes of the predictions. An example of this was the large population decentralisation predicted by LILT, MEPLAN and IRPUD for Dortmund (Wegener *et al*, 1991).

2.4.3 Reasons for lack of use

What are the reasons for this lack of use in practical planning? Several reasons can be identified from the literature; (1) data availability, (2) calibration issues, and (3) lack of validation of the results and practical value to planning. These are discussed in turn.

These models have very precise and detailed data requirements. In the UK case, the detailed disaggregation of demographic or employment data is often not available directly from published, or on-line sources, and has to be estimated (Chapter 8 outlines this task in more detail). These issues are compounded if the zoning is highly disaggregate. Furthermore, data on land use and rents are often not consistently collected, and must be pieced together from available sources. This increases considerably the effort and cost of assembling the data for the models.

Calibration of these models is also complex, but does vary from model to model, as outlined in a review of models by the Hague Consulting Group (1991). For example MEPLAN uses the 'standard' techniques of least squares estimation (for linear functions) and maximum likelihood routines (for non-linear functions). However, the fact that 'everything affects everything else' means that the calibration must be effectively simultaneous, and furthermore, that 'externally calibrated' relationships cannot be introduced consistently, as all the variables in the model are interrelated for one time period (Simmonds, 1994). Calibration is thus complex as it requires fitting a predetermined specification against as much observed data as possible.

One further point is that calibration of dynamic models often relies upon cross sectional data (either because, as in the case of MEPLAN, the model requires it, or because data on processes over time is rare). Therefore changes in preferences over time are ignored, even in 'dynamic' models ('dynamic' thus refers to the interactions of the submodels over time). Southworth (1995), argues that more work is required on calibration of temporal relationships.

The validation of land use transport models is also a subject of much debate. Firstly, as Wegener (1994) observes, there have been very few published validation exercises. One example is Hunt (1994), attempting to validate the MEPLAN model of Naples. This concluded that a good fit could be achieved, but at the cost of considerable effort (a team of four over 18 months). Southworth (1995) reported reasonably good R^2 fits from regression validation for ITLUP and POLIS, especially for absolute values, but much worse for rates of change. He concluded that model validation is a key issue for further study, which needs to be treated in conjunction with calibration. Ideally, as Wegener (1994) comments, the model should be assessed on its performance over a period at least as long as its forecasting period.

A central focus of this thesis concerns the applicability of land use transport models to planning. From the available literature, it would appear that such models are not widely used, partly for the technical reasons outlined above. Ortúzar and Willumsen (1994) comment that land use response modelling is far from accurate, and that its internalisation in models is unlikely to make it more robust. However they stop short of condemning the use of such models in planning, instead focusing upon the need for reliable data.

There are also more general reasons for scepticism towards such models, recently summarised in Lee (1994). He criticised models for their inherent *complexity* (that not even the modellers could explain the results), their claim to be *general purpose* (which lead to unnecessary complexity), and their *centralising influence* on decision making for (American) planning decisions. Dynamic models do not in general include processes not used in partial models, but the linkages mean that dynamic models are considerably more complex.

Southworth (1995) concludes that land use planners in general do not have the skills and/or resources (for example to calibrate their own logit models), and puts this down to a lack of technical training and also the difficulty in using the models. Focusing upon the latter, he proposes adding interactive graphic based front ends to assist in the development of 'decision support tools'. GIS (Geographic Information Systems) would be a central component of this, and add to a framework to consider energy, emissions and fiscal issues as well as land use and transport.

2.5 Discussion of the use of models: a scale of understanding

From the above discussion it can be seen that land use transport modelling is inherently complex, as the phenomena that it is representing are also complex. Simple, static models exist, giving an indication of the changes, but by and large these are giving way to more complex dynamic models. It is in these models that the bulk of the current research effort lies. Moreover, front end 'easy-to-use' graphical interfaces and GIS facilities will also increase the complexity of the modelling system, even if they are not increasing the complexity of the land use transport model itself.

Southworth (1995) touched upon two issues that are important to this thesis. The first was the comment that planners do not have the relevant technical skills to implement complex land use transport models. While this comment was aimed at US planners, it can be hypothesised that the situation is the same in the UK (and Chapter 4 provides evidence of this). This is illustrated by the use of consultants employed to undertake modelling implementation, especially for transport or economic projects. Often the model is handed over to the client at the end of the project, and training provided by the consultant on use of the model, but local authorities no longer have the resources to undertake large modelling exercises 'in house'.

The second issue is the extent to which the land use transport model is suitable for the type of 'black-box' ready analysis that Southworth advocates as part of making the models easier to use. In other words Southworth argues that placing a friendly user-interface between the user and the workings of the model would encourage their use with planning. It is hard to see how this would assist the complex process of calibration or validation, and may in fact run the risk of encouraging the user to use the model in a less 'scientific' manner. Furthermore, making the model easier to use does not make it easier to interpret the results, if a thorough understanding of the processes involved is not maintained.

A lack of understanding of the processes and results of complex models was a central criticism by Lee (1994), and an issue that is central to this thesis. It is useful to categorise the range of possible understanding, as a guide to the skills required both to implement the model and interpret the results. However, as no similar work on this topic could be found, an attempt at such a categorisation, based around six 'levels' is given in table 2.2.

Table 2.2: A nominal scale for categorising the understanding and use of models in planning.

	'BOX' SCALE	Understanding of theory	Model implementation/ Interpretation Capabilities
1	**BLACK**	None	Undertake model tests
2	**DARK GREY**	Basic understanding of linkages and key variables	Undertake model tests, simple interpretation of results
3	**LIGHT GREY**	Basic conceptual understanding	Undertake model tests, basic interpretation of results
4	**WHITE**	Understanding of basic mathematics of theories	Able to construct dataset, run tests, interpret of results
5	**TRANSLUCENT**	Understand interrelations of model, and mathematics	Able to construct, calibrate, run tests and interpret results, some fine tuning
6	**CLEAR**	Full understanding and able to develop models	Able to design, construct, calibrate, run tests run and interpret results, fine tuning

The categorisation in table 2.2 begins with treating the model as a 'black box', in other words having no understanding of the underlying processes: Hence very little interpretation of the results are possible. Only if the model results are treated as 'the answer' can black box use of the model be maintained, as there is the inherent danger that conclusions will be drawn assuming relationships or assumptions not in, or treated differently by, the model. Land use transport models cannot be seen to give this type of definitive forecast.

At the other end of the scale, a 'clear' box represents a full understanding of all the interactions in the model, and hence the best possible ability to be able to interpret the results. Such a person is likely to be the developer of the model, and/or its calibrator. However, other skills are also important in explaining results, as will be explored in Chapter 8.

In between these two extremes four more points on the scale are given. A modeller's place on the scale would be determined by a host of factors based around their knowledge of the model, exposure to the model workings (aside from simply running the model), and their experience of attempting to interpret results. Clearly, both consultant modellers and planners should attempt to be as high on this scale as possible. For consultants it is necessary in order to implement the model, and explain its outputs. For planners it is important if they are to assess whether policy decisions can be recommended on the basis of the forecasts that the method produces.

This 'scale of understanding' is more exploratory than definitive, but does help to show that part of the problem with using complex models is not just the theoretical design, calibration and data collection, but also the ability to interpret the results correctly. This is the case on both sides of the planner/consultant relationship. There is a danger that, by making the model easier to use (but not easier to interpret), interpretation will pass to people with too little understanding as shown on the 'box scale', thus increasing the chances of spurious policy conclusions.

2.6 Conclusions

This chapter has reviewed the ways in which transport can affect the distribution of activities (i.e. households, firms and other users of land), and urban evolution. It was postulated that the nature of the transport policy will influence the degree and order of land use impact, and also that there are various indicators of land use response. The influence of transport on land use is bound up in urban land use transport interaction in general, which makes its analysis complex.

Three frameworks were discussed that model location choice taking transport as a prime determinant of urban form. The first, urban economic theory, provided an economic behavioural mechanism, but there are difficulties in translating this into a practical model capable of forecasting. The second, spatial interaction modelling, was strong in terms of providing a modelling base, but weak in terms of explaining the behaviour it was representing. These two have been combined using random utility theory, which provides a behavioural space for spatial models, and has been widely applied in current land use transport models.

These models tend to represent transport policy solely in terms of accessibility indices, of which variants on the 'weighted opportunities' index are the most popular. Underlying this is the notion that changes in transport can be represented by generalised cost alone. While this is considered adequate for transport only forecasting, the question was raised as to whether it is sufficient for land use response modelling.

These simple theories have been incorporated into a number of land use transport models, both simple and complex. Most recent research effort has been concerned with more complex models, representing land use and transport dynamically over time. However, the use of these models in practical planning applications was limited, as their complexity makes them unwieldy to use, and difficult to calibrate, validate and implement. As a result they have tended to remain in the remit of specialist consultancies and academic departments.

Several authors have commented that these models would be more likely to be used in planning if they were easier to use (via graphical interfaces), and more versatile if coupled with GIS systems. However, such added complexity was cautioned against, as it does not address the main problem of being able to interpret the model results. To begin to address this issue, a six point 'scale of understanding' was proposed, which postulates that an understanding of how the model works is fundamental to being able to interpret the results. From the evidence reviewed in this chapter, it is concluded that such skills appear to be concentrated in private consultancies and research institutions, rather than within the planning authorities themselves.

This chapter has outlined the basic theories that underpin the models to be used later in this thesis. It has initiated the argument that transport impacts on land use are not studied within planning, and that available dynamic land use transport models are not widely used. Simpler models of land use response also exist, but are less theoretically appealing. These issues will be returned to in later chapters. Before this, the next chapter examines the empirical evidence of how transport affects land use, and compares this to the forecasts from the MEPLAN, IRPUD and LILT land use transport models introduced in this chapter.

CHAPTER 3
EMPIRICAL AND OTHER EVIDENCE FOR TRANSPORT IMPACTS ON LAND USE

3.1 Introduction

The aims of this chapter are to review the evidence concerning the nature and scale of impacts that transport can have upon urban land use and activity patterns, in order to determine whether the impacts are important enough to warrant attention from strategic planners.

The chapter begins by introducing some of the complexities associated with studying transport impacts on land use. It then examines the empirical evidence, firstly in general terms, and then focusing on studies of urban public transport investment and road pricing. This empirical evidence is then compared to the outputs from the operational forecasting models introduced in Chapter 2.

3.2 Overview and difficulties in empirical assessment

This section highlights some of the problems in assessing land use impacts from transport. There are several key considerations, discussed in the following paragraphs.

The **timescale** over which impacts are assessed has a bearing on what impacts may be found. Transport moulds urban development over the long term, but in the short term influences such as economic cycles can determine how prices change and when development occurs. This is problematic for the timing and duration of impact studies.

The **spatial extent** of impacts is important. Although a policy such as road pricing may have an immediate impact within the cordon, it may also affect land uses outside the cordon (e.g. if activities relocate outside), or even land uses in neighbouring or competing towns. Empirical studies that focus on the city centre may miss these 'secondary' impacts.

Many other **related variables** that can influence urban development are changing at the same time, making it difficult to isolate the effect of transportation alone. This includes economic cycles (both nationally, regionally, and within the city), investments made for political reasons, social change and technological innovations. Economic influences are extremely important, as without an underlying rate of growth, new development is unlikely with or without changes in accessibility.

A careful choice of **impact indicators** must be made. Such indicators could relate either to land (and floorspace) or activities. The former includes new development or land prices. The latter include the types of activity, or can incorporate land data with measures such as employment or residential density or turnover per square metre. Often however, attempts are made to obtain more indirect indicators such as costs of jobs created, or economic performance indicators.

The **interactions between land use and transport** mean that second order and linked responses occur. For example, increases in accessibility may induce traffic and hence worsen accessibility in the short term. Land use development can compound such effects over the longer term, but tracing impacts back can be difficult.

It is apparent from this list that to study land use effects requires some prior knowledge of what such impacts are likely to be, and also significant resources to conduct a full study. The main methodologies that can be applied are as follows:

1. 'before and after studies', which examine the distribution of activities prior to a transport policy, and then for a period afterwards. The Metrolink monitoring study (Law, 1995), Linneker and Spence's (1991) study of the M25 or Giannopoulos and Pitsiava-Latinopoulou's (1985) study of road impacts in Greece are examples of this type of research. The main challenge is in estimating what would have occurred without the transport policy, i.e. what the counterfactual situation would have been;
2. 'comparative' approaches, that aim to compare an area where a transport policy has been implemented, to a similar area where it has not;
3. 'similarity' studies, that aim to find common impacts from similar transport policies in different urban areas. This has been the aim of many *reviews* of transport impacts, such as Grieco (1994) and Dickins (1987, 1988), and also the Payne-Maxie (1980) study of US beltway (ringroad) impacts;
4. less rigorous forms of analysis, such as empirical and descriptive observation studies. For example Hall (1966 and 1989) in his discussion of London, or Giannopoulos and Curdes' (1992) description of transport's influence in shaping eight European cities. These studies tend to bear out the observation from Hoyt (1939), that urban form is a product of the dominant transportation modes during a city's highest period of growth (Cervero and

Seskin, 1995). Note that this type of analysis tends consider change over periods of time that are too long to be of key interest in structure planning, and hence are not considered further in this discussion.

The first three types generally use statistical techniques to search for relationships between accessibility change and activity change. However, the central problem with all these methods is in being confident in attributing a land use change to a transport cause. In other words land use change can be 'associated' with a transport scheme, but not easily 'attributable' to it (Bonsall 1991). Table 3.1 presents examples of the studies discussed in this research, and the methodologies applied, while table 3.2 presents the reviews of these impact studies.

Table 3.1: A summary of impact studies (see Button, 1993 p.226 for additional examples)

Author	Methodology	System/City	Comments
Botham (1980)	Statistical before/after	Roads and economic growth (employment)	Road programme had small centralising influence on employment.
Davoudi *et al* (1993)	Statistical before / after	Tyne and Wear metro	Property markets little influenced by metro, despite changing accessibility. Helped strengthened city centre
Dodgson (1974)	Statistical (before/after M62)	M62	Positive relationship between lower transport costs and employment growth
Dyett *et al* (1979)	Various	San Francisco, BART (Bay Area Rapid Transit)	Decentralisation
Gentleman *et al* (1980)	Before and after	Glasgow metro	Reversal of downward trend in house prices in areas near stations. Some new development.
Giannopoulos and Curdes (1992)	Historical overview	Athens, Bari, Aachen, Liverpool, Tromsö, Kecskemet, Thessaloniki	Towns have high resistance to change, but transport innovations have left significant marks on urban form.
Green and James (1993)	Statistical	Washington metro	Price premium on development near metro stations
Hall (1966,89)	Historical overview	London /rail/car	N/A
Haus-Klau (1993)	Before and after case study	Traffic calming and pedestrianisation in UK and German cities	Retail concern over implementation, but generally environmental improvements had positive effect.
Keibich (1978)	Before and after	Munich, U-bahn	Service centralisation, residential decentralisation.
Landis, Guhathakurta and Zhang (1994)	Statistical: Hedonic price model	San Francisco, BART (after 20 years)	Small house price premium near BART stations. Smaller impact than that associated with road improvements
Linneker and Spence (1991,96)	Statistical before/after	M25, market potential	M25 has affected accessibility in UK and London. More detailed affects depend upon accessibility measure used (e.g. distance/time)
Moon (1990)	Comparative	San Francisco BART, Washington Metro	Evidence of suburban office and retail decentralisation to stations.
Morisugi, Ohno, Miyagi (1993)	Modelling to measure benefit incidence	Gifu City, Japan, Inner city ring road	Residential suburbanisation, and commercial centralisation. Commercial sector much more sensitive that residential
Mullins *et al* 1989	Before and after	Houston, HOV (High Occupancy Vehicle) lane	No significant impacts

Table 3.1 Continued/

Author	Methodology	System/City	Comments
The MVA Con and ECOTEC (1990)	Statistical	Rail electrification	Rail improvements caused house prices in affected areas to rise faster
Nelson and McClesky (1990)	Statistical before/after	Atlanta, MARTA[1] rail	Increased suburban house prices along MARTA lines
Damm *et al* (1980)	Statistical house prices	Washington State, road infrastructure	High access areas have price premium.
Giannopoulos and Pitsiava-Latinopoulou (1985)	Empirical before and after study	New roads around Athens, Larisa, Thessaloniki	Major developments in commercial sectors. Little housing effect. Changes at junctions most marked, changes within 10 years
Pivo (1990)	Statistical	Toronto, subway	Station proximity important in encouraging commercial development.
Potter (1979)	Before and after / empirical	Atlanta, MARTA rail	Increased high rise development along MARTA line (but route also main road: Peachtree street)
Simon (1987)	Before and after /Survey of local firms	Humber bridge	Mostly impacts on local economy, little impact on employment, but surrounding area in decline.
Payne-Maxie, (1980)	Similarity / statistical analysis	27 US Beltways in a sample of 54 cities	Positive, but mixed results, due to effects of city size, land availability and economic vitality
Voith (1993)	Statistical/ empirical	Philadelphia, SEPTA[2] rail	Suburban housing price premium near SEPTA rail stations.

Table 3.2: A summary of reviews of impact studies

Author	Impact / systems studied	Comments
Cervero and Seskin (1995)	Rail impacts	New rail impacts limited, and mostly redistributive, and incapable by themselves of bringing about lasting changes
Cervero and Landis (1995)	US rail and road impacts (in California)	Some capitalisation benefits from transit schemes, but broad generalisations not possible
Dickins (1987)	LRT impacts in the USA	LRT can bring about urban change, but dependant upon 'image' and a supporting policy package
Dickins (1988)	LRT impacts in Europe	Less study of impacts, but findings generally support Dickins (1988)
Grieco (1994)	Impacts on the inner city	No clear link between transport and economic development, but may be redistributive impacts. Lack of assessment frameworks
Knight and Trygg (1977)	LRT impacts in North America	Little evidence of increases in overall development of urban area, local government policies important for local impacts
Parkinson (1981)	Road impacts in UK	That land use impacts are difficult to assess as part of justification of a road scheme
Walmsley and Perrett (1992)	LRT systems in Europe and USA	Impacts are possible if tied into comprehensive development plans

3.3 Overview of common conclusions from empirical studies

There is a general perception that transport is important in influencing location decisions, and this perception has long shaped both regional and urban development policy (e.g. Commission of European Community, 1993). However, this perception, especially on the

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[1] MARTA: Metropolitan Atlanta Rapid Transit Authority's light rail system.
[2] SEPTA: South East Pennsylvania Transit Authority's rail network.

urban scale, is not generally supported by the empirical evidence. The main argument against transport having a large impact can be summarised as follows:

- transport costs are only a small part of a firm's costs relative to production costs, at around 2-5% (Diamond and Spence, 1989), such that the importance of incremental transport improvements is largely insignificant (Parkinson, 1981);
- furthermore, in most urban areas, accessibility levels are generally so high (due to motor vehicle based accessibility), that transport policy has an insignificant effect on accessibility (this is a reason given for the failure to find strong statistical relationships between accessibility and employment, as in Botham's (1980) study of the national road network, and Dodgson (1974) for the M62);
- this is coupled with the fact that urban areas generally suffer from a shortage of available or suitable sites, which reduces the chances of impacts (Buchanan, 1980, Walmsley and Perrett, 1992);
- transport polices are usually proposed to cater for existing demand (often in form of congestion), implying well established patterns of demand and hence the short run effects would expected to be small (Buchanan, 1980);
- the commercial sectors are generally more sensitive to transport than the residential sectors (Cervero and Seskin, 1995), as predicted by urban economic theory (Section 2.3.2, page 9), but even in these sectors, the impacts from transport projects are more likely to be redistributing activities that would locate within the study area anyway (Grieco, 1994). Whether this is important is dependent upon the spatial scale of policy objectives;
- transport's effect on economic activity can be negative, as improved accessibility allows a local economy to be penetrated, and local residents to travel elsewhere, which may weaken the 'target' area (Grieco, 1994);
- prevailing urban trends are important. For example Lineker and Spence (1996), found the M25 has encouraged economic development locally, but that this was part of a wider counter urbanisation trend in London;
- many other factors influence location choice, making transport a 'necessary but not sufficient' factor in encouraging development, (Guiliano, 1989).

These types of findings may be part of the reason why the influence of transport on land use has generally tended to be neglected in urban planning. As can be seen from tables 3.1 and 3.2, only a small number of the studies concluded that significant impacts had occurred, and then a number of supporting policies had to be in place. This means that, in developed countries, to invoke any impacts a comprehensive planning approach is required. The factors focus upon; (1) collaborative land use and/or fiscal polices to encourage development near the scheme, and discourage it elsewhere, (2) environmental improvements so that the 'image' of the area is attractive, and (3) availability of suitable sites.

However, there are factors that affect the probability of transport related development occurring that are largely beyond the planner's control. The main factor here is underlying economic growth. Studies that have attempted to examine the urban regeneration impacts of transport in economically declining areas (e.g. Grieco, 1994) have generally failed to find much evidence that transport can effect a trend reversal. If there is to be any chance of regeneration, then transport policy must be combined with more direct re-skilling and job creation policies (Parkinson, 1981).

Wegener (1995), comments that this lack of empirical evidence is extremely inconvenient at a time when planners are looking to merge land use and transport planning to reduce the environmental externalities of car use. He argues that the reason empirical studies fail to find a strong relationship between development and transport is due to the 'abundant' nature of accessibility, as outlined in the bullet points above. He compares the situation in Tokyo, where practically all commuting is undertaken by rail, and residential land rents are entirely determined by rail travel time into central Tokyo. Thus accessibility becomes important whenever it is a scarce resource.

Summarising main findings in this way does tend to present incremental transport policies as generally having a small influence on urban development when accessibility is high. Hall and Banister (1995), conclude that these impacts are generally insufficient to have significant impacts on employment growth or the local economy. However, the long run historical evidence does show that transport can be a central moulder of urban form, especially during times of transport innovation. Certainly there is still a perception that transport can be an important *contributory* factor in shaping urban form. Harrison (1991), goes so far as to suggest that capitalisation of rental increases from accessibility increases could form the basis of an efficient taxation system.

Perhaps the key point to draw from the current empirical evidence is that given ubiquitous nature of accessibility, transport impacts are slight. However, if accessibility begins to become limited (through congestion, cost or pricing) then transport will increase its importance as a determinant of urban form.

3.4 Overview of the impacts from light rapid transit (LRT)

There has been a great deal of research into the impacts that rail based transit systems have upon urban development, as seen in table 3.1. For example, Cervero and Seskin (1995) cite over 30 studies of individual transit schemes in the US. This plethora of research is partly to determine whether such impacts do exist, as LRT schemes are still partly justified on their economic potential, (Law and Dundon-Smith, 1994), and partly to find other benefits to assist in justifying transit schemes wanted for other traffic and environmental objectives.

3.4.1 Economic and employment impacts from LRT

The research has tended to focus upon market indicators such as property values or rents, employment densities, and new development. However there have also been attitudinal surveys assessing the importance of LRT in more qualitative terms, such as Hall and Hass-Klau (1986).

Much of the research has failed to find significant impacts. The most thorough UK review remains that of Grieco (1994). In fact, this study was undertaken in 1987, but Grieco comments that since that time *'no new major arguments have been advanced on either side of the fence'* (p. vii). She also warns against taking US conclusions and applying them *a priori* to the UK (Grieco 1994, p.8), primarily for reasons of urban scale and population densities. Grieco's public transport conclusions are predominantly negative. She cites Robinson and Stokes (1986) on the Tyne and Wear metro, and Hall and Hass-Klau (1985), both of whom concluded that there is no clear link between infrastructure investment and urban economic growth. Indeed, Hall and Hass-Klau comparing eight European LRT schemes found that the British appeared more enthusiastic about the development potential of LRT than continental Europeans. They conclude that their questionnaire survey of planners' attitudes to LRT;

> *'confirms a disturbing general impression that significant decision makers in Britain, who should be drawing on good quality research, are simply basing their investment and location decisions on a hunch, in defiance of the evidence - fragmentary and poor as that may be'* (1985, p. 169).

The Tyne and Wear study (Davoudi, Gillard, Healy, Pullen and Robinson, 1993) found no significant evidence of employment or commercial price changes, especially compared to the importance of financial incentives, which encouraged new commercial development in the Enterprise Zone, which was not part of the Metro network. However, this study was undertaken during relatively depressed economic conditions. Added to this is the fact that the metro ran predominantly along pre-existing rail lines, to which land use adjustment may have previously occurred, and which may not coincide with areas where new development was likely to occur. This reason has also been cited for the negligible impacts from the Manchester Metrolink (Law, 1995)[3].

Studies from the US trace the lack of substantial impacts back to the small incremental impacts on accessibility. Dyett, Dornbuusch, Fajans, Gussman and Merchant. (1979) found that the San Francisco BART system offered no travel time advantages over car (in fact it was on average 35% slower). Similar findings exist for other US schemes (Cervero and Seskin, 1995), and this result appears to be due to the rail lines following major road radials. However, it is the case that public transport accessibilities are improved by LRT schemes, for example in Newcastle (Davoudi *et al*, 1993), and with BART.

Historically, continental European cities reflect a morphology shaped by the continued presence of transit systems over this century. Even so, Walmsley and Perrett (1992), studying transit schemes in France found little evidence of commercial transit-related development. In both Lyons and Marseilles, where high quality 'Supertram' type systems had been implemented, little development could be directly attributed. However, there were related developments such as city centre pedestrianisation (in Lyons) which may not have occurred without the 'carrot' of the rail system.

Economic impacts that have been isolated tend to be relatively minor. BART, the Glasgow Metro (Gentleman, Walmsley and Wicks, 1980), the Munich U-Bahn (Kreibich, 1978), the Atlanta MARTA (Potter, 1979) and the Toronto metro all caused small price enhancements around stations and in urban cores. In terms of encouraging commercial development, perhaps the best example is the Washington DC metro, where Walmsley and Perrett (1992) quote results that metro station catchments (2% of the greater Washington region), captured 43% of the region's commercial development, between 1980-86. This includes both the central business district (CBD), and large suburban developments such as Silver Springs. However, Walmsley and Perrett point out that these impacts are not unexpected:

> *'these effects should be viewed alongside the fact that the metro cost $5,500m and is one of the finest systems in the world in one of the finest capitals. It is unlikely that many other systems could be more attractive to developers'* (1992, p.58).

A significant amount of interest has focused upon Toronto, where subway development was accompanied by complementary pro-development policies near stations (the 'Density Bonus'), and controls elsewhere both on land use development and car parking (Knight and

[3]Although Metrolink themselves reportedly attribute 3000 new jobs to the Metro, and £60 million of private investment (Planning Week, 1997 p.15)

Trygg, 1977). Coupled with a healthy economy, in Toronto the subway did revitalise derelict areas and recycled existing commercial cores. Another important feature here is the existence of a comprehensive regional development plan (from 1976), combining both the city centre and the commuting suburbs. This, and later plans, aimed to retain the dominance of downtown, but as part of a multi-centred area, interconnected by public transport routes. Statistical research by Pivo (1993) concluded that proximity to a transit station was one of the most important elements in developing a physical planning policy for the area.

Walmsley and Perrett (1992) also conclude that any public transport scheme must be part of a series of measures to regenerate the urban area, preferably with a strong policy of combined land use and transport planning. In Marseilles, Grenoble and Sacramento, incentives were offered to develop near stations, and disincentives imposed on developing elsewhere. Other associated planning policies include environmental improvements around stations, relaxations in the zoning regulations, and tax or business rate incentives. The impact of local policies in attracting growth is most evident in the UK Development Corporations from the 1980s. This type of 'leverage planning' (Brindley, Rydin and Stoker, 1989), focused at an early stage on the need to improve communications to Docklands, and it was the combination of the Docklands Light Railway with strong planning powers and a great deal of money (via tax incentives) that encouraged growth in Docklands.

Little evidence exists of transit assisting in regenerating declining urban areas. In Atlanta, development was encouraged around the stations, with differing incentives for deprived areas. Even so, MARTA was more successful at generating growth on the N-S axis than regenerating the poorer E-W axis (Potter, 1979). Walmsley and Perrett conclude that transit can intensify existing trends, i.e.;

'transit may stabilise an area, but will not reverse the decline' (1992, p.127)

They cite an example in Lille, where a declining industrial area (Hellemmes) showed no sign of development five years after the transit system was implemented.

Furthermore, the growth due to metro stations must be placed in the context of the growth in development around road developments. For example the development associated with BART since 1972 is about 9 million sq. ft (within 800m of a station). This compares to 35 million sq. ft. built in areas unassociated with BART, but with good road accessibility (Cervero and Landis, 1995). In Tyne and Wear, many developments attracted to the Enterprise Zone were specifically tailored to car access anyway (in particular retail/warehouse parks), and would therefore not have considered the metro in their location choice.

Note that these policies are focused upon economic growth in particular areas within the conurbation, rather than to attracting new growth to the wider urban area from competing conurbations. Most important for the latter is the image of the area, to which new investment in public transport can contribute. Dickins (1987), gives a more positive assessment of LRT development impacts and claims that LRT is important in enhancing the image of an urban area. The investment acts as an advertisement, a symbol of a 'high tech and progressive' approach and a commitment to invest in an urban area from the local authority. However, Dickins admits that quantifying the benefits of an image is extremely difficult.

Finally, an issue dealt with in Cervero and Seskin's (1995) review of transit impacts on land use is whether transit schemes can lead to **absolute economic growth**, or whether they redistribute existing growth. Their conclusion was that most studies believe that transit related growth is redistributive, (if construction benefits are ignored). However, Cervero argues that if rent capitalisation does occur then this conflicts with this finding, unless there is a compensating decline in property rents away from transit routes. For social and economic strategic planning, recognising and understanding this pattern of gaining and losing areas is clearly important.

3.4.2 Residential and population impacts

The impact of schemes on **property values** is relatively localised. Dickins (1988) concludes that a station's sphere of influence is around 150-550 metres. Cervero and Seskin (1995) quoted results stating that BART positively influenced suburban residential prices (i.e. made them rise by up to 4%) up to around 300m from the stations. A hedonic pricing study confirmed these results hold 20 years after the opening of BART (Landis, Guhathakurta and Zhang, 1994). A study of the Atlanta MARTA heavy rail system obtained similar results (Nelson and McClesky, 1990) as did a recent study by Voith (1993) for the SEPTA rail service in Philadelphia.

The Washington metro has also showed similar results, with residences near stations appreciating faster than those further away, (Green and James, 1993). However there is the complicating factor that many of these metro station areas also have very good road access into central Washington. Finally, positive evidence also emerged from the study of the Glasgow underground, where Gentleman *et al* (1980), using the SASINES housing transaction database, found that:

'There is clear evidence, based on sales data, of a reversal of a downward trend in house prices, relative to the rest of Glasgow, in the areas associated with the new services.'

(Section 6.4, p. 10)

However, there is also less conclusive evidence. Cervero comments that hedonic models for San Diego and Sacramento found no relationship between property values and proximity to the rail lines.

3.4.3 Summary

1. Light and heavy rail systems are likely to be a positive selling factor for property located near to a station. Despite this, in terms of attracting development, transit systems are unlikely to persuade a developer to a location compared to fiscal incentives, or compared to high accessibility road locations.

2. A transit system with an associated fiscal package can be a good incentive to development, but only in Glasgow is there evidence that it reversed a wider trend in spatial relocation. Knight (1980) and Cervero (1984) list various factors that encourage development, and these are summarised in figure 3.1.

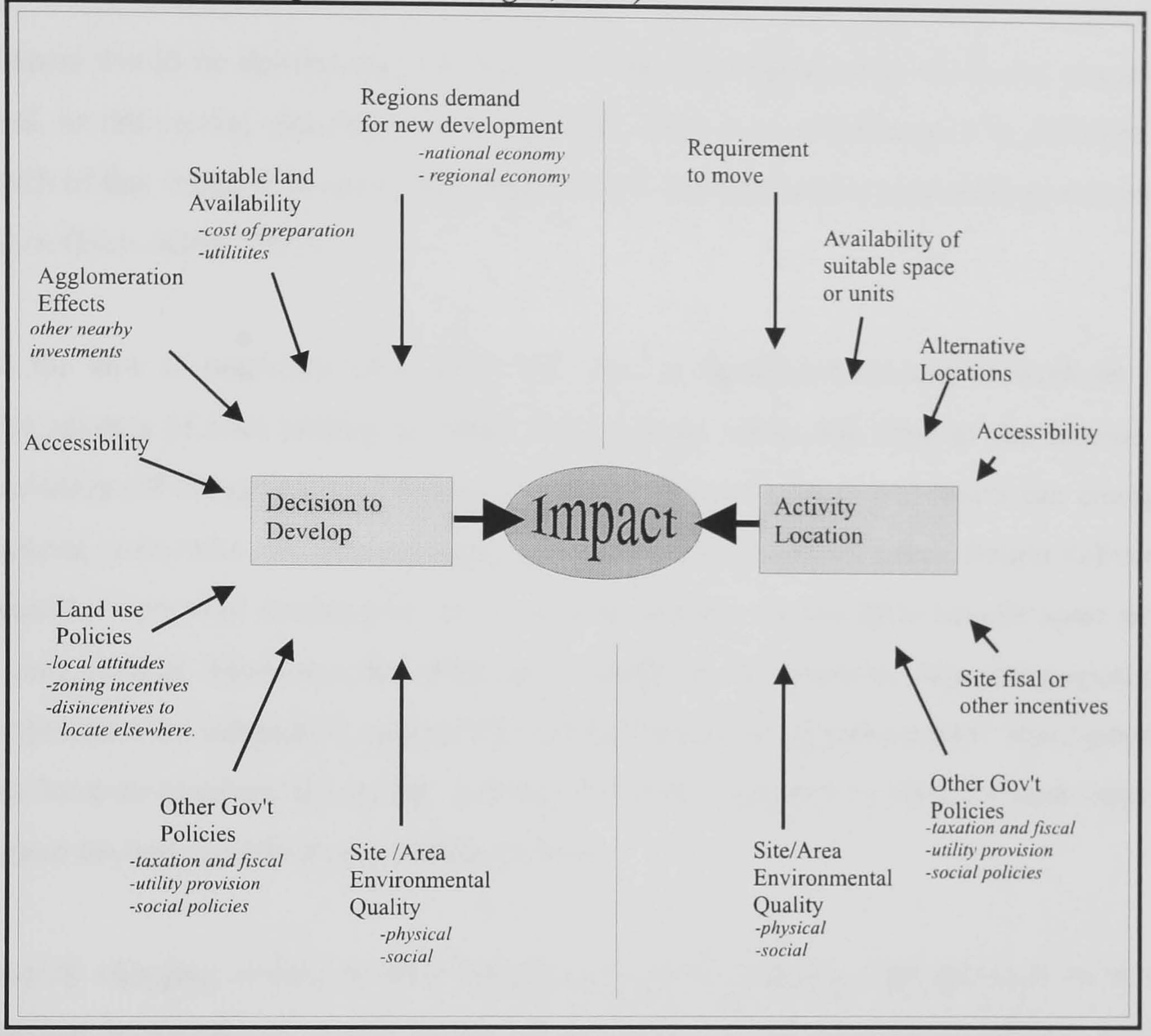
3. Transit's main influence is in intensifying existing trends, for example raising demand and prices for central office or retail locations, by allowing high capacity access (Priest, 1980). City centres are the main beneficiaries of transit schemes, clearly related to the CBD being the hub of most schemes (Cervero and Seskin, 1995). Evidence of residential decentralisation is more difficult to determine, due to the influence of private car ownership, and available housing supply. However, there is some evidence for decentralisation in Munich, Washington, Lille and Atlanta.

4. Scale of impact on new development is very much confined to a corridor level. However, if the network is extensive, or carefully planned, then the wider implications on urban development beyond the neighbourhood level become important.

5. Comprehensive regional planning, as outlined for Toronto, which combines land use and transport elements, clearly assists in achieving development objectives. This implies that understanding transport and land use interaction is fundamental to meeting wider objectives of a transit policy (i.e. objectives beyond just congestion relief). Dickins (1988) states that the chances of success are maximised if there is a single authority responsible for land use, economic and transit planning. Furthermore, policies such as

zoning can be much more powerful shapers of urban development, but may require transit to gain political and public acceptance.

Figure 3.1: The main factors influencing site development and location decisions (adapted from Knight, 1980)



3.5 Impacts from demand management (road pricing) schemes.

In contrast to transit schemes, there has been very little work undertaken on the development impacts of road pricing schemes, primarily because insufficient time has elapsed since implementation of those few schemes currently in place. In fact, 'road pricing' schemes have only successfully been implemented in three cities in Norway, and in Singapore. This has meant that there has been little empirical investigation of operational schemes. Flowerdew and Stevens (1994) have examined that evidence which does exist for Singapore, and found circumstantial evidence that the Area Licensing Scheme implemented there has had a positive effect on business activity.

An alternative method would be to examine the impacts of policies where similar impacts could be expected, such as parking restrictions or city centre pedestrianisation. However, little evidence of research into the land use impacts of parking policies could be found. perhaps because such policies are quite new, and have been implemented in conjunction with other measures. City centre pedestrianisation has been studied in terms of its impacts on retail activity, but very much on the local scale (e.g. Hass-Klau, 1993). The general conclusion from evidence from the UK and Germany was that local shopkeepers thought that the schemes would be detrimental, but that after implementation retail turnovers generally increased, as did central area retail rents. However, there is a problem here in determining how much of that increase is due to pedestrianisation, and how much to prevailing economic conditions (Hass-Klau, 1993).

Despite the lack of empirical data, there has been a significant amount of work on the potential impacts of road pricing on urban development. Given the aims of the scheme to price car users off congested road space, a complex chain of gainers and losers can emerge. For example, users who can pass on their rise in costs (e.g. business users, freight delivery) may benefit. Users who cannot pass on the rise in charges receive little benefit apart from travel time savings. Moreover, the effect on accessibility is uncertain, depending upon the balance between the congestion savings and the increase in travel money cost. Road pricing will also have environmental benefits, and this is a clear example of a policy whose impacts may extend beyond the effect on generalised cost.

The type of charging system is also important. Cordon charging systems, such as those hypothesised in Edinburgh (see Chapter 6), are likely to have boundary effects, where locations just outside the cordon are more attractive than those inside. This applies to all land uses, and especially parking. However, boundary affects will also be contingent upon the charging regime of the scheme, the pattern of local land uses, and travel patterns that the scheme is superimposed upon.

Flowerdew and Stevens (1994) undertook group interviewing and a questionnaire based approach to examine the range of land use impacts from road pricing. Three cities were examined; Birmingham, Leicester and Winchester. The interview results showed it was felt that the type of scheme would influence the impacts. However, if congestion reduction was achieved, the Winchester respondents believed that city centre office sector property prices may rise, whereas the retail sector would lose business to other towns, unless similar schemes were implemented in competing regional centres. There was concern in all the cities to avoid a single centre being penalised if it was alone in operating a charging system. There was no analysis of the impacts of road pricing on the quality of the urban environment.

The questionnaire was then subsequently distributed to experts or professionals, including businesses and estate agents, in these three cities. It asked about the impacts on property prices given cordon pricing. Overall the samples believed that within the cordoned area property prices would decline, the most sensitive being retail, then office, with residential uses being the least sensitive. Outside the cordon prices would increase, again with commercial sectors more sensitive. The higher the charge, the larger the predicted change in prices. It was clear that the expected impacts would depend upon scheme implementation; for example, if residents in a cordoned area were exempt from a charge, then residential property prices may not be so adversely affected.

If the evidence from the attitude surveys and pedestrianisation analogies are accepted, then there is likely to be some local resistance to implementation, but significant environmental improvements to the cordoned area. Despite this, higher access costs may discourage investment. On balance, whether road pricing will encourage activity or discourage it is largely unknown, although in Singapore there is some evidence that the ultimate effects were beneficial. The constraints implemented in the city centres of London (the anti-terrorist 'ring of steel'), Athens (to combat pollution), and in several cities in Norway (to pay for new road infrastructure) may begin to reveal a broader pattern of impacts. However, with all these examples, the certainty of continued implementation of the scheme is an important factor affecting land use response. For example, if the scheme is implemented on a trial basis, it is likely to have different (most likely lesser) impacts compared to a clear commitment to operate it for a decade.

3.6 Forecasts of LRT / management impacts from land use transport models

This section presents evidence from; firstly the ISGLUTI study, which was referred to in Chapter 2, secondly the results from the London Congestion Charging Research (using a MEPLAN model called LASER: London And South East Regional model) examining road pricing impacts, and thirdly work undertaken using LILT to examine rail service quality improvements in London. Section 3.7 then compares these results to the conclusions from the empirical evidence outlined above.

3.6.1 Forecasts from the ISGLUTI study

The results from the 'Phase 1' ISGLUTI study were published in Webster *et al* (1988), which described each model applied to its 'own' city dataset. However, of more relevance here are the comparisons between models and datasets, termed the 'Phase 2' tests. The models used are shown in table 3.3; their key characteristics were summarised in table 2.1 (page 17).

Table 3.3: Phase II applications and key models

Reference (from Transport Reviews)	Model(s) Used	Application	City Data
Mackett, Vol.11, No.1, 1991a	LILT, CALUTAS	Tokyo	Base year: 1975 Population: 27m Employment: 12m Urban area: 14,565 km^2
Echenique *et al*, Vol.10, No.4 1990	MEPLAN	Bilbao (also Dortmund and Leeds)	Base year: 1975 Population: 970,000 Employment: 322,000 Urban area: 355 km^2
Mackett, Vol.11, No.2,1991b	LILT MEPLAN	Leeds	Base year: 1971 Population: 497,000 Employment: 256,000 Urban Area: 162 km^2
Mackett, Vol.10, No.4, 1990b	LILT	Leeds (also Dortmund and Tokyo)	as above
Wegener *et al*, Vol.11, No.2, 1991	LILT MEPLAN IRPUD	Dortmund	Base year: 1971 Population: 1m Employment: 425,000 Urban Area 833 km^2

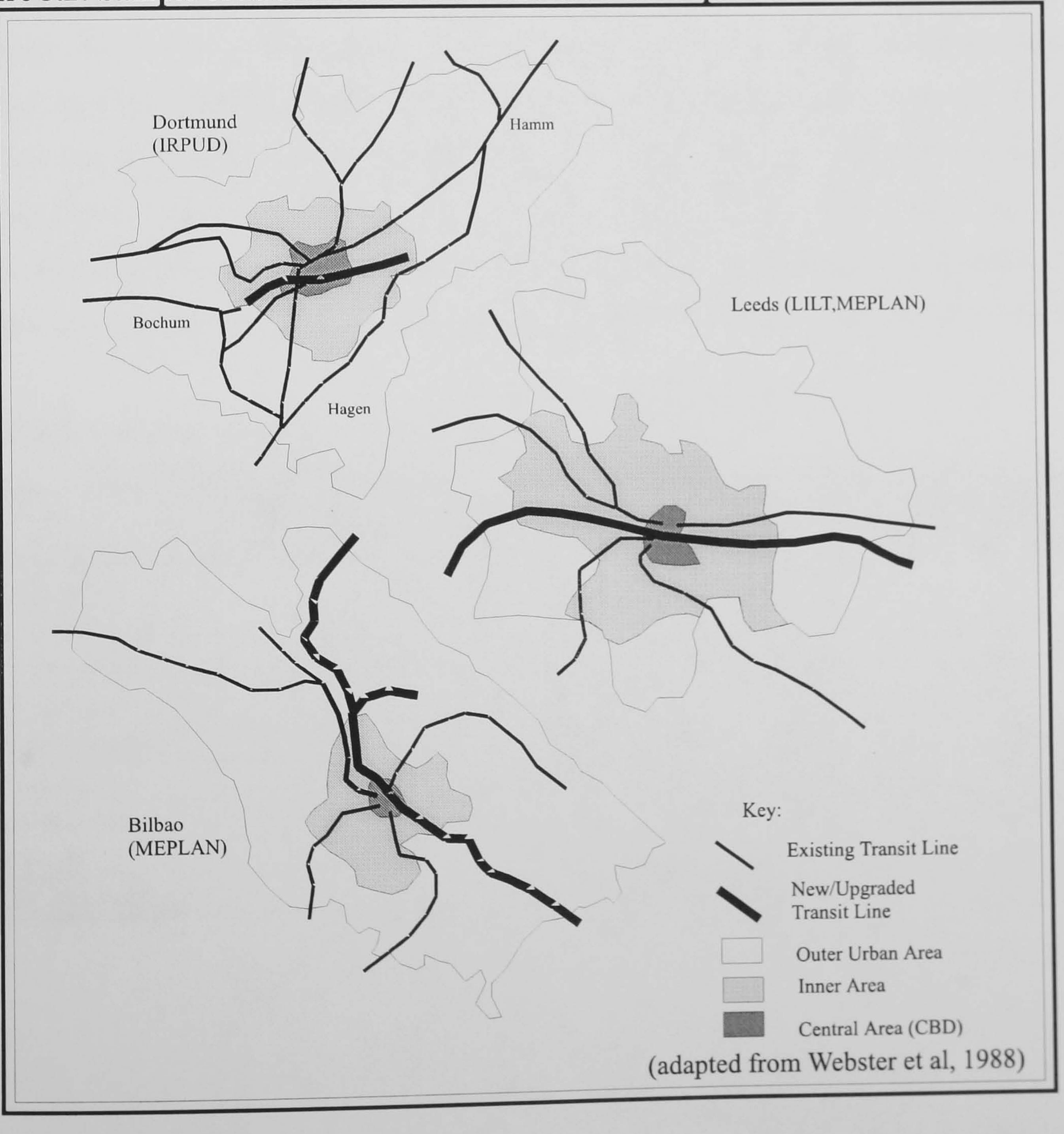
The central feature of the study was the set of common strategy tests that were devised. These were purely hypothetical and designed to test the models rather than provide realistic predictions for the subject cities. There were over 40 individual tests, although not all models could undertake all the tests. For the purposes of this review, the tests presented are those similar to the transit and road pricing policies discussed earlier in this chapter. The tests undertaken (and for which published data was available) are shown in table 3.4. New transit lines were included (test 16.8), but unfortunately road pricing as an explicit policy was not. However, use can be made of some alternative city centre demand management strategies such as cost increases in city centre parking (test 15.5). The study areas and transit lines are shown in Figure 3.2.

Table 3.4: Summary of ISGLUTI tests

ISGLUTI test number	**Description of Test**	Models undertaking test:
	Travel Cost Changes	
15.2	Doubling of costs for mechanised modes	IR LI ME
15.3	Increases in car costs by 400%	IR LI ME
15.5	Central area parking costs triple average travel costs	IR LI ME
15.6	Public transport free	IR LI ME
15.8	Public transport costs increased by 100%	IR LI ME
	Changes in the Transport Speeds/Network	
16.3	Bus speeds up 20%, all other modes down 20%	IR LI ME
16.5	New orbital motorway (80 kph)	IR LI ME
16.6	New inner ring road (60 kph)	IR LI ME
16.8	New cross town transit line (60 kph)	IR LI ME

Key: IR - IRPUD, LI-LILT, ME-MEPLAN

Figure 3.2: Sample of ISGLUTI cities and transit lines implemented for Test 16.8.



(adapted from Webster et al, 1988)

The indicators presented here are solely the impacts on activities, as due to lack of consistency between the models, accessibility and rent data were not published. Furthermore, land use transport models generate large amounts of data with each run. To make the outputs more manageable, the ISGLUTI study constrained the spatial disaggregation to three zones for each city: the city centre, an inner ring and an outer ring. Figure 3.2 shows this disaggregation. The forecasts were also given as a change for the 20 year model run (usually 1970-1990). In terms of analysing the land use impacts, the ISGLUTI study uses an indicator called 'centralisation'. Essentially this is the net percentage of population or employment moving into the CBD or inner zones over the modelled time period.

The transit schemes for the three cities of Bilbao, Leeds and Dortmund are also shown in figure 3.2. The system implemented varied from city to city, although in LILT the implementation of LRT was not possible, so instead a segregated busway was added. The resultant impacts on land use are shown in table 3.5, as percentage changes from the do-minimum tests. The general effects are slight. For Dortmund and Bilbao this can largely be explained by the presence of extensive rail systems already in operation, so that perhaps a fairer comparative test would have been to initially remove these existing systems. In LILT the busway shows some employment centralising influence, especially in retail, but no effect on population. However, the separation of home from work for all forecasts has risen compared to the do-minimum, suggesting some decentralisation. Note also that the MEPLAN implementation for Leeds disagrees with LILT, and on the whole predicts less of an impact.

Table 3.5: Land use impacts from Test 16.8 - transit schemes (% change from do-minimum)

	IRPUD: Dortmund	LILT: Leeds	MEPLAN: Leeds	MEPLAN: Bilbao
Centralisation of:				
Total employment	0.0%	2.0%	-0.1%	0.1%
Retail employment	0.0%	4.5%	-0.1%	0.1%
Other service emp.	0.0%	2.9%	-0.1%	0.1%
Non service emp.	0.0%	0.7%	0.0%	0.0%
Population	0.1%	0.0%	0.0%	-0.1%
Separation home from work	0.6%	1.7%	0.5%	No data
Car/PT mode share		+0.3% / +0.7%[4]	-0.2% / +0.5%	

[4] At first glance this may appear counterintuitive, i.e. that both mode shares fall. However, this implies a rise in the walk mode share. For further details see Mackett, 1990b, p. 330.

Other public transport enhancing tests generally had similar effects. For example, test 16.3, gave an extreme bus priority via a 40% speed advantage to bus relative to other modes. This had comparable impacts to transit, with similarly small impacts on population, but some centralisation of employment (most notable in Leeds).

The impacts of **demand management measures** can be illustrated by the results from test 15.5, (table 3.6) which restricts parking in the central area. This reveals large impacts on service sector employment in most of the models, with the dominant trend being a decentralisation of activities to outside the central area. These impacts on employment are larger in Leeds than the other cities, which is largely explainable by the lack of public transport alternatives in Leeds. Population impacts are much less significant. Echenique *et al* (1990), attribute this change to the fact that city centre residential parking is treated as free in LILT, so the incentive for residents to decentralise is reduced. Again, the MEPLAN model of Leeds is much less responsive than the LILT implementation.

Table 3.6: Land use impacts from Test 15.5 - trebling of city centre parking changes (% change from do-minimum)

Test 15.5: Parking	IRPUD: Dortmund	LILT: Dortmund	LILT: Tokyo	LILT: Leeds	MEPLAN: Leeds	MEPLAN Bilbao
Centralisation of:						
Total employment	-0.9%	-9.4%	1.4%	-9.1%	-1.0%	-2.8%
Retail employment	-8.9%	no data	1.9%	-26.6%	-0.3%	-5.6%
Other service emp.	0.3%	no data	1.3%	-11.1%	-1.6%	-1.7%
Non service emp.	0.0%	no data	1.3%	-3.1%	0.0%	0.0%
Population	-0.1%	-0.3%	0.4%	0.2%	0.0%	-0.2%
Separation home from work	8.1%	0.8%	-2.9%	0.0%	0.3 %	0.0%
Car/PT mode share			-1.4/+1.3	-0.3/-0.2	-0.2/0.0	

Other restraint policies have variable land use impacts depending upon whether they apply across the city, or only in the city centre. For example, quadrupling car costs (test 15.3) had an employment centralising influence in all cities (although it was more marked for cities without rail based transit). This test invoked a decline of the home/work distance, as people moved closer to work (or obtained jobs nearer their homes) to reduce the high car costs. Again the models disagreed when applied to the same city, usually in the magnitude of change, but in the case of non retail service employment in Leeds, in direction also (+4.2% from LILT, -2% from MEPLAN).

3.6.2 Forecasts from the London Congestion Charging study

This study examined road pricing options for London, assessing types of scheme and charging options. The study involved several transport models, including the MEPLAN model of London and the South East (LASER), which was used to assess the urban and social impacts. For discussion of the impacts, London was divided into three zones; the central area, an inner ring incorporating the inner London boroughs (to the A406), and an outer ring to the M25. As such it is reasonably consistent with the ISGLUTI rings.

The analysis of employment changes using LASER suggested that a £4 central London cordon charge would **increase** employment in central London in 2011 by 1%, with compensating decreases in inner and outer London (May, Coombe and Travers, 1996). The population of central London would fall by about 0.2%, with increases in inner London, although households from higher socio-economic groups would concentrate slightly in the centre. However, the authors pointed out that these changes are small, and would easily be swamped by changes due to other economic and social reasons.

Larger changes were obtained with the inner cordon change raised to £8, and another outer cordon added at £4 to include all of inner London. This led to a 2% rise in central area employment, and a 1% decrease in inner London (see table 3.7). Note that retail and private services are the sectors benefiting most. This may be explained by the fact that the centre increases its share of higher income population, at the expense of the middle and lower groups (table 3.8). It is also predicted that rents would rise in the central area for retail and business, but decline slightly lower in the other areas.

Table 3.7: LASER road pricing impacts on employment (2011)

Area	Manufact.	Finance & Prof.	Retail	Education	Public Services	Private Services	Total
Central London	0 *(0)*	+5149 *(2)*	+6118 *(5)*	+71 *(0)*	+483 *(0)*	+1893 *(3)*	+13714 *(2)*
Inner London	-1017 *(0)*	-5608 *(-2)*	-3995 *(-2)*	+84 *(0)*	+519 *(0)*	-2136 *(-1)*	-12153 *(1)*
Outer London	+48 *(0)*	-439 *(0)*	-1317 *(0)*	+143 *(0)*	-597 *(0)*	-211 *(0)*	-2373 *(0)*
Rest of South East	+970 *(0)*	+914 *(0)*	-733 *(0)*	-268 *(0)*	-376 *(0))*	+474 *(0)*	+981 *(0)*

Results from the highest level of charging (£8 central cordon, £4 inner ring). Figures in brackets are % change from the do-minimum (adapted from The MVA Consultancy, 1995).

Table 3.8 LASER road pricing impacts on households for 2011.

Area	SEG1	SEG2	SEG3	SEG4	Total
Central London	+775 *(4)*	-292 *(0)*	+3 *(0)*	-284 *(-3)*	+202 *(0)*
Inner London	+4488 *(3)*	+2849 *(0)*	+577 *(0)*	-369 *(0)*	+7545 *(0)*
Outer London	-1981 *(0)*	+189 *(0)*	-250 *(0)*	+619 *(0)*	-1423 *(0)*
Rest of South East	-2905 *(0)*	-2688 *(0)*	-318 *(0)*	+40 *(0)*	-5871 *(0)*

Results from the highest level of charging (£8 central cordon, £4 inner ring). Figures in brackets are % change from the do-minimum (adapted from The MVA Consultancy 1995).

The general conclusion from LASER was twofold. Firstly the changes are relatively small in magnitude when examined on this aggregate scale, and easily swamped by the other changes occurring over this 20 year period. This is the case even with the cordon charges at very high levels. Secondly, responses which do occur point to a strengthening of central London at the expense of the inner ring. However, there is some debate as to whether some of these results are within the accuracy limits of the model (The MVA Consultancy, 1995).

3.6.3 Forecasts from rail service changes in LILT

As well as Leeds, the LILT model has also been applied to Hertfordshire to model factors affecting the changing demand for rail travel for commuters working in London (Mackett and Nash, 1991). The model was a simplified version of the ISGLUTI LILT model, in that housing and jobs were specified exogenously, and the model only determined how people were allocated to workplaces, residences and modes to work. The underlying trend in the model was that the decentralisation of workers from London will decrease as employment in London falls. In other words, as employment growth in London slows, so workers will be able to satisfy their housing needs closer to the centre, hence reducing both the need to use rail and the average distance travelled.

Improvements to rail services (represented by a 10% fall in journey times) in specific corridors were found to have a clear effect on location patterns, with benefiting areas continuing to increase in population, although this was dependent upon the availability of housing. Mackett and Nash concluded that if relocation effects are ignored then transport only models give misleading results, the scale of the error being a function of the change in generalised cost that is occurring. However, they also found that if other parts of the rail network were ignored, then LILT is likely to overstate the effects in the corridor with the service improvements, by failing to account for relocation induced falls in patronage on neighbouring lines.

3.6.4 Summary of findings from the modelling

The following summary can be drawn from these three examples:

- The models' estimates show that employment is more sensitive to transport costs than population, and that the retail sector is more sensitive than the office sector. Non-service is the least sensitive employment sector. Higher socio-economic groups are generally found to be more mobile than the population as a whole, where the models had disaggregated the population.
- However, in general the impacts from transport policies are small, rarely more than a 5% shift in the patterns compared to the do-minimum. However, it may be that larger effects were occurring on a zonal level, but were lost in the aggregate 'three zone' results. Also, the study focused upon changes over the total 20 year modelling period, preventing the possibility of examining whether impacts on land use may be most pronounced shortly after implementation.
- Webster and Paulley (1990), discuss which policies the ISGLUTI models were best able to represent. The consensus was that the models were better at representing regulation and investment (i.e. LRT) than pricing policies.
- In general, the models did agree on the broad patterns of change. However, when more details were sought, the models tended to disagree, in the first instance on the magnitude, but also in certain cases in the direction of change.
- There are many methodological criticisms of the models as well, some of which were touched upon in Chapter 2. However, the one most relevant here from the ISGLUTI work is that the models set up for additional cities gave results that were not as satisfactory as those for the originally calibrated city. The more data that can be collected, and more resources spent on model calibration, the better the end result appears to be. This is important for the practical planning applications of such models, and is both a resource issue and a conceptual problem.

3.7 Comparisons of the modelling to the empirical evidence

How do the empirical and the modelling methods compare? The first point to stress is that there are no direct comparisons of a modelled policy and equivalent empirical evidence for the same city. Despite this, for transit impacts in general the level of agreement, in terms of directions of change, is good. The ISGLUTI models mostly estimate city centre hub transit to have an employment centralising influence, and this is borne out by the empirical studies of Kreibich (1978) and Walmsley and Perrett (1992), among others. The models tend to predict a decentralisation of households following a transit scheme. Again this reflects the empirical evidence from European cities, and some US cities, for example increases in commuting distances in Washington and Munich. It is of course possible that this consistency results from the models being set up to replicate these observed sensitivities, outside of the calibration process.

However, at a more detailed level, and in terms of magnitudes of change, there is little agreement. This is not surprising, and is due to the differing natures of schemes, different city morphologies, existing infrastructure and varying social and economic trends. As well as this is the additional presence or absence of a co-ordinated policy. Moreover, different models have different base assumptions, and hence can give different answers faced with the same questions. It is also the case that models may be over simplifying the impacts by only considering generalised cost changes.

There is agreement between the methods that transit is unlikely to shape urban form in car dominated cities. However, strategically the accessibility benefits can assist in strengthening urban cores and reducing employment counter urbanisation. The empirical evidence suggests that this is possible only if transit is part of an overall planning strategy for these aims. This type of issue could be examined in a model, but examples of this to date could not be found, as the models have not been used to assess options for maximising transport's impact on land use for policy advantage.

There is much less agreement about the impacts of pricing measures in the city centre, either through increases in parking charges or through road pricing. Firstly, there is little empirical evidence, and that which there is suggests slight increases in central economic activity. Also the pedestrianisation studies showed overall benefits to retail turnover. In contrast, the Flowerdew and Stevens' study suggested that within-cordon city centre retail and office prices would decline.

The LASER modelling results suggested that there would be a small increase in central London employment, and also an increase in high income people living within the cordon. This contradicts the parking tests for the ISGLUTI models, which generally show negative effects on employment, and a mixed effect on population. Again, the variety of schemes and other factors makes absolute comparisons difficult, but it is fair to say that there is considerable uncertainty about the impacts of road pricing on land use change in urban areas. Further reasons for the differing conclusions are discussed in Chapter 9 (page 237), where the LASER results are contrasted against the road pricing tests undertaken with the new land use transport model used in this research.

From the evidence examined in this chapter it is clear that transport does have impacts on land use, and these impacts can be complex and difficult to predict. However, there are no certainties; greater accessibility does not guarantee associated development. With regards to the methods, empirical and modelling forecast evidence should ideally be seen as complementary indicators of possible impacts, given that there is considerable suspicion associated with results obtained by both methods.

3.8 Conclusions

There is a great deal of research interest in determining how far transport schemes (notably rail transit) can alter development patterns, especially focusing upon city centres. However, the methods applied face considerable difficulty in determining the impacts, and isolating the influence of transport. As a recent review concluded:

> *'The links between transport and urban development have interested researchers and policy makers for many years, yet the explanations made have never quite matched the expectations'* (Hall and Banister, 1995 p. 287).

Generally there is less agreement about the magnitudes of impact rather than the direction. Nevertheless, some general conclusions can be drawn regarding the impact of transport on land use.

Firstly, there is agreement that public transport infrastructure is unlikely to shape urban form in car dominated cities, where accessibility is abundant. However, it still appears to be the case that high accessibility is valued as a location criterion, even if it is relative to good overall accessibility. The central factor well may be the type of accessibility that a location offers (i.e. access to particular activities).

Thus left to its own devices, whether public transport will influence location choice will depend upon local economic circumstances, and the relative attractiveness of the transport enhanced locations. However, much of the empirical evidence has been more focused than this; examining transit in a policy role for strengthening the urban core and reducing employment counter-urbanisation. The evidence from impact studies has shown that transit schemes can have development impacts, but that these must be planned and encouraged with other policy measures.

Secondly, much less is known about the impacts of road pricing on city centres. The modelling evidence is mixed, the empirical evidence practically non-existent, although one level of agreement is that there will be some sort of impact. From the attitudinal evidence, it would seen that the strongest opposition to scheme implementation is likely to come from existing city centre activities.

The impacts from changes in accessibility are broadly as the theory discussed in Chapter 2 would suggest, although complexity quickly arises. In part this is due to the other impacts that transport can have, including image and environmental effects. This is a topic that will be examined in greater detail in later chapters of this thesis. However, the ability of modelling to add or remove specific policy elements means that models offer a potential method to examine the individual influence of transport and other policy measures.

The implications of this chapter on the objectives of the thesis are significant. Firstly, sufficient evidence has been provided so show that transport policy can influence land use, both as part of a policy initiative, and due to market processes. Moreover, the influence of transport on urban development is likely to rise as accessibility becomes more limited by congestion and policies to increase car costs. Such impacts can assist or hinder urban policy making, depending upon whether they are expected or not. Only if they are foreseen can policy either make use of, or control for, such effects.

Modelling methods can produce apparently sensible and intuitively correct results, although a great deal more comparative work with empirical evidence is required, and such methods are complex.

However, even if the evidence can be interpreted to clearly show that transport does influence land use, it is important to understand whether practising planners perceive this to be the case. The examination of this issue is the subject of the next chapter.

CHAPTER 4 [1]

POLICY CONTEXT AND CURRENT ATTITUDES: THE PHASE 1 INTERVIEWS

4.1 Introduction

This chapter examines the current treatment of transport impacts on land use by planners. It deals firstly with the legislative and planning guidance frameworks via a review of recent policy documents. Secondly, interviews were undertaken in a number of planning and planning related organisations to examine planners' attitudes and practices. These are referred to as the 'Phase 1' interviews, and they are intended to capture planners' pre-existing attitudes to transport impacts on land use. The original aim was to test the following hypothesis;

> ***that there is no common practice of assessing transport impacts upon land use in the UK, despite the existence of appropriate methods. Lack of data, plus a belief among planners that the impacts are of only minor importance, has restricted study for the purposes of strategic urban planning.***

Initially, interviews were planned and conducted with professionals in the UK. However, in response to some of the initial findings, comparative work was undertaken in the USA, (using an award from the Brian Large Travel Bursary), in order to compare the planning approaches in a context in which the application of 'land use response' models is known to be more widespread. An interview was also undertaken with a land-use / transport expert in Germany, to provide an overview in a country where strategic planning is particularly strong. This chapter compares the contrasting approaches in these countries, and provides the central rationale for the methodology of the thesis.

4.2 Some comments on the nature of planning

It is useful at this stage to outline how study of transport impacts on land use can fit into the structure and nature of planning, and its prevailing ideologies. Planning can be defined as the '*making of an orderly sequence of action that will lead to the attainment of stated goals*' (Hall, 1992). This implies:

1. the determination of the goals;
2. the derivation of actions to meet those goals, and

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[1] An abridged version of this chapter appeared in *Traffic Engineering and Control*, (Still, 1996).

3. some means of assessing whether those goals have been met, or if they have changed.

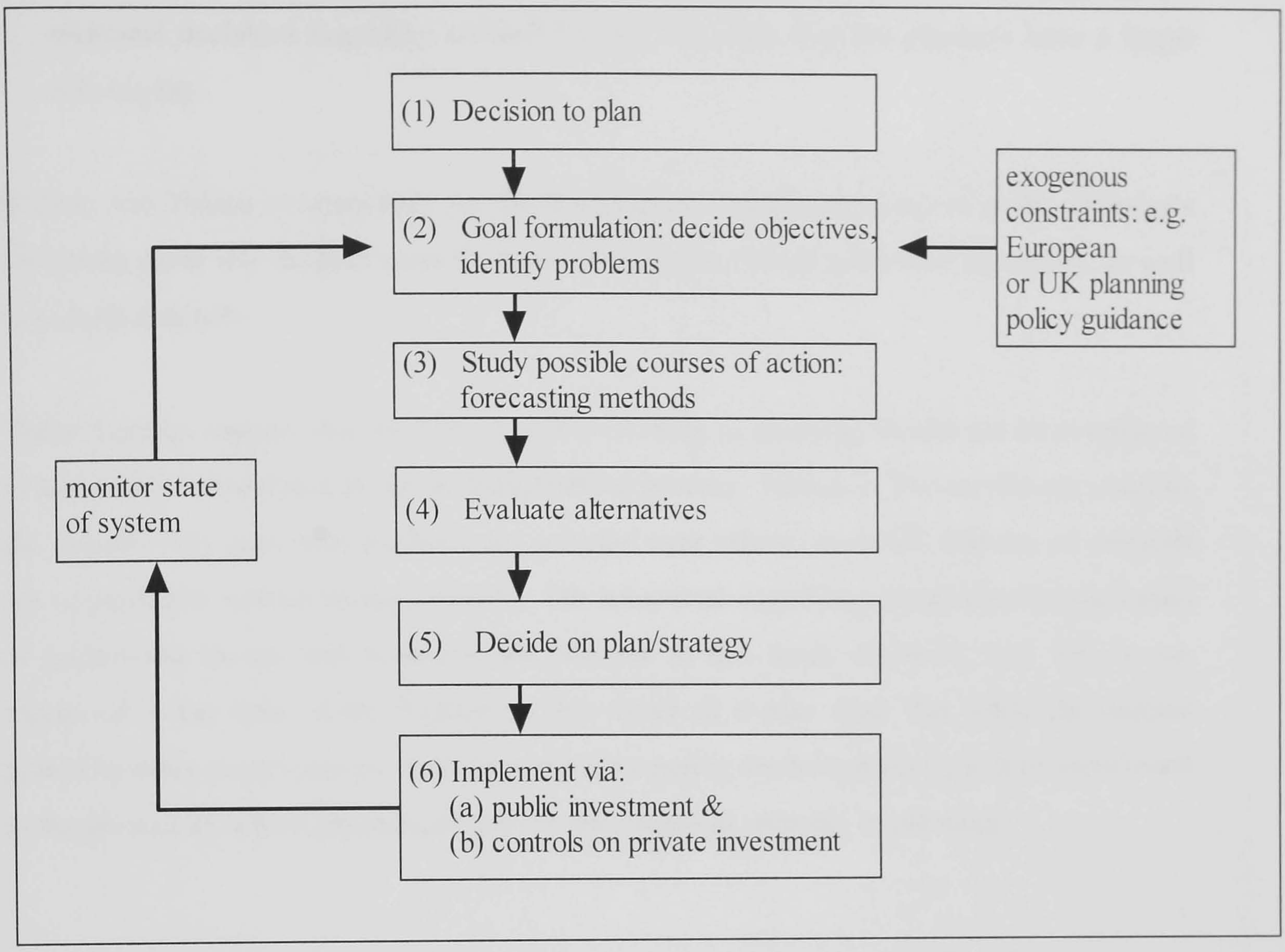
The goals of planning in the UK are constantly changing as the nature of urban problems change, or as perceptions of the best solution to those problems change. The planning system copes with this via a system of continuous adjustment, and a focus on the *processes* that underlie urban change. The ideal is that urban development is monitored, and compared to the predictions and criteria for meeting objectives. Plans (such as Structure Plans and Unitary Development Plans) can be recast in the light of new predictions of change. This process relies upon methods of predicting in advance what will happen in the urban arena.

Thus to a certain extent planning is dominated by the need to predict future urban development patterns and the impacts of potential policies. It can be argued that this fundamental need occurs regardless of the dominant philosophy in planning, although research into forecasting has often suffered under the assumption that incremental or *laissez faire* approaches to planning do not need prior examination of the implications of policy. At the other extreme is a full 'systems' or 'rational comprehensive' type of planning (Wegener, 1982), where a scientific method is applied to solve urban problems, and forecasting of policy options plays a major role. The rational comprehensive model of planning is seen as an 'ideal' form of planning (Wachs, 1985; Hall, 1992), and was the form of planning that dominated the early attempts at comprehensive land use and transport models (van Houten, 1989). However, it is widely acknowledged that the rational model is tempered in reality by political processes and constrained resources (Wachs 1985).

The basic process is outlined in figure 4.1. It is characterised by the ability to forecast the potential outcomes of policy, and monitor the state of the system.

Boxes 3 and 4 of Fig. 4.1 contain the use of forecasting methods in determining and evaluating possible policy, and it is here that studying transport impacts on land use can figure. There are two elements, firstly deciding which elements of the system it is desirable to study, and secondly, how to model them for forecasting purposes. This thesis focuses upon the issues in these two boxes. Note from figure 4.1 that the evaluation (box 4) is distinct from actual decision making (box 5). Actual decision making focuses upon political, economic and social issues, and is undertaken by elected members in a quite separate process from the decisions concerning forecasting and evaluation techniques.

Figure 4.1: A systems approach to planning (adapted from Hall, 1992, p. 231)



The use of methods in transport decision making has previously been examined by Forster (1996). He found that the technical content of models was less important than the use of the results to provide substantive evidence to support existing points of view. He concluded that models were not used to devise new policy or resolve policy disputes. This is consistent with figure 4.1, in that the model is used to examine, rather than devise, policy options. Forster therefore concludes that rational planning as an ideal is only a partial explanation of how policy decisions are actually arrived at. While this may be the case, Forster still argues that certain features make methods in general (in fact his study focused upon 'integrated transport studies'), more or less 'useful' to the planning clients. He commented that such studies:

- required a certain element of quantification, to make a study 'authoritative', as '*essays are not as convincing as a mathematical equation*' (Forster, 1996, p.269);
- do not essentially require the forecasts to be accurate. In other words, counter intuitive although it seems, studies can be used in planning decisions, even if the technical side is flawed;
- do not require highly verified theory to underpin the model, as the interest of the clients lies in the study recommendations rather than methodology;

- should have politicians and senior officers involved in the study process, although for the technical decisions regarding methodologies, it is clear that the planners have a larger role to play.

In fact, the choice of consultant for the Birmingham integrated transport study (Forster's case study area) was decided upon the basis of 'strategic vision', and value for money, as well as technical details.

These findings suggest that the role of technical study in planning should not be overplayed in terms of its importance to the decision making process. However, Forster did not examine the reasons why particular methods are selected over others, or which features of methods are of particular interest to the planners. His somewhat surprising conclusions on the issues of underlying theory and accuracy are relevant to this study however, and will be re-examined in the light of the findings in this thesis. It is also clear that while the rational comprehensive model may be weak in explaining policy decision making, it is more relevant to the process by which planners *attempt* to use technical methods in planning.

4.3 Recent policy regarding land use and transport

4.3.1 Recent policy in the UK

Chapters 2 and 3 have illustrated the complex way in which transport affects land use and the uncertainty in much of the literature about whether it is a significant variable in overall urban development. This, coupled with the shift away from 'comprehensive (systems) planning' in the 1980's, meant that the impacts of transport policy on land use were largely ignored in UK strategic planning, and transport planning has rarely focused on the land use impacts of transport policy in a systematic or consistent way. However, this situation is changing, with more emphasis on integrated, and environmentally aware planning. The stimulus for this change is concern over the environmental effects of traffic growth and congestion, as summarised in the Government's 'Sustainable Development Strategy', (Dept. of Environment, 1994a). This sets out a broad strategy in order to reduce the production of atmospheric pollutants, including CO_2 and other gases, for which motor vehicles are the fastest growing source of emissions.

A series of reports and policy guidance notes have followed as part of an initiative to reduce car travel. Several of these are related to the links between land use and transport, and are summarised in table 4.1. A second area of policy relevance are the revisions to the methods of road appraisal procedures, also shown in table 4.1.

Table 4.1: Key government publications regarding transport and land use 1994-1996

Publication/Report	Date	Main Points	Land Use/Transport relevance
Standing Committee on Trunk Road Assessment (SACTRA) report on Induced traffic *(Road Appraisal)*	1994	Induced traffic does occur and changes are required in the appraisal system to take this into account. The current system is in many cases overstating the benefits.	Part of induced traffic likely, under certain circumstances, to come from land use changes brought about by the network alterations from the scheme.
Planning Policy Guidance (PPG) 13: Transport (DoE/DoT) *(Integrated Planning)*	1994	Focus upon ways to plan land use so as to reduce the need for car trips.	Called for integration of land use and transport planning. Calls for impact assessments of transport on land use to be made, but does not give a method.
Royal Commission on Environmental Pollution (RCEP) *(Integrated Planning)*	1994 (b)	Advocated use of environmental targets in face of growing pollution. Halt roads programme, double fuel duties.	Called for integrating land use and transport, especially creating land uses that minimise the need for car travel.
PPG13: Guide to better practice. *(Integrated Planning)*	1996	Examples of how PPG13 can be applied successfully.	Main tools are parking restrictions and planning with public transport, walking and cycling.
Planning Policy Guidance 6: Town centres and retail *(Integrated Planning)*	1996	Co-ordinates with PPG13, advocates following plan led policy, and aims to reduce out of town shopping centres.	Focuses retail on centres and subcentres, rather than out of town developments, in an attempt to reduce car travel.
Transport: The Way Forward. Government's Response to the Transport Debate. *(Road appraisal and integrated planning)*	1996 (a)	Key recommendations on how transport policy should progress.	Calls for integrating land use planning and transport planning in urban areas and for trunk road planning.
COBA (Cost Benefit Analysis program) 10 *(Road appraisal)*	1996 (b)	Introduces the use of variable trip matrices for complex scheme assessment.	Begins to legitimise the examination of transport on land use as influencing trip generation patterns.

In terms of road appraisal the 1994 SACTRA paper on induced traffic commented that :

> *'given that the pattern of land use and activities is the major determinant of traffic, we would want to take account of any alteration in these patterns which is stimulated by the changes in ease of movement that a new road will afford'* (Dept. of Transport, 1994a, 2.22 p.10).

Hence the concept of allowing land use to respond to transport policy would provide more realistic forecasting, in those circumstances where land densities or activities are likely to change. This led to a change in the current system of road appraisal, which traditionally has used a fixed trip matrix for both the with-scheme and without-scheme situations. With the introduction of COBA 10 (Dept. of Transport, 1996) for complex schemes induced traffic generation is included, although the Government is still in the process of researching into these complex areas (Dept. of Transport, 1994b).

Land use planning has also tended to ignore the influence of transport policies on urban development, even though such impacts may conflict with objectives in structure plans or other guidance policies. However, the adoption of PPG13 (Dept. of Environment/ Dept. of Transport, 1994) is now encouraging planners to consider land use and transport together. Its main focus is upon using development control as a tool to constrain location choice and, by careful planning, increase the possibility of fulfilling activities with non-car based travel. As a result, the role of land use as a tool to reduce car travel demand has a much higher profile currently than the role of transport in shaping land use. This policy has been recently reinforced by the revised PPG6 (Dept. of Environment, 1996), which gives guidance for planners to consider town centre locations in preference to out of town locations.

PPG 13 type principles have been evident in local authority structure plan drafts and Transport Policies and Programmes (TPP) bids for some years (often predating Government Guidance). Good examples are the Bedfordshire Structure Plan (Bedfordshire County Council, 1994), and LPAC's Strategic Guidance for London (London Planning Advisory Committee, 1994). In all cases the thrust has been to use land use planning as a tool to reduce car travel, and focusing development where the county/region can best accommodate it within its 'environmental capacity'. Such use of land use policy is not without its critics, who believe that PPG13 type policies will take too long to work (after all only 1-5% of the urban fabric changes each year), and may not influence car use at all. This is because there is no guarantee that travellers will use opportunities closer to them (Local Transport Today, 1995).

The recommendations of the 1994 SACTRA report are also discussed in the Government's response to its own 'transport debate', published in 1996, although the main recommendation for transport impacts on land use is to undertake more research. For the urban scale, the response supported the PPG 13 approach, and also discussed the importance of roads for the economic well being of urban areas. However, as was found in Chapter 3, unequivocal statements on development benefits are difficult, and the 1996 paper was no exception:

> *'Good transport links alone are not enough to secure the well being of a town or city. But they can play a crucial part in sustaining that well being, and in determining locational decisions between different areas.'* (Dept. of Transport, 1996b, Chapter 14, Box 14(i)).

Chapter 3 concluded that there is evidence of land use impacts, but that most studies err on the side of caution, outlining a range of necessary contributing factors. However, there still appears to be professional and political interest in the economic potential of road schemes. For example, the Association of County Councils commented that investment in transport can often be a '*spur to regional development*' (Association of County Councils, 1994). The government's continued interest in transport as a facilitator and even generator of jobs is shown by its commissioning of SACTRA to examine the links between transport and economic development (Dept. of Transport, 1996a).

However, there is an inconsistency between promoting some transport schemes as spurring development, while ignoring land use impacts when development is unwanted. This has led researchers to comment that the transport impacts on land use are highlighted when they support policies, or are expected to lead to a given benefit, but often ignored when such an expectation is not an aim of the policy (Headicar and Bixby, 1992). Similar issues led one of the committee members of the 1994 SACTRA report to refuse to ratify the report, stating that the effects of roads on communities and human activity are neglected (Dept. of Transport, 1994a Annex IV). From these and other documents examined, no formal requirement to examine the impact of transport policy on land use could be found, even as part of an environmental appraisal.

Thus, coupling of land use and transport planning in a manner to facilitate the examination of transport impacts on land use has very much taken a back seat, despite the fact that an understanding of transport impacts on land use is often quoted as important in policy documents.

4.3.2 Comparable policy in the USA

The policy shift towards integrating land use and transport analysis is much further advanced in the USA. Road and rail infrastructure investment is tightly linked with perceptions of economic development. This is reflected in the relatively large amount of consultancy and academic study concerning the ways in which transport provision affects land use patterns, and under what circumstances it facilitates economic growth (e.g. Meyer and Miller, 1984, Cervero and Seskin, 1995). This was discussed in Chapter 3. In addition, growing concerns about environmental pollution and traffic growth have led to new guidance and legislation. Two recent pieces of federal legislation had direct implications for the consideration of transport impacts on land use.

Firstly, the 1990 Clean Air Act Amendments (CAAA) forced transportation planning on a state and county level to include air quality improvements as an objective. Air quality targets for the major pollutants were set, and metropolitan areas failing to meet these targets have to demonstrate that their intended transportation policies would benefit air quality. USA transport policy has traditionally responded to this by increasing the supply of road space, aiming to increase average speeds and thus reduce emissions. However, the issue of induced urban traffic, increasing volumes and hence lowering speeds, has led to this assumption being questioned, making methods of assessment a key political issue.

Secondly, the 1991 Intermodal Surface Transport Efficiency Act, or 'ISTEA', aimed to change the way in which transportation planning was undertaken in the USA. Recognising that the Interstate system is virtually complete, and that air quality is a key objective, it seeks to shift emphasis to public transport and infrastructure maintenance, via more flexible use of funds and public participation in the decision making process. It also requires that transport policy must understand and take account of the way in which transport interacts with land use (US Dept. of Transportation, 1995). Failure to comply with this regulation can result in federal funding (which is 70%+ of most states' transportation funds) being withheld (see section 4.5.2, bullet point 1 for an example of this).

The net result is that the agencies responsible for city-wide urban transportation planning, the Metropolitan Planning Organisations (MPO), must demonstrate that the transportation planning process has taken into account land use impacts. They must also ensure that these land use changes do not worsen air quality indicators. The legislation also highlights a significant issue; that the resurgence of interest in transport related land use impacts comes as a result of a concern with a different impact, i.e. air quality attainment.

However, this legislation must be placed in the context of wider USA ordinances, legislation and planning case law. This context has been summarised by Freilich and White (1994), who state that both ISTEA and the CAAA support the use of wider 'Transport Demand Management' (TDM). TDM in the USA has similar aims to PPG13 type policies, but works by focusing particularly on what PPG13 calls 'complementary' measures, for example ride-sharing, flexi-time, parking management and car-pooling. Land use 'zoning' controls are also used, especially mixed use zoning to encourage the 'internal capture' of trips (i.e. trips originating and destinating within a given area). There is also a complex array of finance and revenue creating devices designed to cover the cost of public capital improvements. These include 'impact fees' on land capitalisation and joint public-private development along corridors benefiting from transport improvements. Clearly there is an implicit assumption here that accessibility improvements do increase the attractiveness of an area.

The legislative and planning frameworks in the USA are more complex than in the UK. Legislation is undertaken at both Federal and State level, meaning that different states have widely differing powers. Transport policy is determined at a state level, while land use zoning is a closely guarded local power. Such a devolved local system strongly resists regional strategic interests, and this conflict between tiers of government has been termed an 'institutional disconnect' by Carlson and Billen (1996). They concluded that this problem is contributing to the continued urban sprawl, due to the lack of co-ordination between land use and transport planning.

4.4 Phase 1 interview methodology

It was realised at an early stage that the hypothesis outlined in Section 4.1 could not be satisfactorily tested from published literature alone, and that professional perceptions should be sought. Given the depth of perception required, and the relatively small number of possible contacts, face to face interviewing was decided upon as the most appropriate method, both for obtaining a general overview, and gaining the necessary insight. Tables 4.2 and 4.3 present summary details of interviews undertaken in each country. Both the UK and USA samples were selected according to the following criteria:

- to obtain a 'representative' sample, several planning authorities were to be interviewed, on a range of spatial scales, encapsulating the 'tiers' of planning;
- as 'cutting edge' practice was sought, it was decided to target authorities who had published integrated strategies, or were known to be involved in land use and transportation studies (from press reports or published papers). For the USA work this came from the recommendations of academic contacts;
- finally, to balance professional planners' opinions, interviews were sought with a range of 'experts' in land use and transport planning or modelling, both academics and consultants (this included an additional interview with a land use transport expert at the University of Dortmund, who was able to provide some comments on the German experience).

For the UK work, a sample was selected consisting of the following:

- planners from central government, regional associations and strategic agencies (London, Lothian, Avon and Bedfordshire);
- academics and consultants specialising in land use and transport interaction.

For the subsequent USA research the following sample was targeted:

- planners from the federal government;
- planners from various agencies and pressure groups in two case study cities: Atlanta and Chicago. These cities make a good contrast, Chicago a 'rust belt' and mature (in terms of infrastructure) city, and Atlanta, economically, one of the fastest growing cities in the USA. Both are CAAA non-attainment cities, and both were known to use land use response models;
- academics (who are also the main land use / transport consultants).

Table 4.2: UK Phase 1 interviews

Scale	Organisation
Central Government Bodies	Department of Transport Department of Environment Scottish Office: (1) Roads Directorate, (2) Planning Services
Regional Strategic Organisations	London Planning and Advisory Committee South East Regional Planning Conference
Local Authority Planners	Lothian Regional Council*: (1)Planning, (2) Transportation Surrey County Council: Transportation Bedfordshire County Council: (1) Planning, (2) Transportation Merseyside Information Service Avon County Council: (1) Planning, (2) Transportation
University Academics	University of London: University College, Centre for Transport Studies University of Cambridge: Department of Geography University of Leeds: Department of Geography Oxford Brookes University: School of Planning
Consultancies	The MVA Consultancy: Edinburgh Office Marcial Echenique & Partners: Cambridge Office GMAP: Leeds Office Environmental Resources Management: Edinburgh Office

(Note: (1) and (2) imply separate interviews,
*- now replaced by Unitary Authorities.)

Table 4.3: USA Phase 1 interviews

Scale	Organisation
Federal Government	USA Dept of Transportation USA Dept of Housing and Urban Development
Atlanta Planning Agencies	Atlanta Regional Commission: (1) Statistical Services (2) Transportation (3) Planning City of Atlanta
Chicago Planning Agencies	North East Illinois Planning Commission (NEIPC) Chicago Area Transportation Study (CATS)
Academics / Consultants	University of Pennsylvania: Dept of City and Regional Planning University of Buffalo: Dept of Economics Environmental Law and Policy Centre (Chicago)

Note: (1 - 3) imply separate interviews.

Examination of the interview findings takes the following format. Firstly Section 4.5 summarises current consideration of transport impacts on land use in strategic planning in the UK, USA and Germany respectively. Where appropriate, the reasons for an absence of study are also discussed, together with the relative significance of transport impacts on land use to planning. Section 4.6 then examines the methods used to examine such impacts, and attitudes to the available methods. Finally, Section 4.7 compares the results from the interviews.

Note that where statements are referenced or quoted from a specific interview, an interview number is given. This system is in order to retain the confidentiality promised to each interviewee.

In depth interviewing is a method suited to collecting the qualitative views of planners on a subject, where some rationale for their reasoning is required. It allows flexibility to explore unforeseen responses to questions, and to focus upon specific areas if necessary. As such it is dynamic and efficient. However, it places a large burden on the interviewer who will have a direct bearing on the results, and can be seen as the 'research tool' (Taylor and Bogdan, 1984). For example the interviewer must establish a rapport with the interviewee, in order to build the latter's confidence and therefore encourage in-depth answers, must listen carefully to answers in order to spot particular areas for further questioning, and decide when sufficient information on a given subject has been collected. Two further key skills are in posing non-prescriptive questions (e.g. not weighting questions with phrases such as '*surely* *you have...'* or suggestive adjectives), and knowing when to let an interviewee talk at length, and when to re-focus the subject of conversation.

For the interviewing undertaken in this project, several well established in-depth interview techniques were used. Firstly, a list of issues to be discussed was forwarded to the interviewee, and the motives and intentions of the interview were made clear at the outset. The planner was promised confidentiality, and asked if taping the interview was possible. Taping is often considered intrusive (Taylor and Bogdan, 1984), but in these interviews was felt necessary in order to pay sufficient attention to the comments being made. Secondly, the interviews began with 'slow' or easy questions to start the interviewee talking about a familiar subject. More difficult questions were kept until the interviewer was happy that the interviewee was sufficiently relaxed. Thirdly, questions were asked to which the interviewer already knew the answer, in order to obtain the interviewee's specific interpretation of the issues. Finally, the interviewee was asked to justify, or back up comments with examples where possible.

After the interview, the written notes and the tape recording were initially reviewed, and then the interview transcribed. It should be noted that the recording of interviews, although predominantly successful, did occasionally lead to problems. For example several interviewees wished to discuss topics over lunch, or in a coffee bar, where recording was impossible. An open office window next to a busy road made several tapes very difficult to transcribe. Furthermore, transcribing the interviews took a great deal of time, and several interviews were only partially transcribed, focusing upon the topics of specific interest to the research, and ignoring the less relevant parts of the interview. Despite these problems however, the interview methodology was successful in meeting the goals of insight and explanation into the treatment of transport impacts on land use.

4.5 Interview results: consideration of transport impacts on land use in planning practice

4.5.1 Consideration of transport impacts on land use in the UK

In support of the findings from the policy documents in Section 4.3 none of those interviewed identified policy **requirements** to study the impacts of transport policy on land use or activity patterns. As one planner commented *'transport schemes are assessed on transport criteria'* (Int. 4a). The central government planners agreed that there was nothing in the appraisal or structure plan process that specifically required examination of transport policy on land use, in terms of population and employment impacts, and moreover '*this was one of the issues that looks slightly fudged in PPG13*' (Int. 11a).

However, one interviewee commented that they undertake some analysis '*through local discussion*' (Int. 12a). Several planners also commented that the impacts of transport policies on other elements of the urban system are considered in discussion and formulation of structure plan policies, using professional judgement.

However, few local authority planners could quote any studies where transport impacts on land use had been comprehensively examined. The experience in Lothian, where the greatest concentration of local authority interviews was undertaken, was that environmental impact assessments were common, with some examination of development impacts, but rarely extending as far as potential population and employment impacts (Int. 17a). The same was not true for the consultants, who, being involved with land use and transport models, could quote their use in various projects. Some of these have been documented elsewhere, and include the use of LILT to examine the impacts of the Channel Tunnel on property in the South East (Mackett, 1994), and the use of the MEPLAN LASER model (Williams, 1994).

However, one consultant commented that the use of an integrated model does not imply that a client is interested in both land use and transport, and added that it is rare for a public sector client to be interested in both (Int. 23a). Private sector clients are far more interested in land use responses in terms of property price changes over an urban area.

The planners were quizzed as to why they do not tend to consider transport impacts on land use. Their responses can be grouped as follows:

1. **A lack of understanding of the processes involved**: There was a consensus that the ways in which transport affects land use are very difficult to predict. A common viewpoint can be summarised with the following quote: '*it* (modelling transport impacts on land use) *is an area in which we are extremely weak*' (Int.11a). The points mentioned were essentially a subset of those presented in Chapter 3, i.e. the multitude of others factors involved, and hence the difficulty in empirical or statistical observation. In the words of another planner; '*there is no past database to draw upon*' (Int.8a).

2. **Control of impacts via the structure planning system**: Several planners expressed the view that the zoning in development plans could control development, and hence reduce the importance of examining transport impacts on land use (Ints.14a, 15a, 20a). In other

words the development plan system controlled exactly what development would occur and where. However, several other interviewees commented that structure plans and development plans are often circumvented, and unwanted development does occur, for political and economic reasons.

3. **The divide between land use and transport planning**: The differences in approach between these two disciplines, and their evolution in isolation from each other, was also cited as a reason for limited analysis of transport impacts. Planners traced this through separated education, training, methodologies and practice. For example, one planner said that:

   'when I came here in 1975, the view of things was that transport was quite separate, and of no consequence to land use planning' (Int.21a).

4. **A lack of significance of the impacts**: Some commented that transport impacts on land use are very much a *'second order variable in this country, where you still have a relatively high density network'* (Int.13a), due to the small increment in accessibility that any one transport policy may have in an urban area. The dominant response was that the significance of the impacts was not thought to be great in most circumstances, which was argument used to justify a lack of study. However, a few interviewees commented that the pattern of accessibility is dynamic and will affect the relative attractiveness of sites on the urban scale, and thus is important to study. Again, this reflects the findings from Chapter 3, especially regarding the importance of accessibility when a 'scarce' resource.

5. **Irrelevance of the impacts:** In some urban areas, the planners commented that few schemes were being created of the type that may lead to (what they expected to be) large impacts on land use. For example there is a current focus on congestion management, rather than infrastructure projects (Int. 4a,5a). However, other interviewees commented that this was short-sighted, given that all transport policy influences accessibility and the environment.

It should also be noted that this comprehensive range of views arises from the sample selected. Consultants working with land use and transport interaction may inevitably place more weight on the relationship than the strategic planner concerned with many aspects of land use. However, there was a general acceptance that transport impacts on land use need to be considered in more detail, given the changing objectives of transport planning, and increasing environmental concerns. The following quote from LPAC summarises this well:

'In areas as closely linked as transport and development, it would be foolish to plan development without asking what will be the impact of the trips generated by such a development. Similarly, it would be foolish to plan transport infrastructure without considering its development and other impacts' (Gardner, 1994 p.11).

Furthermore, several interviewees mentioned that with the 1991 Planning Act, and the move towards 'package bids', local authorities have to produce coherent strategies, which requires an understanding, not only of how different transport elements complement each other, but also of land use and transport interactions (Int. 13a, 19a).

4.5.2 Consideration of transport impacts on land use in the USA

As described in Section 4.3, USA Metropolitan Planning Organisations (MPOs) have to show that their transport planning methodology takes into consideration land use and transport interaction '*as appropriate*' (Int. 28a). Thus, in contrast to the UK, the ways in which transport influences land use are higher on the planning agenda. It is a relationship that American planners must take into account in order to be eligible for Federal funds, and hence has fallen into the remit of transport planning.

The interviewees' responses on whether this was an important relationship could be grouped as follows:

1. **Legislative requirements** were often cited. For example that *'this is a relationship that we have to look at because ISTEA tells us to'* (Int.33a). Examining transport impacts on land use patterns was not something that would normally be assigned a high priority, but was done for the purposes of the environmental legislation, and meant that land use response was incorporated into the modelling procedures. This is especially the case since the 'Sierra Club Case' (Transportation Research Board, 1995). This court case involved the USA environmental lobby (the Sierra Club), taking the San Francisco Bay Area of Governments (the MPO) to court over the validity of its modelling of transport, land use and air quality. Although the MPO won, this greatly raised the profile of modelling and strategic planning. It should be noted that strategic planning is very weak in the USA, with no binding structure plan requirement (Int. 30a). It is also important to point out that MPOs were seen by the sample as generally weak, with *'little mandatory power, and no elected Government at a comparable* (strategic) *level'* (Int. 25a).

2. **There was also the view that transport impacts on land use are important in planning**. Two main reasons were given here; firstly as part of the relationships to consider for comprehensive rational planning (a view common amongst federal planners

and academics), and secondly as a guide to economic growth potential, especially for the individual counties (in terms of assisting them to estimate development). This latter point is important in the USA, as county development plans tend to be over optimistic in zoning for economic growth. This is in order to encourage and secure certain types of land use, notably 'high tech' industry and office development, which yield high property taxes. One planner called some transport plans: '*bold faced seeking of road improvements to improve location settings*' (Int. 24a).

3. **Impact on the demand for travel:** Land use response was felt by the planners to be an important factor in the unexpected growth in travel on new roads, and so called '*premature obsolescence*' (Int.24a). This is very similar to the 'induced' traffic debate in the UK.

4. **Development potential of urban areas:** Transport policy was also considered important by politicians for economic revitalisation, although not many planners claimed to share this view. For example the construction of a downtown tram system in Buffalo, whilst intended to encourage business back to the city centre, has been seen by many planners as being of only limited success (Int.26a). Portland, Oregon is examining the potential of substituting a proposed orbital bypass with public transport measures designed to focus urban development within the existing urban boundaries and hence strengthen the economic position of the urban core (Int. 25a).

5. It was accepted that large **cyclical economic influences** could swamp transport impacts on land use, but that comprehensive planning is still sought, as the distribution of growth will always be related to transport (i.e. economic cycles will have a spatial component), and that planning maintains some '*rationality*' towards the process of decision making (Int.24a).

Thus in the USA, a situation has arisen whereby transport impacts on land use are examined, but not generally for the aim of undertaking strategic planning. As one academic commented '*land use development is never enough on its own* (to promote study) *always another stimulus is required, in this case concerns over air quality*' (Int.29a). Planners were quick to observe that politicians have a strong perception that transport facilitates economic growth, even if they themselves did not necessarily share this view.

4.5.3 Consideration of transport impacts on land use in Germany

In Germany, spatial planning is under the remit of the Länder (regional government), and the local/district authorities. The strong regional government of Germany would seem an ideal structure for strategic planning, and indeed the Länder are responsible for environmental quality, utility provision, transport and other spatial planning issues. The district level functions like the lower tier of the UK Unitary Development plan, implementing in detail the broad regional policies. As with the UK, there is no requirement to examine transport impacts on land use, and nothing regarding appraisal is explicit (Federal Ministry for Regional Planning, 1993). However with public transport service changes (closures as well as enhancements), the interviewee commented that it is common practice to examine the impacts of transport policy on the economy and the environment (Int. 22a) on the urban/district level. Thus, there appears to be more recognition of the interrelationships between transport and land use than is explicit within the UK.

Furthermore, a central interest within the current German planning philosophy at present is the move back towards a more 'system rationalist' approach to urban planning, which would include the impact of transport on the development of urban form. This move signifies a realisation that the *laissez faire* and incrementalist approaches to urban planning that dominated the 1980's suffer from a lack of long term vision of how the urban area will develop.

4.6 Methods used and their suitability.

In this section, it is important to draw the distinction between **'policy development'** and **'assessment techniques'**. Policy at a local authority level is determined via committee discussions. Assessment methods aim to inform policy development, either for specific *schemes* or for transport (and land use) *strategies*. The sample were quizzed upon the methods used to assess policies, and the usefulness of the results to inform policy making. The interviews were **not** concerned with how committees actually decide policy: although this has been attempted elsewhere (e.g. Forster, 1994).

4.6.1 Methods used in the UK

There are no guidelines for assessing transport impacts on land use in the UK, although it is not uncommon for the UK government to request information on impacts without specifying a method for doing so (Int. 11a). Where such effects are examined, the most common method of impact estimation is by interviewing and gaining the opinions of local businesses and 'experts'. Such '*local discussion*' (Int.12a) was one of the techniques used in 'Setting Forth' (see Chapter 5). However, such discussion stopped short of a formal Delphi exercise, where the more 'scientific' aim is to remove the bias of any individual opinion (see Chapter 6). Although interview data was advocated by some academics, the transport planners' view was generally more cautious, for example saying that *'you get very imprecise answers when you talk to industry'* (Int.12a).

Local authorities commented that the study of impacts, when done, was assessed on the basis of discussions drawing on experience, practical understanding and common sense. For example:

> *'an intuitive, common sense approach.. that is, anecdotal evidence on where was likely to attract development.. as there is no well trodden* (methodological) *path'* (Int.17a).

Likewise, another strategic planning agency commented that their transport strategies were being produced with *'a very unstructured methodology'* (Int.7a), again using anecdotal evidence and empirical case studies. The criticism was given that much of the policy documentation is short on practical methods to achieve the level of land use and transport integration advocated (Int. 8a).

Formal methods of assessment, such as modelling or Delphi, are usually the preserve of consultants and academic research institutions, the local authorities not having the skills or resources 'in house'. Local authorities in the sample generally commissioned land use modelling only as part of a transport study, and treated the results cautiously. In a recent study, one local authority commented that:

> '*the detailed outcome of this* (land use response) *work was viewed with a little scepticism by the client authorities although the general conclusion that the transport strategies supported the land use distributions rather than working in the opposite direction was accepted'* (Int. 9a).

which led to the general conclusion:

> *'I would venture to suggest that local government is very much led by consultants in this field'* (Int. 9a).

Opinion varied on the use of mathematical models for predicting transport impacts on land use. Views expressed ranged from those wanting consistent *'quantifiable modelable representation'*, on broad scales of change (e.g. spatial trends of different social groups), especially structural social and economic shifts, to more cautious viewpoints such as:

> *'what we need at the moment is a decent critique of the models available, and their relation to reality,.. and some suggestions about how they could be made better. I don't think we are beyond that'* (Int. 11a).

All the local authorities were quick to point out that models can only guide decisions. For example, *'transport planning is done by people, not computers'*. and *'never use a model to take away ones professional judgement'* (both Int.4a). However. the point was made by transport planners that models do add weight to a case. and modelling is a justified expense as the council must make decisions on the best available evidence (Int. 4a, Int. 15a).

A common view was that models were *'good for education purposes and informing, but bad if you believe the answers'*, as *'we don't really understand the processes'*, (both Int. 8a) and there is not the experience of modelling land use that is present on the transport side. Comments on the usefulness of models covered a wide spectrum. One modeller commented, rather cynically, that 'numbers', i.e. quantitative output, are a vital part of any scheme justification, and models will therefore always be required (Int.1a).

Land use planners were generally more sceptical about the benefits of modelling than transport planners. For example, with regard to road pricing (for which estimation of the land use impacts is desirable, but which may involve modelling behavioural responses to factors other than generalised cost), they were sceptical that a model could predict the result. The results would be *'interesting'* but not reliable, and very costly to obtain. In addition:

> *'there is a concern that the modelling process .. will mislead politicians, because it gives a spurious certainty to what we are talking about'* (Int.10a).

However, even some transport planners felt that adding land use models to existing transport models was creating too much additional complexity (Int. 18a).

Some academics were similarly sceptical. A modeller mentioned the problems in empirically validating the models, primarily in obtaining consistent time series data. Indeed most modellers commented that the absence of good data (especially land use inventories) was a key constraint. Another issue raised by the academics interviewed was the problem of determining the **response** of individuals to changes in accessibility, and whether these relationships are stable over time, as assumed in model forecasting (Int.1a). Some academics and planners were against modelling of behavioural responses to transport policy. One said that she had *'fundamental doubts about modelling as a way of looking at the world'* (Int.6a), and added that modelling tends to perpetuate the *status quo*, and hence does not lead to imaginative policy developments.

The planners that had experience of Garin Lowry models in the 1970s were familiar with the disillusionment that occurred with these models, and concerned that their demise has taken from the planners a useful tool. As one commented, the fall from favour of modelling:

> *'was a case of throwing the baby out with the bathwater. At least it fell down because were not able to translate this into simple relationships that the councillors could understand'* (Int.3a);

and that with regard to today's planning requirements:

> *'if we had something on that* (strategic) *scale, to look at land use and transportation, that would be simple to use, that would be smashing.'*

This reflected a general observation concerning the sample, that familiarity with the models (which also was associated with a technical education), tended to lead to more positive comments about modelling.

4.6.2 Methods used in the USA

The key reason for undertaking further interview analysis in the USA was the wider use there of techniques that can estimate transport impacts on land use. ISTEA requires land use forecasting, although it does not specify a method that should be used. Table 4.4 below shows a sample of the 34 largest MPOs, and the land use forecasting techniques used.

All are methods of allocating regional growth predictions to smaller zonal scales. What makes them different from UK forecasting is that in all of these techniques transport policy should explicitly be taken into account in the derivation of the land use forecasts. Most of the discussion below will focus upon DRAM and EMPAL, elements of an entropy maximising model developed over several years by Putman (1994), and introduced in Chapter 2. These models are very much the 'standard' approach, originally forming an element in the Federal DoT Urban Transportation Planning System (UTPS) from the 1970s, and currently being the land use models with the most applications in the USA.

Table 4.4: Summary of USA land use forecasting techniques (from Deakin, Porter and Melendy, 1995)

Forecasting Technique	Number employing method (sum to 34)
DRAM/ EMPAL	11
Other models (e.g. PLUM in San Diego, POLIS in San Francisco)	6
Policy based normative land use plan (Milwaukee)	1
Qualitative: regional totals/census tract totals redistributed.	14
Delphi technique (Charlotte, Washington)	2

Although both case study areas were currently implementing DRAM/EMPAL, their histories were very different. Atlanta has used a regression based model, EMPIRIC, for many years, but has phased this out in favour of DRAM/EMPAL (Int. 29a). Chicago has undertaken no new modelling for 20 years, but instead has carried out a process of forecast revision every two years (Int. 32a). The views from the sample on the techniques can be divided into three sections; (1) the use of the models, (2) the adequacy of the techniques and (3) the future and potential improvements. These are discussed in turn.

From the interviews, there seems to be a trend among the larger MPOs to move towards a computer modelling approach to land use and transport interaction in the long term. However, each state has its own individual agency structure, each with different remits. Atlanta, for example, has the regional agencies for both planning and transport planning brought together as ARC (Atlanta Regional Council). ARC have produced forecasts using DRAM/EMPAL (Atlanta Regional Commission, 1995). Chicago, by contrast, has separate organisations, with NEIPC (North Eastern Illinois Planning Commission) traditionally responsible for land use forecasts (and hence DRAM/EMPAL), while CATS (Chicago Area Transportation Study) undertakes the transport modelling. There is some difficulty here co-ordinating the combined modelling resources.

The rationale for using DRAM/EMPAL in Atlanta is chiefly to allocate regional growth forecasts to a zonal (sub-county) level, in order for other agencies (sewage, education etc.) to have forecasts to work with. The model is **not** used to examine the impact of different transport policies on land use policies, as there are few land use policies for the region, the interest being instead upon catering for growth (Int.29a). A good example of this is the Atlanta 1989 Growth Management legislation, which is concerned with co-ordinating counties for anticipated utility demands, i.e. it is concerned only with accommodating economic and demographic development.

This highlights the fact that the use of such models in the USA is primarily for **traffic modelling,** (and hence for the prediction of future year transport patterns to feed into air quality models), and thus the land use predictions themselves are not the final desired outcome of the modelling process. However, this output has been seized upon as useful in debates about transport policy. A good example of this is the current debate over infrastructure projects around Chicago.

In Chicago there has been debate regarding the benefits of expending significant resources on DRAM/EMPAL modelling, when the transport planners do not anticipate significant land use changes from the policies proposed. However these policies include an outer ring road and a third airport, which would be expected to have significant impacts. Consequently there is pressure from various environmental groups to undertake the modelling to examine the impact of these proposals on land use. The environmental lobby believes that the results will show increased urban sprawl due to higher peripheral accessibility to the south of the urban area (see Figure 4.2), which they claim is undesirable on environmental grounds. There is also the claim that the beltway and airport are being located specifically to provide a focus for economic growth south of the city (Int. 35a). The net result is that the impacts that transport will have upon new development and the re-distribution of activities in the Chicago Metropolitan area are high on the political agenda, and there is some pressure to provide estimates of the possible land use changes.

With regard to the adequacy of modelling, as was common in the UK sample, there was a general caution. It was found that planners considered the use of a model more difficult where politics or conflicting objectives were involved, as in the Chicago example. Rather, models were better suited to giving best options in a consensus environment. The idea of using a model for holistic urban development was redundant as '*political realities often making modelling useless*' (Int. 24a). In other words the models were not perceived to represent the chaos of the real system.

There was criticism from the sample on the requirements of the CAAA and ISTEA. An interviewee in Atlanta commented that the regulations were unlikely to survive in their current form, simply because the attainment standards were too high (Int. 29a). Moreover, they required a level of statistical certainty that modelling cannot deliver. The following comment is typical of the view expressed by several state planners:

> '*the current regulatory requirements demand a level of analytic precision beyond the current state of the art in modelling*' (Transportation Research Board, 1995 p.6).

This quote is taken from a study into the relationship between transport policy to reduce highway capacity, and its impacts on air quality.

Similarly the MPO Commission often demanded more from a model than it (and the modellers) could reasonably deliver. For example, zonal disaggregation was cited as a problem, where county planners wished for forecasting on a very fine scale, at which '*the relevance and significance of a statistical model (i.e. EMPAL) is completely lost*' (Int.29a).

Also, one interviewee commented that the concept of probabilities and uncertainty in estimation was not always easy for planners and decision makers to deal with.

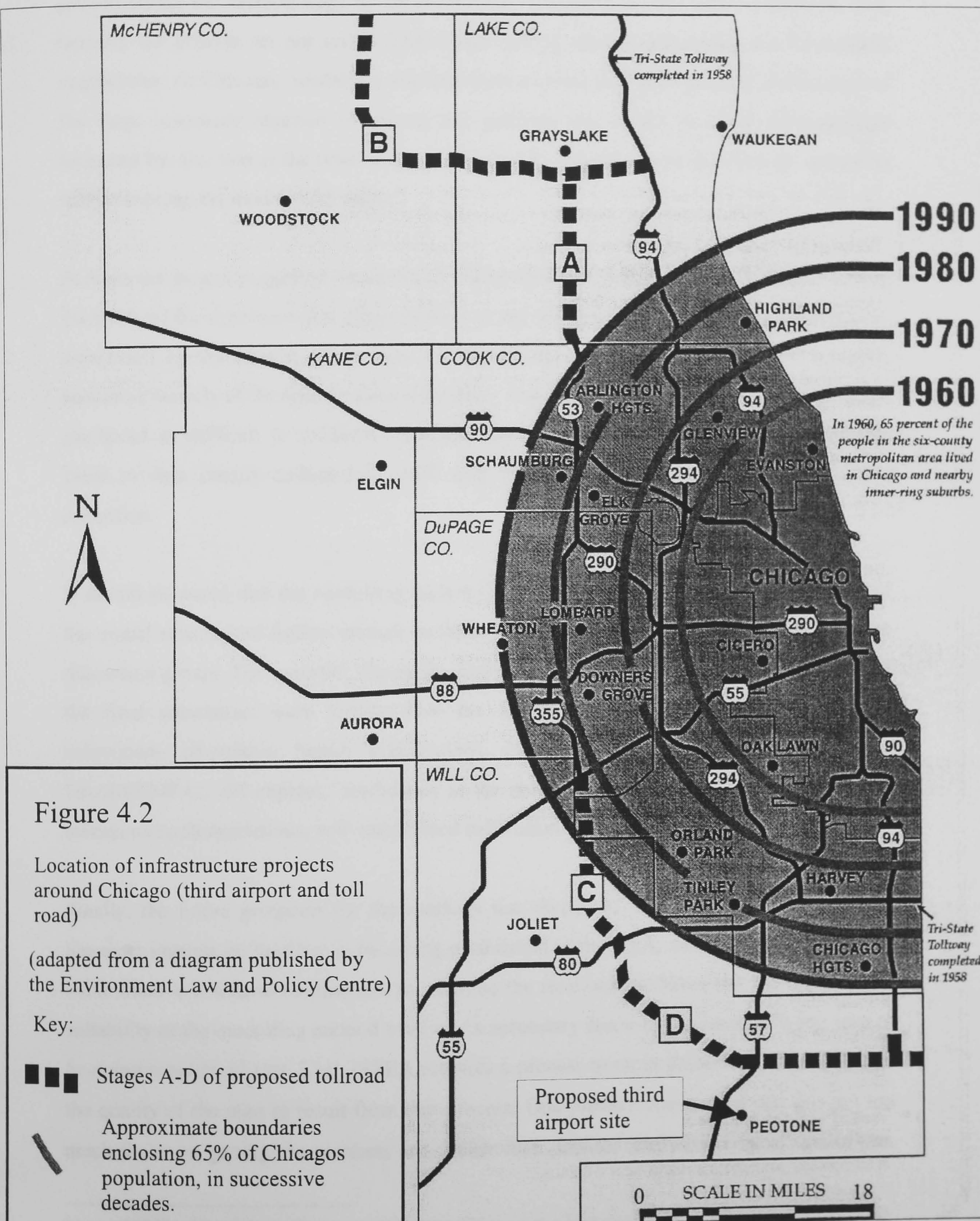


Figure 4.2

Location of infrastructure projects around Chicago (third airport and toll road)

(adapted from a diagram published by the Environment Law and Policy Centre)

Key:

Stages A-D of proposed tollroad

Approximate boundaries enclosing 65% of Chicagos population, in successive decades.

As to the appropriateness of the modelling itself. comments mostly relate to DRAM/EMPAL, which very much is the 'standard' practice model. When asked whether the model met the aims for which it was applied, the answer from the Atlanta Regional Council (ARC) was both yes and no. 'Yes', because the model is the most reasoned method to allocate growth where the methodology of the model and its limitations are well understood. 'No', because the criteria set out under CAAA and ISTEA are too demanding for the model's capabilities. At Chicago, modelling was criticised on more technical grounds and because of the large resources required to set up and calibrate the model (Int.32a). This perhaps reflected the fact that at the time of the interviews, the planners were involved in designing and resourcing the model calibration.

Perhaps the largest suggested weakness of DRAM/EMPAL was that it is unsuited to testing the kinds of fiscal policies that planners wish to test. However, of the other models that were mentioned by the sample, some were too expensive, others too unwieldy. For example, economic models of the type developed by Anas (e.g. Anas, 1985; 1995) were desirable, but perceived as difficult to calibrate[2]. Perhaps more importantly, DRAM/EMPAL used the kinds of data already collected by ARC and NEIPC, rather than requiring specific data collection.

It should be noted that the modelling undertaken at ARC still required detailed analysis of the model results, and further manual reallocation of the output, via a series of Delphi type discussion groups. For example, during the earlier EMPIRIC modelling, only around 40% of the final allocations were results from the model, the remaining 60% coming from subsequent, discussion based, reallocations. However, the modeller responsible for DRAM/EMPAL did express confidence in the results, due in part to its reputation from numerous implementations, and established calibration procedures (Int. 25a).

Finally, the future prospects for the methods was discussed with the planners. Modelling transport impacts on land use is becoming established in the USA, and is likely to remain so while there is a federal requirement to examine the relationship. However, the adequacy or suitability of the modelling method used was a secondary factor to the issue of '*being seen to be doing something*' (Int. 27a). ISTEA requires a process to be in place, and does not judge the quality of the plan to result from that process. One planner commented that this put too much focus on getting the numbers out, rather than detailed analysis of those results (Int.

[2]Anas (1995) outlines the calibration of the NYSIM short run land use model. Calibration was a series of steps that varied for each submodel, and appeared most complex for the shopping model and the derivation of the utility coefficients.

27a). Furthermore, it is true to say that some planners were entering into this formal analysis quite reluctantly. Nevertheless, the modelling frameworks seemed to be increasing in complexity, with integration of the models into Geographic Information Systems and fully automated model iterations (Putman, 1994).

Part of this reluctance is that there is still a large divergence of opinion concerning the circumstances under which transport impacts on land use are significant. Certainly some saw forecasting land use impacts as secondary to network effects (Int. 34a), and not significant enough to warrant the complexities of modelling them.

There was also a realisation that the devolved county structure and general 'bottom up' planning framework in the USA is unsuitable for strategic economic forecasting. However, the hurdles to overcome this are large. For example Atlanta comprises six counties; but its area of economic influence extends into others which ARC does not have a remit to analyse, but which contribute to the transport problems in Atlanta itself. Nor do the peripheral counties wish to be incorporated into the Metropolitan area, due to the higher taxes and urban problem issues that this could involve them in.

The comments from federal government however, were that the environmental emphasis will not weaken, and integration of transport, land use and environmental planning will continue, with perhaps a strengthening of regional government. This view is reflected in the recent Federal Housing and Urban Development document; 'Regionalism: The New Geography of Opportunity' (Cisneros, 1995), which argues towards an elected, and hence accountable form, of regional government in the USA, to further strengthen this process (Int. 24a). This is a significant step, and would provide an elected government on the same tier as the MPO. i.e. on a regional level.

4.6.3 Methods used in Germany

Transport impacts on land use are assessed in an *ad hoc* basis in Germany, and analysis tends to make use of 'impact' studies, rather than dynamic modelling. In fact, the interviewee commented that there was no use of complex urban modelling other than 'traditional' traffic demand modelling. For example, the IRPUD model was applied in Dortmund and Cologne in 1970s, but despite initial enthusiasm, neither city updated their datasets, and the model is no longer used in planning studies (Int. 22a).

Much of this decline was put down to changes in planning ideology, abandoning the 'master planning' approach, and opting for more incremental approaches in the 1980's. In this respect the decline of 'rational systems' approaches to planning was a multinational occurrence. Furthermore, there was a realisation that obtaining data on land use impacts was difficult, and that statistical estimation for calibration was often impossible. A central problem in estimating impacts was that empirical and theoretical evidence may be in conflict, and hence subjective judgements must be involved.

As for whether there was likely to be any resurgence in the use of models, the interviewee pointed to a burgeoning study of land use transport models, and the realisation by planners that a 'vision' of urban areas is required, which is likely to lead to renewed use of modelling for strategic forecasting.

4.7 Comparison between the sets of interviews

Any comparisons or conclusions about treatment of land use impacts between the UK and USA need to be seen in the light of differing planning structures between the two countries. The USA has a very devolved planning system, with weak strategic planning and responsibility for land use development plans generally falling to the counties, i.e. the lowest agency tier. This can be termed a 'bottom up' structure. Unlike the UK there is then no binding urban strategic plan to which the county plans have to comply, only guidance produced by the MPO and Council of Governments (the land use planning equivalent of the MPO). Property development is very much seen as the unassailable right of the individual. Germany also has a 'bottom up' system, but in contrast to the USA, regional government is very strong. The UK is more 'top-down'; although some of the planners interviewed felt that strategic planning is threatened by local government re-organisation, an issue discussed further in Chapter 5.

The interview results presented in this chapter show several areas where treatment of transport impacts on land use are similar in the UK and USA, and some in which they are different:

4.7.1 Similarities

- Both sets of interviews, plus the German interview, point to a **renewed interest** in transport impacts on land use, although for different reasons. The net result is more discussion about suitable methods to understand, conceptualise and forecast the impact that transport policy has upon land use.

- There is a tentative acceptance that forecasting transport impacts on land use produces useful data, that outweigh the cost of producing them in most circumstances.

- However, both the UK and USA interviews also point to a **lack of consensus** in planning as to the circumstances under which transport impacts on land use are important. Different experts will have conflicting views about the same transport policies, as shown with the toll road and third airport in Chicago.

- Another key similarity were comments about the importance of viewing transport impacts on land use **together with** other elements in the urban system, especially economic growth and overall transport policy objectives. There is an acknowledgement that predicted impacts, are just one element in the decision making process.

- The **separation of land use and transport planning** into two distinct forms of functional planning was also common. This is most marked by the presence of separate planning and transportation organisations, as in most authorities in the UK, and some agencies in the USA. However, a key point raised by one interview in the USA was that simply putting land use and transport planners together in one agency is not enough: what is required is a broadening of vision and methods, especially in the **education** of planners.

- Another similarity, although noticeably more marked in the USA sample, was the focus upon effective and consistent **data collection** over time, and the ability of the models to use this existing data. However, maintaining and updating a dataset is expensive, even if it can be used for monitoring without a modelling methodology.

4.7.2 Differences

- The current incorporation of transport impacts on land use into the USA transportation planning process is a major distinction from the UK and Germany. The explicit focus upon **process** in the ISTEA regulations, as a **Federal requirement,** goes beyond UK land use and transport policy. It is forcing the use of explicit techniques, which means that the relationships considered are more clearly demonstrated. As one UK consultant commented:

  '*the Americans do the real avant-garde kind of work, not necessarily the intellectual development, but they do impose the standard*' (Int. 23a).

- The **attitudes towards modelling** also differ. In the UK, land use planners are generally more sceptical about modelling than in the USA. From the American sample there was less debate about whether models are appropriate or not, and more about which method was best, and ease of implementation. It seemed to be the view that when faced with the prospect of **having** to examine transport impacts on land use, modelling approaches were favoured as being more rigorous, with Delphi being a lower cost alternative.

- The **use of models** is also different. The use of land use response models in the USA was not as widespread as first thought, although the number is steadily increasing. Furthermore, most MPOs using a model run 'one shot' (or static) land use models, which vary in the level of interaction with the (mostly pre-existing) transport model. Fully interactive modelling (of the type found in MEPLAN or LILT) is still in the experimental stage (Putman, 1994). Furthermore, it should also be noted that only a small number of MPOs currently use land use models. Far more common, according to the sample, is a discussion based 'Delphi' type exercise.

- The view from several UK experts, that the structure planning and development control system can 'control' land use impacts, is not the case in the USA. Firstly in the USA, structure planning is very weak, spatial zoning is administratively separated from planning, and development rights are very strongly guarded at the local level. Secondly, and perhaps more important; there is a much greater respect of the power of the free market to develop as it wishes than is acknowledged in the UK.

With interview results, the key consideration must be how far the samples are representative of the planning situations in the UK and USA as a whole. It is thought that the sample is representative due to the selection criteria outlined in section 4.3. However, there is a bias in the sample in that 'cutting edge' opinion was deliberately sought. The responses would probably have been less positive if a random selection of planners had been chosen (especially in the UK), as there is little familiarity with transport impacts on land use according to the sample. It is also interesting to note that there was significant overlap in views between different elements of the sample, and in many respects the distinction of the sample via their education and training is more revealing than their current position. This is best illustrated with regard to views on modelling, where the more training and experience with models the respondent had, the more likely they were to give favourable comments towards them.

4.8 Conclusions

The results of this qualitative investigation into planners' views on the importance of transport impacts on land use set the context and justification for the thesis. The evidence presented in this chapter suggests that the hypothesis:

> ***That there is no common practice of assessing transport impacts upon land use in the UK, despite the existence of appropriate methods. Lack of data, plus a belief among planners that the impacts are of only minor importance, has restricted study for the purposes of strategic urban planning;***

is correct. The review of the policy literature, combined with a consensus from the sample, revealed that there is no common practice of assessing transport impacts on land use within the strategic planning process in the UK, either in the derivation of structure plans, or in the appraisal of transport policy.

It was found that the reasons for this lack of common practice focused upon four issues. Firstly the lack of a requirement in government policy or guidance to examine these impacts. There is only brief mention of the issues in PPG13, which focuses only on the issue of reducing travel via land use planning, for which policy instruments are already in place. Secondly, there is a perception that when transport impacts on land use do occur, there is little policy significance associated with them, and the development control process can prevent unwanted impacts. Thirdly, the findings from research into transport impacts on land use, as found in Chapter 3, are often inconclusive and ambiguous. Finally, most planners are unfamiliar with the techniques that can be used to examine transport impacts on land use.

Underlying all these issues is the fact that effective assessment of transport impacts on land use relies upon linking land use and transport planning, linkages which have been eroded during the retraction from comprehensive planning during the 1980's. Thus the current situation is one in which land use response is treated inconsistently, with development benefits highlighted where desirable, and ignored when not. Any methods used tend to be *ad hoc* and rarely comparable with other studies. This hinders developing a clear understanding of the impacts of transport on land use over time.

However, the interviews also showed that there are strong reasons for concluding that the lack of study of transport impacts on land use is in need of reappraisal. There was a general consensus from the sample that:

- a shift back towards comprehensive planning, combining land use and transport, is necessary to address the 'sustainability' and environmental goals of planning, including issues of reducing traffic congestion, increasing air quality and developing energy efficient urban forms;

- land use impacts may be responsible for features such as the '*premature obsolescence*' (Int. 24a) of transportation facilities (e.g. new roads becoming congested far earlier than predicted due to changing land use patterns), meaning that transport planning must incorporate land use elements in order to produce accurate and robust transport forecasts.

From a smaller number of the sample, there was also the realisation that market processes can often subvert the planning system, and that conflicting objectives within planning can often lead to development in areas where development was not intended. Moreover, this often occurs with new or improved transport corridors.

It can be concluded from these findings that the research agenda needs to change. The time for debating whether transport impacts on land use should be considered is over, and research must move on to the critical issue of finding the most practical methods of studying such impacts within the planning system. The hypothesis stated that 'appropriate methods' already existed; a clause that was not substantiated from the planner interviews. In the UK, knowledge of potential methods was sketchy, the preferred approach seemed to vary depending upon the views of the planner or expert concerning modelling in general. Thus there was no consensus on the best overall method (see Section 4.6.1).

However, in the USA, the modelling methodologies were considered the most appropriate and prestigious in order to meet the ISTEA requirements. This was largely without knowledge of the accuracy or reliability of the results that the models could produce, and indeed an important conclusion from the American interviews was that the methods were applied in order to be 'seen to be doing something' rather than to produce high quality forecasts.

On the basis of these conclusions, the remainder of the thesis examines different methods of forecasting transport impacts on land use, and determines their relevance to strategic planning in the UK. From the US interviews, it is clear that assessment of methods needs to be made against issues of cost, complexity, and acceptability. Chapter 5 begins this by introducing the study area for the application of the methods, and its land use and transport planning context.

CHAPTER 5
INTRODUCTION TO THE CASE STUDY AREA: EDINBURGH AND ITS SURROUNDING REGION

5.1 Introduction

This short chapter has two aims. Firstly it introduces the study area where the methods for estimating land use response were applied, and provides the necessary economic and policy background. Secondly it outlines the interview methodology that was applied in the case study area, and summarises some of the Phase 1 interview results that specifically apply to Edinburgh and Lothian.

Edinburgh and its surrounding region was ideal as the study area for this research as it is:

- a growing and relatively self contained city, which is likely to continue expanding, leading to pressures on the strategic planning process to cater for growth and also plan for a more sustainable urban system;
- of a sufficient size to warrant examination on the strategic scale;
- in common with many other cities, facing decentralisation and counter-urbanisation pressures.

Clearly a number of UK regional capitals could also fit these criteria, including Bristol, Newcastle or even London. However, Edinburgh also had a number of practical advantages, including the availability of a suitable transport model, and its consideration of both LRT and road pricing as policy options. On this basis Edinburgh was selected as the case study, and permission obtained to use the strategic authorities' transport model of the study area.

5.2 The geography of Edinburgh and its surrounding region.

5.2.1 Demographics, development and employment.

The study area was largely determined by the zoning of the transport model. It therefore consists of Edinburgh and its surrounding districts of West Lothian, Midlothian and East Lothian, covering 1723 square kilometres (Lothian Regional Council, 1991). The area is Scotland's most densely populated region, with a total population of just over 750,000 people. Summary population and employment data is presented in table 5.1. The region of Fife is also included, due to its social and economic links with Lothian.

Table 5.1: Summary study area population and employment statistics (Lothian Regional Council, 1994)

	Edinburgh	East Lothian	West Lothian	Mid-Lothian	Lothian Total	Fife
1991 Population	439,700	84,900	146,400	80,100	751,000	149,252
LRC Population estimate 2005	*457,600*	*90,200*	*153,700*	*84,700*	*786,300*	*N/A*
1991 Service Employment	204,100	14,200	28,700	13,900	260,900	N/A
1991 Total Employment	248,900	21,400	49,300	20,700	340,300	93,800

Figure 5.1 shows the district boundaries, while figures 5.2a and b show the Lothian and Fife study area divided into 25 zones. From figure 5.2a, Edinburgh clearly dominates, being the capital of Scotland and Britain's second financial centre after London, with the service sector comprising over 80% of all jobs in the city. Zone 1 comprises 'New Town', a largely Georgian area with over half the office space and service sector employment in Lothian (also known as the 'Golden rectangle': Figure 5.3, page 83). During the 1980s there was fast growth in office construction (such as the West Central Exchange, in zones 1 and 14) and increases in service sector employment densities.

Figure 5.1: Study area map showing the district boundaries and study area zoning for the transport and land use models (see Chapters 7 and 8).

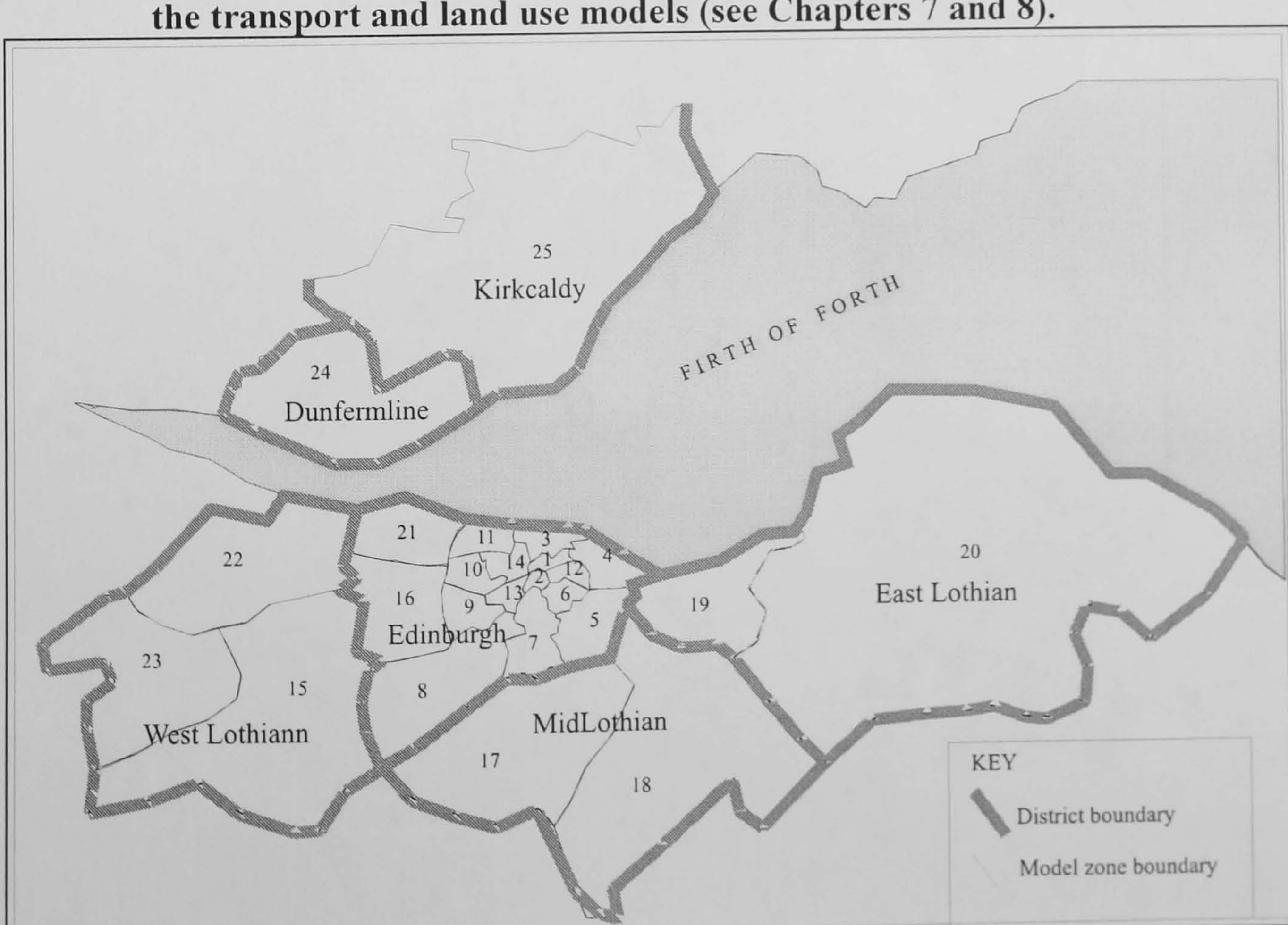


Figure 5.2: ***The study area: Edinburgh and surrounding districts***
(Reproduced from The MVA Consultancy, 1994)

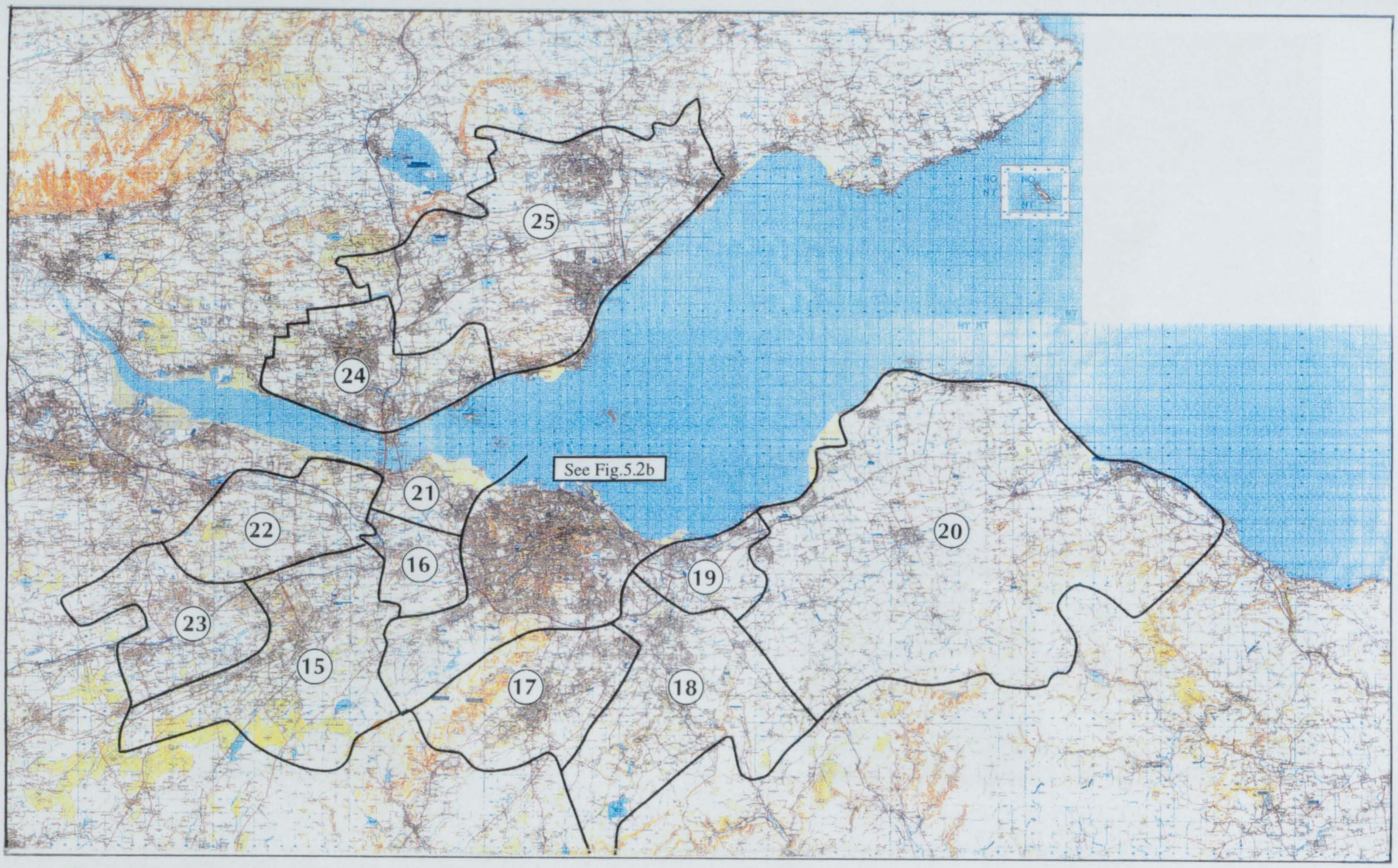


Figure 5.2a: **Map of the study area (Lothian and Fife), showing outer zones for the JIF (JATES into Fife) modelling study.**
Note that for the previous JATES (Joint Authorities Transport and Environmental Study) work, zones 15, 22 and 23 were combined as zone 15, and zones 24 and 25 excluded.

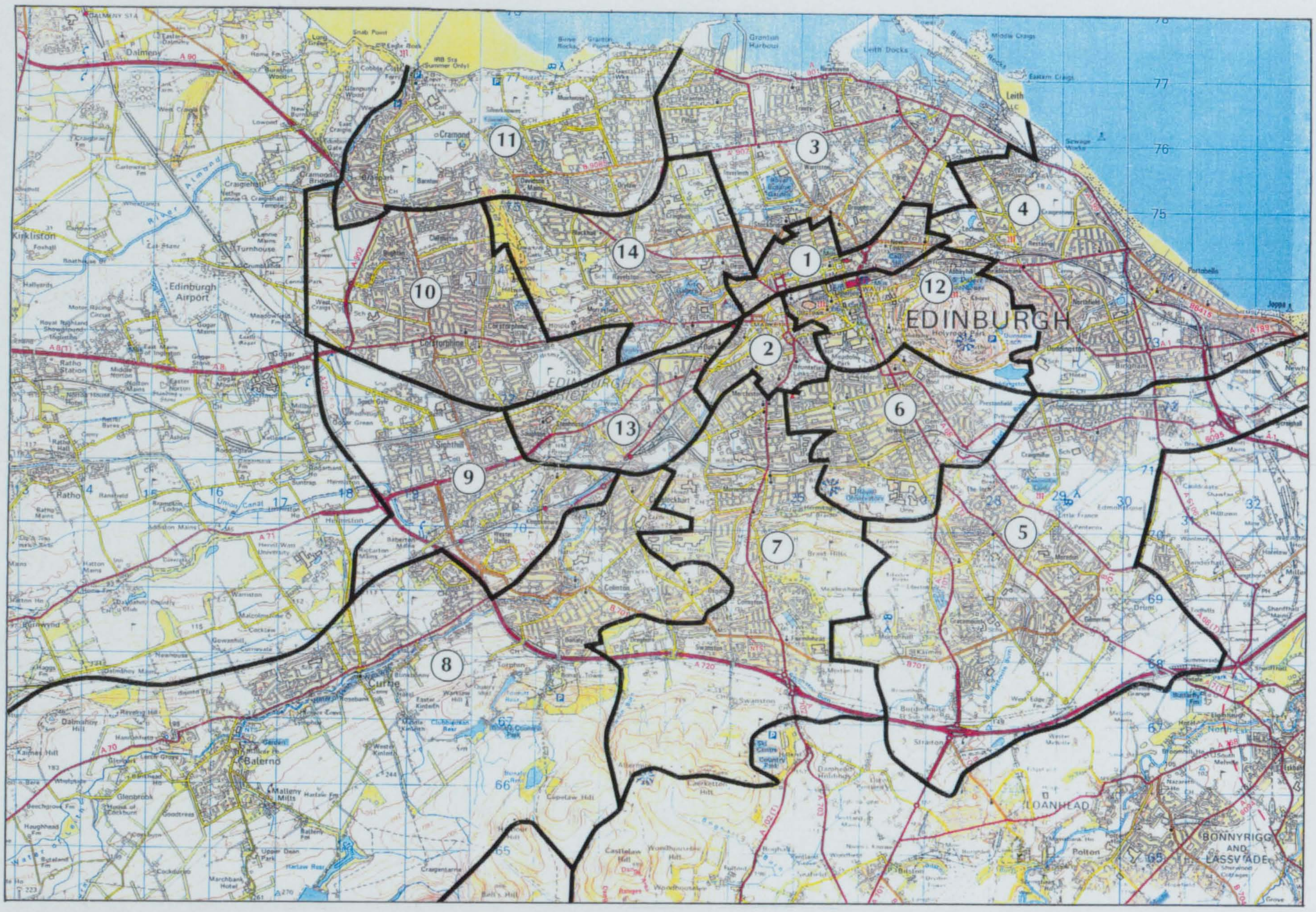


Figure 5.2b: **Detail of Edinburgh divided into 14 zones**

Figure 5.3: Edinburgh New Town. (George Street facing Charlotte Square). This area of the city includes a large percentage of the office space in Lothian, as well as several public attractions such as art galleries and parks. It is under increasing environmental pressure from car traffic.

Figure 5.4: The Scottish Office, Victoria Dock, Leith (looking south). The Scottish Office employs over 1600 workers in this building, which includes a swimming pool and squash courts. This 'London Docklands' type development has accompanied some gentrification of housing and facilities, but much of Leith remains in decay; notice the high rise blocks in the background on Lindsey road, an area where the urban environment is much poorer.

Decentralisation of businesses is also occurring, especially to the west of the city, with developments such as Edinburgh Park and South Gyle (zones 9 and 16 respectively). Further out, West Lothian is also a fast growing area, both as a commuter area for Edinburgh, and as an employment centre in its own right. For example Livingstone has grown by 1000 jobs a year for the last decade, and now has a population of over 41,000 (Estates Gazette, 1995). Most of this has been in either high technology or service sector jobs along motorway corridors.

However, while the centre and west of Edinburgh may have high service sector growth, there are also depressed areas such as Leith and Sighthill, most with bespoke re-generation schemes. Perhaps the most high profile of these has been the regeneration of the Port of Leith (zone 4), including the move of 1600 jobs in the Scottish Office to Victoria Quay (figure 5.4), and current plans for new developments including a large shopping and port development called 'Ocean terminal'. There are also Scottish Development Agency schemes in Wester Hailes and Sighthill (zone 9). Even the 'Old town' (zone 2) has required regeneration, the 'Edinburgh Old Town Renewal trust' acting to increase economic activity and population in this area (Planning, 1997).

In terms of housing, the region is facing a general shortage of stock. The Lothian Regional Council Report of Survey (1994a) comments that housing provision is a central problem in Lothian, both due to a lack of suitable sites, and a lack of spare capacity in utility provision (e.g. water and education). Edinburgh is widely considered to be a city of high cultural and architectural quality, and has a significant tourist industry. However, it is also true that that quality is being eroded by development pressure and traffic growth. Edinburgh has a green belt, and is pledged not to encroach upon it. In spite of this there is a major plan for up to 5000 dwellings 'the South East Wedge' development (in zone 5), itself partly situated on Greenbelt.

5.2.2 Transport and land use planning: organisation and policy

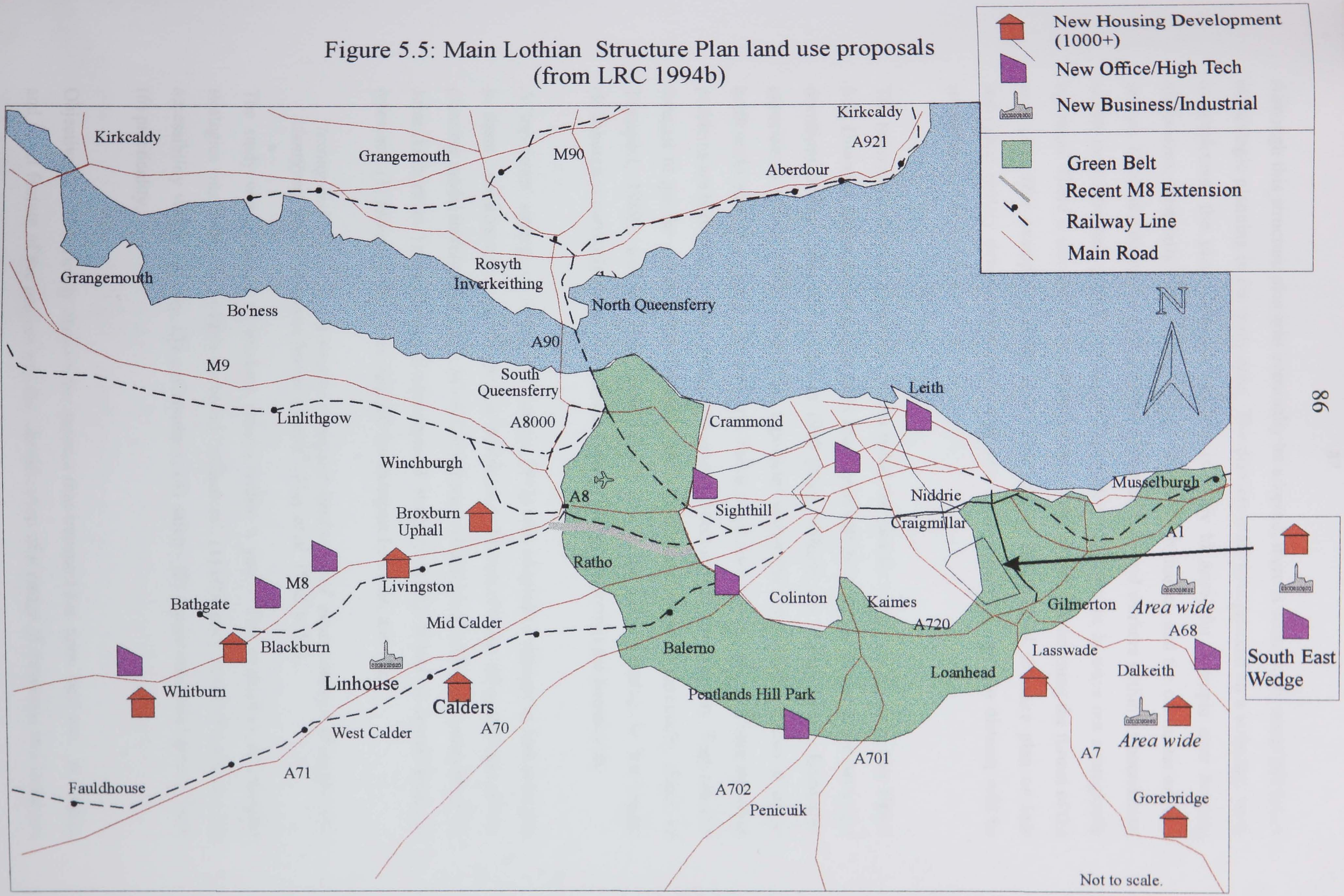
Until the reorganisation of local government in April 1996, transport policy in Edinburgh and Lothian region was determined by a strategic authority, Lothian Regional Council (LRC). This had a Department of Transportation (formerly highways), and also a Planning Department, responsible for the structure plan and public transport planning. Below this strategic tier, the districts were responsible for local planning matters and development control, but had no specific transport planning powers.

However, since April 1996, the local authority structure has been reorganised into four Unitary Authorities, responsible for all local authority activities. This change of structure has meant the fragmentation of LRC, while the new Unitary Authorities maintain the old district boundaries (shown in figure 5.1). This movement of responsibilities, offices and staff has had implications both for planning in Lothian, and for the interviews undertaken as part of this research.

The **structure plan** was produced by the Regional Council in 1994 and has not yet received final approval from the Secretary of State for Scotland. The plan itself was developed in consultation with the Districts (who are now the District Unitary Authorities), and hence is unlikely to be changed as a result of re-organisation, and in fact the new authorities are under an obligation to adhere to the structure plan. The plan cites forecasts of increased decentralisation of population and employment out from central Edinburgh, with the population growing in the outer zones, especially to West Lothian. The main structure plan policies are shown in figure 5.5, which is derived from the draft structure plan (Lothian Regional Council, 1994b). This figure shows that:

- housing development is to be focused in the 'landward' districts, notably at Bathgate, Livingstone, Dalkeith, Lasswade and Mayfield, while the main city development is the 'South East Wedge' development (which is planned to include dwelling, industry, offices and a medical park);
- there is limited housing development in the city of Edinburgh itself, which is seen to be at capacity, and unable to meet substantial increases in demand for housing without a decline in environmental quality;
- economic development is to be focused in existing 'strategic business centres' such as the Gyle and Livingstone, and also in re-generation areas, such as Whitburn, Sighthill and Leith;
- the Greenbelt appears to be largely safeguarded, but the South East wedge and several other developments do encroach upon it;
- there is a focus of development upon road corridors with 'capacity' for example the M8, A7 and A68. In contrast to this, the M9, which is already heavily developed, is to be safeguarded from further significant development.

Figure 5.5: Main Lothian Structure Plan land use proposals
(from LRC 1994b)



Note: '*Area wide*' means industry to be allocated throughout the area.

Although this structure plan will eventually be adopted, there is some doubt about the future of strategic planning in the study area. The districts must now proceed on a voluntary basis to implement the plan. However, friction is likely to arise, for example over housing allocations, especially between Edinburgh, the main job market, and the commuter areas it serves. There is a desire for each district to 'capture' jobs and workers within its boundaries, which may introduce pressure to spread economic development in ways not strategically optimum. There is also a great uncertainty amongst the planners concerning the format of the next plan, (for example possible options include another unified structure plan or four individual unitary development plans) and how much agreement between districts will be necessary.

The transport system is dominated by the radial corridor focus upon Edinburgh, (see figure 5.5). However, there has been little other road construction in the last 20 years, the last major development being the city bypass in 1990 (May, Roberts and Mason, 1992). Edinburgh experiences severe traffic congestion, especially within the city itself, but also at major bottlenecks such as at South Queensferry. Parking is a particular problem. These transport problems are high profile given the historic and architectural nature of the city. They are also forecast to get far worse given the travel growth forecasts produced nationally, (Dept. of Transport, 1989), and the high potential for growth in car ownership in the region (Edinburgh is currently below the national average for car ownership per household).

A 'top-down' strategy (Coombe and Copley, 1993) was adopted to attempt to find solutions to these environmental traffic growth problems. This made use of a strategic sketch planning model developed by The MVA Consultancy (Bates *et al,* 1991), and was called the Joint Authorities Transport and Environmental Study (JATES). It had as central terms of reference (1) assessing the future demand for transport by mode, and (2),

> "*testing and evaluating alternative transport, land use and environmental strategies and identifying the interactions between these*" (May *et al,* 1992, p. 52).

The study was designed to produce results within a year. The evaluation of transport strategies was determined within six broad 'indicators': (1) efficiency in use of resources, (2) accessibility within the city, (3) environment, (4) safety, (5) 'economic development' and, (6) practicality.

Objectives 2 and 5 clearly involve the impacts that transport has upon land use. A central, and novel feature of the project was the identification of a **range** of measures and strategies to meet the objectives, giving the client flexibility to determine the final strategy through the '*local democratic process*' (May *et al*, 1992 p.58).

The model itself is discussed in more detail in Chapter 6, however, it is worth noting that it was a 'sketch planning model' that estimated future travel patterns for motorised modes, and also gave information on the environmental and financial implications of transport strategies. The study period was from 1990 to 2010. The most obvious feature which differentiates it from a 'standard' transport model is the absence of an explicit network, and the coarse zoning system. The original model had 22 zones for all of Lothian. This coarseness allowed for a fast run time, meaning that a large number of transport strategies could be tested.

In JATES four 'land use scenarios' were modelled, where different levels of population and employment in 2010 were assumed. Essentially these were a 'high' and 'low' economic growth scenario, with a 'trend' and 'balanced' in between these estimates. This was to allow for a range of likely economic growth, and also for the 're-arrangement' of land uses in 2010, to show the possible outcome of land use policies attempting to balance jobs and housing in study area zones[1].

The do-minimum projections (under different scenarios) gave predictions of an increase of between 10-24% in trip numbers, and an increase of 13-30% in trip km, with a fall of 4-12% in traffic speeds. In all scenarios, it was the city centre and areas to the north of the city that experienced most accessibility decline. All zones experienced decline in terms of the indicator of 'economic development', which was based upon accessibility, congestion and environmental indicators. Note that there was an assumption here that businesses would be attracted to zones in which these conditions were improving, hence leading to economic development.

A series of strategies were developed to attempt to mitigate the problems identified in the do-minimum. Ultimately, six 'cartoon' strategies were suggested as performing the best in terms of reducing car travel while maintaining accessibility and environmental quality. These are shown in table 5.2, with the performance indicators of each strategy.

It is useful at this point to outline the LRT and road pricing strategies from table 5.2, as they were central to the JATES study, and also are the tests applied in this study. Both are shown

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[1]Some work examining the sensitivity of transport indicators to different land use patterns was undertaken by Still (1992). This showed that a concentrated land use pattern could reduce total trip km by up to 7%. The Dept. of Transport is currently undertaking modelling of a similar kind using a similar strategic model of Bristol.

in figure 5.6. The LRT consisted of high quality 'Metrolink' type trams, with two lines. The 'north-south' line was proposed to run from Davidson's Mains (zone 11), going south through the city centre to Burdiehouse and Gilmerton (i.e. zone 5: which is also the site of the proposed 'South East wedge' development). The 'east-west' line was intended to run from the airport through the city centre, and on to Leith. The proposed frequency was 12 trams an hour, with fares matching bus equivalents.

Road pricing consisted of a cordon around the city centre Old and New Towns, (i.e. zones 1,2, and 12). Cars were charged £1.50[2] each time they passed through the cordon (in either direction), but buses were exempt from the charge. It was also assumed that the system operated effectively (i.e. drivers could not avoid the charge).

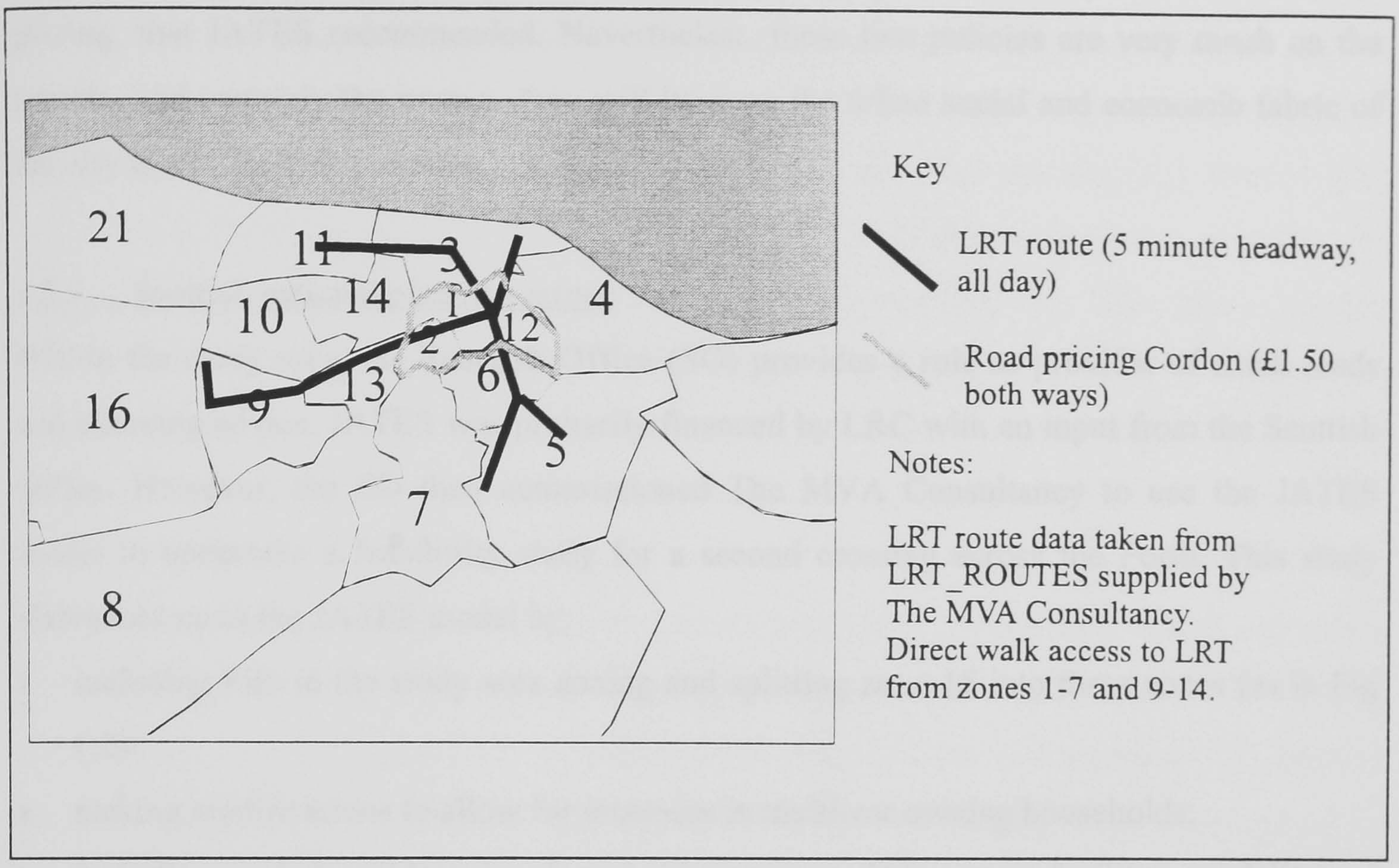
Table 5.2: Features and performance of the final six JATES strategies (The MVA Consultancy, 1991 p.70-4)

Strategy	Do min	C1	C2	C3	C4	C5	C6
Finance (PVF £m)	N/A	-260	-270	-100	-160	+10	0
Infrastructure included	No	NS LRT EW LRT W. radial	NS LRT EW LRT W. radial	NS LRT EW LRT W. radial	NS LRT W. radial	NS LRT EW LRT W. radial	NS LRT W. radial
City centre road capacity reduction	0	10%	10%	25%	10%	25%	10%
Public transport fares (chg.: 2010 Do Min)	N/A	-50%	0	-25%	0	-10%	25%
Road Pricing £1.50 all day each way	No	Yes	No	Yes	No	Yes	No
Performance							
Access by car	-----	+++	-	++	--	++	--
Access by public transport	----	+++	+++	+++	-	+++	-
Environmental Quality	-----	+	--	+	---	+	---
Economic Activity	-----	++++	-	++++	--	+++	---
Fuel Consumption	+16%	-2%	+7%	0	+10%	+1%	+12%
Capital Costs 1990	N/A	530	520	530	340	530	340
NPV £m	N/A	+410	+300	+330	+180	+310	+110

(PVF: financial outlay required: measured as a present value net of revenues.)
(NS -LRT: Light rapid transit from north, via the city centre and into the south of the city)
(EW LRT- Light rapid transit from the airport, via the city centre to Leith)
(W. radial - a new 'western approach' radial road from the bypass into the city)
(Note: nominal scale of better (+) or worse (-) relative to 1990)

[2] 1991 prices (see Chapter 8 for more details on of how prices are handled in JATES).

Figure 5.6: Study area map showing LRT routes and road pricing cordon



Two findings from the JATES study in particular are relevant to this thesis. Firstly, these strategies included the infrastructure elements which made the best use of finance, and in which LRT figured prominently. Secondly, road pricing was the central financial issue. Not only did road pricing strategies lead to improved environmental conditions and higher accessibility, but if the funds from road pricing could be hypothecated locally, then this could meet a large part of the infrastructure costs. In JATES, road pricing was concluded to have a positive effect on economic development (The MVA Consultancy, 1991 p.94), as it generally reduced congestion, and improved accessibility and environmental conditions in the city centre.

Using JATES as one of its technical inputs, LRC produced a transport strategy entitled 'Moving Forward' (Lothian Regional Council, 1992). However, initially this has concentrated upon local measures such as Greenways, park and ride and pedestrianisation schemes. Larger schemes include the re-opening of orbital rail services to the south of the city, and a guided busway west to the airport, which was seen as a more practical (and cheaper) substitute for LRT. Road pricing is now being discussed in the political arena.

It is apparent from this discussion that Edinburgh is (and formerly LRC was) very proactive in attempting to address its transport related problems, and the strategic model was a key element in the strategy formulation process. It has been pragmatic in terms of examining all the options, although it has not found ways to implement the two key policies. LRT and road pricing, that JATES recommended. Nevertheless, these two policies are very much on the agenda, and certainly the impact they will have on the urban social and economic fabric of the city is a prime consideration.

5.2.3 Scottish national planning issues

Within the study area, the **Scottish Office** (SO) provides a role as provider of trunk roads and planning advice. JATES was primarily financed by LRC with an input from the Scottish Office. However, the SO then commissioned The MVA Consultancy to use the JATES model to undertake a feasibility study for a second crossing across the Forth. This study elaborated upon the JATES model by:

- including Fife in the study area zoning and splitting zone 15 into three zones (as in Fig 5.2);
- making modifications to allow for increases in multi-car owning households;
- including explicit rail based park and ride matrices. This was to facilitate modelling of rail park and ride from Fife, where a previous study (SOFTER: The South Fife to Edinburgh Rail study) had determined the proportions of rail users using park and ride;
- guided bus was also added as a new mode, given its inclusion in 'Moving Forward';
- the planning data was updated, and new data obtained from Fife Regional Council.

The model implementation was also switched from a proprietary evaluation package called JAVELIN, to the consultants' own suite of computer programs, called START (STrategic And Regional Transport model). The model became known as JIF (JATES into Fife). It was used to test options for the second Forth crossing, and moreover, to determine whether a second crossing would have negative impacts on the Edinburgh. The study (Environmental Resources Management, Oscar Faber TPA and The MVA Consultancy, 1994), concluded;

- that those strategies tested with a second crossing performed better under the objective of enhancing accessibility north of the Forth, and;
- that the environment of Edinburgh is best served by measures to discourage car use in the city, and this is independent of an additional bridge.

It is interesting to note that as part of the JIF study, a study of the economic and land use impacts of the bridge was undertaken by the consultants (Environmental Resources Management, 1994). The crossing was evaluated in terms of how it would impact upon the existing development plans. It was concluded that the new bridge and its new landward roads would increase development pressure in West Lothian and West Edinburgh. This was seen as beneficial where development was encouraged or Green Belt land released (e.g. South Gyle, Dunfermline East). Where development was not desired, it was concluded that the development plan policies could '*counter any pressure for development adjacent to new roads*' (Environmental Resources Management, 1994 p.37). There was no modelling of land use response, and no use of the JIF accessibility outputs. The methodology instead was 'expert judgement' driven, based upon the assumption that higher accessibility increases the attractiveness of locations and that development was planning led. This bears out the conclusions reached in Chapter 4, that land use implications have been assessed using an *ad hoc* methodology, and given little prominence within the report. This is despite the fact that the economic development of Fife was a key objective within the study.

The Scottish Office are also involved with land use and transportation via the production of a draft **National Planning Policy Guidelines for Transport and Planning** (Scottish Office, 1996). This is the Scottish Office equivalent of PPG13 (outlined in Chapter 4). It contains the same policy thrusts as PPG13, but is arguably weaker in emphasis. For this reason it has been criticised for focusing upon managing growth, rather than reducing current demand (Local Transport Today, 1996). In terms of transport and its influence on land use, the draft is forthright that the role of the road network is to:

> '*maintain the existing trunk road network,... and where appropriate undertake selective improvement in support of economic activity*' (Scottish Office, 1996 p.8)

The report is attempting to strike a balance between acknowledging that transport is seen as essential for facilitating economic growth, especially in regeneration or rural areas, and taking on board the travel limiting arguments from PPG13. This perhaps is another example of the issue raised in Chapter 3, of high political expectations from improving accessibility.

In summary, the situation in Edinburgh and its surrounding region is dominated by planning aims similar to many cities, that is providing for continued growth, while not adversely affecting the environmental quality of the city. A decline in the environment may reduce the attractiveness of Edinburgh as a service, tourist and shopping centre, sectors that are vitally important to the local economy. There is a very strong spatial component to the land use plans, as shown in Figure 5.2, with employment being focused in specific areas; including those which are growing and expected to grow (e.g. Livingstone, South Gyle), and those where growth is desirable (e.g. SW Edinburgh, Leith, Whitburn and Bathgate).

The situation outlined above makes Edinburgh a good area to study. There is planning interest in several transport policies which are likely to have significant impacts on land use. Moreover, the impact that these policies may have upon land use (and perhaps more importantly, economic growth) is of central interest to the policy makers. Furthermore, on a more practical scale, the involvement of the CASE Consultancies and co-operation from the Regional Council in 1994 meant that access was granted to the JIF model for the purposes of this research.

5.3 Introduction to the more detailed interview research in the study area

This section introduces further interview research that was undertaken in the study area after the Phase 1 interviews. The aim was to investigate attitudes towards methods of forecasting transport impacts on land use in more detail that was possible in Phase 1. To meet this aim, a smaller sample of planners, familiar with the study area, were used from the Phase 1 interviewees, and re-interviewed as outlined in Chapter 10. These were called the 'Phase 2' interviews, and required the planners to examine the forecasts from three methods (described in the next three chapters).

In addition to these two rounds of interviews, some planners from the study area were involved in a 'steering group', which provided comments on the dynamic land use transport modelling and implementation. This model comprised START, and a new land use model, DELTA (Development, Employment, Location and Area quality model), discussed further in Chapter 8. Table 5.3 shows a matrix of planner participation. The first column of data shows the Phase 1 interviews, described in Chapter 4, although additional comments relating specifically to the study area, are given in Section 5.3.1 below. The second column of data presents the planners involved in the 'steering group', which is discussed in Section 5.3.2. Note that the composition of this group changed over time, represented by the bracketed figures in the table. The Phase 2 results are discussed in Chapter 10.

Table 5.3: Matrix of UK Planners participation in this research project

Interview Phase	Phase 1: (Results discussed in Chapter 4)	Steering Panel: (Discussed in Chapters 5 and 10)	Phase 2: (Results discussed in Chapter 10)
UK Central Government	2		
London and South East	4		
Avon	2		
Academic/ Consultancy	7		
Scottish Office	2	1 (+1)	2
Lothian Regional Council	4	2 (+2)	3 City of Edinburgh 1 West Lothian
Study Area Consultancy	2		
Total Interviewed	**23**	**3 group meetings**	**6**

5.3.1 Additional results from the Phase 1 interviews specific to the study area

The main results from the Phase 1 interviews were summarised in the last chapter. However, there are some points particular to the study area that were mentioned by the Lothian planners.

First was the general point that several of the planners involved with JATES (especially in the planning department) had hoped for more interaction and better treatment of land use in the original model. In fact, some simple modelling of land use response was undertaken by Simmonds (1991), but was not widely disseminated. Two interviewees in Lothian mentioned this work, one commenting that it showed that the transport policies would have little adverse impact on land use, the other saying that the work did not go far enough, and was cut when other budgets became tight. This is illustrative of the differences between professions; the former comment came from a transport planner, the latter from a land use planner.

When asked about other methods of assessing land use response to transport, the Lothian planners' comments were in accordance with those from other areas. Even where detailed environmental and land use impacts were being undertaken, for example as part of 'Setting Forth', the planners did not expect formal methodologies, and relied instead upon intuitive approaches (Int. 17a). The approach adopted by the consultant in Setting Forth was to look for conflicts between structure plan objectives and the pressures caused by the new bridge developments (Int. 14a). More complex network implications and 'knock-on' land use effects were not examined.

The lack of study of land use response was frequently attributed to a lack of resources, and more pressing requirements to examine other issues. It was also thought most likely that consultants would be leading the way in terms of developing the methodologies. However, there was some scepticism that a land use model could provide believable forecasts. The view was expressed that the 'scenario' approach to transport modelling, as outlined in Section 5.2.2, can take into account potential variations in land use, and negate the need for further land use modelling. It relies of course, on the planners 'second guessing' the land use response, rather than assessing it in a formal methodological framework (note that Chapter 8, Section 8.5.6, discusses this issue further).

There was the general view that land use response needs to be better understood, but it was not thought to be of primary importance in Edinburgh, as the impacts on travel demand of the changes in land use over a 20 year period still are small compared to the travel demand that is 'fixed' (Int. 4a). A planner summed this up thus:

> *'You move a big chunk of land from here to there, and it does not seem to have very big effects on the transport strategy... Now is that because so much of your travel is determined by your existing land use, or is it the nature of the model being insufficiently sensitive, or is it something else that we don't know about?'* (Int. 4a).

From these points it can be seen that the planners in the study area form an interesting cross section for further study. There are a variety of views, both on the importance of transport impacts on land use in planning, and methods to assess them. There is also some prior experience of possible methods.

5.3.2 The steering group sessions

The aim of the steering group meetings were to facilitate the development of the DELTA/START dynamic land use transport model developed as part of this thesis, and outlined in Chapter 8. This was undertaken as a means to; (1) keep planners involved with the research, and (2) replicate the 'usual' process of model implementation, whereby a client would be consulted during the major steps of the consultant's work. Such a process is especially important when a new technique or a new model is being applied, as there is not a routine methodology to be followed. This was certainly the case for the model development in this research.

In seeking to involve a body of planners as a 'steering group' for the development of a land use response model, the following problems must be recognised, all stemming from the fact that the planners are being asked to participate in research, rather than initiating the project for their own aims. Firstly, it is likely that the planners may lack the time and resources necessary to spend time considering the issues surrounding the model development. This creates a strong need to get information to the planners concisely and cogently. Secondly, from the Phase 1 interviews it is apparent that few planners may have direct experience of, or skills in, land use modelling. This compares unfavourably with transport forecasting, where the steering group are likely to be experienced in at least the theory of transport modelling. Thirdly, and of most concern, the planners may lack desire or enthusiasm to take time out from their work to take part in this exercise, as they have no immediate interest in the outcome. However, one advantage of this approach is that the lack of vested interest means and the views expressed are likely to be unbiased.

The steering group meetings were held in Edinburgh. Initially four planners were invited. Encouragingly, none refused to participate, and the first steering group consisted of planners from both the SO and LRC. In addition at each meeting were several consultants from The

MVA Consultancy and David Simmonds Consultancy who were directly involved in the model implementation. The dates of the meetings, and their key objectives are shown in table 5.4.

Table 5.4: Details of the steering group interviews

Date	Planners / Consultants Present	Prime stated purpose of meeting
24th May 1995	4 / 2	Introduction to the PhD research project Outline of the proposed land use model, and links to transport model. Data sources
24th August 1995	4 / 3	Outline of model Progress on main sub models to date Remaining data issues
17th June 1996	4 / 5	Outline of model Discussion of implementation and calibration Presentation of results

In addition to these stated objectives, the steering group sessions allowed the views of the panel to be obtained regarding the modelling approaches to land use, and attitudes to transport impacts on land use in general. The format of the meetings generally involved a presentation of modelling progress, followed by a discussion. Given the limited time available from the planners, it was decided not to circulate information before the meeting, but to distribute minutes and any slides afterwards. The meetings generally took two to three hours. The following paragraphs summarise the key points of interest relating to how the planners perceived the model and its working. It should be noted that, primarily due to local Government re-organisation, the steering group changed composition over time despite efforts to prevent this. However, the positions represented (i.e. strategic planners from land use and transport fields) remained constant as desired. Only the first two meetings are discussed here, the third, which was primarily a discussion of results, is better placed in Chapter 10.

The first meeting on **24 May 1995**, was essentially an introduction to the modelling aspects of the research, in which the structure of the land use model DELTA was outlined. A discussion then ensued. The questions asked by the planners at this meeting divided into two types, those concerned with what the planners would like to do with the model, and those concerned with probing questions (usually critical), about how it was proposed to undertake the modelling. On the first issue, the planners saw the model being used for examining how restraint policies would impinge on the economy, with use being focused upon '*practical* *policies in a financially restrained situation'*. The comment was also made that a total cost model, which represents all the costs in an urban system, would be useful, although it was probably some way off.

On the second issue, the planners were primarily concerned with how the model would represent planning policy. The central issue was that to represent planning policy simply as spatial zoning while ignoring planning powers for determining the density of development was unrealistic. The planners were also concerned with the issue of 'other factors' influencing development, that the model could not be expected to predict, a good example being the citing of the Scottish Office in Leith, which in the model would have to be specified exogenously. Coupled with this were the 'quality' factors associated with locations, and how the model would represent these. Another issue of central interest to the planners was how the model's study area interacts with the outside world. For example migration across Scotland, or labour markets both inside and outside the study area.

Thus this first meeting generated many issues, especially that of modelling planning policy, and although it did not resolve them all, it did provide a focus for continued model development.

The second meeting, on **24 August 1995**, was held three months into the model implementation. Progress on the modelling was described, including;

1. the modifications to START (see Section 8.3.1), including the disaggregation of the travel to work matrices (see Section 8.3.2);
2. the development and structure of the household transition model (see Section 8.3.5);
3. progress on the location model (see Section 8.3.6);
4. plans for the development model, employment and area quality models (see Section 8.3.7).

On reflection, too much detailed information was probably given to the planners at this point, leading to the meeting being rather one-sided. It would perhaps have been better to allow issues to be discussed in response to questions, rather than providing information at the outset. However, the submodels and their processes were very 'new', it could not be assumed that the planners were familiar with them. Certainly, in presentations of this type, there is a fine balance to be struck between the amount of information delivered in a lecture style, and that generated through discussion.

Perhaps as a result of too much presentation, the discussion was more muted than in the first meeting. However, there was an interesting discussion concerning how much the economic scenario may 'swamp' the effects of other changes. Indeed, the general influence of 'non-modelled' factors was a central theme of the questions asked. Furthermore, the argument was presented that the land use model should be run under a variety of economic growth scenarios, in a similar manner to the JATES model (a point raised by a different planner in the Phase 1 interviews). With regard to location choice modelling, the planners wondered whether financial incentives could be modelled as an attractor of business, and whether homeworking or flexible working hours could be modelled. All of these are desirable, but constraints on resources meant that none were implemented in the final DELTA/START application.

In general, the planners did seem interested in what was being presented. However, there was clearly some confusion concerning what the combined land use transport model offered over the existing JATES/JIF model. It was very difficult to gauge exactly how much the planners learnt about the model (short of testing them!), although it would probably be difficult to gain little more than an understanding of the basic processes from an afternoon's presentation.

5.3.3 The impacts of local government re-organisation

As has been mentioned in this chapter, local government reorganisation occurred in the study area in April 1996. This disrupted the research project in several key ways:

- prior to re-organisation was a period of turmoil, with planners winding up their existing operations, and facing an uncertain future;
- key planners were involved with implementing re-organisation, and hence were effectively not involving in planning tasks;
- once re-organisation occurred the planners' remits had often changed. All the planners interviewed at LRC either joined the City of Edinburgh Council or West Lothian Council (Scottish Office planners were unchanged);
- this impacted upon the Steering panel sessions particularly for the final meeting, where two of the four planners were not on the original panel. The continuity was instead in the remit or position that they represented;
- for the Phase 2 interviews, planners tended to approach the use of the model results from their 'new' job perspectives, as will further discussed in Chapter 10.

The most noticeable impact on the results was the apparent change of interest in the spatial scale, as will be discussed in Chapter 10. Despite these problems, local government reorganisation proved useful in that the land use and transport departments were merged in both West Lothian and Edinburgh, giving the planners a new perspective, which suited the land use transport interaction theme of this research. Furthermore, the planners responsible for the study area were exceptionally helpful and gave some very illuminating opinions and insights. Moreover, despite the re-organisation issues, the same planners were interviewed for the Phase 1 and Phase 2 interviews, providing a good degree of continuity.

5.4 Conclusions

This chapter has provided an introduction to the Edinburgh and region study area, and outlined the structure of the interviews that will be the subject of the rest of the thesis. Some further results from the Phase 1 interviews revealed that Lothian makes a good study area for the interview research, containing planners with a variety of views and experience.

The study area is also interesting from a transport planning context. Road pricing and LRT are major planning issues for the study area, and both of these policies performed well in the JATES study. Both policies are likely to have significant land use effects on Edinburgh and Lothian region, and although neither policy is scheduled to be implemented, both are subject of political and technical study.

More recently, the JIF study utilised essentially the same strategic planning model to examine the impacts of a second Forth crossing. The new JIF model was not used to examine land use impacts however, this being studied under the remit of the environmental impact analysis. The methods used here underlined the conclusions about examination of transport impacts on land use reached in Chapter 4; that they are *ad hoc*, limited and largely based upon professional judgement.

Finally, the findings from the first two steering group meetings have been outlined. The steering groups were held as a means to guide the model development, and introduce the planners to the model. The meetings revealed how complex it can be to succinctly outline a complex model, even for the key modellers within the Consultancies. However, they also raised some interesting issues, especially regarding the range of factors that can influence location choice, and how the model will react to influences outside of the study area.

This chapter has introduced a number of issues that will be re-examined in the next four chapters, culminating in turning 'full circle', and asking the planners to give their attitudes towards the methods and results as part of the Phase 2 interviews. Chapters 7 and 8 deal with the land use transport models developed out of the JATES and JIF models. However, before this, Chapter 6 maintains the theme of utilising expert opinion by using the Delphi technique to examine transport impacts on land use in the study area.

CHAPTER 6
APPLICATION OF THE DELPHI TECHNIQUE TO THE STUDY AREA

6.1 Introduction

The aim of this chapter is to investigate the use of the Delphi questionnaire technique to obtain forecasts of transport impacts on land use. The Delphi method aims to use the opinions of 'experts' in a subject area, in a systematic and non-biased manner, using feedbacks from the opinions of the panel. The application of this method in the context of assessing transport impacts on land use is relatively novel (see below), and hence this exploratory study is primarily interested in the following issues:

1. what kinds of information on land use response can the technique be used to obtain?
2. how reliable or plausible is this information?
3. how do the planners perceive results obtained using this method?
4. how do the results compare to those of the formal modelling methods?

This chapter will address the first two of these questions, the second two being addressed in Chapter 10. As in any Delphi study, significant resources were devoted to the two central issues of, (1) creation of a panel of experts (called the 'Delphi panel') to participate in the survey, and (2) the design and implementation of the questionnaire instrument. However, before proceeding to these issues, it is worth examining past uses of the Delphi technique, to highlight its key strengths and weaknesses for this type of study.

6.2 Previous use of the Delphi technique

The Delphi technique was devised as a method of formalising the opinions of experts concerning a common issue, usually via the following method:

1- identifying and recruiting an expert panel on the subject topic;

2- issuing each with a questionnaire, and eliciting a response;

3- collating the panel's responses and providing the panel with results;

4- asking the panel to review their responses in the light of the first round results with a fresh questionnaire;

5- repeating steps 3 and 4 until either, (a) there is agreement between members of the panel, (b) the results are not changing between iterations, or (c) study resources are exhausted.

The central facet of this technique is this use of repeated sampling to obtain agreement between members of the panel, while preserving the anonymity of the responses. This eliminates both 'interpersonal static', and 'personality effects' that could occur if the experts met together, where one or more individuals through rank or personality could dominate the proceedings. Anonymity allows panel members to revise their forecasts without embarrassment or the knowledge of others, except the researcher (referred to as the Delphi manager). The manager is able to focus the questionnaire between iterations and hence maximise the efficiency of the exercise. The technique is most suited to quantitative (direction and magnitude) estimates of change, where the variance associated with the estimates can be minimised by repeated iterations.

The use of experts in this way has been investigated and justified by Amara and Lipinski (1972). Experts provide more than merely a sensible guess as to the results, as they bring to bear past experience of similar situations, plus an understanding of the event and its context. Hence Amara and Lipinski argue that results, even from small samples of experts (as low as eight to twelve), are more likely to be realistic than larger samples of 'laypersons'.

However, there are some initial drawbacks to the method. Perhaps most importantly, there is no formal way to obtain the reasoning behind individual panel responses. Partly this is by design, as different experts may have entirely different reasons for supporting a similar direction of change. However, a lack of reasoned explanation is a limitation when rationalising the results. A second drawback, common to all questionnaire surveys, is its inflexibility to explore related issues at low additional cost.

The Delphi technique has been widely applied in a variety of fields. For example, interrogation of the BIDS computerised citation index reveals over 300 entries in the social sciences between 1988-95. Most are concerned with the fields of healthcare, social change, or economic and technological trends. Transport related Delphi studies are more scarce. However, the technique has been used to examine technological influences such as IVHS (Underwood, 1992). It has also been used recently by the Office of Science and Technology (1995) in the 'Technology Foresight' programme. This study covered a broad range of topics of technology in transport (e.g. head up motorcycle displays) and asked the panel to assess their likelihood of implementation. This is very much the traditional use of Delphi panels to estimate the 'unforecastable' impacts of new technologies.

The Delphi technique has also been used for the derivation of likely long term land use scenarios. For example a Delphi type exercise was used in the development of the Belfast Area Plan, to derive a 'best guess' scenario for forecast (2030) land use patterns (Smyth, 1995). A more hypothetical study was that undertaken by the Network on European Communications and Transport Activities Research (NECTAR), into transport scenarios in Europe to 2020. This made use of the NECTAR membership (of academics and researchers) to provide a ready panel of professionals interested in the topic. Both studies recognise that for such long term forecasting, Delphi is the most suitable method to deal with the large uncertainty and wide range of factors involved.

Two more Delphi studies are of direct relevance to this study, in that they concerned transport's influence on land use. The first examined the impacts of three transport policies in San Jose, California (Cavalli-Sforza and Ortolano, 1984). 17 individuals were recruited into the panel, with 12 completing three rounds over the 18 month study period. The panel came from a variety of fields, including education and the Chamber of Commerce, although there was a strong bias towards a background in transportation. The first questionnaire was designed to determine several 'future states' or scenarios of different transportation strategies. The Delphi managers used these results to devise three 'scenarios'. Following this, three Delphi iterations then examined the impacts of these scenarios on land use and transport variables, including population, employment, commuting patterns, housing and mode choice.

A key problem with the method identified during this study was the length and complexity of the questionnaire, which was estimated to take between two and four hours to complete. This was thought to discourage the panel, as the time required to receive responses back from the panel increased with each iteration. The solution proposed to this problem would be the monetary remuneration of the panel, which may also encourage additional panellists to participate without financial loss to their business. A second problem encountered was the marshalling of data, where a solution would be to reduce the data items on each questionnaire. Nevertheless, the study concluded that the Delphi offered several advantages. It allowed forecasting without the need for large data collection and mathematical model building. Secondly, and perhaps more importantly, it used the opinion of people who were actually making land use decisions, and were very familiar with the study area and the issues concerning it. The researchers concluded that the study was a success given that land use forecasts were obtained, although there were no data or comparable forecasts available against which to compare them.

The second Delphi study examined the impacts of the Sheffield Supertram on property prices. This was a small part of a larger study of the impacts, transport or otherwise, of the Supertram which became operational in 1994. The Delphi focused upon actors in the property market, and assessed their views of impacts from the opening of the tram. It was undertaken with more limited resources than the Cavalli-Sforza and Ortolano study, and as such there was no scenario development, and only two rounds of questionnaires. The first round results were presented in Antwi and Hennebury (1995). The panel size was large, with 31 experts, 52 having been approached. In order to discuss this study in more depth, the project supervisor was interviewed (Int. 1.d), and the survey design and piloting discussed. A central finding from the first round mentioned by the supervisor was that the sample of experts gave a very homogenous response, and hence the results were relatively uniform, which (the supervisor felt) undermined the usefulness of the results. This problem was attributed to the use of only one type of expert, i.e. property specialists.

Neither study was able to compare the results with other forecasts for the same area and timescale, which will be attempted in this research. Nor have the results been verified with subsequent events (although enough time has passed for this to be possible with the San Jose study). This means that until now the accuracy, or rather plausibility, of the Delphi technique in a transport context has not been examined in detail.

This review has illustrated the use of Delphi to assess transport impacts on land use. The main strength of the technique is the ability to collect quantitative information from experts in a systematic way. This provides estimates of change at a much lower cost than the data collection required for mathematical modelling. Moreover, it provides human insights that cannot be obtained using other techniques. However, its weaknesses are that the panel needs to be carefully assembled, and there are clearly practical limits to the number of questions that can be asked and their complexity. With these points in mind, the next section discusses sample selection.

6.3 Indicators and sample selection

The selection of a sample is closely related to the information required from the Delphi exercise. Professionals in different occupations will have familiarity with different indicators. This is shown in table 6.1, which shows the indicators of transport impacts on land use and the experts who are likely to have knowledge of them. Thus estate agents, planners and property specialists are likely to have knowledge in several sectors. However, it is also true that specialisms are likely to be dependent upon the individual, i.e. not all the members of a given profession will have expertise in land use response.

Table 6.1: Experts and their specialisms.

Indicator of Land Use change	Potential Experts
Demand for development / land use change	Property agents / estate agents / developers
Property / land price changes	Local businesses / estate agents / developers
Relocation within existing stock	Estate agents / local businesses
New speculative development	Developers / planners*
New bespoke development	Developers / businesses / planners* / estate agents
Floorspace changes by sector	Developers / estate agents
Employment changes	Planners* / estate agents / developers
Demographic changes	Planners* / estate agents / developers / welfare

* note that 'planners' includes both public sector planners and private sector land use or transport consultants.

In addition to those shown in table 6.1 are the small number of 'land use transport' experts, for example those interviewed as part of the Phase 1 interviews (see table 4.2 on page 58). These people would be expected to have knowledge in all areas, but with very few exceptions do not have particular experience with the study area. This raises the interesting question of the difference between 'local area' experts and 'subject area' experts. The latter would require much more detailed information concerning the characteristics of the study area compared to the local area experts, and also would not be privy to insights into the area. For this reason it was decided to concentrate upon local area experts rather than divide resources between the two groups. However, the use of a Delphi panel comprising subject area experts would be an interesting future exercise.

The expert panel must have familiarity with the necessary indicators of change. Ideally a range of indicators would be sought, with the experts giving estimates of change on aspects in which their specialism lay. However, given the problems of laborious questionnaires encountered in the San Jose study, it was decided to limit the main study to two indicators. From the list in the first column of table 6.1, it would appear that price/rent changes and demographic changes are familiar to the widest selection of experts. Moreover, these two complement each other well, being at different ends of the 'land use response' spectrum, as discussed in Chapter 2. Prices are an initial indicator of the desire (or otherwise) of a response, while demographic redistribution is a resultant second and third order outcome.

From table 6.1, developers, estate agents and planners are the professionals most likely to have expertise with these two indicators. Selecting experts from several different professions would be expected to avoid the homogeneity problems encountered in the Supertram study. Table 6.2 shows the strengths and weaknesses of these for the purposes of the Delphi. The aim is that these two groups should complement each other, the planners being stronger on the demographics, the property experts stronger on the price changes, but both with some knowledge of the other indicator.

Table 6.2: Strengths and weaknesses of the panel regarding the influence of transport on land use.

	Strengths	Weaknesses
Planners	- Familiar with land use - Familiar with expected changes - Know development pressures	- Unfamiliar with price changes - District planners have limited spatial area of interest. - Very few in number
Estate agents / developers	- Grasp property market - Understand market trends - Familiar with prices	- May have a limited spatial area of expertise - Limited sector knowledge

The sample was obtained using contacts supplied by the CASE consultancies, plus supplementary trawling of the local business directories. One planner each from Lothian Regional Council and Fife Regional Council was approached, plus one from each of the Lothian District Councils. From the data collected, a potential sample of 36 property firms was established (each with a contact expert), comprising property developers, investors, surveyors and planners. In addition to this, another planner, a property expert, and a director of a transport consultancy were asked (and agreed) to act as respondents for the pilot study.

6.4 Experimental design

Delphi sampling invariably involves the use of a questionnaire. In this case the aim was to present the panel with a series of transport scenarios, and ask them to identify rent and population impacts. The key issues to face in developing this Delphi questionnaire were as follows:

1. the development of a scenario;
2. the treatment of space;
3. the treatment of timescales;
4. the transport strategies and sectors to examine;

5. development of indicator scales;
6. presentation of the questionnaire;
7. the background information pack.

These are now discussed in turn. Many Delphi studies (including the San Jose study) have issued a preliminary questionnaire which aimed to determine the views of the panel on the '**future likely scenario**', i.e. expected land use and transport trends for the study area (as undertaken in the Belfast and NECTAR studies). This allows the Delphi manager to construct a 'do-minimum' that accords with the majority view of the panel. Given the time constraints on this Delphi exercise, it was not practical to issue a separate do-minimum questionnaire. However, for the indicators selected it was decided to include a do-minimum scenario set of questions in the 'impact' questionnaire, and ask for changes from this individually estimated do-minimum situation.

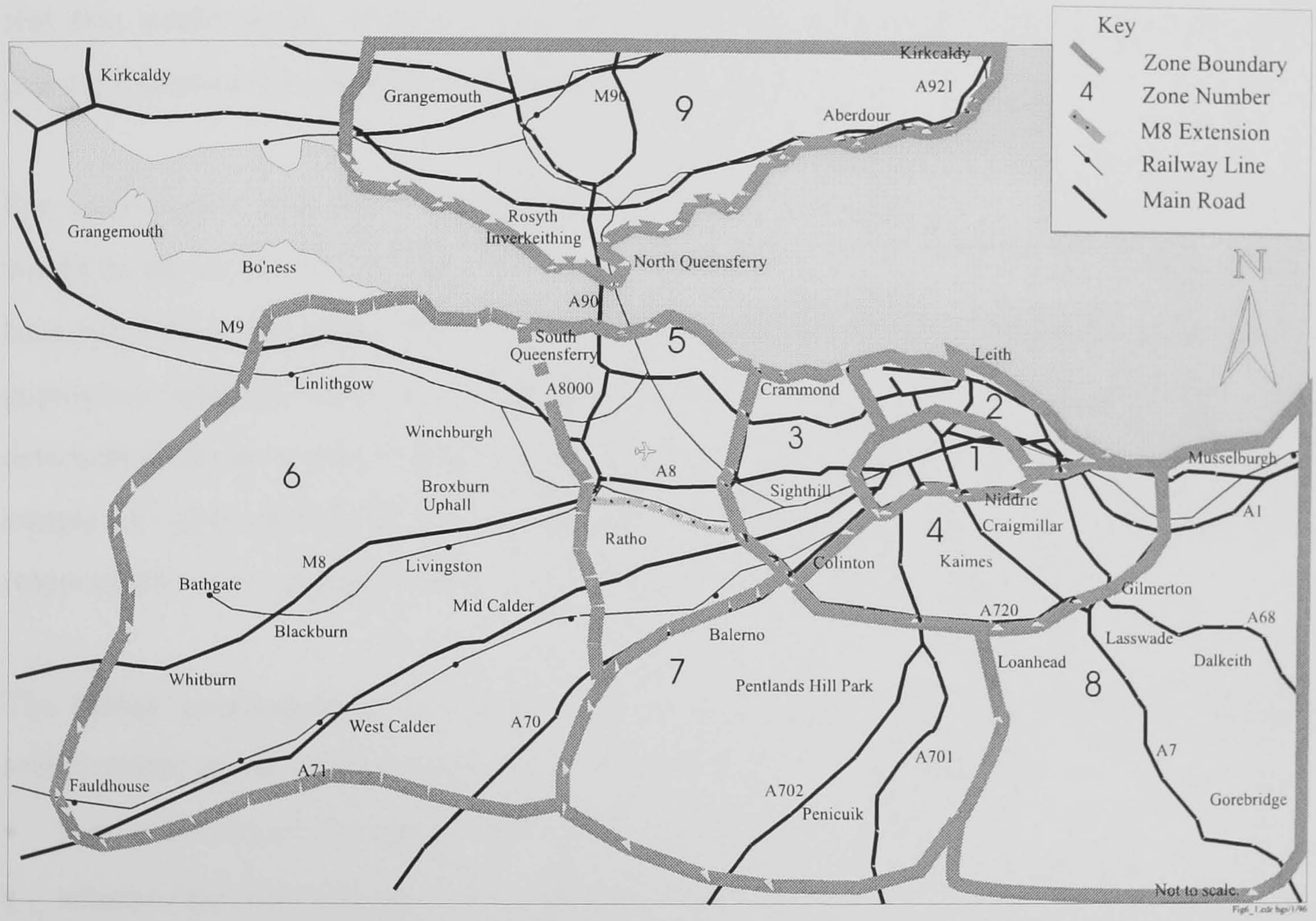
The treatment of the **space** in the Delphi exercise was the subject of considerable thought. The Supertram study did not specify explicit zones, but had a section asking for the views of the panel on areas of the city likely to experience specific impacts. The San Jose study divided the study area into four zones. However, for this Lothian Delphi, a more disaggregate zoning was important to allow comparison with the modelling methods, for which the zone system was already fixed (see figure 5.1). However, to ask the panel to comment individually on 25 zones for a number of impacts was clearly impractical. The 25 zones from figure 5.1 were therefore aggregated to nine zones, maintaining a finer zoning in central Edinburgh. The alternative would have been to maintain the JIF zones but concentrate on only a part of the study area, (i.e. central Edinburgh). This was considered, but rejected as it was felt that this might reduce the number of experts familiar with the study area. It would also have reduced the relevance to strategic planning. The final zoning pattern is shown in figure 6.1, with an accompanying table, which shows the zoning aggregation from the 25 JIF zones.

Given the complexity of the spatial scale, it was decided to treat **time** in a simple fashion. The panel were asked how many years they thought it would take for the impact to occur after implementation.

The choice of **transport strategies** has already been discussed in Chapter 5. Three strategies were presented[1]:

1. a Light Rapid Transit scheme (as outlined in figure 5.6, page 90). Note that two other rail improvements were included; frequency increases on rail services from Fife, and the opening of a short section of line in the south of city (these were included to be consistent with the policies that were implemented in JIF);
2. the road pricing cordon around zone 1 (which was equivalent to zones 1,2, and 12 of the JIF zoning);
3. both road pricing and the public transport improvements together.

Figure 6.1: Map of Delphi zones and table matching JIF to Delphi zones



Delphi	JIF	Delphi	JIF	Delphi	JIF
1	1,2,12	**4**	5,6,7	7	17,18
2	3,4	**5**	16,21,8	**8**	19,20
3	9,10,11,13,14	**6**	15,22,23	**9**	24,25

A more difficult choice involved determining which **sectors/activities** to include in the questionnaire. Although for the initial questions, inclusion of four (housing, retail, office and industry) was possible, for the spatial questions, space constraints coupled with possible respondent fatigue increased the need to reduce the number of sectors. Ultimately two

[1] Maps of the strategies were given in Chapter 5, figure 5.6, and also in Appendix 1.

employment sectors were included, focusing upon those likely to be more responsive to transport policy; i.e. retail and office, as concluded from Chapter 3. Population was also included as a 'planning type' variable, and representative of the physical impacts from transport policy.

The development of the **indicator scales** is important, as it determines how the panel will express any impact on land use. The San Jose study used a rating scale from 1 to 20, while the Supertram study used percentage changes in price. For this study it was felt that percentage changes in price would be the most appropriate for the rent changes. An ordinal rating scale may have lead to confusion concerning the relationship between points, while asking for actual changes would have involved supplying zonal data on current prices. Such rent data would ideally have to be circulated to obtain an initial consensus from the panel, placing it beyond the resources of this study.

For demographic changes it was decided that percentage changes in population per zone would be the easiest for the panel to deal with. It was decided not to present the panel with base populations per zone. This was because, firstly, the experts should have an idea as to population trends per zone, and secondly because it was not essential information needed to determine whether a zone would be beneficially or adversely affected. Figure 6.2 shows a sample of Section 3 from the questionnaire. As the figure shows, the table allows the respondents to give any estimate they choose; there are no fixed end scales.

The **initial questionnaire** piloted comprised four sections over twelve pages. The first section asked general questions about the respondent. This consisted of;

- how long the panel member had been professionally active;
- which of the nine zones they were familiar with;
- which of the four main sectors they were familiar with (residential, retail, office, industrial);
- what kinds of work they did.

The questionnaire then asked the panel to estimate the do-minimum situations (i.e. the scenario), with tables, using formats as shown in figure 6.2.

Figure 6.2: Example of Delphi zone tables (from the Delphi questionnaire)

Table for recording do-minimum base forecasts

Zone	1	2	3	4	5	6	7	8	9
% Impact (+ or - change in prices)									

Table for recording impacts of transport policy on rents.

Zone	1	2	3	4	5	6	7	8	9
% Impact (+/- change in prices)									
Timescale (in years)									

Sections 2, 3 and 4 of the questionnaire then asked for impacts from the three transport strategies; Section 2 for the public transport improvements, Section 3 for road pricing, and Section 4 for both public transport and road pricing combined. In each section, the first question asked if the policy would have **any** affect, followed by a question asking which sectors would be most affected. A third question asked for estimates of the timescale of impact by sector. The remaining three questions then asked for impacts for each sector by zone, for retail rents, office rents, and population change. It is important to point out that the panellists were asked to give impacts **additional** to the do-minimum, rather than total impacts. A final section of the questionnaire left space for any additional comments that the respondents may have had. In total, the pilot questionnaire booklet consisted of ten A4 sides.

Much of the decision making for the content of **the background information pack** has already been discussed. The concept of giving the panel demographic and rent information on the current situation in the study area, combined with details of the transport policies, was rejected at an early stage due to the additional material that this would force the panellist to read. It is clearly desirable to make the information as concise as possible to avoid deterring potential panellists, while providing sufficient information to make the exercise worthwhile. For the pilot questionnaire, information was given on the committed do-minimum transport policies, as included in the JIF do-minimum. No information was given on the land use policies, partly because to do so would have been very complex, and partly because of the hiatus between approved structure plans that existed in 1995. Each transport policy was described and a location map presented showing the rail lines or road pricing cordon. This comprised four sides of A4, including the maps.

6.5 Piloting and revisions

The questionnaire was piloted to a planner, a property developer and a transport planner, as mentioned at the end of Section 6.3. The respondents were aware that they were part of a pilot exercise, and were asked to comment in general on the aims and methods that the questionnaire implied. The pilot questionnaires were distributed in mid-November 1995. Comments from two of the respondents were obtained by early 1996, but disappointingly, the third did not reply within the two months allocating to piloting the survey. Nevertheless, the comments from the two respondents, in conjunction with additional comments from the CASE consultancies, were extremely useful. The main points are outlined below:

- It was decided that the best course of action would be to send the questionnaire out to potential panellists directly, rather than firstly send out an 'introductory letter', to secure the panellists in advance, as had been done in the Supertram study. This had the disadvantage of not knowing the size of the panel initially, but it was felt that this method would secure the largest response rate.
- At ten pages, it was apparent that the questionnaire was, (or appeared to be) too long. Furthermore, both respondents complained at having to turn back in the booklet to their do-minimum answers to work on changes due to the transport strategies. Subsequently, the format of the questionnaire was reorganised, maintaining the same questions, but adopting a more tabular format, with both the do-minimum and impact tables on the same A3 sheet. The resultant 'First Round' questionnaire is shown in Appendix I, and is only five pages. It took the respondents 35-40 minutes to fill out the questionnaire, which they considered reasonable.
- A particular problem concerned the transport policy implementation dates. The pilot questionnaire asked for impact timescales in years from 1996, stating that this should be assumed to be the 'implementation' years for the policies. The pilot respondents thought that as this was not true it hampered the logic of the questionnaire. As a result, this was changed to ask for impact timescales 'x-years after implementation'.
- There was some confusion regarding the elements that should comprise the 'do-minimum' transport scenario, and when its elements would be implemented. As a result, this was dropped from the information pack, leaving the panellists to form their own

views on the likely direction of transport development. This reduced the information pack to three pages.

Appendix I contains the initial pack of covering letter, background information and questionnaire, that was distributed to the potential panellists in January 1996. It was intended to undertake two iterations (termed 'rounds' 1 and 2') of the questionnaire, which would remain within the timescales of the project, while giving an indication of whether a consensus was forming.

6.6 Results from the first round

In January 1996, 42 first round questionnaires were distributed. Within two weeks most potential panellists who had not returned the questionnaire were contacted by telephone, and quizzed as to whether they would be able to assist in the survey. Of the 42, six did not see themselves as expert enough, or returned the questionnaire unanswered. By the end of February, 24 had been returned, a response rate of 66%, which exceeded expectations. However, it should be noted that, as expected, not all of the panellists completed all of the questionnaire, and unsurprisingly, it was Section 3 (asking for the detailed spatial responses) that was omitted, or partially answered, by six respondents. This left 18 fully answered questionnaires, and several more 'Section 3' responses partially complete. Only Section 3 of the questionnaire was repeated in the second round. Sections 1 and 2 concerned the attributes of the panellist, while Section 2 dealt with initial attitudes to transport impacts. Although this latter section could have been applied in Round 2, it was decided to focus attention on Section 3, and hence keep the second round questionnaire length to a minimum.

6.6.1 Characteristics of the Delphi panel

The average length of experience of the panel was 17 years, which was cumulatively 353 years of experience (from question 1a). Question 1b revealed that 71% of the sample dealt with all the zones in the study area. Unsurprisingly, it was mostly the district planners who did not deal with the whole study area. Zone 8 (East Lothian) had the least experts, probably due to its more rural nature.

The panel comprised six planners and 18 property experts, although the areas of expertise were more varied that this simple demarcation would suggest, as shown in Table 6.3, which gives the specialisms of the sample from question 1d. This shows that most of the sample worked in more than one sector, and there is breadth of expertise across the panel, including most of the main professions in the property sector. The implications of the apparent bias towards property experts is discussed in Section 6.9.1. From question 1c data is not presented, but it was clear that while most of the panel worked in several areas, most property experts had a specialism in one or two particular sectors.

Table 6.3: Professional experience of the sample

Sector	Number Working in Sector
Development and Construction	14
Investment	11
Transport Planning	6
Land use Planning	8
Surveying and Valuation	5
Other related Sectors	14

6.6.2 General impacts of transport policy on the property market

The panel were asked whether they thought that the three transport policies (public transport, road pricing and both combined), would have **any impact** on the four property sectors and on population. The results are shown in table 6.4.

From this table, it is clear that a majority of the panel believe that these transport policies would have impacts on the property market. Both commercial rent sectors were considered by most of the planners to experience impacts, especially from road pricing. Residential impacts were also seen as likely from all of the polices. The industrial sector was thought (unsurprisingly) the least likely to experience impacts, although half the sample still thought that there would be some effects. The combined policies tended to be have more planners expecting an impact, and more thought that road pricing would have an effect compared to the public transport strategy.

Table 6.4: The general impacts of transport on the land use indicators

Policy	Residential price impact (%)		Office price impact (%)		Retail price impact (%)		Industry price impact (%)		Impact on pop'n (%)	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Public Transport:	87	13	77	23	73	27	50	50	83	17
Road Pricing:	78	22	100	0	86	14	50	50	65	35
Both Policies:	91	9	92	8	86	14	56	44	94	4

This table simply gives an indication of whether the sample thought there would be an impact. It was a straightforward question, and was answered by all of the sample. It also served as a consistency check between this and Section 3 of the questionnaire.

From table 6.4 it is interesting to compare the results from the residential property impacts with the population impacts. As may be expected, these results are broadly similar, but there is less impact on population distribution than on residential prices, especially for road pricing impacts. This suggests that the panel consider population to be slightly less sensitive than residential prices, most likely because residential location choice is dependent upon other factors in addition to price.

Question 2b asked the respondents to rank the property sectors according to the sensitivity of the sector to the transport policy. A scale of 1 to 4 was used: 1 being the sector most sensitive to the policy, 4 the least. The results are presented in table 6.5, showing measures of the average response. Note that 'sensitivity' was not defined to the panel, although it was intended to mean the overall magnitude of response.

The closer the averages are to one, the more responsive the panel believe the sector will be in Edinburgh and the surrounding area. Note that the ranks should be read horizontally, i.e. by transport policy. For the road pricing strategy, the office sector is predicted by the sample to be the most sensitive, followed by the retail sector. For public transport the average mean scores are slightly closer, but the modal average reveals the panel's view that residential prices are likely to be most affected, followed by office and then the retail sector. For the combined strategy, the influence of road pricing dominates. This implies that it influences the combined results more than the rail strategy. However the number of people placing office sensitivity as highest is smaller for the combined strategy compared to road pricing alone; indicating that the transport policies interact in their influence on property markets.

Table 6.5: Average rank of market sensitivity: mean figures (mode in brackets)

Transport Policy	Residential	Office	Retail	Industry
Public Transport	1.7(1)	2.0(2)	2.2(3)	3.5(4)
Road Pricing	2.6(3)	1.5(1)	2.0(2)	3.6(4)
Combined policy	2.2(3)	1.7 (1)	2.2(2)	3.6 (4)

Note that tables 6.4 and 6.5 give very similar and consistent results, although the data that they present is quite different. This data is also concordant with the empirical findings from Chapter 3, although the high sensitivity of residential markets to public transport not widely reported. It is also worth noting that 'industry' is ranked last (least sensitive) for all three strategies. This probably reflects the 'basic' nature of the sector, especially primary industry, and fact that transport costs generally make up only a small fraction of the total costs of industry. In addition industry is not generally located in the city centre, where public transport accessibility is highest, and hence is less able to take advantage of changes in levels of service.

6.6.3 First round: additional comments from the panel.

Section 4 of the first round questionnaire gave the panellists the opportunity to give additional written comments. These were invited on the following topics:

1. rationale for panellists' own responses;
2. other factors that the panellists believe are important;
3. comments on the ease of the questionnaire, or aims of the survey.

In terms of the rationale for comments from the panellists, most justify their individual replies, which assisted in assessing whether the panellist had produced an internally consistent response. Some of the comments upon the impacts of the transport strategies are discussed in Sections 6.8 and 6.9 below. The **'other factors'** that were mentioned as being important in determining the base levels of growth included: changes to the road network in the future; the prospect of Scotland obtaining its own assembly in Edinburgh; parking policies, (especially if they continue to be restrictive), Green Belt policies; and finally, the fact that commercial rental leases are typically five years, and hence changes would occur relatively quickly.

Seven panellists commented critically on the questionnaire itself. Several commented that the questionnaire took longer to fill in than the covering letter suggested[2]. One panellist who only completed the do-minimum scenario tables commented that the impacts of the transport policies were too complex to calculate net zonal effects, given the pattern of gainers and losers. Several commented that Section 3 was too lengthy, asking as it did for 108 individual estimates, with the impacts of the policies building upon the base forecasts, which may compound errors or poor forecasts in the base cases. These criticisms are to be expected given the demands that the questionnaire placed on the respondents. In many respects they

[2]Note that a conservative estimate of the completion time was given in the introductory letter.

are to be welcomed, not only as they provide valuable feedback, but also because it shows that the panel were aware of the complexities of the task they had been asked to undertake, and gave some thought to their responses.

6.7 The second round and results

The previous section has discussed the views of the panel on the sensitivity of different sectors to the hypothetical transport policies. These questions were not repeated for the second iteration of the Delphi, which focused upon the quantitative responses in Section 3 of the questionnaire. It was distributed to 20 of the 24 respondents, as four of the first round panellists did not complete enough of Section 3 to make sending the second round sensible.

The second round questionnaire was thus shorter than the first round questionnaire. It included the median and mean responses from the first round, but no other statistics, in order to keep the information presented to a minimum. Other statistics (including measures of dispersion) were included in an accompanying summary report of the results. Space was provided for the panellists to revise their estimates if they wished. Note that timescale questions were not repeated in the second round, partly to save space in the second questionnaire, but primarily because it was felt that it would be difficult to obtain further improvements on this timescale data. Appendix 1 contains a example of the second round questionnaire.

The second round was distributed in early April 1996, and panellists were 'chased' until mid June. 15 panellists returned the second round questionnaire, of whom only ten wished to amend their responses from the first round. Attempts were made to contact the remaining panellists, of whom three stated that they wished to make no further changes. This gave a second round sample of 18 panellists, a loss of two from the first round. Only one panellist changed his views radically (i.e. a shift from a positive to a negative impacts for road pricing), but many altered the magnitude of their predicted impacts, in most cases reducing the scale of impacts they predicted in the first round.

The results of Section 3 of the first round, plus the second round results are presented as follows. The remainder of this section (6.7) discusses the do-minimum results, and the trends between the two rounds. Section 6.8 then discusses the various transport strategies, focusing upon the results from the second round. Section 6.9 appraises the method and results. Note that the full tabular results are shown in Appendix II.

The questions in Section 3 of the first round questionnaire and the whole of the second round questionnaire, asked the respondents to give their estimates of percentage changes for retail and office property prices, and population shifts over the forthcoming 10-15 years (i.e. to 2005-2010: the period of the present draft structure plan).

6.7.1 The do-minimum forecasts

The do-minimum results for the three sectors are shown in figures 6.3 to 6.5. Each shows the difference in the average estimates from the panel between the first and the second rounds for the mean and standard deviations. The lower standard deviation for the second round results illustrates the process of 'convergence' that is associated with re-sampling the panel. The measures of dispersion associated with some of these results are very large, even in the second round, and often larger than the percentage change itself. This suggests caution in the use of these results, especially as the subsequent iterations were unlikely to obtain significant changes in the data (as more of the panel would be unlikely to revise their forecasts).

The distribution of estimates is also a useful guide to the relative certainty of predictions. Note that it was the zones where the first round deviations were largest that improve the most in the second round, for examples zones 1 and 2 for retail (figure 6.3a). If this is compared to figure 6.3b, then it is clear that the largest falls in standard deviation occur where the largest impacts are predicted. This is also true for figure 6.4, but is less obvious in figure 6.5 (for population) as there is no obvious zone of greatest impact. However, the general picture is of a wide 'spread' of potential magnitudes of impact.

The charts of the mean impacts (the 'b' figures), show that in general the second round tended to revise the forecasts of do-minimum change downwards, although there is no clear pattern here. The most obvious downward revision is zone 3 for office. The predictions for the outer zones are for rents to increase slightly, probably due to the panellists' knowledge regarding available floorspace. The changes in zones 3 and 4 for population growth are also interesting, with downward revisions even in the zones including the 'South East Wedge' proposed developments (although this is very small). Within the panel as a whole there is no sense of the overall study area growth being maintained between rounds. In other words, the second round results predict lower overall study area rent and population levels compared to the first round. This is likely to be a by-product of the decision not to specify overall study area growth in the information packs.

Figure 6.3: Do-minimum estimates and standard deviations: retail prices

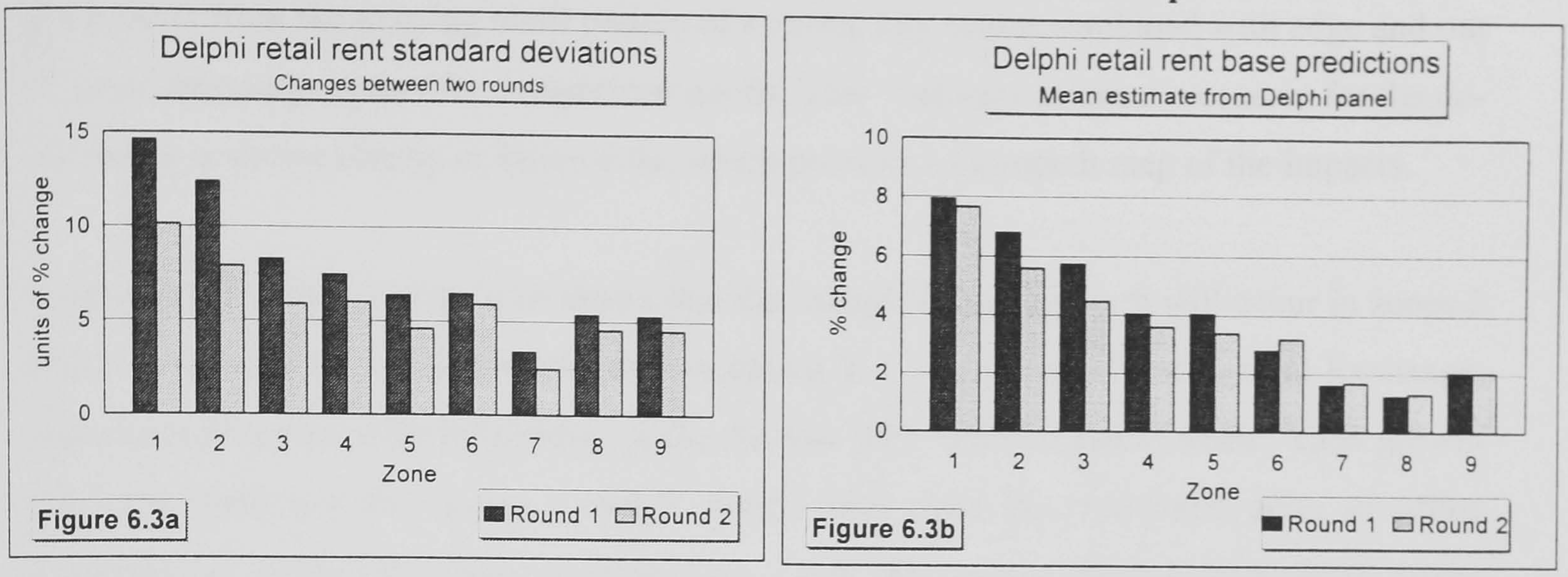


Figure 6.4: Do-minimum estimates and standard deviations: office prices

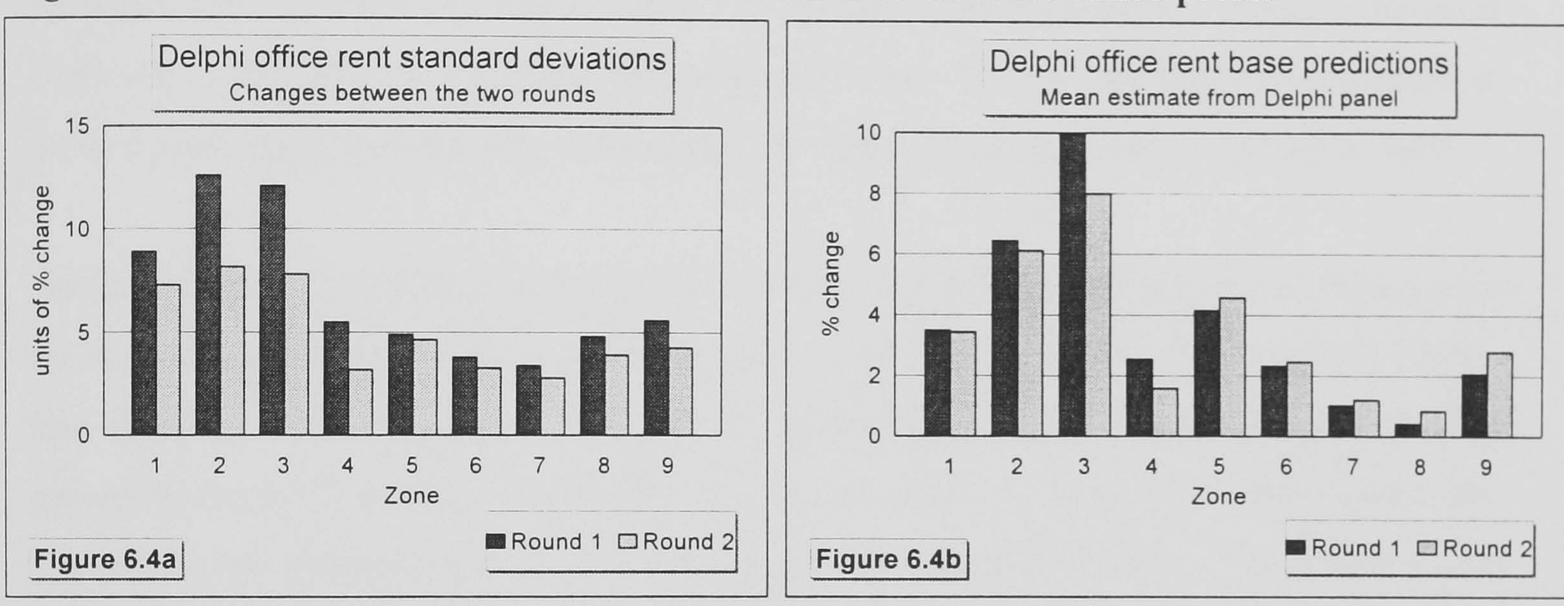
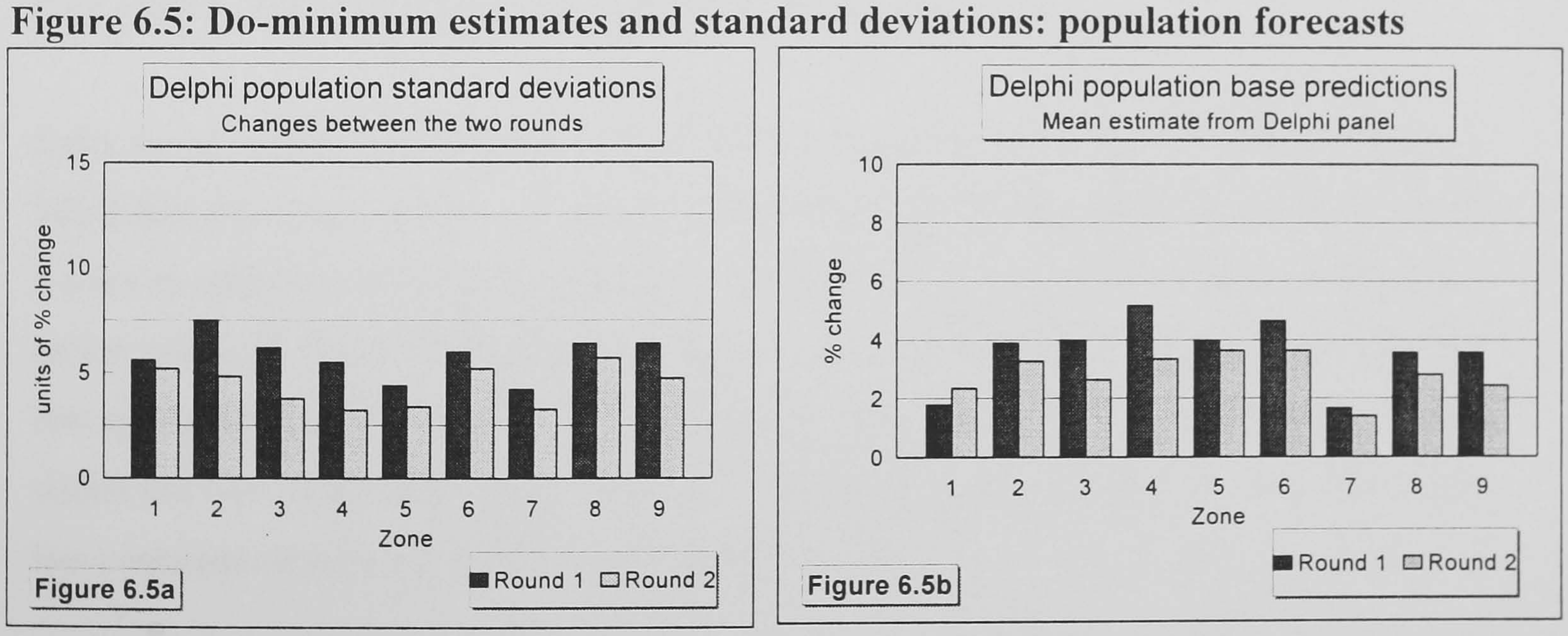


Figure 6.5: Do-minimum estimates and standard deviations: population forecasts



In terms of what the panel think will happen to **retail rents**, there is relatively strong agreement that rents are likely to grow in the central areas of the city centre, plus Leith and West Edinburgh. Least growth is expected in Fife and East Lothian (zones 7 and 8). Figure 6.3b shows that although city centre prices were predicted to grow by around 8%, this is not much greater than the other zones. This perhaps points to a tailing off of retail growth in central Edinburgh, and a continuation of growth in outer city areas such as Leith and near the airport. However, if prices indicate a desire to place retail activity, then the panel expect no great shifts from the existing retail pattern of a strong city centre combined with edge and out of town shopping centres for comparison goods. This 'business as usual' scenario for the do-minimum is shown clearly in figure 6.6a, which presents a cloropeth map of the impacts.

For the **office sector**, figure 6.4b shows that the sample expect growth will occur in zones 2 and 3. This may be due to the current investment in Leith and the West Central Exchange, plus the high levels of development on the A8 and A90 (western radial roads). Less growth has been predicted for zones 1 and 5, which have been the traditional areas of office development during the 1980s. Looked at on a map, this places office growth firmly to the north and west of Edinburgh (figure 6.6b). For the outer zones, growth is focused to the west of the city, although it is surprising that more office growth is not predicted for Livingstone (zone 6), although the large size of this zone may have served to lower the overall impacts.

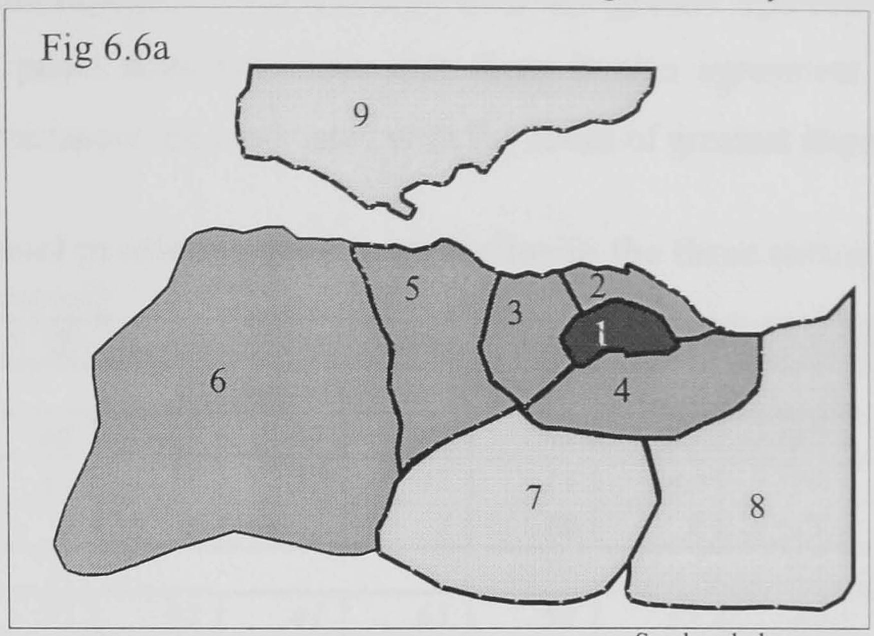
The **population** do-minimum forecasts do not show a clear focus of growth. As figure 6.5b shows, the panel forecast that growth will occur in zones 2, 4, 5, 6, 8 and 9; in other words, that population will continue to decentralise and grow in the outer areas, with more limited growth in the north and west of the city. This is shown clearly when mapped in figure 6.6c. The fall in the variance between the first and second rounds is similar in magnitude to the price sectors, although without the extremes in standard deviation.

Table 6.6 presents the proportions of the panel who predicted a given direction of change. This table shows some of the complexity that underlies the results discussed above, but gives a more simplistic picture by ignoring the magnitude of change. For example, in the retail sector, table 6.6 shows a large measure of agreement of the impacts within Edinburgh, and less agreement in the outer zones, although still several panel members predict retail decline within the city. For office there is more agreement that zones 2 and 3 will grow, but much less consensus about what will happen in the other zones.

Figure 6.6: Maps of Delphi do-minimum estimates by indicator

RETAIL PROPERTY

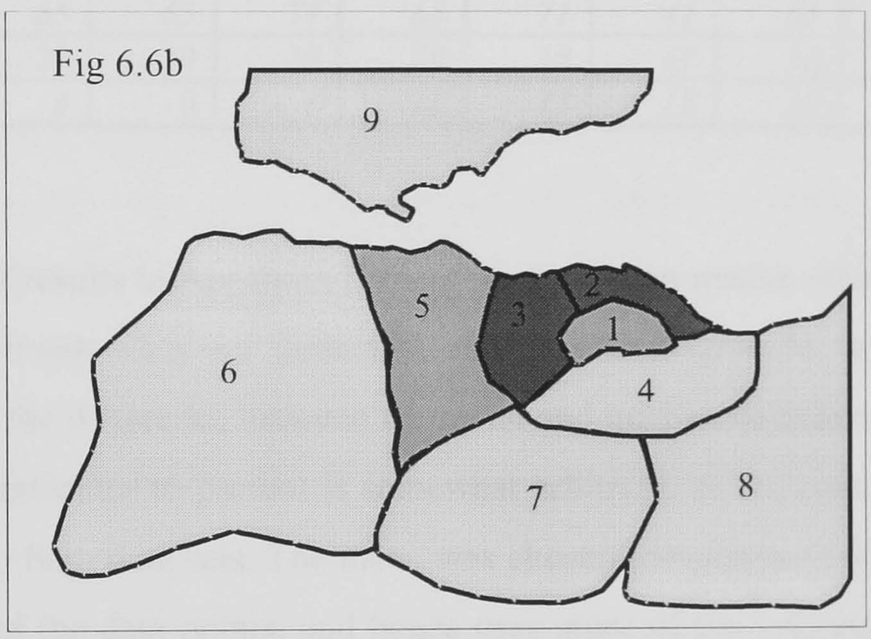
Base Conditions: Mean Estimates of Change next 15 yrs



See key below

OFFICE PROPERTY

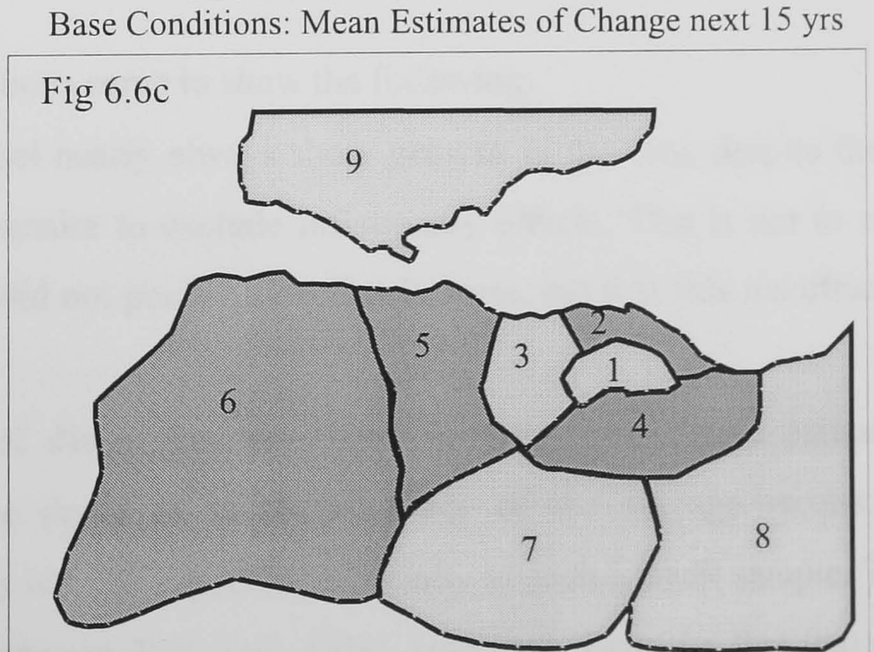
Base Conditions: Mean Estimates of Change next 15 yrs



See key below

POPULATION DISTRIBUTION

Base Conditions: Mean Estimates of Change next 15 yrs



See key below

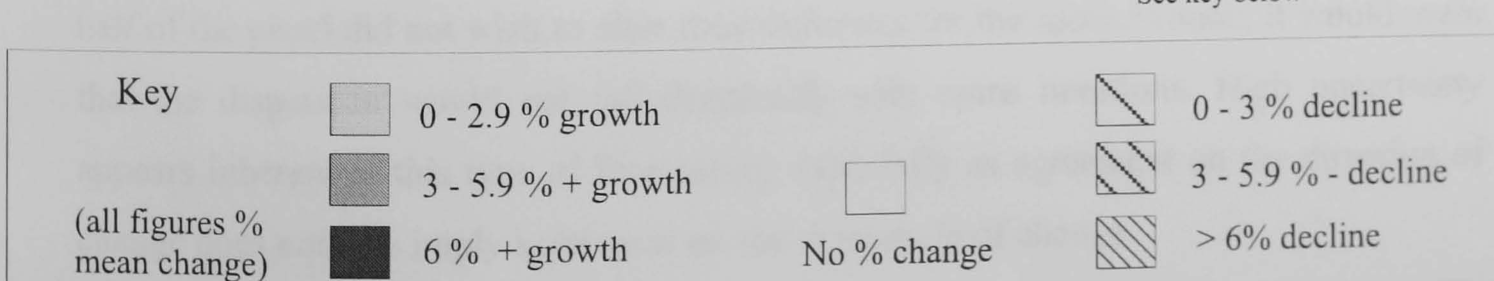


Fig6_6.cdr

If this pattern is compared to the figures 6.3-6.5 it can be seen that greater agreement for a direction of change from the panel does not mean that there is also agreement on the magnitude; indeed, the largest variances are associated with the zones of greatest impact.

Table 6.6: Proportion of panel predicting growth or decline in the three sectors (for do-minimum forecast)

Zone	1	2	3	4	5	6	7	8	9
Retail									
% predicting growth	*80*	*60*	*67*	*67*	*47*	*67*	*53*	*47*	*50*
% predicting no chg.	*7*	*40*	*27*	*27*	*47*	*13*	*40*	*40*	*38*
% predicting decline	*13*	*0*	*7*	*7*	*7*	*20*	*7*	*13*	*12*
Office									
% predicting growth	*59*	*77*	*82*	*41*	*65*	*53*	*35*	*41*	*72*
% predicting no chg.	*24*	*18*	*18*	*47*	*35*	*41*	*47*	*35*	*6*
% predicting decline	*18*	*6*	*0*	*12*	*0*	*6*	*18*	*24*	*22*
Population									
% predicting growth	*59*	*65*	*65*	*71*	*65*	*71*	*41*	*65*	*72*
% predicting no chg.	*24*	*29*	*29*	*29*	*29*	*18*	*47*	*18*	*17*
% predicting decline	*18*	*6*	*0*	*6*	*12*	*12*	*18*	*18*	*11*

An examination of the tables of results in Appendix II shows that median results often differ from the mean for the do-minimum. They are generally of a smaller magnitude, and often indicate no change. However, the difference between the mean and median decreases in the second round. The choice of indicator to present is somewhat arbitrary, as the conclusions drawn from the results apply to both data sets. The mean was chosen (despite outlying data) as it uses the absolute values of the data points, and hence uses more of the information in the data than the median.

Thus these initial 'base' predictions serve to show the following:

- The averages from the panel nearly always show **growth** in the city, despite the panel being asked in the questionnaire to exclude inflationary effects. This is not to say that individual panel members did not predict a decline in rents, but that this manifests itself as a low growth average.
- There is a large degree of **dispersion** associated with the quantitative estimates of change, which casts some doubt as to the accuracy of the average results. Wide dispersion in Delphi results is to be expected, especially in such a small sample. Typical spread in this study was between 30% and -10%. However, from the fact that around half of the panel did not wish to alter their estimates for the second round, it would seem that the dispersion would not fall drastically with more iterations. High uncertainty appears inherent in this type of forecasting, especially as agreement on the direction of change does not also imply agreement on the magnitude of change.

- That said, the overall impact of the repeated questioning was to reduce the extremes of the first round, and consolidate the averages.
- A central issue must be how much **confidence** is associated with the results. Certainly the results in terms of spatial patterns of growth seem reasonable, in that they are not dissimilar to the structure plan patterns of growth outlined in the last chapter. However, the high dispersion of results may reduce planners' confidence in the method, an issue to be further examined in Chapter 10.
- The averages from the panel suggest that property prices will increase in the range 1-10%, and population growth around 1-5% in the do-minimum. This compares to the LRC Lothian area population forecast growth of around 4.7% (calculated from table 5.1). Table 5.1 also presented LRC estimates of growth in all the districts, which are not dissimilar from the Delphi results. Of course the panel may well have used these forecasts in their own estimates, but nevertheless, this does increase faith in the results. However, no such comparison is possible for retail and office property price predictions at this stage (although comparisons are made with the DELTA/START model in Chapter 9).
- In summary, the base results appear promising. However, one concern is not knowing the full reasoning of those who did not wish to amend their responses second time around. This could this be partly respondent fatigue, opting out of considering these issues again. However, given that several of the 'no-change' panel members justified their decisions with a brief accompanying letter, it is thought that respondent fatigue did not figure too largely.

6.8 The impacts of transport policy

Having established do-minimum estimates above, this section examines the differences brought about by the transport policies that the panel were asked to consider. Full tables of results are presented in Appendix II. For each indicator, figures 6.7 to 6.9 contain maps of the second round mean impacts, as changes from the do-minimum (as specified in the questionnaire). Cloropeth maps are used so that the general banding of the responses is clear. Clearly the nature of the grouping in such maps is arbitrary, although the banding has been selected to separate out the main differences that are considered of interest, and reduce the emphasis on the smallest percentage changes.

6.8.1 Impacts from the LRT (public transport policy)

It is clear from comparing the maps, that the panel believe that the transport policies will impact upon these sectors, and in a variety of ways. From figure 6.7a, the public transport strategy impacts on retail are focused upon the city centre, clearly the LRT is estimated by the panel to enhance retail property prices. There is also a positive influence on the other zones, with the exception of Midlothian and Fife. For Midlothian, its lack of proximity to the LRT may make it less attractive. However, another possibility, more likely in Fife, is that better rail links allow people to reach the city centre of Edinburgh more easily, to the detriment of Fife's own shops.

Figure 6.7b shows a similar impact for the office sector, with the city centre office prices increasing, and all the other zones in the study area also benefiting by a tiny amount. Note that the impacts are still small in percentage terms, less than a 10% impact on price, but this is having the most effect on the highest rents in the study area, i.e. in the city centre. Also, these figures show that office prices in general rise as a result of LRT, in other words no zones decline to compensate for the growth in the city centre.

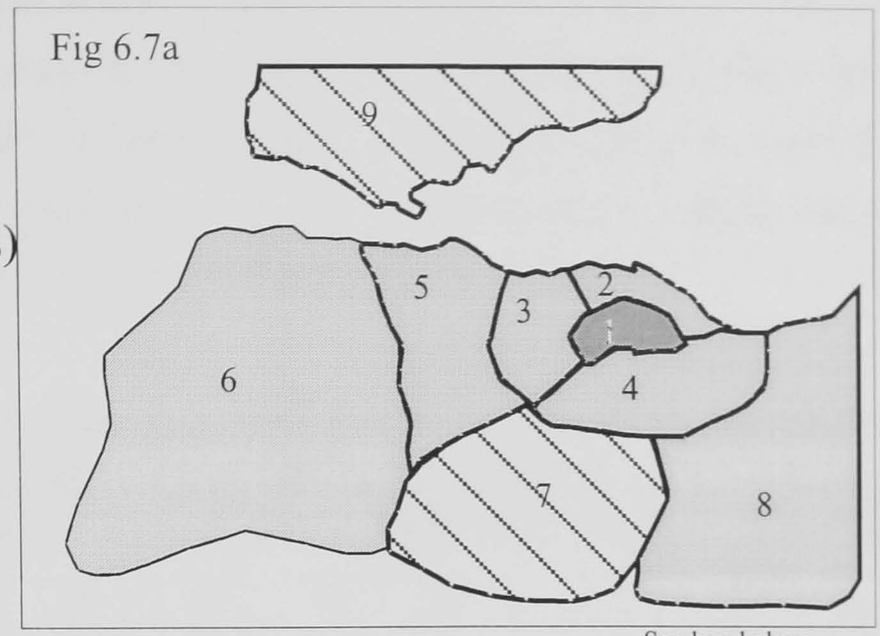
It was suspected at the outset that the population impacts would be the hardest to predict, given that this is a 'final stage' of an impact from transport to land use. As such it is dependent upon many other influences, including price changes, new building, in-migration and economic factors. Perhaps as a result of this, figure 6.7c shows a much more neutral impact on the distribution of population, with a small amount of growth (less than 3%) in all zones. In other words there is no significant impact on the population trends that were predicted in the do-minimum, which may mean that there is no impact at all, or that the zones are large enough to net out any redistributions. These results are therefore reasonably consistent with the conclusions about the sensitivity of sectors from Chapter 3, but downplay the relative sensitivity of residential prices obtained from Question 2b (table 6.5).

Table 6.7 shows the percentage of agreement in the panel regarding the direction of impacts. The greatest consensus is for the direct impact on the city centre, where 86% of the panel agree that zone 1 retail property prices will be enhanced by the public transport improvements. However, there is less agreement on the impacts in the other zones, with the majority indicating no change outside the city centre. There is less agreement on the impacts for the office sector, although the majority predict growth for zones 1-3. Outside of this area most predict no impact on office prices, with the remainder predicting growth.

Figure 6.7 Maps of Delphi panel estimates of impacts from LRT (plus other minor public transport policies)

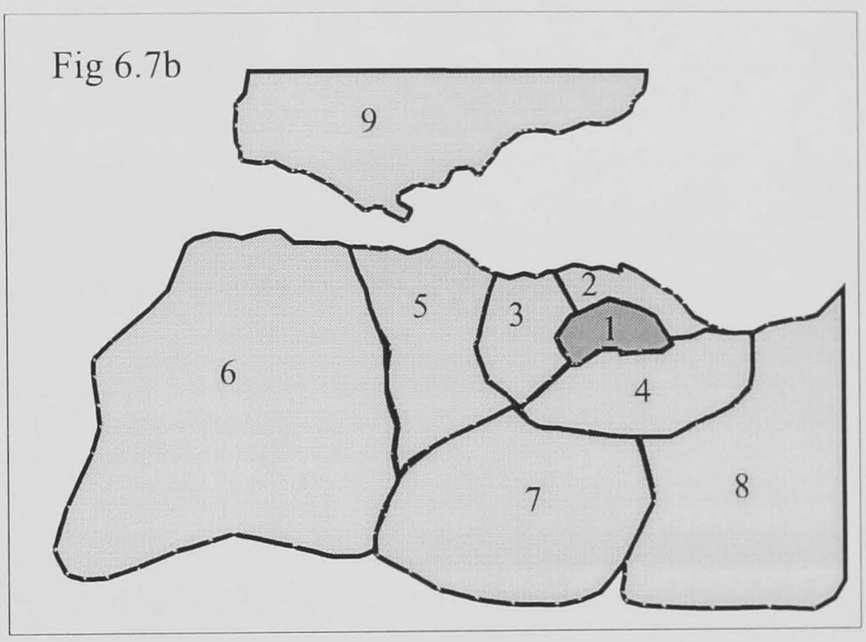
(changes additional to do-minimum)

RETAIL PROPERTY
Mean estimate of change from do-minimum due to public transport



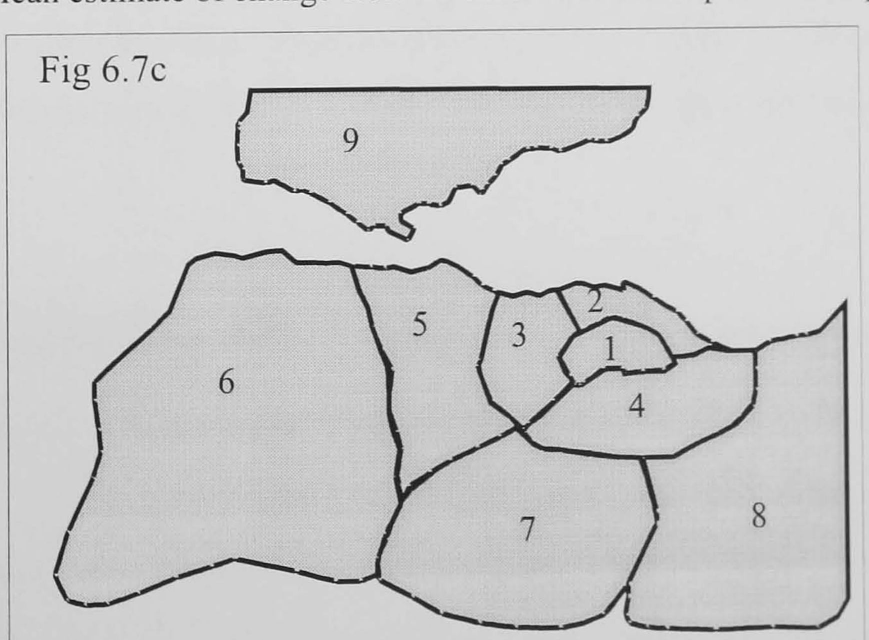
See key below

OFFICE PROPERTY
Mean estimate of change from do-minimum due to public transport



See key below

POPULATION DISTRIBUTION
Mean estimate of change from do-minimum due to public transport



See key below

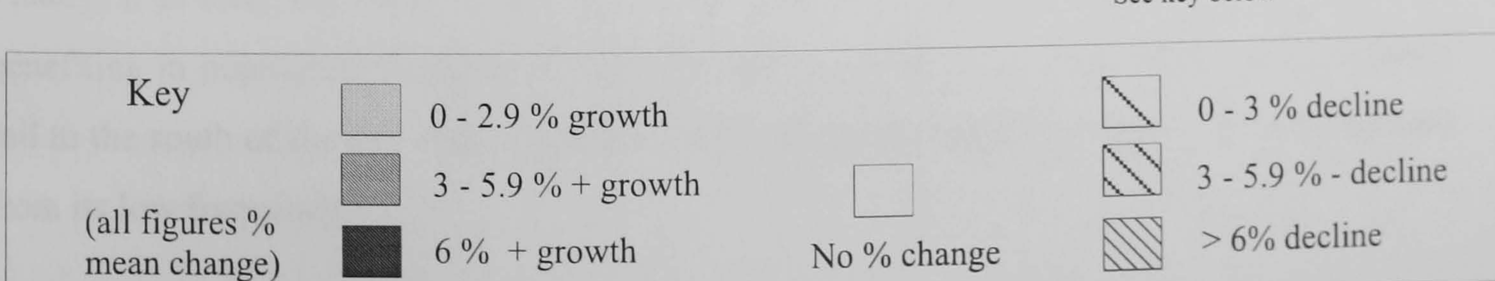


Fig6_7.cdr

For the impacts on population, as would be expected, most of the sample generally predict no change, although zones 2, 4, 5 and 9 are stated as likely to benefit. All of these zones benefit from either the LRT or the Fife rail improvements. Therefore, within the panel there are more differences concerning perceptions of how public transport affects the location decisions of households than for the commercial sectors.

Table 6.7: The proportion of panel predicting growth or decline in the three sectors due to the LRT (over and above the do-minimum)

Zone	1	2	3	4	5	6	7	8	9
Retail									
% predicting growth	*86*	*43*	*36*	*29*	*21*	*14*	*7*	*14*	*13*
% predicting no chg.	*14*	*57*	*64*	*64*	*71*	*79*	*79*	*79*	*60*
% predicting decline	*0*	*0*	*0*	*7*	*7*	*7*	*14*	*7*	*27*
Office									
% predicting growth	*56*	*56*	*63*	*38*	*38*	*19*	*13*	*19*	*24*
% predicting no chg.	*38*	*38*	*38*	*63*	*63*	*75*	*81*	*75*	*59*
% predicting decline	*6*	*6*	*0*	*0*	*0*	*6*	*6*	*6*	*18*
Population									
% predicting growth	*33*	*47*	*20*	*53*	*53*	*33*	*13*	*20*	*63*
% predicting no chg.	*67*	*53*	*80*	*47*	*47*	*60*	*80*	*73*	*38*
% predicting decline	*0*	*0*	*0*	*0*	*0*	*0*	*7*	*7*	*0*

Table 6.8 gives the average timescales of impact that the sample predicted from the first round. The majority of the sample stated they expected full impacts in between five and ten years, without great differences between the sectors. Small differences indicate that the city centre impacts are likely to occur faster than impacts in the outer zones. These timescales are shorter than the empirical evidence would suggest, although economic growth would be expected to quicken impacts. Note that it is meaningless to estimate by which time a 'full impact' could have occurred, instead the focus is upon the period of activity re-adjustment. The population impact timescales are also slightly longer than the rents, although this is too small to be a certain feature.

Table 6.8: Average time scales of impacts from the LRT

Impact in years from implementation	1	2	3	4	5	6	7	8	9
Retail rents	6.9	6.9	7.3	7.5	7.6	7.8	7.6	7.6	6.1
Office rents	6.5	7	6.9	8.2	7.7	7.6	8.3	8.4	8.4
Population	7.1	7.6	8.4	8.3	8.2	7.6	8.7	8.1	8.6

Finally, it is clear the most of the predicted impacts relate to the LRT system, with Fife benefiting in population from the cross-Forth rail improvements. The section of re-opened rail to the south of the city (see Appendix I for a diagram) had little impact, as was expected from its low frequency.

6.8.2 Impacts from road pricing

Maps 6.8a and 6.8b show that the panel predict that road pricing will have a negative impact of over 6% on retail and office prices in the city centre. This is compensated for by growth in most other zones in the study area, especially west Edinburgh and West Lothian in the case of the office sector. Thus the panel are registering a strong belief that road pricing will have a detrimental impact on city centre commercial prices, with the implication being that this would affect the distribution of commercial activities as well.

The panel also predict that road pricing would impact on the population by causing a displacement from zones 1 and 2. The panel were not given information about whether residents would be exempt from the charge, and several added in written comments that they had assumed that residents would have to pay. Given this, the forecast of population decline is perhaps not surprising, especially given rising car ownership. More interesting is the magnitude of the impacts. Comparing figure 6.6c (the do-minimum), with 6.8c, it appears that the panel are indicating an absolute decline in city centre population. This is an example where it would be desirable to know who the sample consider will be forced out, i.e. is it the higher SEG residents, those involved in 'gentrifying' these zones (especially zone 2), or the lower SEG residents?

A depressive impact of road pricing on commercial prices in central Edinburgh is considered likely by most of the sample, as shown by table 6.9. For the other zones there is most consensus on the impacts for retail, most predicting no change outside Edinburgh district. For the office sector, its greater dispersion throughout the study area appears to lead to less consensus among the panel regarding whether outer zones will benefit or remain unaffected. Certainly most of the sample see zone 3 (west Edinburgh) as benefiting, and also Fife. Again it would be interesting to know why more of the panel thought Fife would benefit compared to West Lothian or the airport area (zone 5), although certainly Fife is following a strong growth oriented development policy (Environmental Resources Management, 1994).

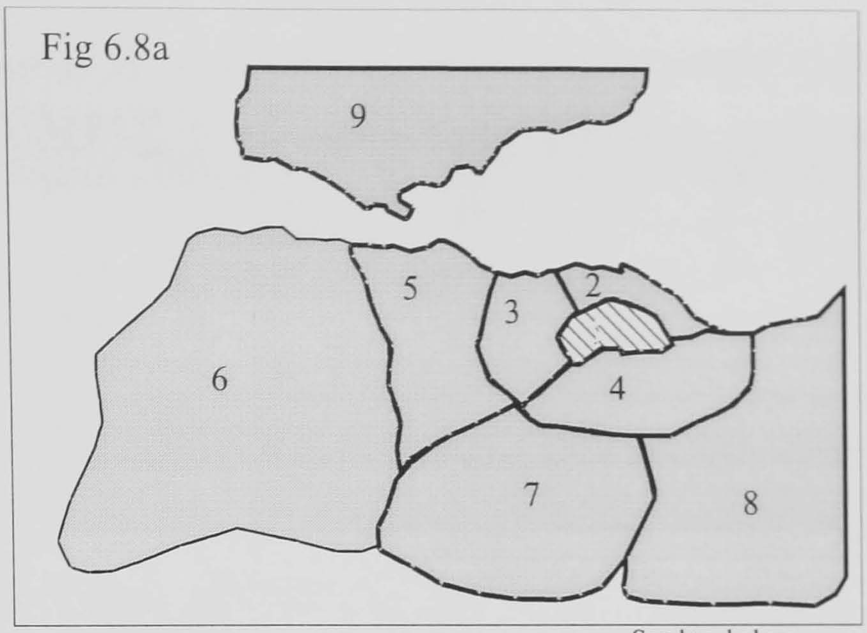
For population impacts, only just over half that panel predict population decline in the city centre, and indeed over half predict no impact for zone 2. The population estimates generally have less consensus among the sample than the commercial rent impacts, and without a doubt the impact of road pricing on long term city centre population remains unclear. Outside the city centre there is more consensus that no significant impact will occur.

Figure 6.8 Maps of Delphi panel estimates of impacts from road pricing

(changes additional to do-minimum)

RETAIL PROPERTY

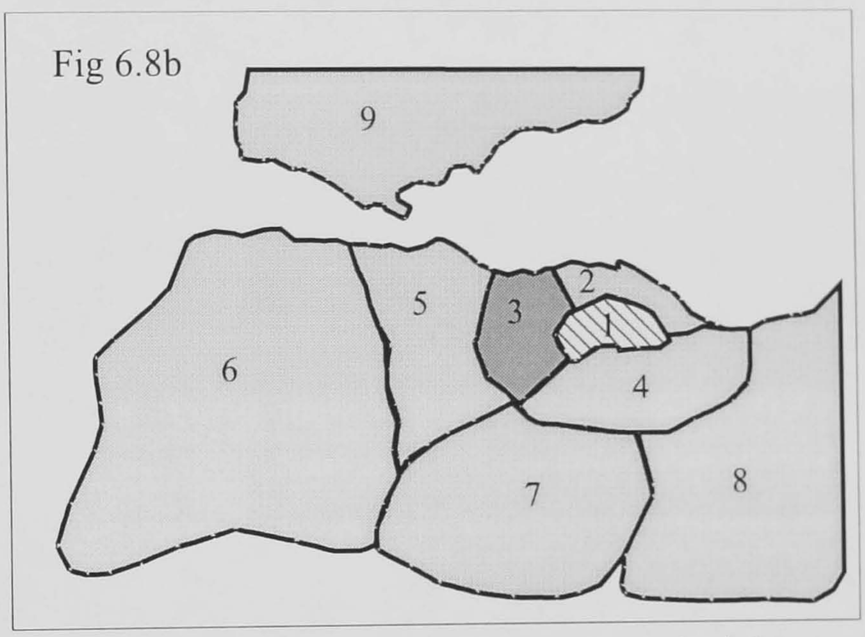
Mean estimate of change from do-minimum due to road pricing



See key below

OFFICE PROPERTY

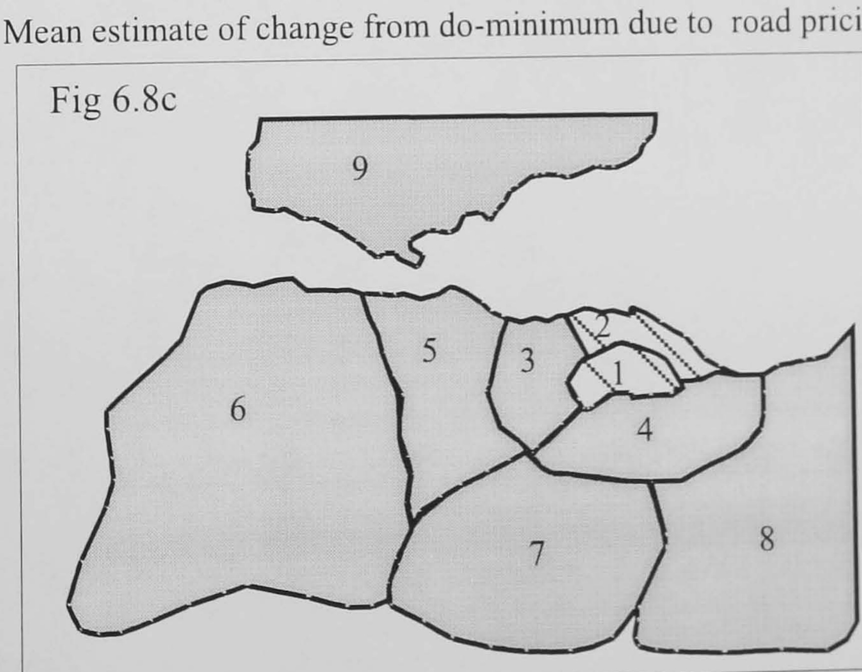
Mean estimate of change from do-minimum due to road pricing



See key below

POPULATION DISTRIBUTION

Mean estimate of change from do-minimum due to road pricing



See key below

Key

(all figures % mean change)

0 - 2.9 % growth

3 - 5.9 % + growth

6 % + growth

No % change

0 - 3 % decline

3 - 5.9 % - decline

> 6% decline

Fig6_8.cdr

Table 6.9: The proportion of panel predicting growth or decline in the three sectors due to road pricing, (over and above the do-minimum)

Zone	1	2	3	4	5	6	7	8	9
Retail									
% predicting growth	*0*	*50*	*57*	*50*	*14*	*29*	*21*	*36*	*53*
% predicting no chg.	*14*	*36*	*36*	*43*	*86*	*71*	*79*	*64*	*47*
% predicting decline	*86*	*14*	*7*	*7*	*0*	*0*	*0*	*0*	*0*
Office									
% predicting growth	*0*	*38*	*69*	*44*	*50*	*44*	*44*	*38*	*59*
% predicting no chg.	*6*	*44*	*31*	*56*	*50*	*56*	*56*	*63*	*41*
% predicting decline	*94*	*19*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Population									
% predicting growth	*33*	*27*	*27*	*27*	*20*	*33*	*20*	*20*	*31*
% predicting no chg.	*13*	*53*	*67*	*60*	*73*	*67*	*80*	*80*	*68*
% predicting decline	*53*	*20*	*7*	*13*	*7*	*0*	*0*	*0*	*0*

The timescales of the impacts from road pricing exhibit the same patterns as the public transport timescales, with no clear differences between the indicator sectors, as shown in table 6.10 below. Despite this uniformity, it does seem to be the case that the road pricing impacts occur slightly faster than the public transport impacts, being closer to five years than to seven in the city (table 6.10 compared to table 6.8).

Again, impacts forecast to occur in the outer zones, (for all the sectors), are forecast to take longer. For example the average is five years in the city centre, but eight years in Fife, where a much smaller impact is predicted. This raises the interesting practical issue that a small (i.e. 1% or less) change in prices over eight years would be extremely difficult to isolate in any empirical study. Furthermore the differing timescales imply a complex series of transfer and 'knock-on' effects, with firms responding to the situation created by the initial response to road pricing.

Table 6.10: Average time scales of impacts from road pricing.

Impact in years from implementation	1	2	3	4	5	6	7	8	9
Retail rents	5.1	6.6	6.1	6.1	6.1	7.6	6.5	6.1	7.1
Office rents	4.9	5.3	6.2	6.3	8	7.7	8.3	9	8.3
Population	7.6	7.4	8.1	8.6	8.7	7.7	8.2	8.7	8.9

6.8.3 Impacts from the combined strategy

With both the LRT public transport and road pricing policies in place, the impacts predicted are a combination of those discussed so far. Figure 6.9a shows that for the retail sector, the pattern is very similar to the road pricing pattern (figure 6.8a), but with the negative price effect of road pricing mitigated by the presence of LRT. For the office sector, the distribution again shows a depressive price impact on the city centre, again mitigated by the LRT, but with the displaced office activity affecting prices to the west of the city and in Fife. When compared to figure 6.6a, this supports the expected do-minimum trends, apart from the lack of growth in the city centre.

The effect of the combined strategy on population is to displace people from zone 1 as in the road pricing only policy, but cease to do so for zone 2. There is also more focused growth of population in Fife, (although not shown in figure 6.9c the impact predicted for zones 5 and 6 is very close to 3%), probably related to the rail routes into Fife. Thus in general, the effect of combining the policies is to mitigate, but not remove, the price decrease and population displacement from the centre of Edinburgh caused by road pricing.

Table 6.11 shows that there is slightly less agreement amongst the sample as to the direction of these impacts relative to the individual strategies, and much less agreement for zone 1. This is probably a function of the different pressures on the city centre that the polices are exerting. For example for retail, panellists forecasting growth are matched by those predicting decline, resting on whether the 'positive' influence of LRT on rent is greater than the 'negative' influence of road pricing. For the other zones there is generally more consensus that growth will occur in the rest of Edinburgh, and no impact in the surrounding districts.

Table 6.11: The proportion of panel predicting growth or decline in the three sectors due to the combined strategy (over and above the do-minimum)

Zone	1	2	3	4	5	6	7	8	9
Retail									
% predicting growth	*43*	*71*	*64*	*50*	*29*	*36*	*21*	*36*	*27*
% predicting no chg.	*14*	*21*	*36*	*43*	*64*	*64*	*71*	*64*	*60*
% predicting decline	*43*	*7*	*0*	*7*	*7*	*0*	*7*	*0*	*13*
Office									
% predicting growth	*19*	*63*	*81*	*56*	*63*	*50*	*38*	*50*	*41*
% predicting no chg.	*19*	*25*	*19*	*44*	*38*	*50*	*56*	*44*	*59*
% predicting decline	*63*	*13*	*0*	*0*	*0*	*0*	*7*	*7*	*0*
Population									
% predicting growth	*33*	*40*	*33*	*53*	*60*	*60*	*33*	*53*	*81*
% predicting no chg.	*27*	*40*	*53*	*40*	*33*	*40*	*67*	*47*	*19*
% predicting decline	*40*	*20*	*13*	*7*	*7*	*0*	*0*	*0*	*0*

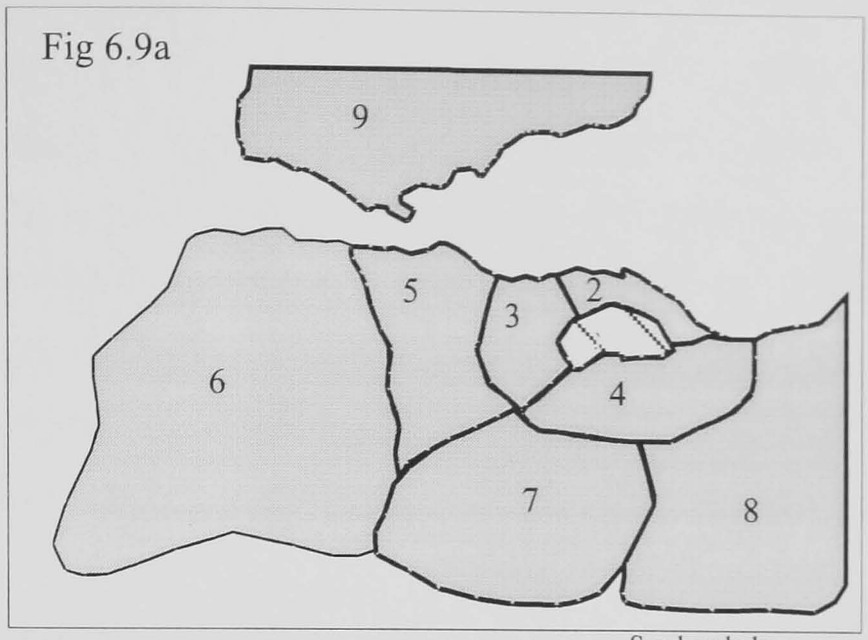
Figure 6.9 Maps of Delphi panel estimates of impacts from the combined strategy

(changes additional to do-minimum)

RETAIL PROPERTY

Mean estimate of change from do-minimum due to both policies

Fig 6.9a

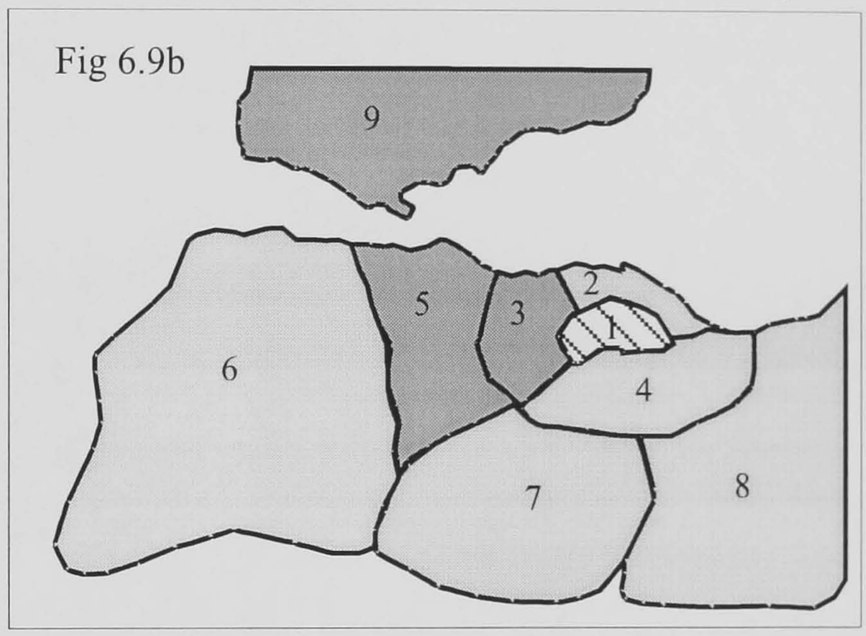


See key below

OFFICE PROPERTY

Mean estimate of change from do-minimum due to both policies

Fig 6.9b

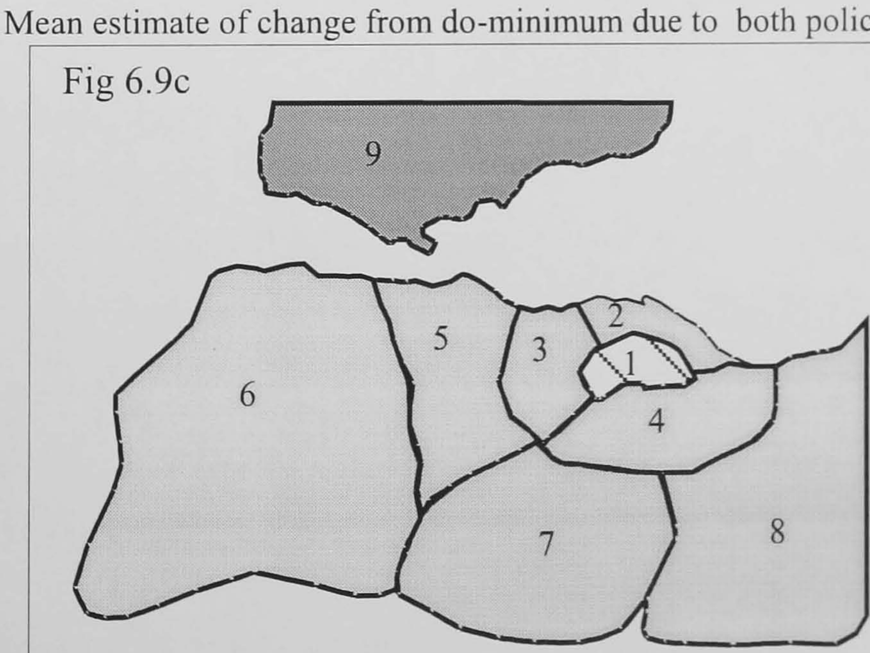


See key below

POPULATION DISTRIBUTION

Mean estimate of change from do-minimum due to both policies

Fig 6.9c



See key below

Key

(all figures % mean change)

0 - 2.9 % growth

3 - 5.9 % + growth

6 % + growth

No % change

0 - 3 % decline

3 - 5.9 % - decline

> 6% decline

Fig6_9.cdr

For the office sector a majority of the panel expected city centre office prices to fall, with compensating growth to the north and west of the city. It appears that the office sector is more sensitive than the retail sector to accessibility changes, especially declines in values. For impacts on the population distribution, there is still a displacement effect on zones 1 and 2 foreseen by some of the panel, although more predict growth in zone 2 (due to LRT) than in the road pricing only strategy. However, in the outer zones, there is less agreement on where the growth will go. Thus table 6.11 provides a good indication that it appears harder for the panel to agree on transfer impacts in the outer zones.

Table 6.12 shows that the timescales of impact in the combined strategy are similar to the individual strategies, with the characteristic of the faster timescale of road pricing impacts maintained in the combined strategy. One interesting point to note is that the panel did not think that a larger impact will take longer to occur for any of the three sectors; indeed in the case of road pricing it occurs more rapidly.

Table 6.12: Time scales of impact from the combined strategy

Impact in years from implementation	1	2	3	4	5	6	7	8	9
Retail rents	5.9	6.6	6.8	6.6	6.5	7.3	6.6	6.5	6.3
Office rents	5.7	6.3	6.9	7.1	8.2	7.2	8.6	8.6	8.7
Population	7.6	6.6	7.8	7.7	7.6	7.5	7.4	7.8	8.2

6.9 Discussion

6.9.1 Characteristics of the Delphi panel

As discussed in Section 6.6.1, the majority of the panel were property experts, and it is useful to investigate whether they gave different responses compared to the planners. Such analysis reveals that in general the forecast impacts were similar, especially for the pattern of zonal growth. An example of this is given for the office sector forecasts in tables 6.13 and 6.14 (the other sectors showed a similar magnitude of divergence between the two groups). This illustrates that the dispersion of the panellists' views is apparent both within and between professions.

However, there were some differences. A good example is given in table 6.14, which shows that the property experts predicted a greater negative impact for road pricing (especially for Leith in zone 2), but smaller impacts to the south and west of the city centre (zones 3 and 4).

Similar differences were given for the retail impacts. However, for the public transport test there was little obvious divergence between the groups.

Table 6.13: Office base forecasts; differences of means within the Delphi panel (planners and property experts for round 1)

Zone	1	2	3	4	5	6	7	8	9
Planners (6)*	5.0	6.8	10.0	2.5	2.5	3.3	1.3	1.3	2.0
Property (18)	3.2	6.3	9.8	2.7	4.5	2.1	1.1	0.4	2.2

*number in brackets refers to number of panel answering section.

Table 6.14: Office impacts from road pricing; differences of means within the Delphi panel (planners and property experts for Round 1)

Zone	1	2	3	4	5	6	7	8	9
Planners (5-6)	-5.0	5.0	7.5	4.7	0.5	3.3	1.3	1.3	3.4
Property (15-18)*	-8.6	-1.8	1.9	1.3	2.8	1.9	1.9	1.9	2.1

*number in brackets refers to number of panel answering section.

A second issue of interest in this examination of the panel are the changes in opinions between rounds. It was reported in Section 6.7.1 that the second round had a lower dispersion of results in the do-minimum. For the estimated transport impacts, the same trend generally occurs, with a decrease in the impact predicted from round 1 to round 2. There were some exceptions however, for example the zone 1 retail impacts from road pricing changed from -3.8% to -6.9% in round 2[3]. Changes in the estimates of several planners caused this swing, most notably in the response of one planner who reversed his city centre road pricing impact from positive to negative. Thus repeat sampling did prove a useful mechanism to refine the forecasts.

An important issue in Delphi studies is how representative is the panel of their profession as a whole. By default the panel are self-selecting, and hence there is a danger of strategic bias (discussed further on page 134). Clearly any bias in the survey means that it should be interpreted more as market research than a source of forecasts. Some suggestions on determining whether strategic bias is occurring is discussed in Chapter 11 (page 278), where possible enhancements to the Lothian Delphi method are suggested.

[3] Comparisons between the rounds can be made by comparing the results in Appendices I and II.

6.9.2 A comparison of the strategies

From the previous sections it is clear that the panel see the impacts from the two strategies being very different, and different again when the two policies are combined. The group consensus from the panel was that road pricing would have a downward depressive effect on prices, reducing growth in both the office and retail sectors, and displacing population from the city centre. Growth was likely to occur to the west of the city as a result of this. The LRT public transport strategy, in contrast, was seen to strengthen the city centre, increasing commercial rents and encouraging some movement of population towards the newly served LRT corridors (although further detail is not possible due to the coarse zone system).

It is interesting that when both policies are combined, the 'negative' rent impacts in the city centre from road pricing prevail over the 'positive' effects from the public transport strategy. In particular it is evident that the sample forecast that the west of Edinburgh would benefit from synergy in the displacement of city centre activity from road pricing **and** the new LRT services. Fife also benefits more from road pricing when its public transport to Edinburgh is improved.

6.9.3 Comparisons of the Lothian Delphi results to other Delphi studies

There have been two past Delphi studies discussed in this chapter, plus the non-Delphi questionnaire study undertaken by Flowerdew and Stevens (1994) on the impacts of road pricing, discussed in Chapter 3. The findings from this Lothian Delphi accord with Flowerdew and Stevens' findings, in so far as a comparison is possible (as different questions were asked). Both studies predict that the retail sector within the cordon will be adversely affected by road pricing. The office sector is more complex, in that the Lothian Delphi predicted a decline in rents from road pricing, while Flowerdew and Stevens concluded from their interviews with experts that office rents may rise if congestion relief occurs. However, their questionnaire survey predicted that all property prices would decline inside a cordon, with commercial sectors being the most sensitive, as was found in the Lothian Delphi.

Compared to the first round of the Supertram study (Antwi and Hennebury, 1995), the Lothian Delphi results are broadly comparable, but not as generally homogenous as the Sheffield results. This is likely to be due to the mix of professions, coupled with the rather more complex spatial disaggregation. Despite this, for city centre impacts, there is considerable agreement between the studies. For example, the largest percentage of respondents thought that the Supertram would affect property values by 6-10%. Furthermore, over 75% thought that office and retail prices would experience property value increases in the city centre, with the retail sector most likely to be affected. Both these results are very similar to the Lothian Delphi. A central difference was that the Sheffield respondents thought that the impacts would be felt within five years, slightly faster than forecast in Lothian. It was also estimated that leisure property prices would be affected, a sector not considered in the Lothian Delphi.

Nevertheless, the general impacts and magnitudes of changes are similar between the two studies. This is not necessarily a verification of the Lothian Delphi, after all, Sheffield has a relatively depressed property market, whereas Edinburgh's would be expected to be more buoyant as it emerges from the early 1990s recession. However, the fact that the Sheffield tram system was under construction at the time of the survey may have led to bias towards its impacts depressing prices, especially during the disruption caused by construction. This may mean that the Edinburgh property experts, unwittingly or not, may have given conservative estimates of change, in a situation where LRT is still only being debated, not implemented.

Another factor discussed in the interview with the Sheffield project supervisor was the possibility of strategic bias in the sample. The concern was that property experts would want to create the expectation that the LRT would increase prices in Sheffield, in order to create a positive image and hence really influence the market. In the same way, the Lothian panel, especially the property planners, may be registering their disapproval of road pricing by presenting it as a depressant for the city centre property market.

Comparison with the San Jose study (Cavalli-Sforza and Ortolano, 1984) is harder as its format was very different from the Lothian Delphi, and the transport strategies were also more complex than the hypothetical policies considered in the Lothian Delphi. That said, it was far less detailed spatially, and hence could not give much information on the distribution of impacts. In general though, the study found that public transport improvements do tend to lead to net increases in population, and stimulate the commercial sector, which is a similar finding to the Lothian Delphi results.

6.9.4 Comments on the Delphi methodology

The above discussion serves to demonstrate that the results from this Delphi, whilst intended to be specific to the study area, do not seem unreasonable when compared to the findings from other opinion or Delphi surveys. Unfortunately, the experimental nature of this survey does not lend itself to rigorous consistency tests, such being able to derive household density by zone (for comparison with other forecasts), or matching price changes to historical data.

To examine the accuracy of the forecasts would require a rolling programme of Delphi exercises and empirical data collection over many years. The closest that can be obtained in this study is a comparison of the results to those from the other methods applied in this thesis (see Chapter 9). This is still a large improvement compared to undertaking no comparison at all.

This application of the Delphi methodology has revealed several constraining features (note that recommendations on the design of future Delphi surveys are discussed in Chapter 11, page 278). Perhaps the most obvious limitation is the inability to trace the explanation for the responses. Thus we cannot be sure what rationale the panel applied to their forecasts, unless they recorded their reasoning on the questionnaire. Some did this (as outlined in Section 6.6.3), for example several had based their view on road pricing on the basis of what was already occurring with stricter parking controls. However, there is clearly a danger of interpreting results in ways other than the panel intended. Whether this is a limitation to the potential users of the data will be examined in Chapter 10.

A major constraint on this Lothian Delphi were the limited resources available. This meant that the number of questionnaire iterations was limited, and that no initial scenario building questionnaire was issued. The development of a Delphi questionnaire requires significant resources, and can be complex if panel members from various fields are sought. This was a central reason for excluding 'subject area' experts from the Lothian Delphi study, as they would have required much more information on the study area. Furthermore, the questionnaire development process itself requires an understanding of three issues; land use and transport interactions, who the relevant experts are, and how to elicit the most precise and useful response. Therefore, the Delphi questionnaire designer requires a good level of understanding of the processes involved, in much the same way as proposed in the 'scale of understanding' introduced in Chapter 2.

The ultimate constraint on a Delphi is the demands placed on the expert panel. The Lothian Delphi attempted an ambitious set of estimates based upon a pre-determined spatial zoning system. While this undeniably helps the interpretation of results, and their comparison with the other methods, it was a large task for the panellists to complete, and it was fortunate that a panel was found who were willing to do this.

When asking for spatial estimates, which require a great deal of thought, the size of Section 3 of the questionnaire is probably as large as can be produced without deterring the panellists. Even if incentives are offered, respondent fatigue may well set in. This is a serious problem if a local authority is genuinely interested in a variety of strategies in four or five land use sectors. Coupled with this is the concept of adding more data, especially study area 'control totals' (i.e. giving the study area totals and asking to panel to forecast changes within these constraints). While this may improve the consistency of the results, it creates a far harder task for the panellists, and it was for this reason that it was rejected in the Lothian Delphi.

Related to this is the issue of the number of iterations. It is likely to be the case that the interest of panellists declines the more iterations they are asked to complete, and a lower response rate reduces the sample size in the final results. This places practical constraints the length of the study. Certainly without some form of incentive (e.g. either financial or as a 'duty' of membership of some prestigious organisation), it is difficult to recruit large samples and expect committed results during repeated sampling.

Despite these limitations, the Delphi technique does offer not only a set of forecasts that are reasonably cheap to collect, but also the views from a set of major actors in the urban system. Therefore, the data could be used in two ways. Firstly it can provide stand alone forecasts of transport impacts on land use, that could be used to adjust existing land use forecasts, and to examine how the transport policy may affect land use policy. Secondly, the Delphi can be seen as a method of gaining experts' <u>attitudes</u> towards transport policies. Here the planner can make use not just of the forecast, but also whose views underlie it, and what additional experience they can bring to bear.

This highlights the issue of examining results. Throughout this chapter, the temptation has been resisted to assume that price rises are a positive impact, while price falls are somehow detrimental. Whether a transport impact is beneficial or unwanted relates to the perspective of the individual actor. Thus a property developer is likely to see office price decreases caused by road pricing as a negative effect, whereas a planner may see this as less important if it reduces local overheating of the economy, or is mitigated by improvements in other objectives (such as the raising of environmental quality).

6.10 Conclusions

This chapter began with four questions regarding the use of the Delphi for forecasting transport impacts on land use in strategic planning. Having undertaken the study, two of these questions can be answered. The second two, regarding the comparisons of the results to other forecasting methods, and the planners' perception of results, must wait until Chapters 9 and 10 respectively.

The first question posed was 'what kind of information on land use response can the technique be used to obtain?' From this Delphi study, plus a review of others, it has been shown that land use response data can be obtained using this method. However, there are limitations, especially regarding how complex the scenarios and questions can be. Furthermore, the lack of overall study area control totals means that the results cannot be used as strictly internally consistent forecasts. There are also constraints on obtaining a multi-disciplinary panel with expertise on specific indicators.

Secondly, there are limitations in the complexity of the transport strategies that can be tested, and on the number of sectors that can be assessed, due to constraints on the panellists' resources. This places the Delphi as a 'first shot' method, aimed at establishing quick analysis of impacts. It is clearly not suited to detailed policy testing, but does have the advantage of not having to obtain a complete land use / transport dataset, (required to produce a mathematical model). However, even in this respect, the zoning is a limiting factor. The more detailed the zoning, the fewer panellists will be able to deal with it, and hence the more information would have to be supplied to the panel. There are clear practical limitations to the complexity of the exercise that can be undertaken.

The second question asked how reliable or plausible was the information generated. It is not expected that the Delphi results should be empirically verified in order to be seen as reliable. Indeed, as has been mentioned in the analysis, empirical validation is probably extremely difficult given the small magnitude of the changes predicted, and their timescales. However, some idea of whether the views of experts do at least resemble what occurs in the future would be required if the Delphi technique is to become more widespread in planning. This would require the kind of 'rolling assessment' discussed in Section 6.9.2, and relates to building confidence in the method, an issue returned to in Chapter 10.

It is encouraging that the results were found to be consistent with the findings from other methods, in terms of general directions of impacts. However, the lack of explanation for the results means that it cannot be said with certainty that the forecasts are similar for the right reasons. It is also the case that the magnitude of the predictions for several zones in each sector forecast has a large variance associated with it.

A better resourced Delphi study should be able to overcome some of these difficulties in explanation via more contact with the panel members, but the issue of the large variance in the forecasts remains. Undoubtedly however, data on impacts from a group of experts, collected in a systematic and non biased way, is an improvement over individual judgements.

This Delphi study of Lothian and Fife has revealed some interesting issues, both about the method and the impacts on several sectors as a result of transport policy. Although far from flawless, the results compare well to other similar studies of land use response. However, the drawbacks in the method suggest that it is most appropriate to broad brush, or exploratory work on impacts. It is the aim of the Phase 2 interviews to resolve some of the unanswered questions regarding the applicability of the Delphi to planning, especially:

- What are the planners' views on the plausibility of the results?
- How plausible do the results have to be before they could be used to inform planning decisions?
- Do they agree with the estimates of the panel?
- How appropriate are the spatial scales, and indicators that have been selected?
- What views do planners hold on the method itself, and how does the method fit into their views on the ways in which planning should be undertaken?

These issues will be addressed in Chapter 10. Before this, the next two chapters discuss the two related mathematical modelling methods that were applied to the study area.

CHAPTER 7
APPLICATION OF THE LAND USE CHANGE INDICATOR MODEL TO THE STUDY AREA.

7.1 Introduction

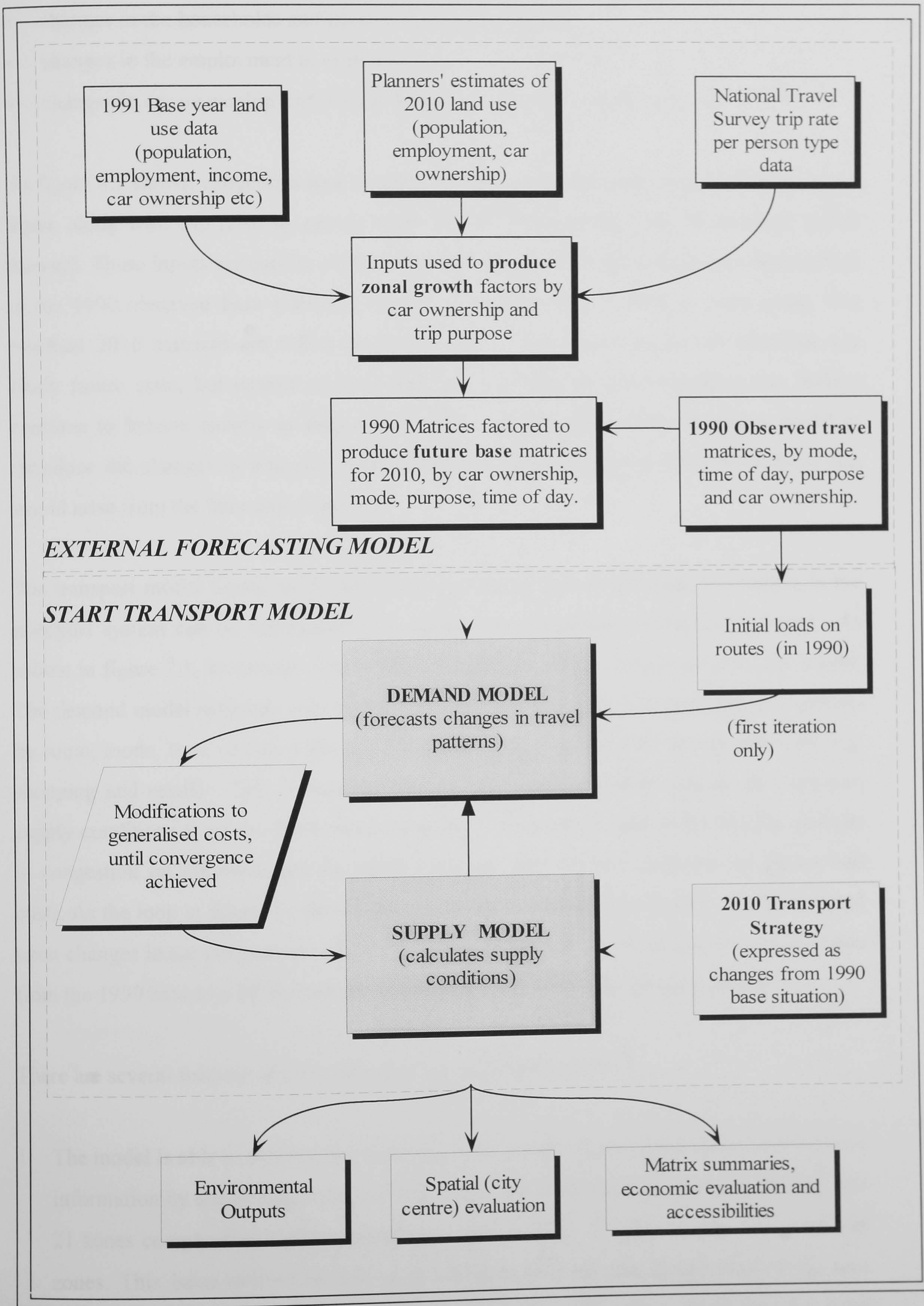
This chapter discusses the structure and implementation of the Land Use Change Indicator (LUCI) model, that was designed by David Simmonds Consultancy, and applied as part of the JATES study of Edinburgh in 1990/91. The LUCI model was linked to the JATES transport model. This chapter therefore begins by outlining in more detail the JATES strategic transport model, introduced in Chapter 5. This is discussed in terms of its 'generic form', termed START. This model provides the transport element of both the LUCI model and the more complex land use model discussed in the next chapter. Sections 7.3 and 7.4 then describe the implementation and results from the LUCI model, updated and re-applied to the study area for this research project.

7.2 Overview of the START strategic transport model

The START strategic transport model was developed by The MVA Consultancy to facilitate transport planning using the 'top-down' approach, appropriate when an overall transport strategy for an area needs to be formulated (Coombe and Copley, 1993). As such it is designed to be able to test a large number of strategies in as short a time as possible. The model is designed to encompass all the major elements of a transport strategy, plus all the expected effects of these policies on the transport system.

The model represents a 16 hour 'average day' as three time periods, and contains three modes, six journey purposes and car availability. It is able to represent mode choice, destination choice, time of day choice and frequency of travel, as well as; limited route choice, the effects of congestion, parking, public transport capacity and operator responses. Figure 7.1 shows the structure of the model. There are two parts; (1) the external forecasting model (EFM), which calculates growth in trips from the base year to the future year, and (2), the transport model proper, which determines what will happen to the transport system. The model relies upon detailed matrices of the base situation which for Edinburgh were collected as part of an origin-destination road side interview survey.

Figure 7.1: Outline of the standard START model process



The EFM functions as a trip generation and distribution model. It assumes that if there was no change in transport conditions, then demand for travel would be a function of:

- changes in the households and persons living in each zone;
- changes in the employment in each zone;
- changes in car ownership (influenced by household income and structure).

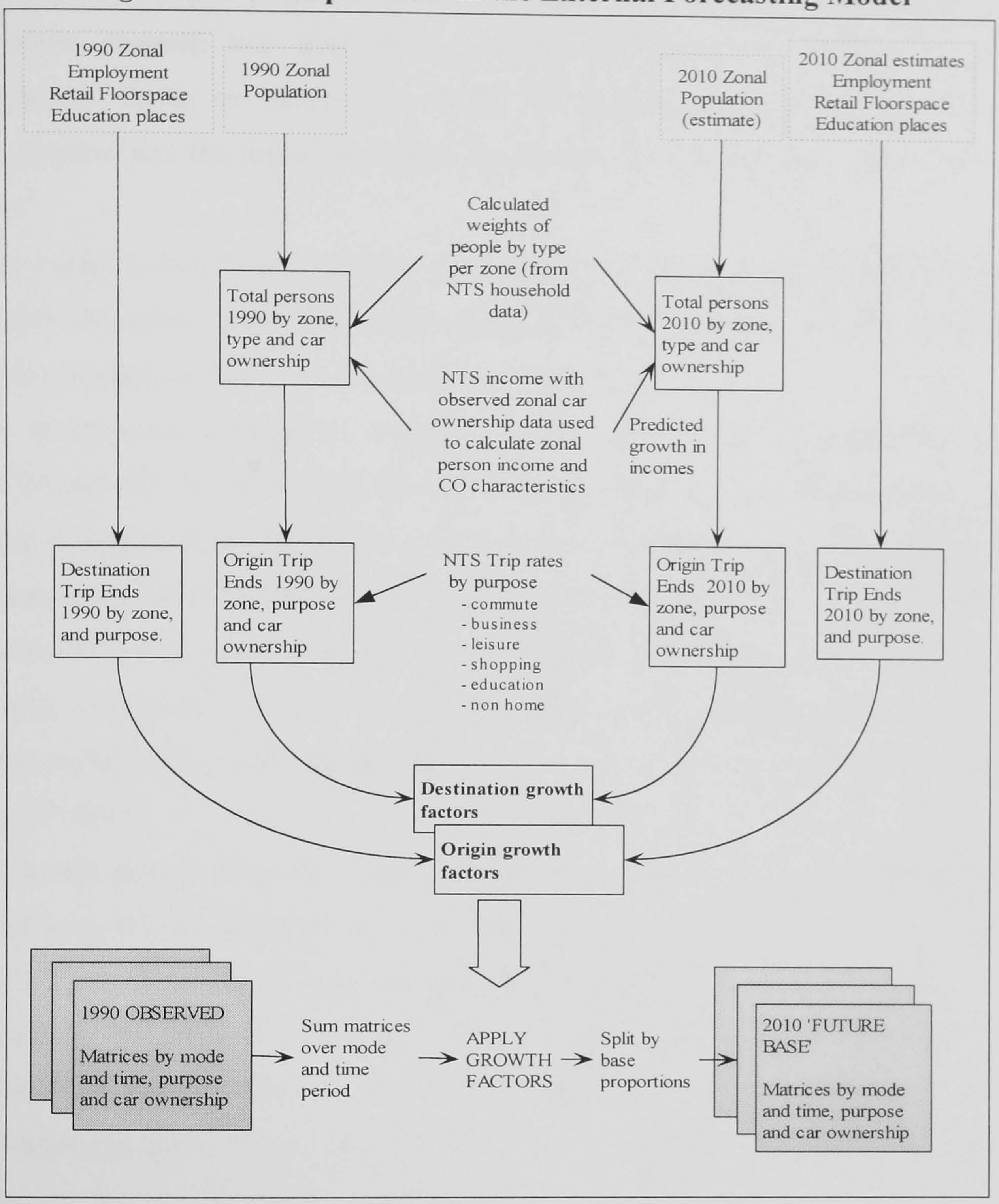
As figure 7.1 shows, exogenous land use data for the base (1990) and future (2010) years are input, along with trip rates by person type (for JATES from the 1985/86 National Travel Survey). These inputs are used to produce a set of trip growth factors, which are then applied to the 1990 observed base matrices. Figure 7.2 outlines this process in more detail. The resultant 2010 matrices are called the 'future base'. These matrices do not represent any likely future state, but consist of predicted travel patterns in 2010 assuming trip makers continue to behave exactly as they did in 1990. It is the task of the transport model to introduce the changes in transport conditions (and hence changes in travel behaviour) that would arise from the base case factoring.

The transport model works on the basic premise that all travel responses to changes in the transport system can be represented by changes in components of generalised cost. As shown in figure 7.1, it consists of two basic elements, a demand model and a supply model. The demand model responds only to changes in generalised cost, and re-assigns trip makers by route, mode, time of travel and trip frequency (the latter only for certain purposes: e.g. shopping and retail). This is then fed into a supply model, which contains the transport supply conditions from the 2010 transport policy. The supply model calculates the changes in congestion on the roads and on public transport, and in turn modifies the generalised costs. As the loop in figure 7.1 shows, the model iterates until a convergence criterion (based upon changes in the components of generalised cost) is satisfied. Note that the model jumps from the 1990 base to a 2010 situation. It thus iterates to solve one '20 year' period.

There are several features of the model that are important to note:

1. The model is able to achieve fast run times with complexity in segmentation and purpose information by compromising the spatial detail. The Edinburgh study area is divided into 21 zones compared to a network transport model which would probably have over 100 zones. This issue is discussed in more detail in Roberts and Simmonds (1995), who argue the model should be seen as an *'aspatial city-wide policy model that has been given a spatial dimension'.*

Figure 7.2: Main processes in the External Forecasting Model



2. As such the model does not have a transport network, but represents 'corridors of movement', with traffic flow determined by area speed flow relationships, and the road network represented simply by three 'links' per zone (see Bates *et al,* 1991 for more detail).
3. The choices in the model are determined by a series of hierarchical logit models. These models are entirely incremental (i.e. they work with changes over time). This allows the model to work without explicit constants, except when a 'new mode' is introduced. This has a bearing on the accessibility calculations, which does require explicit constants as absolute accessibility levels are required.
4. It was known by the consultants at the outset that there was insufficient data available to attempt a formal cross sectional calibration of the model, and this was never the

intention. Instead, the 1990 matrices were intended to represent the existing travel patterns as closely as possible, and the parameters on the choice models have come from previous research into elasticities, coupled with sensitivity testing of the model responses. Being an incremental model, the features of the base matrices will be perpetuated into the future, and hence the model relies (as most do) upon accurate base data[1].

5. The model is based upon random utility theory, which is consistent with the land use models described below, but assumes the trip maker possesses perfect information and makes rational decisions, as discussed in Chapter 2.
6. The model gives accessibility outputs, although the functional form differs between JATES and JIF. In fact the JATES model has two different accessibility indices; firstly a series of isochronic accessibilities, which were discussed in section 2.3.1 and used in the evaluation of the JATES transport strategies, (and also used in Still, 1992); and secondly, a series of spatial interaction type accessibility indictors intended for use in the LUCI model (see Section 7.3). In JIF the START accessibility indicator calculation is different again, being based upon logsum formulations using the generalised cost components from START.
7. The model gives a range of environmental outputs. These are very aggregate measures based upon vehicle speeds and flows, given by zone. Details can be found in the START user manual (The MVA Consultancy, 1993), but the key outputs are a measure of noise (based on the Dept. of Transport, 1988), carbon monoxide, nitrous oxides, volatile organic compounds (VOC), and carbon dioxide. Again, these should be seen only as indicators, as clearly there will be large variations in the emissions within each strategic zone.

These features of the model imply that there are specific applications for which it is suited. Given the coarse spatial nature of the model, the focus should be upon area wide policies such as road pricing or public transport fare changes. More spatially specific policies, such as junction improvements, cannot be represented individually due to the lack of specific links. There are also limitations in the implementation of transport policy. For example, to represent traffic calming, a percentage decrease in capacity was added to the relevant routes.

Clearly this is a simplification, and shows that in some cases, the strategic model is very dependent upon the modeller's estimations on what effects the policy will have. As Forster

[1]Note that a validation was attempted by 'back projecting' the model from 1981 to 1991. This found a good fit between the observed flows across the Forth and the models' estimates.

(1996) commented, the START model was not intended to be a highly accurate predictive tool, but a method to provide reasonable indications of strategic change. Used for suitable applications, START is a powerful strategic transport planning model, and has been applied by The MVA Consultancy in many locations, both in the UK and abroad (see Roberts and Simmonds, 1995).

7.3 The Land Use Change Indicator (LUCI) model

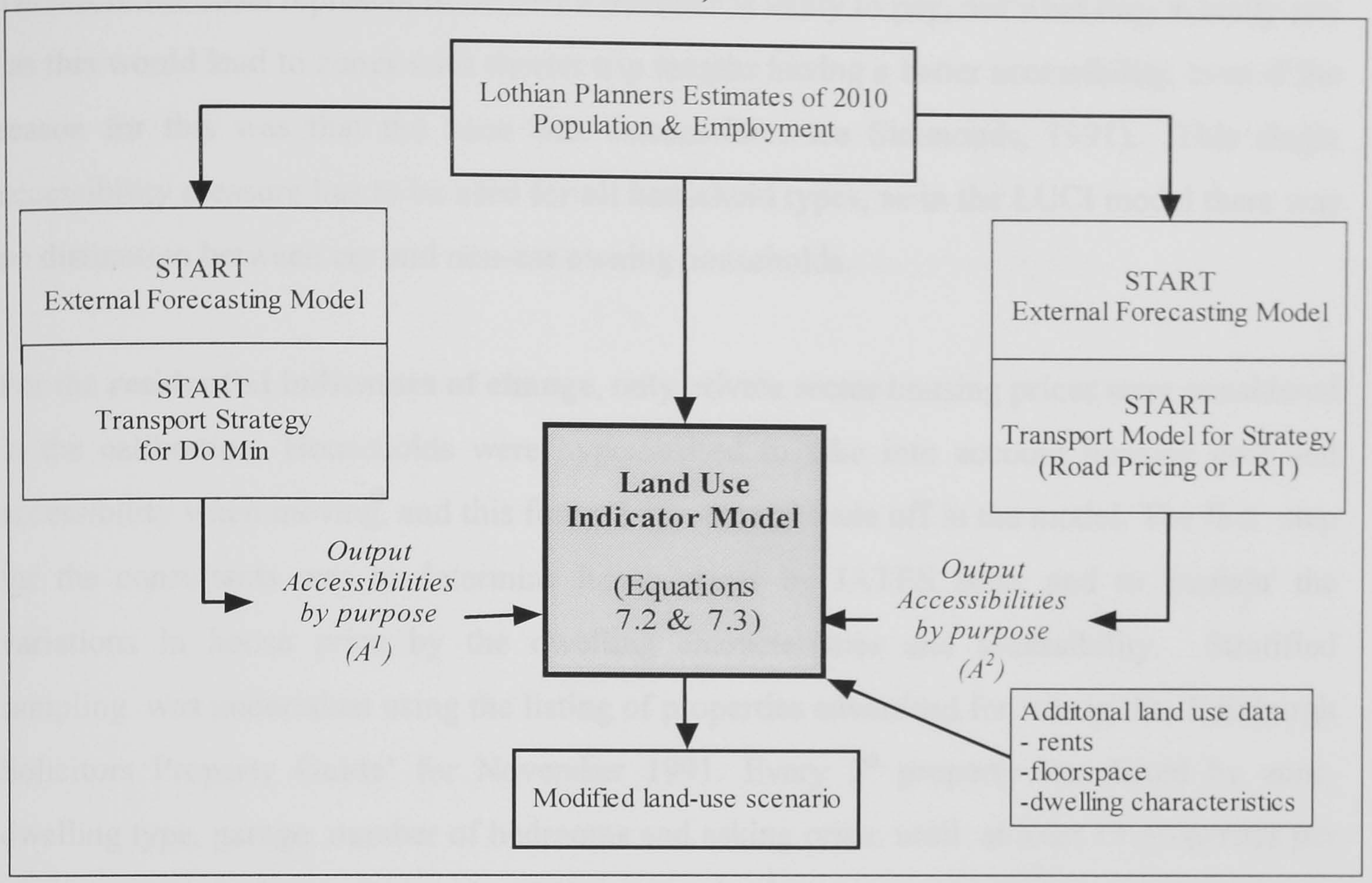
The Land Use Change Indicator model was developed by David Simmonds Consultancy, initially for the JATES study. The need for such a model arose due to the limited way that START takes land use into account. As was shown in figure 7.1, START relies upon exogenous forecasts of land use in order to produce the future base matrices. However, no attempt is made to determine how the transport strategy may influence that future land use pattern, in other words there is no representation of transport's impact on land use. The LUCI model was designed to go some way to meet this need, without building a full land use transport interaction model. In the strategic model 'tradition', the results were intended as a basis for discussion of possible impacts, rather than a definitive estimate of what the impacts were likely to be.

The LUCI model thus takes a change in accessibility, for example between the 2010 outputs of two different transport strategies, and gives a quantitative estimate of how population and employment may respond to those changes. This is shown in figure 7.3.

It can be seen from this figure that the basic model requires the following information:

1. land use (population and employment) data by zone for the 'base-case'. This corresponds to the exogenous planning information from Lothian in figure 7.1;
2. a set of zonal accessibilities for 2010 from the Do-Minimum run (called A^1), and also for the alternative 2010 strategy run, (A^2 ; which would also have used the same exogenous land use inputs);
3. information to represent the behaviour of the population with respect to accessibility;
4. information to represent the behaviour of businesses with respect to accessibility.

Figure 7.3: Structure of the Land Use Change Indicator (LUCI) model (adapted from Roberts and Simmonds, 1995).



The accessibilities used were spatial interaction indices derived from the JATES model. A full description of the calculations can be found in Simmonds (1991). The accessibilities had to be calculated as absolute values rather than as changes from the base situation in order to be used as independent variables in the calibration (which was cross sectional). Several different accessibility measures were produced, including an average cost of travel. However, the best performing index (in terms of producing sensible parameters in the calibration) was that based upon generalised cost, of the form:

$$A_i = \frac{\sum_j X_j \, exp(-\lambda \, c_{ij})}{X_*} \qquad \text{(Eqn. 7.1)}$$

Where: A_i is the generalised cost accessibility of origin zone i;

X_j are the destination weights (for example work or shopping opportunities);

c_{ij} are the modal generalised costs weighted by modes;

λ is the distribution parameter;

X^* indicates a summation of the zonal destination weights, thus giving an index accessibility measure (i.e. where a greater number indicates a better accessibility).

Note that this function is similar to those outlined in Chapter 2. based upon the 'Hansen index'. The transport costs are taken from the final ij pairs weighted by the modal flow. Therefore the costs represent those that a traveller is likely to pay. not what they actually pay (as this would lead to zones with shorter trip lengths having a better accessibility, even if the reason for this was that the zone was inaccessible: see Simmonds, 1991). This single accessibility measure has to be used for all household types, as in the LUCI model there was no distinction between car and non-car owning households.

For the **residential indicators of change**, only private sector housing prices were considered in the calibration. Households were hypothesised to take into account housing cost and accessibility when moving, and this formed the central trade off in the model. The first step for the consultants was to determine house prices by JATES zone, and to 'explain' the variations in house price by the dwelling characteristics and accessibility. Stratified sampling was undertaken using the listing of properties advertised for sale in the 'Edinburgh Solicitors Property Guide' for November 1991. Every 5th property was listed by zone, dwelling type, garage, number of bedrooms and asking price, until at least 15 properties per zone were reached. Analysis using SPSS determined that a 'residual (non-explained) house price' variable could be taken to represent the influence of accessibility, environmental and other 'non explained' factors, having removed variations in house size and types.

The second step was the calibration of the residential indicators themselves, which involved explaining the distribution of the population (expressed as working persons by employment sector z and two socio economic groups g) in the study area, in terms of accessibility to work and housing cost. In addition, an independent variable representing the proportion of total dwellings in each zone was included. The cross sectional logit model for calibration was as follows:

$$P_i^{gz} = \frac{D_i^{\alpha 1} \exp(\alpha_2 A_i^z + \alpha_3 R_i)}{\sum_i D_i^{\alpha 1} \exp(\alpha_2 A_i^z + \alpha_3 R_i)} \qquad \text{(Eqn. 7.2)}$$

Where:

P_i^{gz} is the proportion of workers in SEG g employed in sector z, who live in zone i;

D_i is the number of dwellings in zone i;

A_i^z is the accessibility of zone i for the sector z, as expressed in equation 7.1;

R_i is the residual house price variable for zone i;

$\alpha 1, \alpha 3$ are the parameters to be calibrated.

As would be expected, the co-efficient on accessibility was positive (+1.963), and that on housing price was negative (-0.751). The parameter on zone size was sufficiently close to one (1.049) to show that a change in the zoning would not arbitrarily alter the results (Simmonds, 1991). Note that the model only explains the behaviour of working people (responding to changing accessibility to work), but that other segments of the population were assumed to move in the same way as the workers. This simplifying assumption means that the indicators can be applied to total workers, households or population.

The final models are shown below. For the residential choice model, the following logit model was applied:

$$P_i' = P^* \frac{p_i \exp(\alpha_1 (A_i^2 - A_i^1))}{\sum_i p_i \exp(\alpha_1 (A_i^2 - A_i^1))} \qquad \text{(Eqn. 7.3)}$$

Where: P'_i is the new zonal population modified by the accessibility change;

P^* is the fixed total population;

P_i is the exogenously forecast population of zone i;

α_1 is the calibrated coefficient on accessibility (+1.963);

A_i^2 is the accessibility for zone i for the transport strategy; and

A_i^1 is the accessibility for zone i *for* the base strategy (see equation 7.1).

Determining the **non-residential** indicators of change was more difficult for the consultants as businesses are much more heterogeneous than households, both in size and location requirements. Data on employment numbers in each of seven employment sectors was obtained from the census of employment. It was decided by the consultants to concentrate the calibration upon the retail sector initially, and floorspace and rental data were obtained based upon the situation in 1991.

It was found that employment was strongly correlated with floorspace, but not with densities. Attempts were then made to explain the location of employment by rents and accessibility. A relationship was found, with a positive co-efficient on accessibility (+0.37), and negative on retail rents (-1.19). Note that this high value on rents implied a very high elasticity of location with respect to rent, but this was deemed acceptable by the consultants as feedbacks between rent and demand for space were not considered in the model (i.e. prices do not rise if demand increases).

Although the analysis was undertaken for the retail sector only, it was also applied to the non-retail service sector by halving the influence of accessibility, and to the non-service industries by removing any influence of accessibility altogether. The assumed insensitivity of these sectors to accessibility was clearly a simplification, but was justified using the conclusions of the ISGLUTI study (Webster *et al*, 1988, p.382).

For the incremental employment model, a multiplicative function was found to allow the best calibration. Constraining the study area totals, the resultant incremental model was:

$$E_i' = E^* \frac{E_i\,(A_i^2 / A_i^1)^\alpha}{\sum_i E_i\,(A_i^2 / A_i^1)^\alpha} \qquad \text{(Eqn. 7.4)}$$

Where: E_i' is the modified zonal employment in zone i;

E_i is the current employment in zone i

E^* is the fixed study area employment;

A_i^2 is the accessibility (to shoppers) by zone for the transport strategy;

A_i^1 is the accessibility (to shoppers) for the base strategy; and,

α is the coefficient on accessibility.

The model was implemented for the retail and service sectors, with α at 0.37 for retail employment, and 0.18 for service sector employment.

As discussed above, two strategies were tested. Firstly a rail strategy, which featured LRT at a headway of five minutes, fares to match buses and also park and ride facilities[2]. Secondly a road pricing strategy, which also featured some pedestrianisation of the city centre. Both strategies were forerunners to the final JATES strategies discussed in Chapter 5.

7.4 Implementation and results from the LUCI model

As stated above, the implementation of the LUCI model for Edinburgh and Lothian region was undertaken by consultants in 1991 as part of the JATES project. For the purposes of this thesis, it was important that the input data should be as comparable as possible with both the Delphi study and the DELTA/START model. There were several limitations here.

[2] It should be pointed out here that new runs of JATES were not undertaken for this project, and the accessibilities used were those generated by MVA in the early 1990's.

Firstly the future land use estimates from the planners were updated between the JATES and JIF studies once the 1991 Census data became available. Secondly there were changes in the definition of the study area, with the subdivision of zone 15 (West Lothian) and the addition of Fife (see Chapter 5). Thirdly, as outlined above, there were changes in the definition of accessibilities between JATES and JIF.

Thus if the LUCI model was to be made fully compatible with the implementation of DELTA/START, the following tasks would have to be undertaken:

- re-base the model with the JIF land use estimates;
- replace the old accessibility terms with those standard in JIF START for the road pricing and LRT strategies;
- recalibrate the model including the new zones and new accessibilities.

This process would effectively mean re-doing the entire LUCI process. Although this was the intention at the outset, constraints on resources caused by the implementation of DELTA/START meant that to do this was not feasible. Instead it was decided only to re-base the model on the new JIF planners' estimates, and essentially use the model unchanged from its consultancy implementation. The implication of this was that the activities in the LUCI model would be responding to a different set of accessibilities compared to those in DELTA, although the general directions of change in the accessibility indices were consistent between the two models. These issues are discussed further in Chapter 9 where the methods are compared.

The population forecast updating was therefore simply an issue of substituting the new estimates. For the employment forecasts the situation was more complex as the JIF forecast planning data did not include the employment data by the 'blue collar/white collar' distinction, nor were the JIF employment forecasts revised between JATES and JIF. Therefore the proportions of service and retail employment were obtained for the study area from the NOMIS dataset, and the same growth applied as had been forecast by the Lothian planners. Clearly this method is simplistic (for example the planners' estimates would not be exactly the same with different base data), however it represents a good compromise between the aim to make use of exogenous Lothian forecasts, and the more current base data used in the DELTA modelling.

For the subdivision of zone 15, the new zones (15, 22, and 23) had to be given the same accessibility as the original zone 15. As Fife was not included in the JATES model, it was also omitted from the new LUCI work.

7.4.1 Do-minimum forecasts from the Lothian planners

Table 7.1 presents the exogenous land use population and employment data that was used in the LUCI model. In other words, this is approximately how the planners in Lothian predicted that the study area would change from 1991 to 2010.

Table 7.1: Lothian planners' population and employment forecasts

	Population do-minimum forecasts				Employment do-minimum forecasts		
Zone	1991 Census	2010 estimate	% change		1991 Census	2010 estimate	% change
1	12686	14200	11.9		57700	60934	5.6
2	10977	13700	24.8		12600	16504	31.0
3	57925	58500	1.0		34500	37721	9.3
4	46869	41700	-11.0		9800	10250	4.6
5	41099	43100	4.9		8100	10468	29.2
6	24735	22600	-8.6		8200	8780	7.1
7	32282	28900	-10.5		11700	13406	14.6
8	32589	27300	-16.2		4700	5213	10.9
9	25070	22400	-10.7		16900	31858	88.5
10	35839	30600	-14.6		10100	10756	6.5
11	27646	24100	-12.8		13700	13141	-4.1
12	13606	15200	11.7		32100	35037	9.1
13	23833	24900	4.5		12200	12852	5.3
14	17089	17400	1.8		26100	29036	11.3
15	74135	97666	31.7		30500	35708	17.1
16	7248	7500	3.5		12200	11951	-2.0
17	42885	40100	-6.5		10200	9973	-2.2
18	35960	49500	37.7		10500	12049	14.8
19	44963	54100	20.3		9200	10222	11.1
20	39151	42200	7.8		12200	12659	3.8
21	9419	7500	-20.4		3400	3036	-10.7
22	17847	25045	40.3		4300	4725	9.9
23	52155	60989	16.9		14600	17003	16.5
24	0	0	0.0		0	0	0.0
25	0	0	0.0		0	0	0.0
Total	726008	769200	5.9		365500	413281	13.1

Figure 7.4 shows the Lothian Regional Council forecasts for population. Three basic features can be seen from this figure. Firstly there is limited population growth in the central zones (1,2 and 12), which is low in absolute terms but high in percentage terms. Secondly, apart from zone 5, there is decline in the outer areas within the city (zones 4-11, 13-14, and 21). Finally, there is most absolute growth in the non-Edinburgh districts, most notably in West Lothian and East Lothian. The total study area growth is just under 6% (as shown at the bottom of table 7.1). Thus the dominant trend is of population counter-urbanisation.

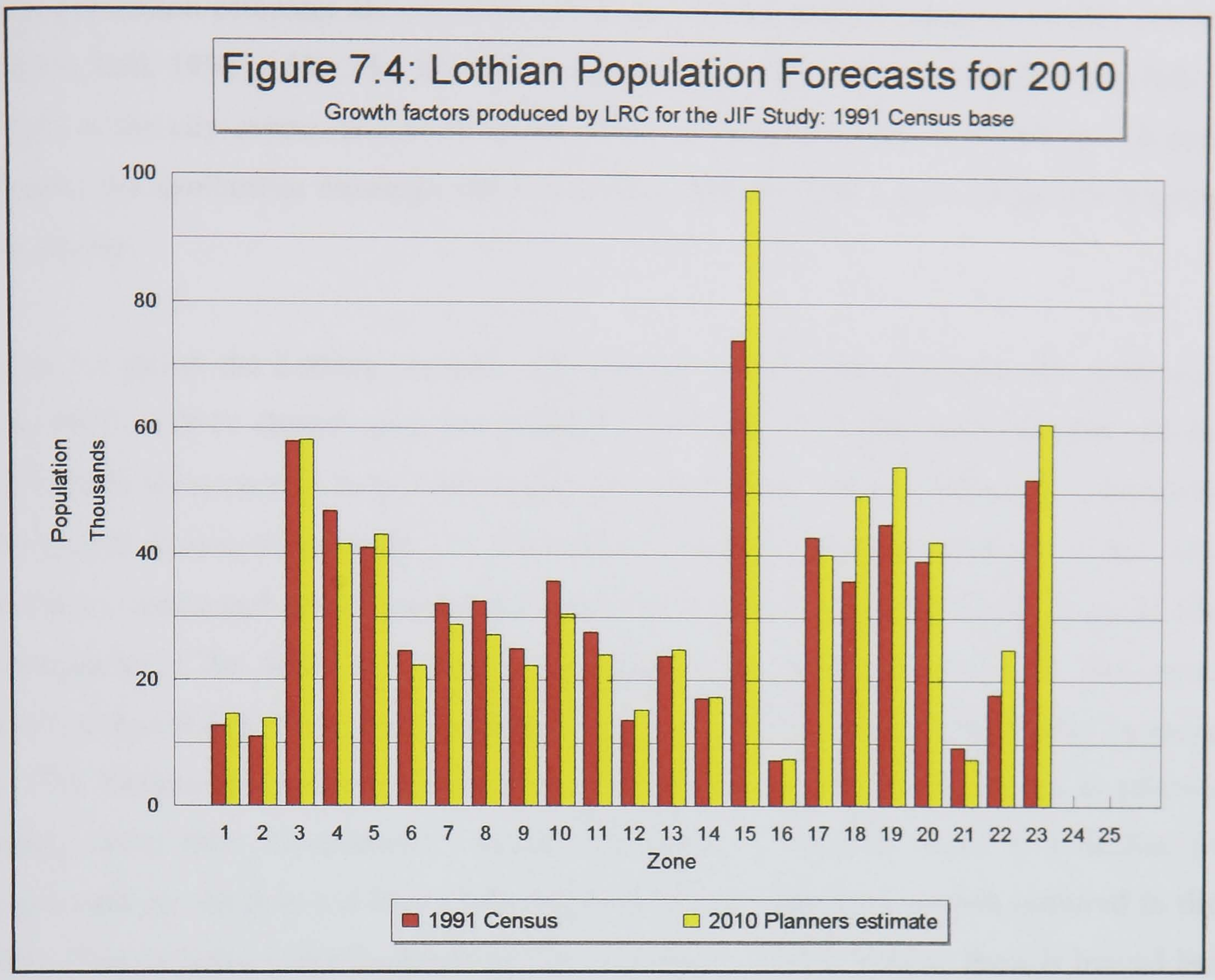


Figure 7.4: Lothian Population Forecasts for 2010
Growth factors produced by LRC for the JIF Study: 1991 Census base
Population
Thousands
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Zone
1991 Census
2010 Planners estimate

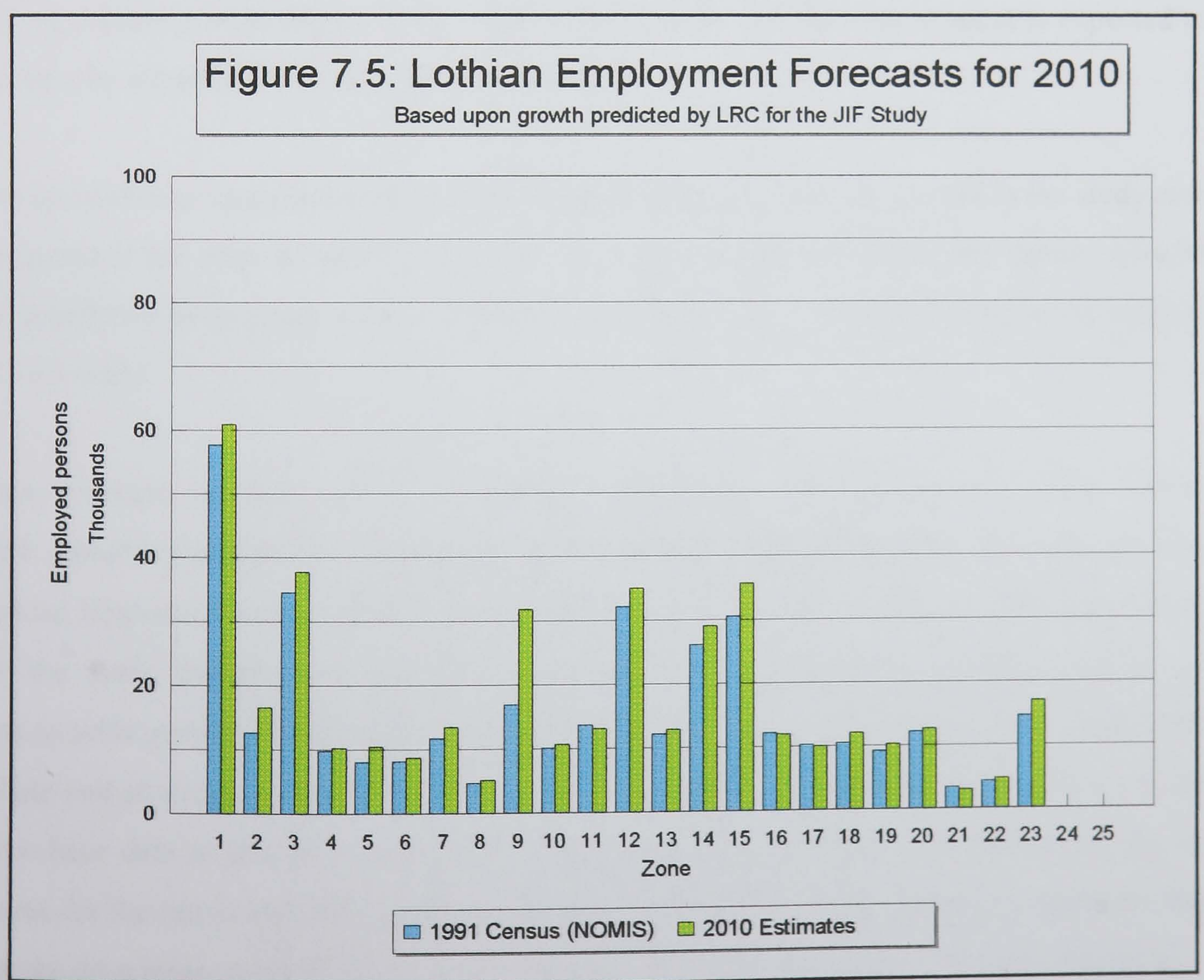


Figure 7.5: Lothian Employment Forecasts for 2010
Based upon growth predicted by LRC for the JIF Study
Employed persons
Thousands
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Zone
1991 Census (NOMIS)
2010 Estimates

These population estimates are not identical to the original JATES estimates (which can be found in Still, 1992 p. 55). The JIF 2010 estimates from LRC tend to show less population growth in the city centre, and more in the south of the city (zones 5, 6 and 7). Overall however, the similarities outweigh the differences, and the study area total growth remains very similar.

Figure 7.5 shows the Lothian planners' estimates of employment growth in the study area from 1991 to 2010 (based upon the NOMIS 1991 dataset). Again, the forecasts can be described in three parts. Firstly there is high growth (around 30%+) in zones 2, 5 and over 80% growth in zone 9 (see table 7.1). This reflects the growth and development of the new conference centre and offices around the Castle Street area of the 'Old Town' (zone 2), the development of the South East wedge (including a new hospital) in zone 5, and, most significantly, the Edinburgh Park and South Gyle in zone 9. It should be noted that by using the 1991 Census of employment data from NOMIS, the zone 9 absolute change is actually slightly lower than the planners original predictions. Secondly, there is a decline in employment in zones to the west of the city; the areas where most growth occurred in the 1980s. This includes South Queensferry and around the airport. Thirdly, there is limited but still significant growth (up to 15%) in most other zones. Overall, employment is expected to increase by around 13% over the 20 year period.

The updated employment forecasts show higher employment growth overall in the study area compared to the original JATES forecasts. This is most apparent in the city centre. As with the population projections though, the basic distribution of growth is similar to the original JATES study.

These forecasts are thus entirely exogenous to the LUCI/JATES modelling process. They were initially produced by consultants, and then fine-tuned in a series of meetings with Lothian Regional Council. This required the planners not only to forecast planning policies for the study period, but also the impacts of these policies, and the economic and demographic growth of the region. As a result the forecasts were subject to considerable debate and scrutiny, particularly the population scenarios. In addition to this, they use the same base data as the DELTA/START model. For the 2011 forecasts, using LRC as the source for the future estimates is also consistent between the models. It was hoped therefore that the do-minima would be similar between the LUCI model and DELTA (see Chapter 9).

7.4.2 Impacts from the LRT

Figure 7.6 shows a cloropeth map of the impacts of the LRT strategy on population, over and above the do-minimum forecasts presented in table 7.1. It is clear from this that the magnitudes of the impacts from the rail strategy are very large; around a 15% increase in population in the central zones, rising to over 20% in zones 5, 11 and 19. These responses are larger than any of the empirical evidence discussed in Chapter 3, or the impacts predicted by the ISGLUTI models, which barely showed any impact at all (table 3.5, page 41). While it is true that the Lothian LRT scheme does not run on previous rights of way or in unpopulated areas, the main reason for this growth is the extremely high frequency of the LRT providing a large change in relative accessibilities. This can be seen from the table of accessibilities in figure 7.6. The large scale of the changes are noticeable when compared to the equivalent road pricing table in figure 7.9. Note that all the accessibility indices have been factored up for ease of comparison.

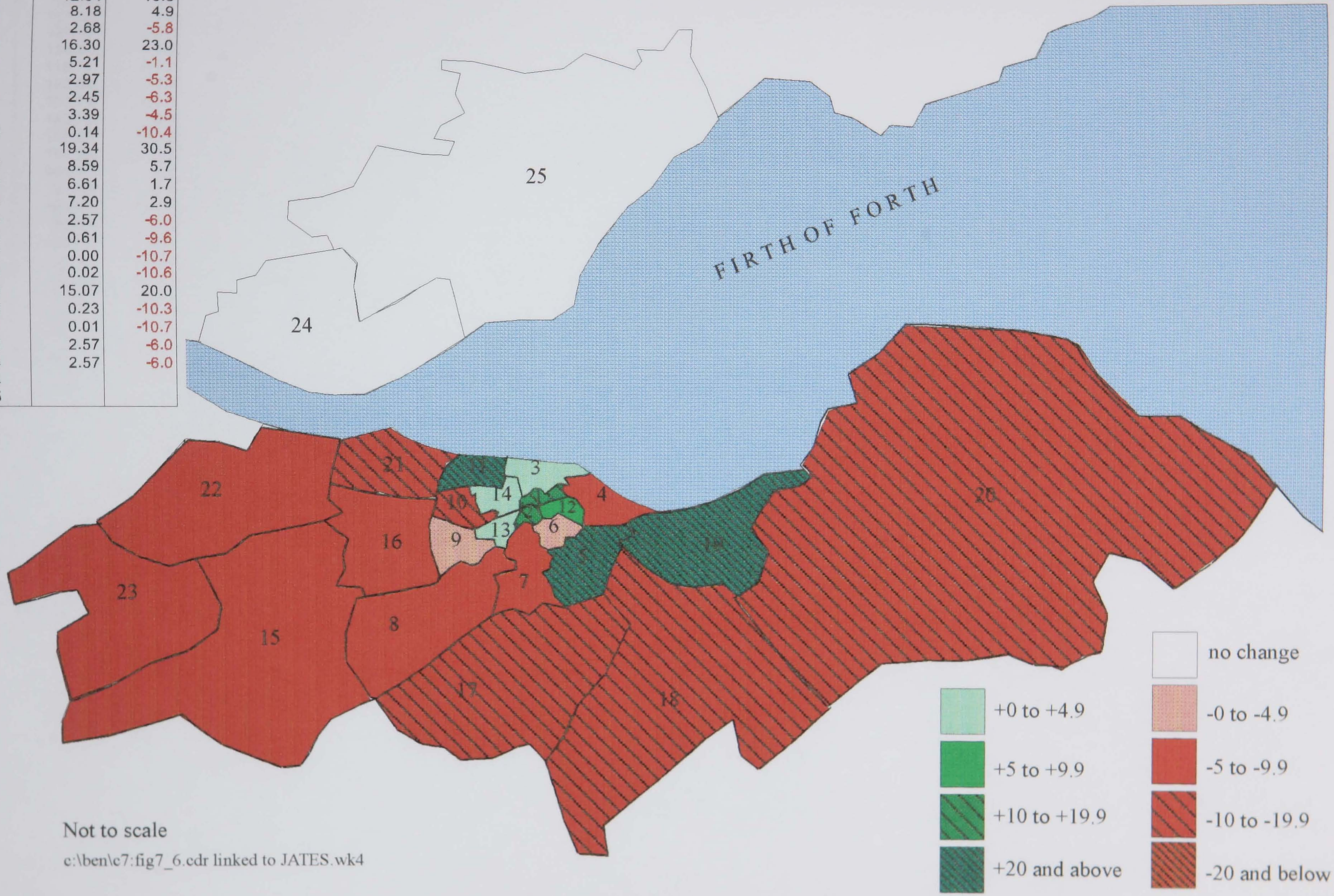
The zones increasing in population (except 19) are all benefiting from an LRT line, the magnitude of the population response being in line with the magnitude of the accessibility change (as can be seen from the table in figure 7.6). The large growth in zone 19 is curious, given that the accessibility increase is high in spite of the fact that the zone is not served by LRT. Zone 19 does have park and ride, but this alone would intuitively seem insufficient to account for the large benefits (especially given that accessibility is calculated in relation to all other zones). Thus, the next step (which was beyond the resources of this research) would be to look for the source of this change (or the error causing it) in the transport model itself. In other words, given the variables in the model, the only source of variation is the change in accessibility, which must explain all the population shifts that occur.

Zones not benefiting from LRT show a relative decline, as would be expected (in general they have to decline as the model was constrained to the study area do-minimum totals). However, it is curious that the population in zone 9 does not rise, given that it has LRT. As with zone 19, the explanation for this must be sought in the transport model generating the accessibility indices.

Finally, the lack of price feedback effects in the LUCI model may also explain why the shifts are so large, as demand does not increase prices and hence price some locators out of the property market.

Figure 7.6: Study area map of the impacts of public transport strategy on population (percentage change from do-minimum 2010)

Zone	Change in access (x100)	% chg in pop
1	12.49	14.1
2	12.34	13.8
3	8.18	4.9
4	2.68	-5.8
5	16.30	23.0
6	5.21	-1.1
7	2.97	-5.3
8	2.45	-6.3
9	3.39	-4.5
10	0.14	-10.4
11	19.34	30.5
12	8.59	5.7
13	6.61	1.7
14	7.20	2.9
15	2.57	-6.0
16	0.61	-9.6
17	0.00	-10.7
18	0.02	-10.6
19	15.07	20.0
20	0.23	-10.3
21	0.01	-10.7
22	2.57	-6.0
23	2.57	-6.0
24		
25		



Not to scale

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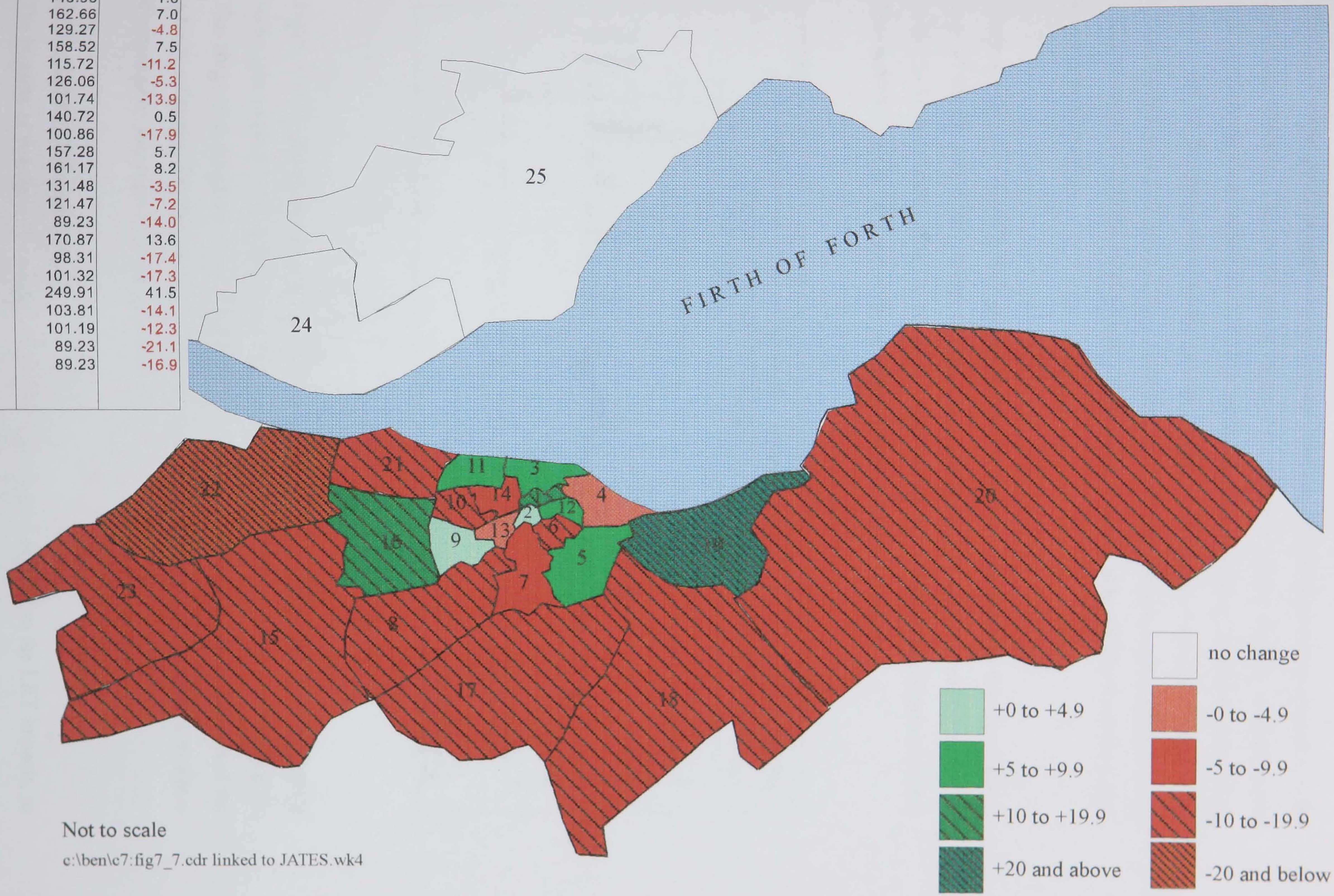
Figure 7.7: Study area map of the impacts of the public transport strategy on employment distribution (percentage change from do-minimum 2010)

Zone	Chg in retail acc (x100)	% chg in emp
1	175.88	14.5
2	143.96	1.8
3	162.66	7.0
4	129.27	-4.8
5	158.52	7.5
6	115.72	-11.2
7	126.06	-5.3
8	101.74	-13.9
9	140.72	0.5
10	100.86	-17.9
11	157.28	5.7
12	161.17	8.2
13	131.48	-3.5
14	121.47	-7.2
15	89.23	-14.0
16	170.87	13.6
17	98.31	-17.4
18	101.32	-17.3
19	249.91	41.5
20	103.81	-14.1
21	101.19	-12.3
22	89.23	-21.1
23	89.23	-16.9
24		
25		



The LUCI model predicts employment impacts from the LRT to be similar in direction to the population impacts. This is shown in figure 7.7. There is a clear pattern of employment moving to those zones where the LRT has enhanced the accessibility, namely zones 1, 3, 5, 11, 12 and 16. To compensate for the growth in these 'LRT zones', there are declines in the non-benefiting zones of up to 21%. Note that the LRT does little to enhance the zones in which planners believe the most growth will occur (2, 5 and 9), although the New Town area benefits substantially.

There is again the curiously high growth in zone 19, but note that although this figure shows zone 19 has the largest percentage change, the absolute changes would reveal the impact on zone 1 to be larger than zone 19, due to the latter having low levels of employment in 1991. This is shown by the bar chart of the absolute impacts in figure 7.8 below.

Figure 7.8: LUCI employment impacts from public transport strategy
Absolute employment changes from 2010 do-minimum by sector

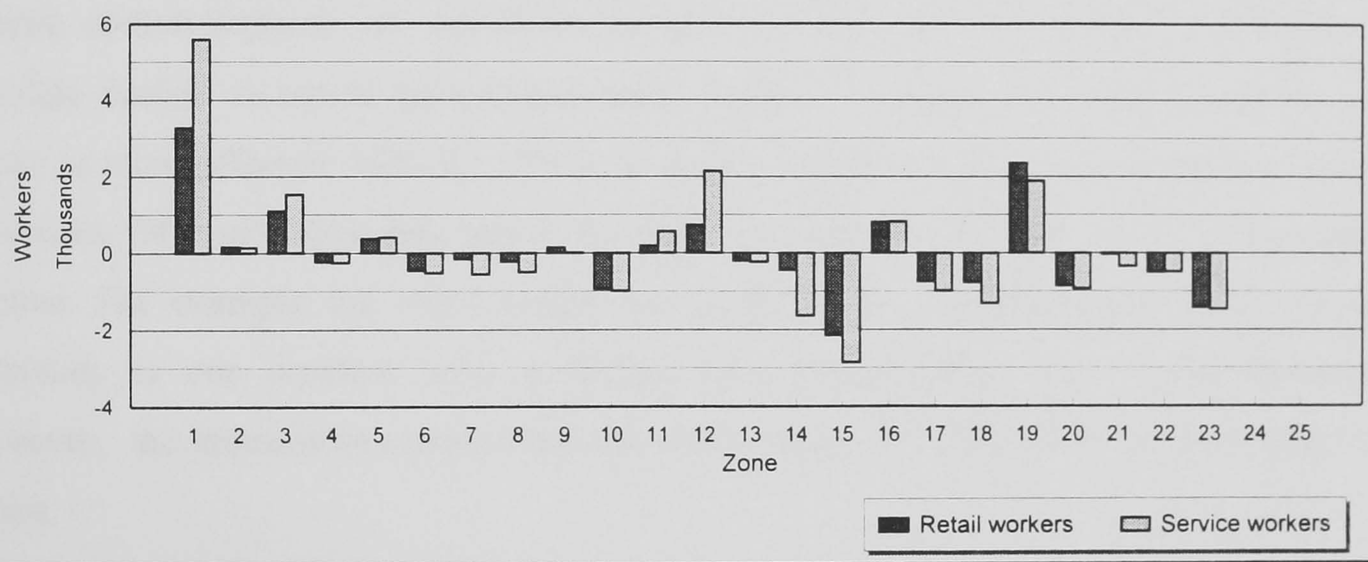


Figure 7.8 also shows that despite retail being more sensitive to accessibility than the service sector (see section 7.3), the larger size of the service sector creates a greater absolute impact. This shows that sensitivity (as modelled) can be seen to be defined by the proportion of the activity influenced by the transport policy, not the overall magnitude of the impact, as this is determined by the overall size of the sector.

7.4.3 Impacts from road pricing

The impacts of road pricing on population are very slight compared to the LRT impacts, as can be seen from comparing figure 7.9 with figure 7.6. This is entirely due to the lesser impacts that this policy had upon the accessibilities in the transport model.

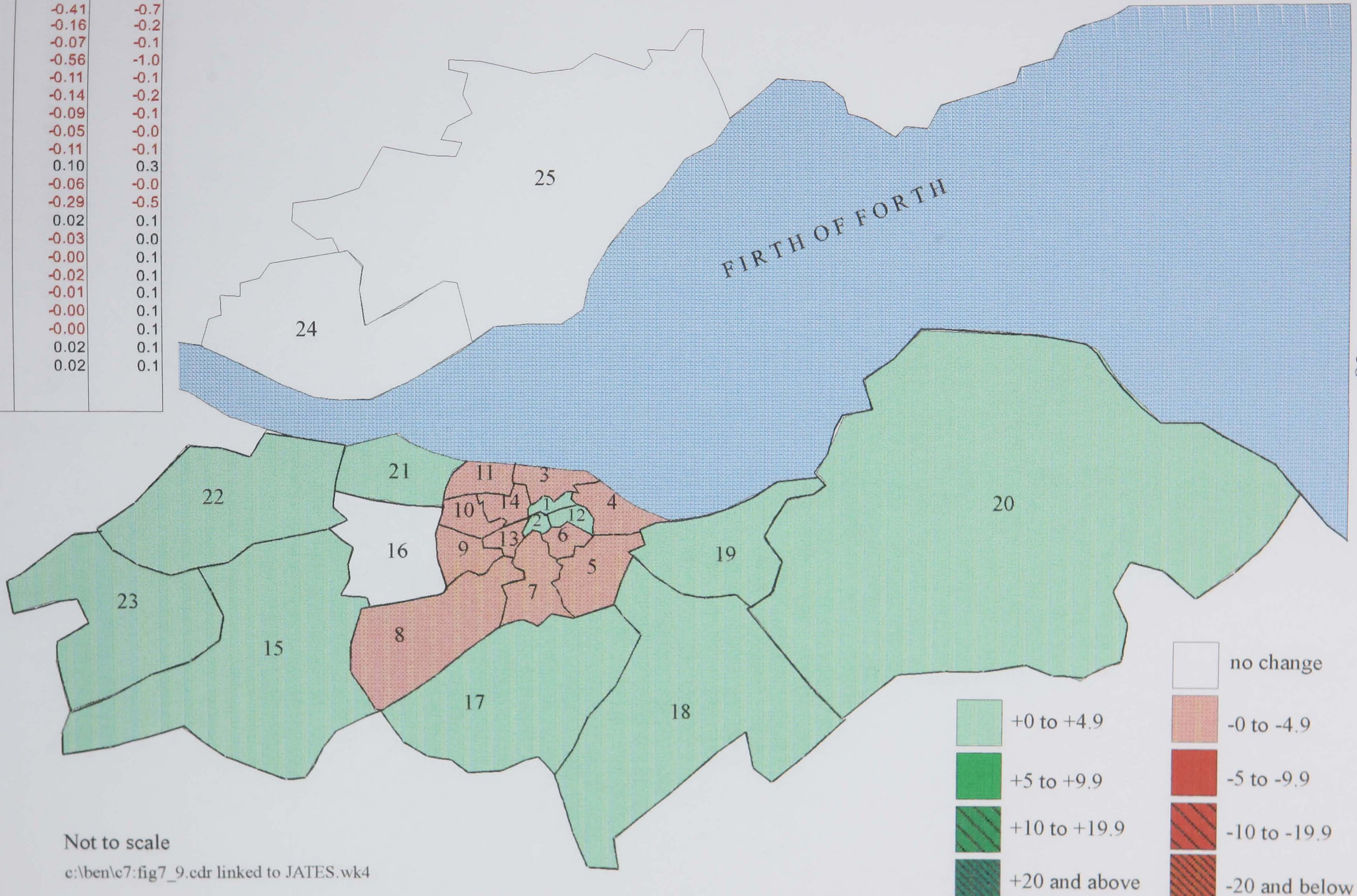
The most obvious distributional impact of road pricing from figure 7.9 is the centralisation of population in zones inside the cordon, and compensating, although very small, decreases in much of the rest of Edinburgh (zones 3-11 and 13-14). Outside of the city there is a small rise in all the other districts, in some cases in spite of a small worsening in accessibility. This shows two points: firstly that the pattern of gainers and losers may be complex from road pricing, for example it would appear that the redistribution of population mostly occurs within the city, which may place pressure on the distribution of available and suitable housing. Secondly, that the land use impacts will be small overall, with changes comparable to the LASER model of London, generally under five percentage (Chapter 3, table 3.8, page 44).

The impacts of road pricing are far more marked on employment than on population. The clearest impact is a decline within the cordon of around 7%, evident from figure 7.10. This equates to a decline in over 5000 workers in zones 1 and 2. These percentage changes of the 'within cordon impacts' are significant enough to mean that road pricing would force an absolute decline in central area employment. Figure 7.11 (page 160) shows that the retail sector is more affected, with 12-15% less retail employment in zone 1 relative to the do-minimum. Of course this does not mean that retail turnover or shoppers will necessarily decline. For example the retail sector may respond by employing less staff, and this ambiguity is one problem with modelling employment rather than actual businesses. However, the implication remains that the retail sector as a whole will contract in the city centre.

There is a corresponding rise in most of the other zones, most marked in zone 9. Care is needed with the interpretation and description of the model results here. The LUCI model effectively reallocates all the employment (and population) in the city 'instantly', and does not model the complex process by which the profitability of firms changes to the point that they wish to relocate. Therefore it would be incorrect to say that firms have been forced out of the city, as such temporal processes are not modelled, nor is the potential inertia of firms finding themselves inside the cordon but unwilling to move out. However, what the model is saying is that given this pattern of accessibilities, employment tends to be located further away from the city centre (in other words the city centre is a less profitable location). It also avoids those zones just outside the cordon, which suffer due to their reliance on travel through the cordon for access to other zones. This means that 'boundary' effects, of firms relocating just outside the cordon, are not predicted to occur.

Zone	Change in access (x100)	% chg in pop
1	1.11	2.3
2	0.85	1.8
3	-0.41	-0.7
4	-0.16	-0.2
5	-0.07	-0.1
6	-0.56	-1.0
7	-0.11	-0.1
8	-0.14	-0.2
9	-0.09	-0.1
10	-0.05	-0.0
11	-0.11	-0.1
12	0.10	0.3
13	-0.06	-0.0
14	-0.29	-0.5
15	0.02	0.1
16	-0.03	0.0
17	-0.00	0.1
18	-0.02	0.1
19	-0.01	0.1
20	-0.00	0.1
21	-0.00	0.1
22	0.02	0.1
23	0.02	0.1
24		
25		

Figure 7.9: Study area map of the impacts of road pricing on the population distribution (percentage change from do-minimum 2010)



Zone	Chg in retail acc (x100)	% chg in emp
1	82.36	-6.9
2	78.81	-9.4
3	94.41	0.6
4	96.16	2.0
5	97.83	2.8
6	95.75	1.7
7	96.63	2.1
8	96.64	1.9
9	97.95	3.0
10	98.05	3.2
11	98.28	2.7
12	86.39	-4.0
13	99.35	3.8
14	96.77	2.2
15	98.46	2.0
16	98.15	3.3
17	96.27	1.8
18	98.66	3.5
19	99.45	3.7
20	98.06	2.7
21	98.72	2.6
22	98.46	3.0
23	98.46	2.5
24		
25		

Figure 7.10: Study area map of the impacts of road pricing on employment distribution (percentage change from do-minimum 2010)

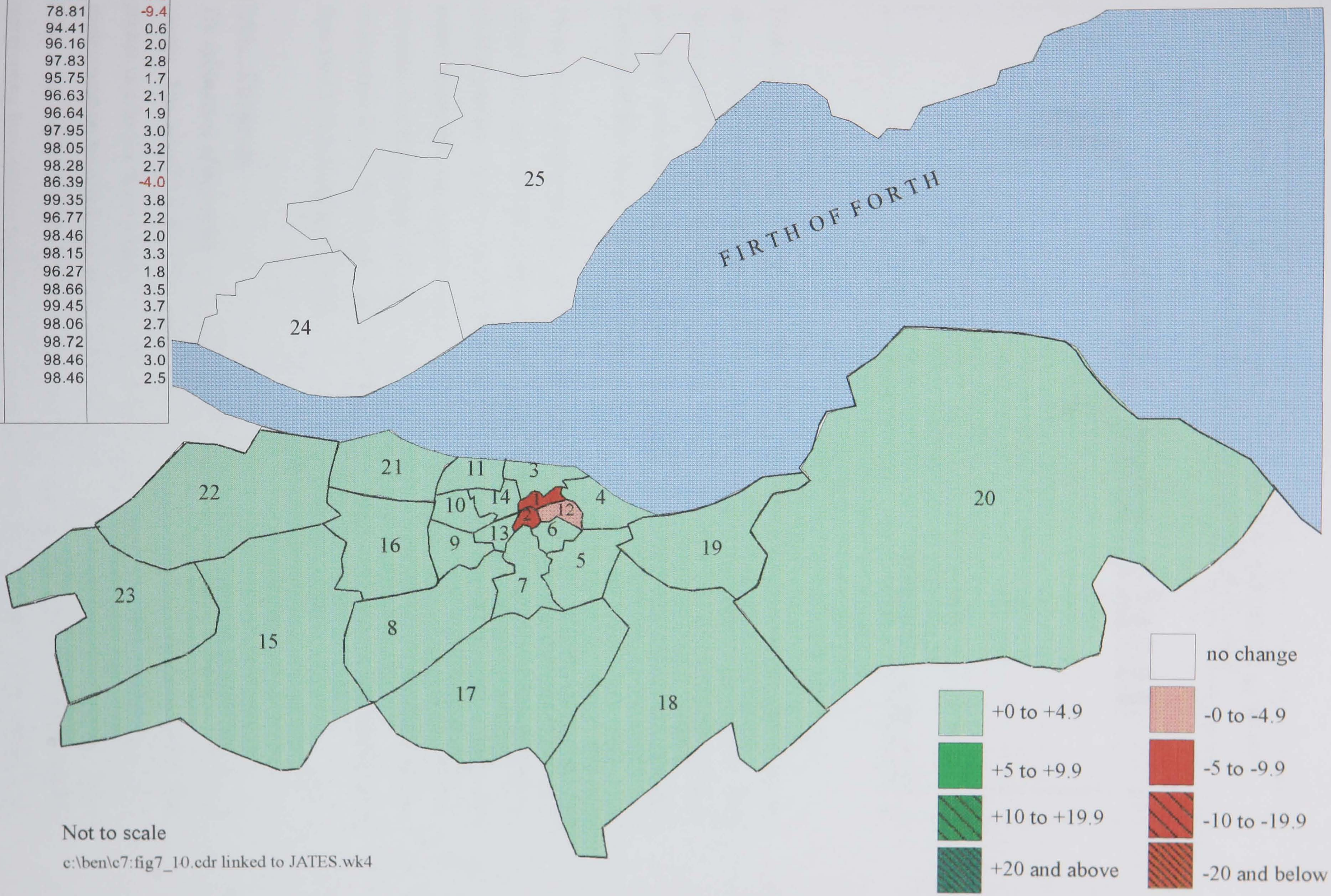
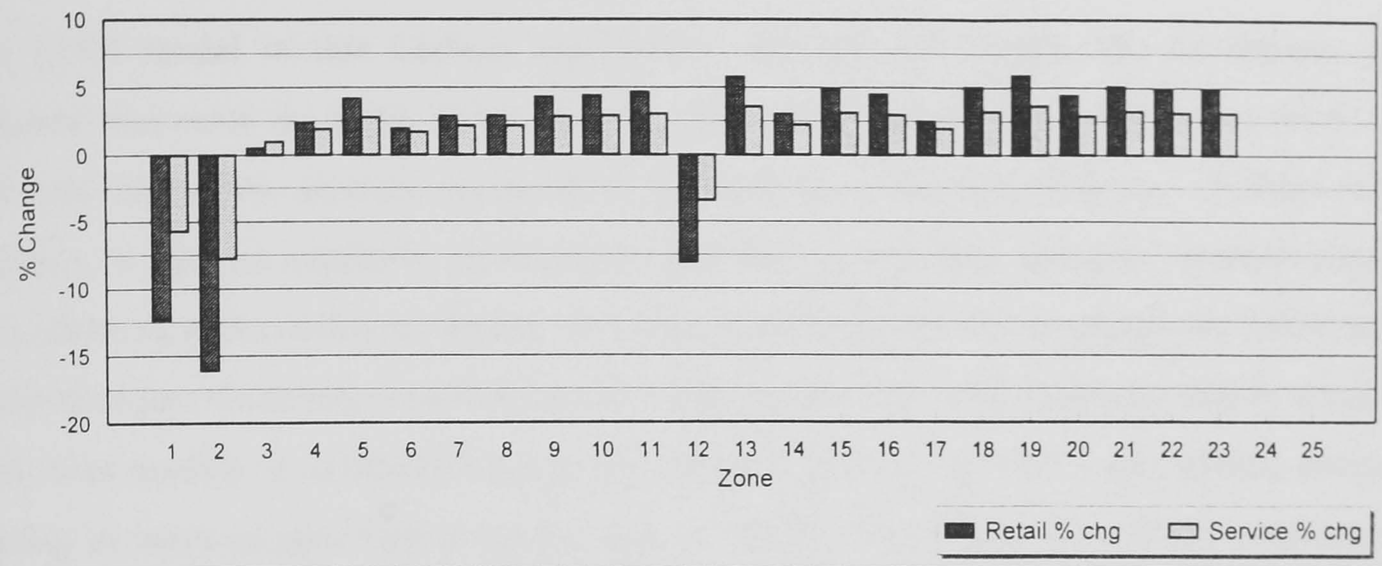


Figure 7.11: LUCI employment impacts from road pricing by sector
Employment percentage change from 2010 do-minimum



Finally, as mentioned in relation to figure 7.8, the retail sector is more sensitive than the service sector to accessibility, shown in the percentage changes given in figure 7.11. This shows clearly the sensitivity of the model to its parameters, and that sweeping, even if grounded, assumptions concerning these parameters can have a dramatic influence on the forecasts of how transport affects land use.

These road pricing impacts are consistent with the previous ISGLUTI (for the parking charge test) and LASER evidence that employment is more sensitive than population. LASER predicts retail to be the most sensitive employment sector, as input to the LUCI model. However, the models also differ in their forecasts, most notably where LASER estimates that the highest road pricing charge (£8) would increase retail and other service employment within the cordoned area (see table 3.7, page 43), in contrast to the results found from the LUCI Lothian application.

7.4.4 Discussion

The application of this model to the study area by the consultants took between six and eight months. The actual person time involved was around 30 days, but the elapsed time was greater due to the time required to receive the land use data and accessibility data. This implementation time was consistent with the JATES targets of implementation within a year (May *et al*, 1992). The LUCI model is an extremely simple means of producing indicators representing how activity patterns may respond to accessibility changes. The model itself makes use of random utility theory, but has no wider deductive hypothesis concerning how the urban system operates. The model is simple precisely because it ignores all the complex interactions with other elements of the urban system.

The LUCI model in this Lothian application has ignored supply side constraints, and assumed that rents are static. It has assumed that all the population behave as workers do, and only takes into account accessibility to work as a location criterion. Perhaps most crucially, it has not explicitly represented other factors affecting activities' location choice, only allowing accessibility to change. It relocates all activities for its alternative future state, rather than just those who would be in the market at any one time. Note also that in common with most models, it assumes that a given transport policy (e.g. LRT) only affects decision making in terms of generalised travel costs, in other words it does not use any empirical or statistical evidence of the particular behavioural responses to LRT or road pricing. This is a major limitation, given the importance of image and environmental features concluded from Chapters 2 and 3.

Despite its simplicity, the calibration has taken into account the trade-off between house price and accessibility (for workers), and rents and accessibility (for businesses), and has used this to determine how much of an effect accessibility changes could have on the distribution of activities. It has been designed to be used under the 'scenarios' approach to transport planning, where several future states of the system can be envisaged. Thus unlike LASER, LILT or the DELTA model (to be described in the next section), it does not generate its own land use forecasts, unless accessibility data for two different years is given to the model. The problem with this is that there is no concept of time in the model, and hence no underlying trend.

This means the LUCI approach is an abstract representation of the location decision process. Consequently, the consultants stress that the model produces 'indicators', rather than 'forecasts' for future states. This is both a strength and a weakness. As a strength it increases the planners' involvement in the modelling, as they (usually) produce the initial land use scenario(s). As a weakness these scenarios will have been generated independently of the transport strategies that are to be tested. In other words, it is assumed that the transport strategy has no impact until the horizon year, which is clearly unrealistic.

The LUCI model has been expanded in subsequent applications, in Bristol, Merseyside and Dublin. Several of these later applications included a price feedback mechanism. This meant that as demand for a zone rose, so rents could rise; reducing the utility of locating in that zone and affecting the ability of activities to locate there. This is an improvement, but it does not overcome many of the conceptual limitations that have been outlined in the preceding discussion.

It is a weakness of the 'scenarios' approach, as implemented in the JATES study, that the model is often tested against an initial range of scenarios, but then the bulk of the testing is undertaken with a single 'most likely' scenario. Although the initial discussion of JATES (May *et al*, 1992) did provide results as a range, certainly the LUCI work for JATES used only the 'trend' scenario, and the JIF work also focused (after some initial testing) upon a single economic forecast scenario (hence the use in this study of only one scenario). The use of different scenarios quickly increases the number of runs required, and constrained resources often means that the results from a single scenario are seen as 'the answer', rather than as one point in a range of possible results.

7.5 Conclusions

In summary, the LUCI model provides quantitative estimates of activity location preferences based upon accessibility changes. Essentially, it converts the accessibility changes into activity redistributions, with magnitudes determined by the calibrated parameter on accessibility. It was designed to examine whether a transport policy or strategy may support existing land use strategies, or undermine them. This partial model is perhaps the simplest, and quickest way to produce a quantitative estimate of land use response if a transport model is already available. However, this simplicity means that the model does not represent any recognisable processes of urban change, or include any notion of time. As such it is highly abstract.

It is evident that explanation for the pattern of activities generated by the LUCI model must be sought in the accessibilities from the transport model. As the original JATES model that had generated these accessibilities was not available, this limited the analysis that could be undertaken. However, if the pattern of accessibilities is taken as given, then the changes forecast by the LUCI are relatively simple to interpret.

This chapter presented the results of the LUCI approach to land use response modelling for Lothian region. It was found that in general the LUCI model results do conform to the expectations of the literature review from Chapter 2, at least for the LRT public transport test. Indeed, some overall similarity should be expected given the nature of the calibrated parameters and the direction of the changes in accessibility caused by LRT.

Despite this level of agreement, some of the magnitudes of change predicted by the LUCI model are higher than would be expected, especially for the public transport test, where the level of service of the LRT (5 minute headway) was perhaps unrealistically high. However, more thorough comparison with other results, against the Delphi and the results from DELTA, will be given in Chapter 9.

Before this, Chapter 8 builds upon this approach towards land use modelling with START, and discusses the implementation and testing of the new dynamic DELTA/START model.

CHAPTER 8
OUTLINE, IMPLEMENTATION AND RESULTS OF THE DELTA / START MODEL

8.1 Introduction

This chapter discusses the design, implementation[1] and results from the DELTA/START model. However, in addition, it outlines the process of building a model, and aims to:

- break down the modelling endeavour to a typology of identifiable stages or processes;
- give examples of these stages;
- examine the level of understanding that is required for the various processes.

In addition the typology will be used in Chapter 10 to help analyse which of the processes are likely to be of most relevance to the planner/client. To meet all of these aims this chapter is significantly longer than the others in this thesis, but is self contained in dealing with the DELTA/START model, and thus maintains the consistency a single chapter discussing each of the three methods applied in this research.

The chapter begins by outlining the structure of the DELTA model[2], and its interactions with START. The land use model, DELTA, was designed by David Simmonds Consultancy, and implemented for the study area by the author and consultants during 1995 and 1996. Note therefore that the author was not involved in the design, specification, or programming of the DELTA or START models. The START transport model already existed as the JIF model for Lothian (see Chapters 5 and 7), although modifications were made to allow it to run dynamically with DELTA. The main stages of the implementation are discussed, although the focus is upon those elements of the model with which the author was involved. The results (to be used in the Phase 2 planner interviews) are presented and discussed. The typology is then introduced, and examples given to illustrate the elements, using the experiences gained in the implementation of DELTA/START.

8.2 Structure of the DELTA/START model

The LUCI/JATES model (discussed in the last chapter), while an improvement on transport

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1 'Implementation' is defined as the process of developing and calibrating the model for the study area.

2 Necessary as no papers on DELTA/START had been published by June 1997.

models with no land use element, still suffers from the absence of a dynamic land use feedback into the transport model. It was in response to the need for a full land use transport interaction model which could be applied to the study area that the DELTA/START model was proposed. The development of a new model for the purposes of this research may seem an inefficient means of obtaining a range of different methodologies for the study area planners. After all, with a new model there is no possibility that the planners would have any experience with the model, and there is a possibility that they may be more sceptical in comparison with models of which they are already aware.

However, the development of the new model did confer several very large advantages to the research project. Firstly, the proposed model design used the pre-existing JIF model for Edinburgh and its surrounding area. This meant that resources did not have to be applied to implementing a new transport model for the study area, a task which would have consumed most of the resources for this PhD. Secondly, the DELTA model builds upon the concepts of the LUCI model, which should facilitate introduction of the model to the sample of planners. Thirdly, being involved in the development of a new model provided insights into the design and implementation process that allowed some useful conclusions to be drawn of major relevance to the thesis as a whole.

8.2.1 DELTA model characteristics

This section outlines the structure of the DELTA model, as designed by David Simmonds Consultancy. The model was designed to represent a wide variety of urban change processes, over successive time periods and with full interaction with the transport system. It represented the processes of floorspace development, demographic change, residential and employment location and changes in environmental quality, all with an explicit time element.

Figure 8.1 shows the links between DELTA and START. The main point to note is that the model moves forward over time in successive periods. START runs in exactly the same way as described in Section 7.1, but is given new land use inputs from DELTA each period. In turn, START supplies accessibility and environmental information to DELTA. Thus in a typical 20 year forecast, using two year periods, START would be run ten times. Clearly this has serious implications on the model run times, and reduces the total number of tests[3] that could be undertaken within a given budget, relative to the number of START only tests.

[3] Please note the terminology here: 'test' refers to producing a 20 year forecast for a given transport strategy; 'run' refers to the physical process of running the computer programs once.

Figure 8.2 gives the basic structure of the land use model, which shows the five major submodels that comprise DELTA. The submodels reflect, as far as possible, urban processes with which planners (and others) should be familiar. Figure 8.2 shows that there is relatively little interaction between the submodels in any one time period. That which does take place is related to competition or constraint (shown by the arrows within the DELTA box), for example the effect of available space in constraining the location choice of activities. Instead, most interactions take place over time, with activities responding to changing conditions of past periods. This follows a characteristic of many urban models, which comprise a set of relatively simple submodels, but with a complex set of linkages between them.

Figure 8.1: Simplified operation of DELTA/START over time

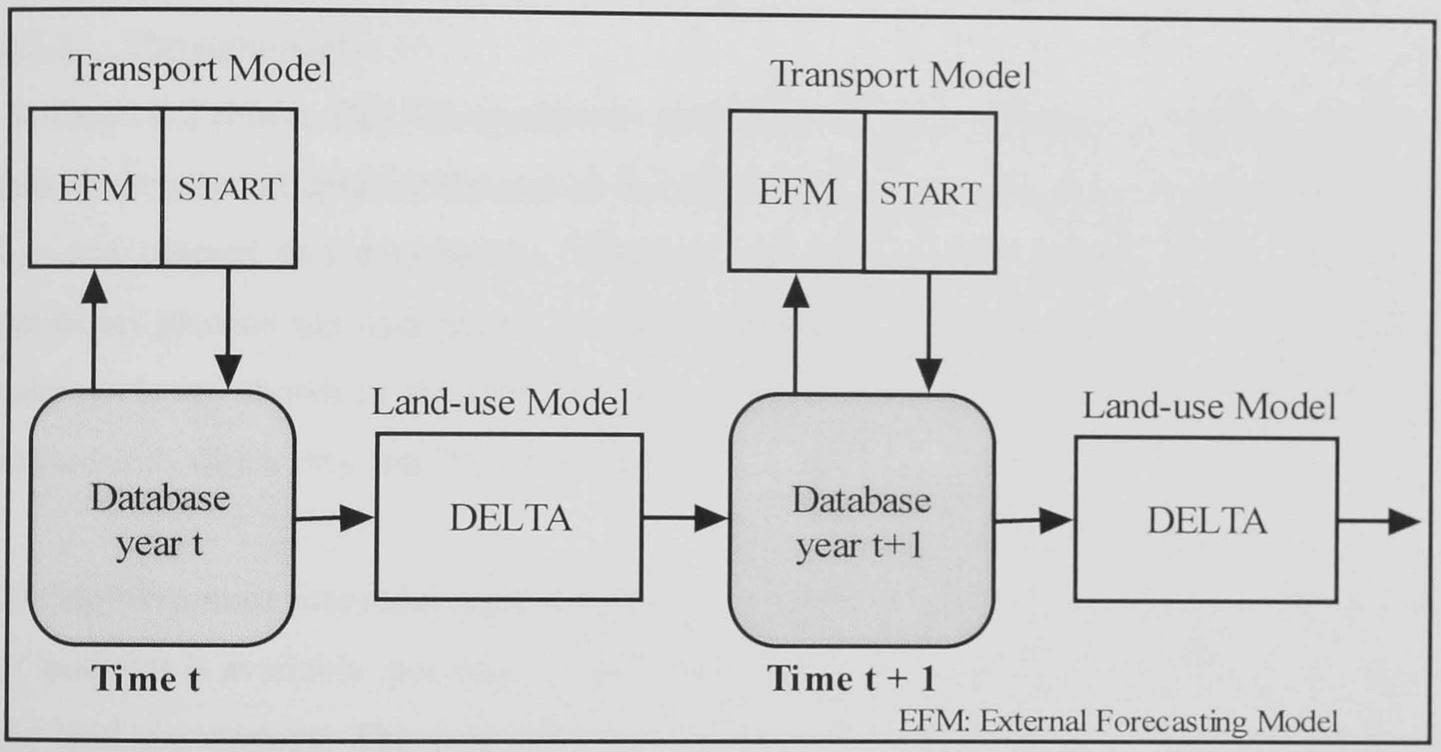
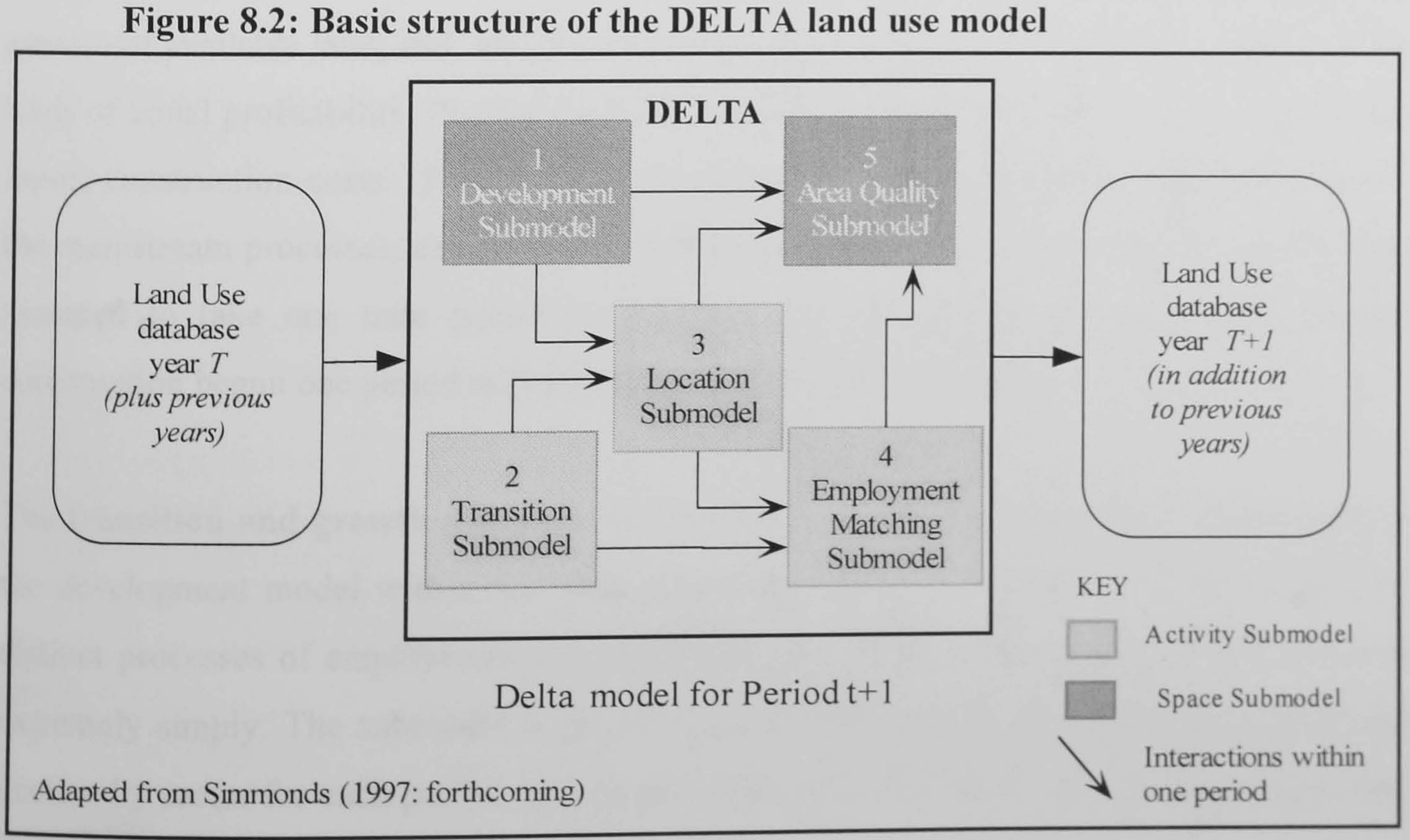


Figure 8.2: Basic structure of the DELTA land use model



DELTA requires land use data not only for the base year, but for successive years before the base year, in order that the location choice in the early years is responding to a previous situation. The model does not therefore begin from a completely static equilibrium point (as compared to START, which begins from a converged 1991 base). DELTA then works forward using the differences between previous database years.

The model is aggregate in formulation, in common with the majority of the land use models outlined in Chapter 2. This means that it works with categories of activities, representing numbers of them and their average characteristics. In fact the model shares the incremental period approach and other concepts of IRPUD with the location and market clearing processes of MEPLAN.

8.2.2 The submodels

As figure 8.2 shows, DELTA operates by reading a 'database' of land use, activity, transport and environmental data for the end of the last period. It then calculates the changes in land use and outputs this data to the 'database' for the new 'end' year. These successive databases provide the data points for the changes with which the model works. The five submodels are shown in the DELTA box in figure 8.2, and are numbered to indicate the sequence in which they run. These are now briefly discussed in turn.

The **development** submodel represents the private sector construction process. The amount of land that is available per zone in each space category is specified exogenously as part of the land use strategy. The submodel then predicts the total quantity of floorspace that the construction sector would like to build if unconstrained. It then constrains this total given the amount of available land, and allocates the resultant total to zones using a logit model on the basis of zonal profitability. Profitability is calculated as the current rent minus (exogenously input) construction costs. Public sector developments, or developments which are outside the mainstream processes, can be specified as exogenous floorspace inputs. Construction is assumed to take one time period to complete (i.e. an average of two years), so that construction begun one period will only become available in the next.

The **transition and growth submodel** is run by the model next, although it is unrelated to the development model within one time period (figure 8.2). This submodel deals with the distinct processes of employment and population change over time. Employment is treated extremely simply. The submodel is given, as exogenous inputs, the percentage growth and decline by sector for each period. It then calculates how this affects the current employment by sector.

The population transition process is more complex. This, as in many land use models, works in terms of households. The model deals in total with 72 different types of household, although different parts of the model use different aggregations of these. Table 8.1 shows the main disaggregations used in the transition submodel and those required for START. From the household type descriptions in the left hand column it can be seen that for the calculation of person trip rates employment status is important for START. In contrast, for the household transition model the age of the household occupants is more relevant, as shown in the right hand column. The maximum 72 types arises from 18 household categories (including both an age and employment status split) each divided into four socio economic groups (SEGs). The four SEG types were as follows:

(1) professional and managerial;

(2) other non manual;

(3) skilled manual workers;

(4) other semi or non skilled workers.

Table 8.1: Household categories used in DELTA and START

START Categories (split by employment)	(Intermediate step) →	DELTA Transition submodel Categories (split by age)
Single person, non-retired, non employed	Single person, not retired	Young single person
Single person, non-retired employed		Older single person, not retired
Single person retired	Single person, retired	Single person, retired
Single person at least one child	Single person at least one child	Single person at least one child
Retired couple	Retired couple	Retired couple
Couple without children, non retired, non-employed	Couple without children	Young couple without children
Couple without children, non retired, one employed		Older couple without children
Couple without children, non retired, both employed		
Couple with children, non retired, non employed	Couple with children	Couple with dependant children only
Couple with children, non retired, one employed		
Couple with children, non retired, both employed		
Three or more adults without children	Three or more adults without children	Couple with one or more non-dependant children
Three or more adults with children	Three or more adults with children	Couple with one or more non-dependant children AND with one or more dependant children.

The transition submodel itself calculates changes in each household type given a series of exogenous transformation rates from one type of household to another. Households may **form** (e.g. children leaving home), **transform** from one type to another (e.g. by ageing, or the birth of a child) or **dissolve** (i.e. if the last member dies). **Migration** is allowed for as a rate of departure and a ratio of arrivals to departures by household type. As table 8.1 shows, there are ten household types used in the transition submodel. A feature of this approach is that only part of the total households (i.e. formations, immigrations and all transitions) will be viewed as 'mobile' by the model, and hence be relocated in the location model. Note that the transition submodel does not represent the transfer of households between SEGs, which was considered too difficult to attempt to do within the resources of this PhD[4]. However, it should be noted that while the household transition submodel is complex, it was not intended as a sufficient demographic model in its own right. The intention from the outset was that independent population forecasts from other sources would be applied as constraints in developing the transition rates.

The **location submodel** is based upon random utility functions and locates or relocates activities within the available space that they can use. These space constraints are firstly from space made available from planning policy, secondly from space released by household transitions, and thirdly from new floorspace completed. Activities take more factors into account when locating than in the LUCI model, and are assumed to choose a location based upon:

1. changes to the rent of floorspace, expressed along with the costs of all other goods and services (OGS) in a utility of consumption function, (or a cost minimisation function for employment activities);
2. changes in accessibility (but rather than accessibility of a single type, as in the LUCI model, each activity type in DELTA uses a weighted average of accessibilities by several purposes to represent perceptions of access more realistically);
3. changes in an index of transport related environmental outputs;
4. changes in area quality, as calculated in the area quality submodel.

The utility of consumption function works on the basis that households behave so as to maximise the utility they gain from spending their income on a combination of floorspace

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[4] The primary reason for this was a lack of estimates concerning the ways in which the SEG mixture of employment would change in the future, and then reconciling this with the SEG of the available worker households. Therefore, although the model design was undertaken by David Simmonds, its implementation was subject to the timescale and resource limitations of the author.

and all other goods and services. This can be seen from the following utility function, which gives the utility of consumption for each household type h by origin zone i:

$$U_{ti}^{h} = (a_{i}^{hH} - b^{hH})^{\alpha^{hH}} . (a_{i}^{hO} - b^{hO})^{\alpha^{hO}} \qquad \text{(Eqn. 8.1)}$$

Where:

U_{ti}^{h} is the utility for household type h in zone i for time period t;

a_i^{hH} is the outcome of the utility maximisation function for space (H) consumed per household of type h in zone i;

a_i^{hO} is the outcome of the equivalent calculation for other goods and services (O);

b^{hH} and b^{hO} are the minimum amounts of space and other goods and services that can be consumed (which can be zero), and;

α^{hH} and α^{hO} are the propensity of households by type h to spend available income on space (H) or OGS (O).

The derivation of the α term for this function is described in section 8.3.6. The rent (which affects the a terms in equation 8.1 but is not actually in it) influences both how many households by type will locate in one zone, and how much space they will occupy. Within one time period, the rent is adjusted until the space demanded by activities matches the supply.

The current utility of consumption then feeds into a function for the change in utility of location, along with the other variables influencing location choice. This is expressed as:

$$\Delta V_{ti}^{h} = \theta^{hU}(U_{ti}^{h} - U_{(t-n)i}^{h}) + \theta^{hA}(A_{ti}^{h} - A_{(t-n)i}^{h}) + \theta^{hQ}(Q_{ti}^{h} - Q_{(t-n)i}^{h}) + \theta^{hR}(R_{ti}^{h} - R_{(t-n)i}^{h}) \qquad \text{(Eqn. 8.2)}$$

Where: $\Delta V_{ti}{}^{h}$ is the change in total utility to be gained in a zone for a given household type;

$U_{ti}{}^{h}$ is the utility of consumption for households h locating in zone i at time t;

$A_{ti}{}^{h}$ is the accessibility of zone i for household type h at time t;

$Q_{ti}{}^{h}$ is the quality of housing in zone i at time t;

$R_{ti}{}^{h}$ is the transport related environmental quality as perceived by households h in zone i at time t, and;

θ parameters on each term determine the relative sensitivity of households between accessibility, the environment, quality and utility of consumption, and also the overall sensitivity of households to each factor.

This change in utility $\Delta V_{ti}{}^{h}$ is then used in a logit model location function. The *(t-n)* subscripts show that the change in the variable can be from the previous time period, or from several time periods ago, as discussed further below.

Employment activities use a simpler form of equation 8.2, with the utility of consumption for households replaced by cost minimising behaviour, and the environmental variables excluded. The cost per employee function is shown in the following equation, giving $a^{su}{}_{(t+1)i}$, the units of floorspace type u per employee in zone i at the current time period:

$$a^{su}_{(t+1)i} = a^{su}_{ti} \cdot f^{s}_{p} \cdot \left[\frac{r^{u}_{(t+1)i}}{r^{u}_{ti}} \right]^{\gamma^{s}} \qquad \text{(Eqn. 8.3)}$$

Where: $a^{su}{}_{ti}$ is the units of floorspace from the previous period (i.e. *t-1*),

r is the rent in the current period, and

γ^{s} is the elasticity of space per employee with respect to rent per unit of space (which has been estimated for the purposes of this study).

The factor f^{s}_{p} in equation 8.3 (the 'space-factor' by sector s and time period p) allows the space requirements per employee to change over time due to other non-modelled factors, for example the retailing trend towards warehouse stores, where the floorspace per employee is hypothesised to be increasing.

The location submodel is entirely incremental. Thus, if none of the four variables in equation 8.2 change, then relocating activities will tend to remain in the same location, and newly locating activities will locate in proportion to the existing distribution of the same activity. This of course means that if there are irregularities in the base data, then these will be perpetuated in the future. Another feature of the use of 'changes' is specification of the length of the lag, as denoted by the *(t-n)* in equation 8.2. It is hypothesised that the length of the lag should reflect the average length of stay in a dwelling. For example if a household moves every four years, then the lag should equal this. Households thus compare conditions when they last had to make a location choice with current conditions. Any transport changes that occurred outside this period (i.e. six or more years ago), will therefore not directly affect their choice.

The **employment submodel** deals with the match of employment to population. Note that at this point in DELTA, all activities have been forecast and located in a zone. The employment model takes as input the new jobs by sector and zone, and has to turn this into jobs by SEG. The zonal totals of jobs by SEG are then used to alter the employment status of households until there is a match of total workers by SEG to total jobs by SEG. The outputs of this submodel thus affect the next time period, as they generate 'potential relocators', i.e. households who have changed their employment status and thus may relocate.

A feature of this submodel should be made clear. The submodel assumes that the study area is a single labour market. In other words all workers can reach any job, and hence accessibility does not influence whether a household will obtain a job or not. This has the implication that if employment is created in a given zone, workers in or near that zone will not automatically gain a high share of the new jobs, even if they are of the correct SEG. *Changes in the l*ocation of jobs will only have an influence *on the distribution of employed residents* via the change in accessibility as in equation 8.2. The assumption of a single labour market was considered acceptable for the study area, which was sufficiently compact that it was feasible to live in any zone and consider working in any other zone.

Finally, the **area quality** submodel represents the 'desirability' of parts of the city, as influenced by the activities that take place there. For the Lothian DELTA model, this is only implemented for residential floorspace, and is determined by the average income of residents. It assumes that increasing average income will lead to improvements in the quality of the built environment, and vice versa. The area quality is expressed as an index with an arbitrary starting value of 100, and represents the premium (or discount) on the rent that is paid for such quality. This submodel was thought highly desirable by the model architect, as it moves away from the assumption that urban quality is constant over time. Moreover, the effects outlined above do seem intuitively to occur (despite the lack of formal research into their magnitude and speed), representing 'positive' feedback processes, (such as vicious circles of decline, as outlined in Knox, 1987). It should be noted that this function operates slowly, to represent the relative robustness of the urban environment (i.e. it takes a long time, on average, for buildings to decay).

8.2.3 Links with START accessibility measures

The DELTA model treats the START model as a 'black box': giving it land use activity data, and taking accessibility and transport related environmental measures. The accessibility measures currently implemented in START are based upon the following form:

$$A_i = \frac{1}{\lambda_i} \ln\left[\frac{\sum_j w_j e^{\lambda_j C_{ij}}}{\sum_j w_j} \right] \qquad \text{(Eqn. 8.4)}$$

Where; A_i is the accessibility for zone I;

λ_j is the trip distribution parameter as used in the START model;

w_j is the weight variable for the opportunities; and,

c_{ij} is the composite cost.

This function weights the opportunities in each zone by the function of cost from the origin zone. The function is a variant on the logsum, and corresponds to the logit model used in the transport modal choice process[5]. It also scales the results to comparable levels. Note that it uses the opportunities in all other zones, regardless of whether the choice maker actually visits those zones or not. It is thus an aggregate measure, measured in generalised minutes, where higher values indicate worsening accessibility. The above accessibility calculation is produced for car, public transport or a modal average. It is the composite cost (i.e. average) version that DELTA uses (as households in DELTA are not disaggregated by car ownership). Despite the complexity of these functions, the accessibility function is still basically the 'weighted opportunity measure' as outlined in Chapter 2.

The w_j weights come from DELTA, and represent the opportunities present in each zone for each journey purpose, for example retail floorspace is used as the 'attractor' weight for shopping trips. These weight the cost of travelling between an ij pair. The current weights output by DELTA are given in table 8.2. DELTA reads in the average zonal accessibility outputs from START (by purpose and zone) and factors them into a single 'activity-based' measure for each household type and zone. This reflects the concept that different households will have different accessibility preferences. For example, accessibility to work will not be important for retired households, compared to those with two working adults.

The environmental outputs from START are output from a dedicated environmental module. Four environmental indicators are used; noise, nitrous oxides, VOCs and carbon monoxide. These are aggregated into a single measure using a set of environmental factors for DELTA, giving the sensitivity of households to transport related environmental indicators (see Section

[5]Note that the accessibility calculation has to deduce the 'alternative specific constants', which are not calculated in the transport model. There is concern about the calculation of these measures, but this is beyond the technical level appropriate to this thesis.

8.3.8). This accessibility and environmental data is then used, along with similar data for a previous period, to calculate the changes which feed into the location model.

Table 8.2: Accessibility weights output from DELTA

Accessibility	Purpose	Weight Used
Origin weights	Work (by SEG) Educate Shopping Business Non-home based Visit	Employed residents Zonal under 16 population Zonal population Zonal population Zonal population Zonal population
	Purpose	**Weight Used**
Destination Weights	Work (by SEG) Educate Shopping Business Non-home based Visit	Zonal employment (by SEG) Zonal school places Zonal retail floorspace (zero) Zonal employment Zonal employment

8.3 Outline of the model implementation

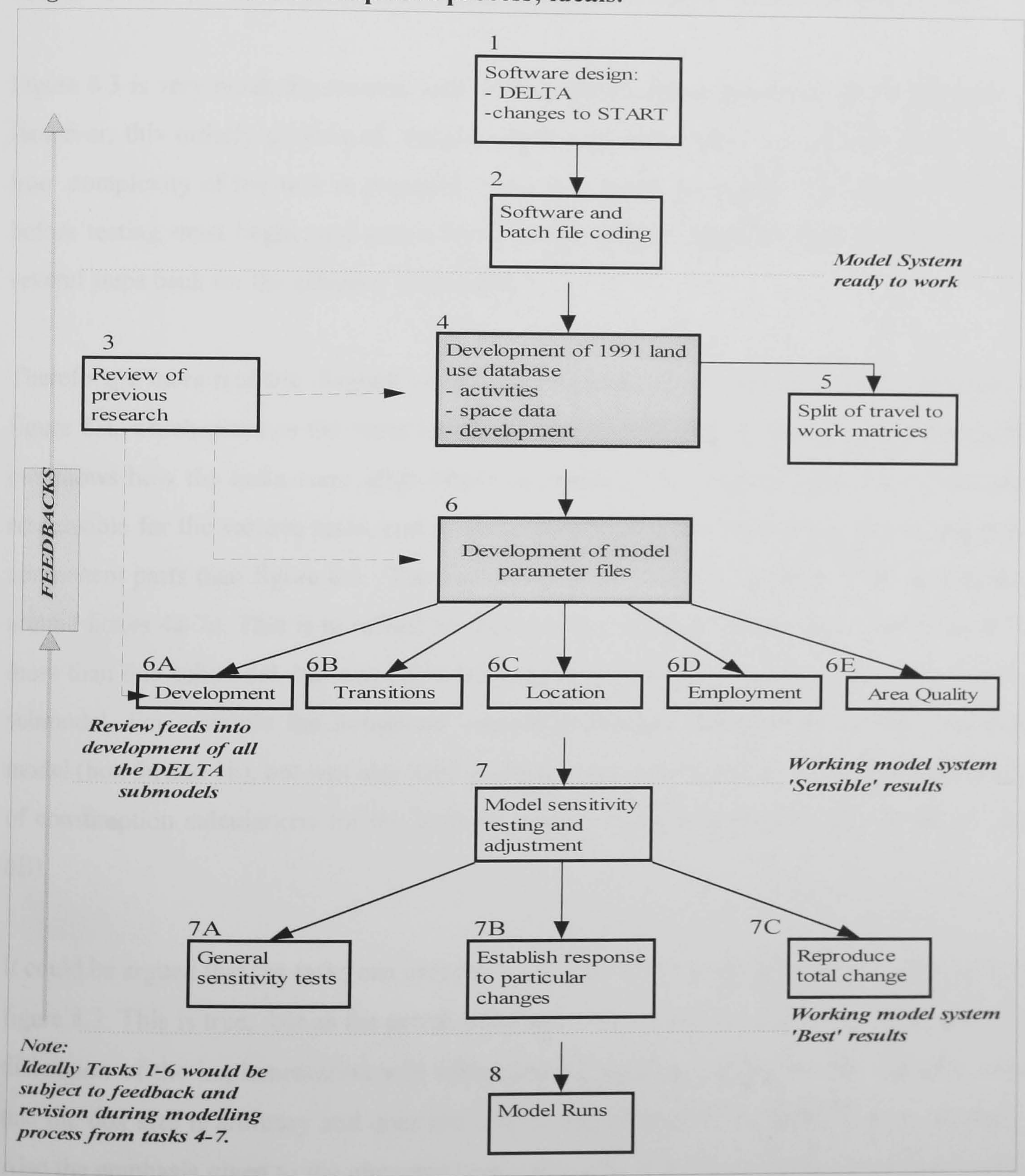
The implementation of the DELTA/START modelling system was a very large task, which although initiated by the need for an interactive land use model for the purposes of this thesis, actually involved several individuals from The MVA Consultancy and David Simmonds Consultancy. At a later stage, the Institute for Transport Studies was also involved as part of an EPSRC 'Sustainable Cities' project that was intending to use the DELTA/START model (May, Bristow and Shepherd, 1997:forthcoming). The main tasks can be specified as follows:

- David Simmonds Consultancy (DSC): designed and programmed the DELTA model, and also designed the implementation and calibration process;
- The MVA Consultancy (MVA): supplied the JIF model and made necessary alterations to the START and EFM code so that the model would run interactively with DELTA;
- The author (BS), worked with David Simmonds Consultancy in the implementation of DELTA, and was responsible for testing the joint model and implementing policy tests (working in DSC's office as part of the CASE arrangement);
- Institute for Transport Studies (ITS): assisted in implementing policy tests, and is undertaking research into parameter improvements.

Despite the work that the author undertook in the model development, the technical design and implementation issues of DELTA and its interface with START are not prime concerns of this thesis. The design of DELTA is considered in more detail in Simmonds (1997; forthcoming), and the technical details of the implementation are described in Simmonds and Still (1997).

However, in order to understand which elements of the model implementation are relevant to the end user of the model, it is essential to outline the main processes of implementation. Conceptually, an ideal process of implementing a land use transport model would be organised as shown in figure 8.3.

Figure 8.3: The model development process; ideals.



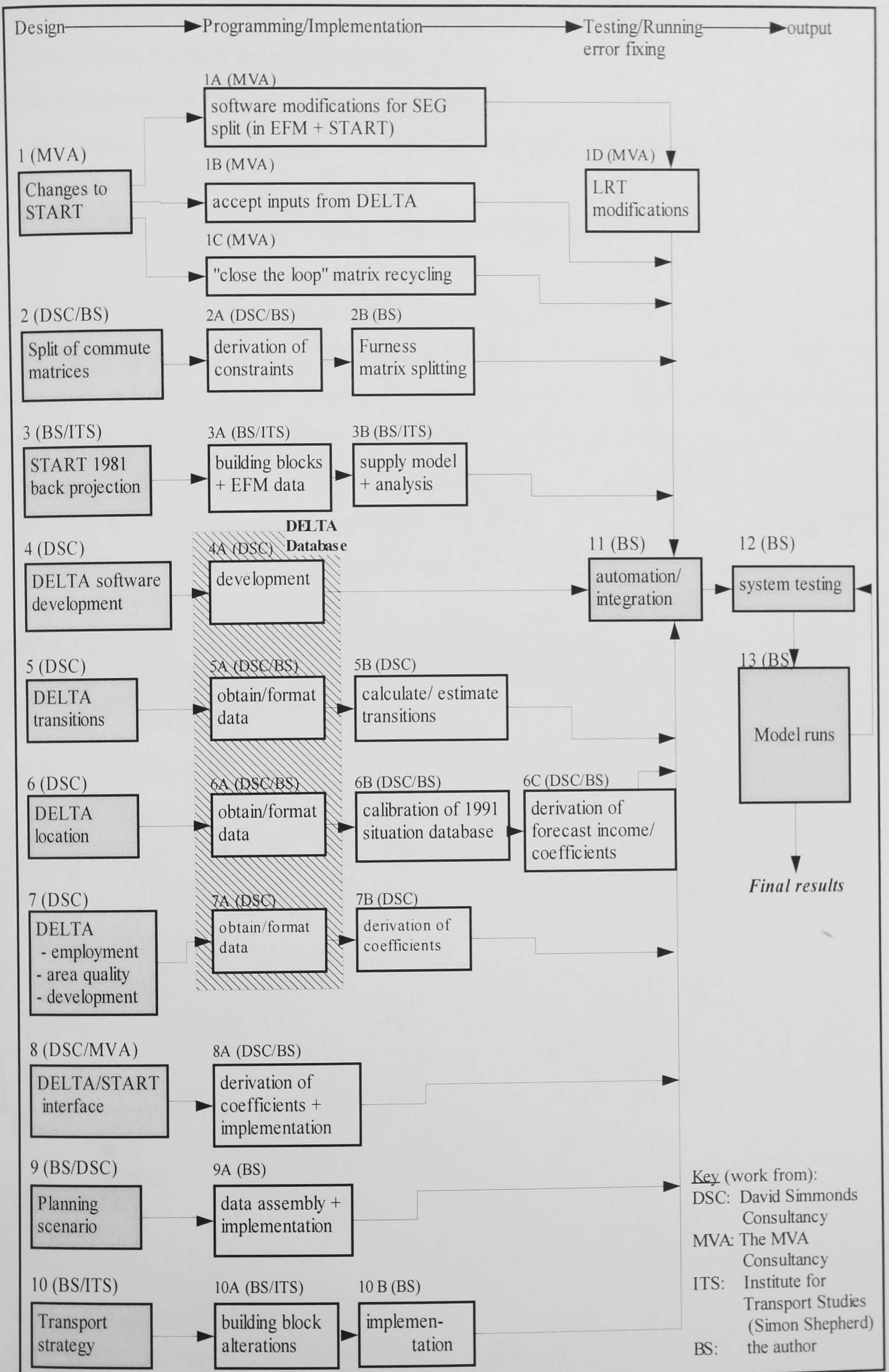
This presents an orderly process of design, implementation of the datasets and parameters, followed by testing. A central feature is constant feedback to allow for revision of past elements in the light of new evidence. It can be seen that the implementation of DELTA ideally involves two distinct processes, firstly the creation of the 'database', predominantly for the base year (1991), but also for years prior to 1991; and secondly the development of the model parameter files. These are for forecast years. and DELTA requires such files for each period that it is run. Having created the model, a thorough set of sensitivity tests would be undertaken, examining the model's ability to reproduce both particular changes (e.g. estimate the correct response to a known exogenous land use development), and total changes (e.g. its overall growth levels compared to other forecasts). After this, the results of testing specific policies could be disclosed to, and discussed with, the client planners.

Figure 8.3 is very much the rational ideal of how model development should be undertaken. However, this orderly process of 'design, implement, test, feedback and use' conceals the true complexity of the task in practical terms. It is often impossible to complete a dataset before testing must begin, and errors found in the software code or data can mean taking several steps back for the affected submodels.

Therefore, a more realistic diagram of how the implementation actually occurred is given in figure 8.4, which presents the same four basic stages at the top of the figure (left to right), but shows how the tasks were often begun in parallel. This diagram also shows who was responsible for the various tasks, and consequently divides the tasks down further into their component parts than figure 8.3. The derivation of the database appears as the shaded area around boxes 4a-7a. This is to reflect the fact that the database information is often used by more than one submodel, but was often prepared as part of the implementation of a specific submodel. For example the household cross-classification was derived for the transition model (box 5a and 5b), but was also used in the derivation of the base year density and utility of consumption calculations for the location model coefficients (Figure 8.4; boxes 6A and 6B).

It could be argued that the tasks can proceed in parallel, while maintaining the overall plan of figure 8.3. This is true, but as the actual tasks taken are better represented by figure 8.4, the discussion of the implementation will follow the 13 numbered boxes in this diagram. Note that the box size is arbitrary and does not reflect the complexity or time taken for the tasks. Also the emphasis given to the elements here reflects their relevance to the arguments in the thesis, and their familiarity to the author.

Figure 8.4: The main stages in the actual implementation of DELTA/START



As can be seen from figure 8.4, the author was primarily responsible for:

- splitting the (pre-existing) travel to work matrices by SEG (box 2);
- undertaking the back projection (box 3);
- implementing the DELTA location model (box 6);
- developing the DELTA land use scenario, and implementing the START transport scenarios (boxes 9 and 10);
- automating, testing and running the complete modelling system (boxes 11-13).

It is useful to begin by outlining what comprises the 1991 database. Table 8.3 outlines the 'land use' data that DELTA requires, and what sources were used. It should be noted from this table that the household data cannot be obtained directly from the published Census, although special cross tabulations could (in theory) be commissioned. This may well occur for commercial applications, but was not possible here. As a consequence, many of the categories had to be estimated from available Census data, often on the basis of some simple assumptions, examples of which will be outlined in the following sections.

Table 8.3: 'Land use' data required by DELTA or START

		Activity / Space	Source
1		Households by type, zone, SEG	Published Census, LRC
2		Employment by sector and zone	NOMIS: Census of Employment
3		Floorspace by space category and zone	Pieda data from JATES, and some estimation
4		Floorspace rent by space cat. and zone	JATES, and synthesised data
5		Development undertaken in 1991-93	Lothian Report of Survey
6		Education places by zone	JIF planning data (LRC)
7		Transition, formations and mergers of households	BHPS, GRO(S)
8		Activity mobility rates	Estimated
9		Activity migration rates	Census of Migration
10		Growth and decline of employment sectors	Lothian Report of Survey
11		Employment proportions by SEG	Published Census
12		Number of workers by household type	Published Census
13		Children and retired persons per hhd.	Published Census

Key:	GRO(S)	General Registrar's Office: Scotland
	BHPS	British (National) Household Panel Survey
	NOMIS	National On Line Manpower Information Service
	LRC	Lothian Regional Council

8.3.1 Changes to START

The START model as outlined in section 7.1 of Chapter 7 required several software alterations, all undertaken by The MVA Consultancy. As Figure 8.4 boxes 1A to 1C show, there were three main tasks, which appear simple in concept, but were very time consuming to implement. The first task was to take account of the split of workers by SEG. This involved increasing the trip purposes in START and the EFM from six to nine, hence allowing four SEGs to be represented. The rationale for splitting work trips by SEG was to allow for distinctions in the labour market (e.g. professional workers are assumed to respond to the location of 'professional employment').

The second task was to alter the EFM to accept the more detailed activity and space data that would be available from DELTA. This included more detail on the trip makers in households than had been used in JIF previously. The EFM also needed to be altered to accept growth factors (for study area growth, car ownership etc.) in two year steps.

The third software modification was to write (from scratch) the procedure to take the 'forecast future year' output matrices from START, and convert them into a format suitable for use by the EFM in the next period. This was called the 'close the loop' procedure.

In addition to these three areas of software modification, came an additional issue that was not foreseen in the original specifications. This was the problem of implementing an LRT system (figure 8.4 box 1d). The problem was that if LRT is implemented in the 'transport supply' for 1997, then a series of LRT trip matrices (by purpose, segment and time of day) are generated, in addition to the matrices for the other 'existing' modes. In the next time period (1997-99), these new matrices must be taken into account in the growth factoring and START procedures. However, this required a different version of START (with an extra set of arrays to handle the extra mode), and additions to the EFM.

8.3.2. Split of the commute (travel to work) matrices

Although MVA created the software to allow for four travel-to-work trip purposes, they did not have the necessary data to actually generate the trip matrices. DSC and the author thus undertook to split the existing single travel to work matrices by SEG. This involved two steps, firstly the assembling of the necessary employment and population data by SEG to act as 'splitting factors', and secondly splitting the matrices and ensuring consistency using a Furnessing technique.

The land use data that was used came as a by-product of the 'activity' database being assembled for DELTA. This used employment in the workplace by SEG, and population at the residence by SEG as constraints. The Furnessing technique then was applied to the travel to work matrices, resulting in 60 output matrices (15 for each SEG).

8.3.3 START 1981 'back projection'

DELTA required accessibility and transport related environmental data for years before 1991, in order to have changes to respond to in the first period run. Such data was output from START, and was not available elsewhere. Therefore, START had to be run to produce a set of 'past' outputs. This was undertaken by running the original JIF version of START for the same 'base year' (i.e. 1991), but for a 'future' year of 1981. Resources did not permit an extensive search for data on the 1981 situation, or time for labour intensive tasks such as route capacity recoding within START itself. Fortunately, MVA had already undertaken a similar exercise in order to examine historic traffic flows across the Forth, but their model could not be used directly as it used an older version of the START software. Thus in order to capture the major changes in the transport system between 1981 and 1991 the following strategy was implemented (figure 8.4 box 3a):

- planning data and car ownership data for 1981 was supplied by MVA and directly input;
- additional EFM external trip growth factor files were set to zeros where no other data was available (e.g. 'no change' versions were applied: see Simmonds and Still, 1997);
- the main change in the route network was the absence of the city bypass, for which a file for the 'routes' was obtained from MVA in Edinburgh.

Thus the 1981 historic model was not very dissimilar to the 1991 do-minimum, apart from the removal of the bypass. The main change was use of 1981 population, employment and car ownership data. This model did successfully produce a fall in car ownership, reduced traffic flows, and a set of accessibilities. However, resources did not permit any comparison between this and historical empirical data to test the goodness of fit.

8.3.4 DELTA software development

The DELTA software was designed and coded entirely by DSC. Perhaps the key point of interest is in the difference in run times between DELTA and START: the former taking under one minute on a Pentium computer, the latter taking 45 minutes. This is due to the much greater amounts of data (i.e. matrices) in the transport model, and the larger amount of data copying and processing that START undertakes.

8.3.5 DELTA transition submodel implementation

The transition submodel required two basic processes. The first was to disaggregate and tabulate the household data (figure 8.4, box 5a) which formed part of the 1991 database. The second was to derive the transition rates themselves. The household disaggregation required households by composition, employment status, and SEG. This could not be obtained directly from Census data, although Lothian Regional Council had tabulated eight household types by JIF zone and composition, and this was re-used as control totals for creating the divisions by SEG. Estimation from published census data was used to generate 18 household types, split into 25 zones and four SEGs.

An area of particular conceptual difficulty here was in calculating the SEG of households. SEG is related to the occupation and status of workers. The Census classifies household SEG by the SEG of the head of household. If the head of household is not a worker, then the household is not given an SEG. To avoid this problem, the SEG proportions of households in a given zone were determined using the travel to work Census tables, with the assumption that the SEG of the worker reflects the zonal household SEG. Clearly this is a simplification, but it gives a good example of how the assumptions were made to obtain the data in the correct disaggregations within the limited resources available.

The data on the transition rates were derived by DSC from the ESRC British National Household Panel Survey (Buck, Gershuny, Rose and Scott, 1994). Further information from the Census and/or General Registrar Office for Scotland (GRO(S)), was used to generate birth, death, marriage and divorce rates for Scotland and Lothian region. The full set of transitions are presented in Simmonds and Still (1997). Changes over time in employment activities were derived from the Report of Survey (Lothian Regional Council, 1994a).

The remaining data required for the forecast years of the transition model were the mobility rates of the different activities and the migration rates in and out of the study area. For households the mobility rates were derived by DSC from the BHPS data. Much less data was available for employment activities. After some experimentation, it was decided to set all the employment activities as mobile, replicating the process used in models such as MEPLAN for non-basic employment. The migration rates were estimated from the Census Migration tables with a net in-migration of younger households into the study area.

8.3.6 DELTA location submodel implementation

This submodel dealt with the impacts that transport has upon land use. It is therefore useful to discuss its implementation in greater detail than the other submodels. As figure 8.4 shows, it can be loosely divided into three areas: (1) creating the datasets required, (2) 'calibrating' the 1991 situation, and (3) deriving the coefficients required by the model for the forecasts. These are discussed in turn.

The 1991 database information required both the data for activities (that had been assembled for use in the transition model), and also the data relating to floorspace and rents. This latter data was assembled by DSC using data from the JATES study, originally used in the calibration of the coefficients for the LUCI model. Note that space is treated in the model as a continuous variable, in the sense that households do not consume dwellings, but an amount of floorspace. This simplifying assumption means that the model does not need to attempt to match particular types of households to particular types of dwellings.

Once this data had been assembled, the coefficients for the location model needed to be estimated (figure 8.4 box 6B). This consisted of:

1. the parameters on the utility of consumption function the b and α (Equation 8.1), which control the marginal propensity to spend income on space or 'other goods and services' (OGS);
2. the space/activity relationships; namely density and the utility of consumption values themselves;
3. a factor to reconcile the observed supply of housing to the estimated demand.

The main source of data for (1) was the Family Expenditure Survey. This was used to estimate the coefficients (in equation 8.1), as shown in figure 8.5, via tangents and intercepts on a 'curve' of income against the net expenditure on housing. While the Stone Geary utility function of the type in equation 8.3 was seen as the best fit of the data, the minimum values prevented the location model from converging. Thus after some testing, it was decided to adopt the more simple 'Cobb Douglas' function instead, which has no minimum values.

Once these values had been estimated, the activity space relationship data (2, above), could be calculated directly, for example for the demand for space for each household type:

$$a_i^{h(H)} = k^h \left\{ \frac{\alpha^{hH}\left(y_i^h\right)}{r_i^H} \right\} \qquad \text{(Eqn. 8.5)}$$

Where:

$a_i^{h(H)}$ space (H) demanded by household type h, for zone i;

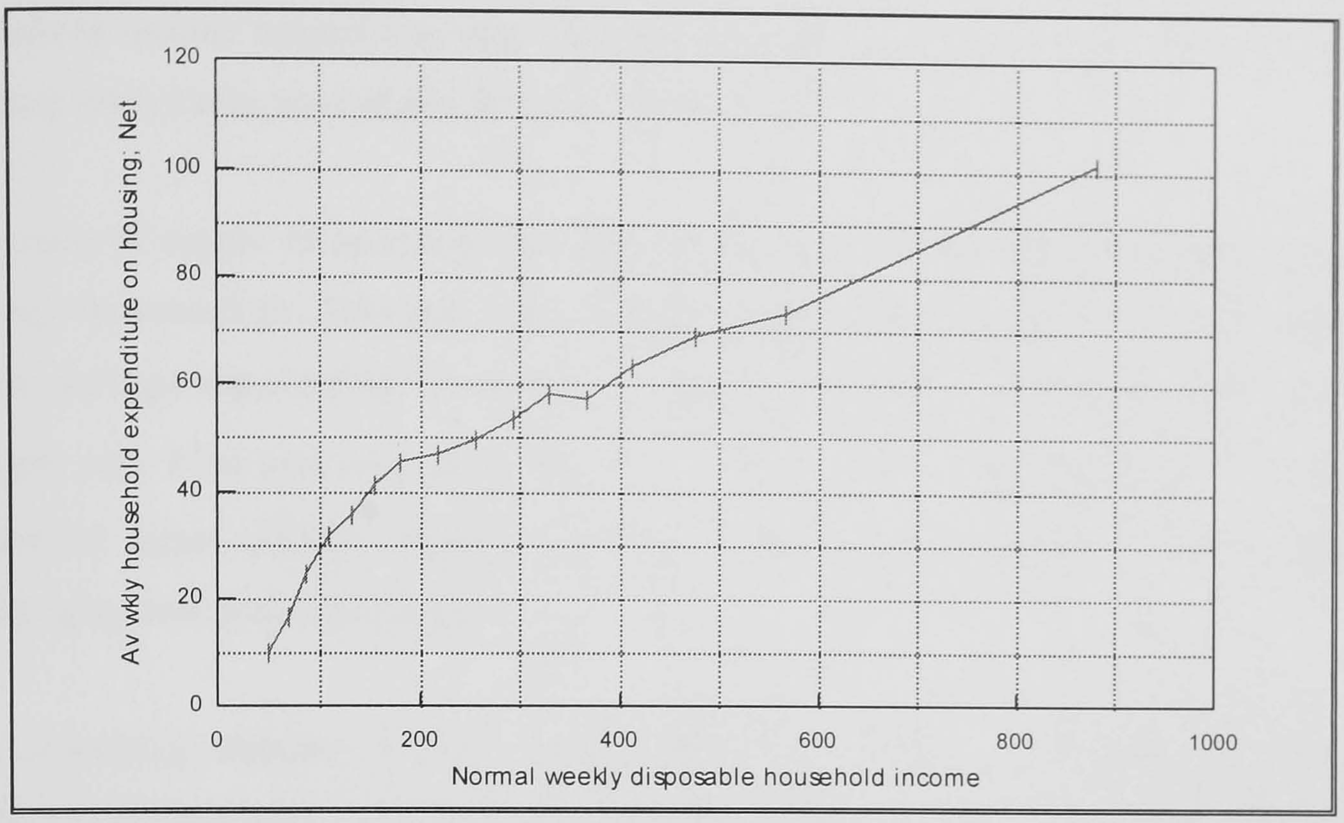
k^h the adjustment factor for housing subsidy;

y_i^h the income per household type;

r_i^H the (observed) rent for space in a given zone in 1991;

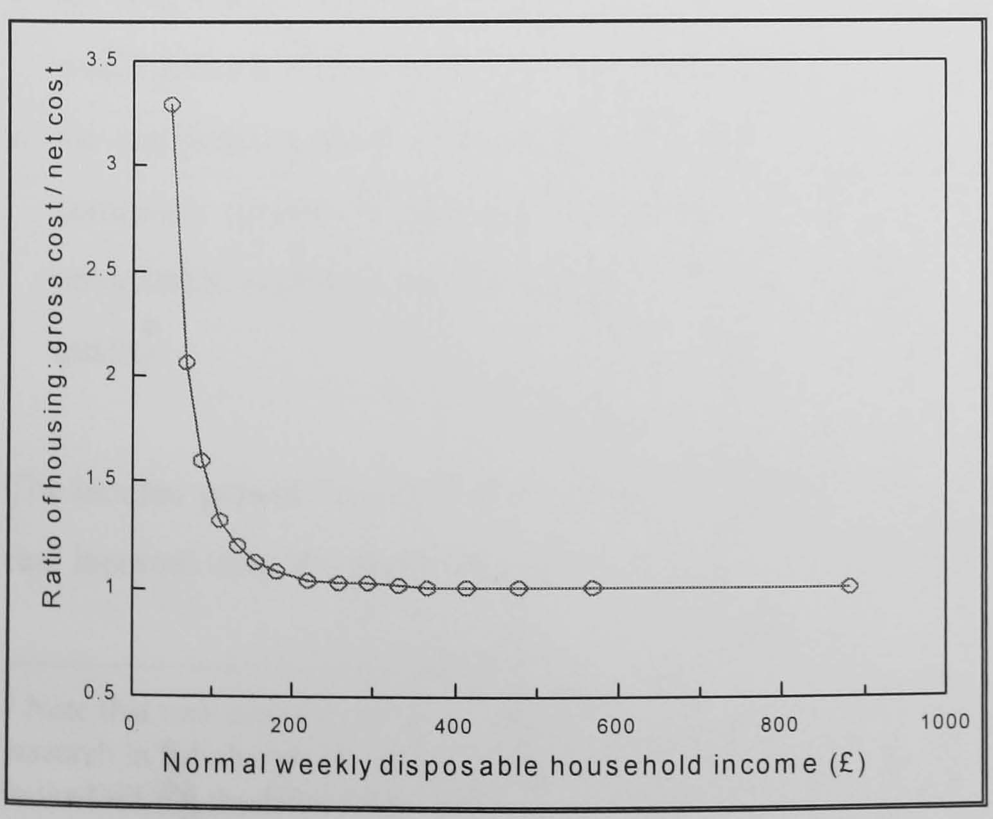
α^{hH} parameter on the utility function.

Figure 8.5: Graph to determine the parameters in the utility of consumption function



Notes: the graph shows the amount of floorspace consumed by households rising with income, but by a decreasing amount. Ideally, at the income level for each household, the tangent to the curve at that point (relative to the origin) gives the marginal propensity to spend money on housing as income rises (i.e. the α parameter). Where the tangent intercepted the y-axis gave the minima for the Stone-Geary function. However, in the event this substituted by the more simple Cobb-Douglas function, due to convergence problems in the location submodel.

Figure 8.6: Graph of housing consumed by households relative to their income



This graph shows that as household incomes rise, so the amount they pay for housing matches their consumption.

However, at lower income levels, notably under £100 a week, people actually consume more housing than they pay for, indicating that a subsidy is being paid to them.

The Family Expenditure Survey was also used to calculate the 'k' factor in equation 8.5. This is shown in figure 8.6, and represents the amount of housing subsidy (e.g. council tax exemption) that households of a lower income receive. This is achieved by plotting household income against the ratio of gross over net housing cost (i.e. what a family's housing really costs, over what they actually pay for it).

The ratio of supply of available floorspace against the demand for floorspace calculated above, was termed Q_i. This represents the 'unexplained' take up of floorspace in particular zones, perhaps representing differences in quality or dwelling sizes. This term was then merged with k^h to give a single factor (q_i^{hH}), for input as a constant term in the location model for future periods. In other words it serves as an alternative specific constant, unchanging over successive periods.

The remaining elements of the residential location model implementation were the derivation of the coefficients for the location model (figure 8.4 box 6C), and the exogenously forecast levels of income for each household type. The basis of the location model coefficients is outlined in Simmonds and Still (1997). A brief summary of this is as follows[6]:

- the coefficients on the **utility of consumption function** were derived by DSC as part of a cross sectional calibration for Bristol[7];
- the coefficients on **accessibility** was also derived from the Bristol study. This produced values generally showing that the higher the income of the household, the lower the sensitivity to accessibility;
- the coefficients on **area quality** was estimated assuming that a higher income household would place a higher value on environmental quality than lower income households;
- the coefficients on the **transport related environmental variable** are complex as they comprises various environmental indices. They were also set up so that higher income households would be more sensitive to changes in overall transport related environmental quality.

The income growth factors were taken from those levels explicit in JIF, that is a rise of 1.8 in real incomes over the study period. As a simplifying assumption (to aid in the interpretation

[6] Note that new estimates of the relative value of accessibility have been derived from stated preference research in Edinburgh, as part of the ITS 'Sustainable Cities' research project, and these will be applied to the DELTA model to improve the basis for its coefficients.

[7] Towards the end of the study, further work refined these values using the results from the Delphi study. This novel application of the Delphi results is outlined in Appendix IV.

of the forecasts), all household types were assumed to rise in income equally (i.e. the rich do not get relatively richer than the poor).

8.3.7 The other DELTA submodels

The remaining three DELTA submodels, employment, development and area quality are discussed together because they either required little external data, or were given synthesised data derived by DSC. The employment model required average numbers of retired persons and children in households by type, as well as the average number of workers in each household type. This was estimated from the Census data. It also required the SEG proportions per sector to calculate the new demand for labour. This data had been estimated as part of the calculations for the attraction end constraints to split the travel to work matrices.

The development model required various calibrated parameters that determined the rates of floorspace development, the constraints on development, and the sensitivities to profitability of developers. However, these were estimated with 'best guesses' for the purposes of this model, as resources were not available for a full calibration. Construction costs by space category were also estimated by DSC.

The area quality model required parameters on the relationship between income and area quality, and also an estimate of the proportion of change in quality that occurs in the current period. Again, these values were not calibrated, but estimated by DSC.

8.3.8 The START/DELTA interface

The land use data estimated by DELTA is read directly into the EFM. However, the accessibility and environmental outputs from START need to be converted from measures by zone (and purpose for accessibility), to a measure by household. For the accessibility measures, the weights are an estimate (taken from National Travel Survey data) of the average number of trips per week for a given household type and a given purpose. At present, each household type is influenced by three of the accessibility purposes from START, while employment responds to two. Some examples are given in table 8.4, where it can be seen that more weight is given to accessibility to work for working households (where the two adult households, both working, in the table make an average of just over 12 trips to work per week) compared to non-working households (the table shows that non-working single person households make, on average, just under half a trip).

Table 8.4: Example of weightings on accessibility measures from START

Activity	*Accessibility Measure*	*Weight (trips per week)*	*Accessibility Measure*	*Weight (trips per week)*	*Accessibility Measure*	*Weight (trips per week)*
SEG1 Single person hhd, non working	SEG1 to work	0.491	Education	1.123	Shopping	3.549
SEG2 Young Couple no children, working	SEG2 to work	12.384	Education	0.658	Shopping	4.2
SEG 4 Retired couple	SEG 4 to work	1.228	Education	0.092	Shopping	7.828
Retail	Non home based	0.5	retail to SEG1 population	0.5		
Financial Services	Non home based	0.5	work to SEG1 population	0.5		

For the environmental indicator, different procedures were developed for each of the environmental measures that comprise the indicator, and this is discussed further in Simmonds and Still (1997). However, the basic process was that weightings for each environmental improvement were applied representing a willingness to pay (WTP), which was then converted into a utility measure comparable to those already in the model. This is another area where improvements are being investigated as part of the ITS 'Sustainable Cities' project.

8.3.9 Development of the planning scenario

The planning scenario (figure 8.4 box 9) required five main elements:

1. the rates of change for activities, including migration rates;
2. the rates of change of people's income over the forecast period;
3. the amount of floorspace under construction in the base period;
4. the supply of floorspace in the base period (i.e. outstanding consents), and;
5. land use policy, represented by the granting of consents over time.

Strictly speaking, only the last of these is a policy instrument. The others are variables which in reality would be dependent upon the economic performance of the study area. Element 1 refers to the growth rates of employment sectors, and the migration rates discussed in section 8.3.5. Element 2 was set at the overall growth rate already assumed in JIF as discussed in section 8.3.6. Elements 3 and 4 are simply part of the development of the 1991 database. Data was obtained from the Lothian Report of Survey, although some estimation was required where the data was not given at a disaggregated spatial scale.

The land use planning policy itself was specified as two components. The first involves increases in the amount of land that are made available for development via the granting of planning permissions. This does not guarantee that development will actually occur, and was estimated for each of the space categories, using the Lothian Structure Plan as a guide for the expected supply of land. As such the distribution of available land closely follows the Structure Plan as outlined in Chapter 5, figure 5.2. The second component is development that occurs outside the mainstream development process. This is input directly as new floorspace, and it is intended to represent large developments that the model could not be expected to predict. The Scottish Office moving to Leith would be a good example. From the Lothian Structure Plan three major retail developments were added in this category.

Two points need to be made here. Firstly the available planning forecasts from the Structure Plan only consider the period until around 2005. After some consideration, it was decided to initially test the model with no further land allocations, but to spread this allocation over the entire forecast period. Adding new development was intended to be undertaken in later tests, but has not been implemented to date.

Secondly, it was realised that in reality land use or transport planning policies are not simply implemented and left unchanged for a twenty year period. There are continual adjustments made to the policies, which currently are not represented in the model. This process could be considered by manually examining the model outputs after each two year period and altering the land use policies and other elements (such as economic growth rates or migration) as thought fit. Alternatively, and more complex, a 'policy submodel' could be designed which would react to changes in predicted land uses by strengthening or reducing policies as appropriate to meet defined (input) policy goals.

8.3.10 Development of the transport strategies

The transport strategies needed to be consistent with those tested in the Delphi and LUCI model applications, i.e. a do-minimum, a road pricing and an LRT strategy. These policies already existed as 'supply' files from the JIF study undertaken by MVA. The main implementation task was that rather than have a single 'supply' file, the ten time periods required ten 'supply' files; one for each period. This allowed policies to vary over time, or be implemented in certain years. For the strategies to be consistent with the Delphi, it was decided to introduce the changes in 1997, and have the strategy remain in effect thereafter.

Box 10a from figure 8.4 refers to a step called 'building block' alterations. This refers to the process by which a supply model is constructed, taking inputs from a series of strategy specific building block files each representing an element of the transport system. For example different building blocks dealt with highway routes, bus routes, bus fares and road charges. The changes to the building blocks depended upon whether START 'remembered' the cost changes through successive iterations. For example a road pricing charge need only be entered in 1997. Unless the strategy required another charge level, the model would continue to include the charge in the generalised costs for successive years. However, infrastructure elements, such as routes or parking spaces, needed to be given each period.

The situation was further complicated by the underlying growth rate in real incomes over time. This meant that any changes in prices had to be offset against the income growth. For example parking charges were set to increase by 50% over the 20 year period, but incomes rose by 80%, so the following calculation had to be applied to each period to give the charge in 1991 terms:

$$\text{Parking charge year X} = \text{1991 charge} * \sqrt[10]{(1.5/1.8)}^{(\text{year X-1991})}$$

In other words parking charges would fall relative to the rise in real incomes. Thus START included no explicit time trends, and the effect of income rises on charges is only apparent through calculations of the type above. This is necessary as then trip makers in START are only responding to changes in generalised cost, rather than to changes in their income over time.

The **do-minimum strategy** had the following features, all implemented in 1993:

- parking rising by 50% over the 20 years;
- bus fares rising by approximately 30% over the 20 years;
- numerous highway improvements to the major radials including the M8 extension and A71 widening to dual carriageway;
- zero tolls on the Forth bridge (for simplicity of implementation).

Three hypothetical policy tests were developed, a light rapid transit (LRT), road pricing, and both of these combined. The **LRT** was identical in terms of infrastructure to the version used in the LUCI model. The fares were set equal to the bus fares, and a high frequency of five minutes was used (as in the previous work by The MVA Consultancy), in order to be consistent with the LUCI/JATES modelling from Chapter 7. Note that it was not possible to implement the other rail elements as was originally intended (and which appear in the Delphi public transport policy). This was because of the 'new modes' issue discussed in

Section 8.3.1. However, given that LRT was the focus of the study, this was not considered a significant problem. It is still directly comparable with the LUCI model LRT test.

The **road pricing** strategy had a charge of £1.50 in 1991, and rising in line with incomes thereafter (in order to remain an effective deterrent over time). A **combined** strategy of road pricing and LRT was also implemented. Some other test strategies were also run, such as reducing all bus fares by 50%, and implementing different road pricing charge levels in order to check the model sensitivities, but these are not discussed further.

8.3.11 Integration and automation of the modelling system

As figure 8.4 (page 177) has shown, all of the elements discussed so far only formed one cohesive model at the stage of integration and automation. Integration was the process of adding the elements into the modelling system. This occurred incrementally as and when procedures or datafiles were completed, and this is a good example of how the process was more *ad hoc* than figure 8.3 would ideally suggest. In addition procedures were written to automate the process. This was simplest with regard to DELTA, which was written to run automatically. For the links between them and for START itself, a number of JAVELIN[8] and DOS 'batch' procedures were required to link submodels together, or to manipulate data files into suitable formats.

8.3.12 System testing and model runs

The initial model runs were dominated by testing the component submodels, to assess whether they were working correctly. Then the various model parts were combined, and again tested to ensure that they ran as required. Once the full DELTA/START system had been assembled the tests outlined in table 8.5 were undertaken. This began with a 'no change' dataset, in both the land use and transport models (B1). Once this successfully reproduced constant results through successive time periods, the correct dataset was added, firstly to the transport model and secondly to the land use model. This finally formed the B6 test.

With the full system running, analysis then switched to examining the outputs, determining whether they were reasonable, and how they could be explained. This is discussed further in the next section. Numerous problems were overcome, culminating in the B7 tests that were discussed with the planners (see Chapters 9 and 10), and the R4 tests resulting from further model refinements partly as a result of the planners' views. The grey shaded areas in the

[8] JAVELIN is a spreadsheet type software package used for START data assembly.

table highlight the B7 tests used for the Phase 2 planner interviews, and R4 tests reported in Appendix IV.

Table 8.5: DELTA/START tests undertaken 2/96 to 12/96.

Run code	Approx date	Aim	Features	Comments / problems identified
B1 (NC)	3/96	No change in DELTA or START	No land use change database, no change transport supply or EFM	System operates correctly.
B2	3/96	DELTA 'no change'. Transport model switched off.	Uses 'no change' accessibility files from B1, START not run.	No change results produced over time.
B3	3/96	Transport model only, constant land use inputs.	'No change' supply or EFM files, DELTA model not run.	No change results produced over time.
B4	3/96	Transport model only, constant land use	Transport model do-min strategy	*NHB trip growth problem identified* (i.e. growth was only occurring in NHB trips).
B5	4/96	Test DELTA dataset.	DELTA included transitions, employment growth. No changes in START.	DELTA outputs results consistent with those obtained by running DELTA on its own.
B6 DM	4/96	Test DELTA with do minimum START	'best versions' of the models as of 26/4/96.	It was noted that growth in trips was low compared to previous JIF runs. Memory problem identified.
B6 series	4/96	Examining reasons for the low growth.	*A series of tests to identify why growth was so low*	
B6 PT1	4/96		Bus fare test of corrected B6	
B6 RP1	4/96		Road pricing test of corrected B6	'Spike' in accessibilities identified. Problem in development model identified by DSC.
B6 RPPT1	4/96		Combined bus and road pricing	Spike problem persists
B7	5/96	Test implemented DELTA with full change START.	Version with corrected growth factors, and development model corrected.	At this point model still required 'spike' problem to be fixed.
B7-L NC	5/96	Test START LRT version.	'No change' model run, to test LRT.	No changes obtained: system operating correctly.
B7 series	5/96	Test START LRT version	*Test to produce working LRT version of model. Problem in LRT educate trip rates identified. Tests of new method for calculating accessibilities to remove the spike.'*	
B7 DM1	6/96		Do-minimum (as distributed to the Phase 2 interview sample)	High population growth in Fife identified. Large rent changes identified, but accessibility results clearly incorrect.
B7 PT1	6/96		Bus fares (as discussed in phase 2 presentation).	As above.
B7 RP1	6/96		Road pricing (as distributed to phase 2 interview sample)	As above.
B7 LRT1	7/96		LRT (as distributed to phase 3 interview sample)	As above.
B8 DM	10/96	Test Fife corrections	Do-minimum, Fife growth corrected.	This version now has the dataset correct
R4a	11/96		*Adjustments to retail mobility, available floorspace allocations and the 'space factor' (eqn. 8.3) to test rent relationships.*	
R4b series	11/96		*Adjustments to employment location sensitivities after identification of large swings in employment from LRT strategy tests in R4b* This became the R4'**Current Version**'.	
DM1(R4)	12/96	Current version	Rent changes now smaller.	Memory problems solved.
RP1 (R4)	12/96	Current version	Road pricing.	
LT1 (R4)	12/96	Current version	LRT.	
LR1 (R4)	12/96	Current version	Combined.	

8.4 Discussion: a typology for model implementation

This section aims to place work outlined above, and particularly the model testing, within a typology of the modelling process. This will allow an examination of the different tasks in terms of the understanding that the planner should have of the processes. As such it complements the 'levels of understanding' introduced in Chapter 2, and will be further discussed in Chapter 10. The typology was derived from breaking down the patterns of work, analysis and decision making that was undertaken during the implementation of the DELTA/START model. The typology to categorise the various tasks in model implementation falls into four parts:

1. deductive design (and implementation);
2. mechanical analysis;
3. rational analysis;
4. deductive fitting.

Deductive design is the process of model design. In other words it is the process of taking a theory and developing it into a series of mathematical and computational processes. In practical terms the design process is a fusion of the pure theory, with the practicalities of resource limitations and data availability, which constrain what can be made into a 'workable model'. Models are devised from a mixture of prior expectations concerning relationships, past modelling and past evidence, together aiming to form a clear process of reasoned explanation. The two examples of deductive design for the models used in this thesis are found in Bates *et al* (1991), and Simmonds (1997; forthcoming).

Implementation then involves creating the dataset for the model. The specification of the dataset is part of the deductive design process, although there are usually pragmatic decisions regarding data sources or manipulations to be made during the process of implementation. Once the dataset is complete, model testing can begin. This experience (in the early stages of testing) tends to be dominated by the discovery and fixing of errors in the dataset or modelling process. Such errors can be broadly classified into four types of 'mechanical' error:

1. errors in the programming of models;
2. errors in the database, in terms of having the wrong, or incorrect data;
3. errors in the database, in terms of having the right data, but with typing errors, or format mistakes, and;

4. errors due to computer related issues.

The process of examining the model running and outputs to find these errors can be called a **mechanical analytical** process. This is the process of determining causes of 'non-expected' results in the code, automatic procedures, databases or model set-up. In the case of the DELTA/START implementation, this type of analysis took up the majority of the analytical time, primarily because the process being constructed was new. In other words, this is the search to rectify errors without recourse to explanation from the hypotheses and relationships within the model itself. The kind of testing that isolated these kinds of errors used 'no-change' versions of the model (to isolate spurious trends). Changes were then introduced one at a time, so errors and problems could be easily identified.

The second type of analysis of results can be termed '**rational analytical**', which generally occurs after the process of mechanical analysis. It is the search for explanation of results (expected or not), within the dataset and relationships in the model. In other words these are the explanations which can be rationally sought assuming that the model is operating correctly (an assumption that should be determined via the mechanical analysis). Errors related to 'rational analysis' can be termed 'rational errors', and can only relate to:

1. errors in the assumptions in the model (i.e. in the deductive design);
2. poor quality calibration or sensitivity testing leading to low quality parameters.

Although 'rational' and 'mechanical' describe the main sorts of analysis undertaken, there is of course a grey area in between them, where searching for errors becomes more problematic. A common example of this is searching for a rational explanation to a mechanical error. This can lead to the embarrassing situation of having derived an explanation for what turn out to be incorrect results. Another example is determining when all the mechanical errors have been identified and removed. This can be difficult especially if errors only appear when specific policies are being modelled.

Rational analysis extends from the construction of the do-minimum to the testing of different land use and transport strategies. Part of 'rational analysis' is the process of **deductive fitting**. This term represents the actual process by which the forecasts of the model design are investigated. Ideally, the outputs from a model would be compared to empirical data. In other words, a new model would be run for a historic period of time, and the results compared to test the goodness of fit. Alternatively the effects of a particular policy could be compared to an empirical example. However, such validation is not always possible, either because resources do not permit historical model runs, or the data for the past years are not of sufficient quality, or simply not available. Alternatively the model forecasts can be compared to other forecasts for the study area but these are often not available or not compatible.

An outcome of this is that the modeller resorts to a process of what is termed here 'deductive fitting'; that is, estimating what the results should be on the basis of anecdotal or intuitive reasoning, coupled with sensitivity testing of the model. The outcome of the deductive fitting exercise is a model that produces forecasts that the modeller is prepared to 'put on show' either in publication, to a client, or both.

8.4.1 Typology illustrations

The typology is now illustrated with examples from the DELTA/START implementation, following the author's experience in the development of this model. Section 8.2, outlining the structure of DELTA, comprised the deductive design. Several pure theory elements can be seen as assumptions that govern the operation of the model. Some examples are:

- the assumption that household change can be represented by aggregated transition rates;
- utility maximisation behaviour in the location of households;
- the factors that households and notionally businesses, are hypothesised to take into account when making location choices;
- the choice of accessibility function.

Each of these elements is justified by the use of past evidence and other research where available. This is most clear in the transition submodel, where the work of Buck *et al* (1994) and Keilman, Kuijsten and Vossen (1988) was extensively drawn upon, not only in the derivation of the rates themselves, but also in an acceptance that the method was tenable. The use of accessibility is another good example of deductive design. The logsum formula (equation 8.4) seeks to incorporate all the aspects of generalised cost, over all routes and times. It is thus a formulation of travellers' potential, rather than their actual, travel costs and for a variety of travel purposes. Clearly this is making a number of assumptions concerning how people perceive accessibility, with recourse to 'average' perceptions from the population.

However, it is apparent that the ideal deductive design is often constrained by findings of the rational analysis. A good example of this is the change in the form of the utility of consumption function, as discussed in section 8.3.6 concerning the location model. While it was theoretically elegant, and a better fit of the data, to use the Stone Geary function (which assumes that households have a minimum level of consumption of floorspace below which they will not go), it was found that for some tests, where demand changed rents radically, the minimum consumption became unaffordable and stopped the model calculations. Therefore as a stop-gap measure a simpler utility function had to be used instead.

It is fair to say that well over 50% of the entire modelling work was taken up with mechanical analysis. Without a doubt this was because many of the model elements were new, and required testing not only to examine the input data, but also to test the software itself. In doing so, examples of the four types of 'mechanical' errors outlined in Section 8.4 were identified and are now discussed.

Errors in model programming were to be expected in the development of the new routines, and those which led to obvious incorrect results, or prevented the system working at all, were easily rectified. More irksome were errors which did not lead to easily identifiable results. The error in the development model, (due to a factor being incorrectly applied) was an example of the latter as it passed unnoticed through the 'DELTA-only' and 'no-change' testing of the model. It is perfectly possible that such minor errors still reside in the model code. Often such errors are only spotted by chance or through minor anomalies in the results.

Errors in the database, in terms of the DELTA or EFM databases containing the wrong data were also a source of error. Given that the model system was using over 150 input files, it is unsurprising that errors occurred in this respect. A good example was an error in the car ownership files. The model was expecting a single car ownership growth factor constraint for the study area, but the datafile actually contained values for each zone, and hence was taking the first zonal value as representative of the study area. A further example was an error in the transition rates for single households. Young single households had a probability of transforming into retired couples, without any intervening steps! Once such errors such find their way into the data input files, they are very difficult to spot.

Typing errors and formatting mistakes also occurred in the car ownership files. For example an error in the format of the car ownership files led to the 'low growth' issues in table 8.6. The data columns did not match the required column formats, leading to the spurious results (which underlines the importance of documenting all aspects of the model). Another example here was the high growth of population in Fife that characterised the B7 runs. This was traced to an error in a decimal place for residential floorspace, giving Kirkcaldy ten times as much available floorspace as was intended.

Finally, throughout the modelling process, computer related errors hampered the implementation. Two problems dominated the DELTA/START application: firstly the large size of the (transport) files meaning that the computer disk space was rapidly consumed, and secondly the memory problems (see table 8.5), caused by third party software not releasing the computer's memory once the program was completed. These problems led to system crashes that slowed down the process of running the model, as manual intervention was required. It also took time to search for the source of the errors[9]. Many of these problems were not due to the modelling software, but bugs in the software used to develop or run the model (such as JAVELIN and DBOS).

The mechanical analysis of the type outlined above is rarely reported, despite the large amount of time that it often consumes. This may be because such analysis is not of interest to those concerned only with the results. However, where a client expects to run the system within the client organisation, these issues perhaps should be more prominent, especially if they are persistent or permanent. Certainly it would be useful to have a general idea of the percentage of model implementation time concerned with mechanical analysis. This is less true of rational analysis, although a large part of this type of analysis invariably goes unreported, as it is often not concerned with the final results or relevant to them. Nevertheless, it is this process that increases the analyst's familiarity with (and faith in) the model system, and hence increases the chances that errors will be spotted and results explained.

However, rational analysis also involves examining the results against prior expectations and other sources of data to indicate whether the model is giving sensible results. For example the DELTA household and population forecasts were compared to those produced by LRC, and the transport indicators were compared to past JIF (START only) runs. The sensitivities of the model responses were compared to the responses from other land use models and published sources where possible. Part of this work also involved setting the sensitivities of the model to match other sources of data, but not as part of a formal calibration exercise. The specification of the sensitivity of the area quality index on rents is one example of this.

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[9] This was partly a problem of the *ad hoc* manner in which the elements of the model were combined, coupled with the consistency and communication problems of developing different parts of the model separately by different consultancies. The CASE consultants are now working to integrate the models more closely, using a common programming framework.

It is the process of validation and sensitivity testing that perhaps was most constrained by the limited resources available to modelling as part of this research project. This can be seen in the difference between the 'ideal' process of figure 8.3 (page 175), and the actual process from figure 8.4 (page 177). Ideally, three types of sensitivity testing would be undertaken (see figure 8.3, box 7a-c); firstly establishing the general sensitivities of the model, secondly the validity of the model's response in its individual components, and thirdly the model's ability to reproduce total changes. Practically, this whole process was limited, and hence represented by a single box (12 of figure 8.4).

Even this three step process to sensitivity testing and validation can be fraught with problems, especially the issue of altering the model to reproduce one set of 'expected' changes, which then fails to reproduce another set, or leads to unexpected changes when applied to a transport strategy. The submodel nature of DELTA was designed by the consultants to avoid this problem (compared to a more unified model such as MEPLAN), as the individual elements can be validated independently. However, knowing that all the submodels are giving sensible results when run alone does not guarantee a sensible result when run together.

Where there was no other data for comparison, the process of 'deductive fitting' occurs, in other words assessing the validity of results on the basis of the analyst's judgement. At this point the analyst will search for any benchmarks against which to compare the model's forecasts. Often this may be the agreement of the model team (or steering group) that the results are acceptable and sensible. This is often the only way to assess whether results can be disseminated; as forecasts are by their very nature unable to be verified when they need to be used.

An illustration of deductive fitting was the process by which the rent sensitivities were altered in response to the B7 outputs. This process involved:

1. the acceptance that the current rent estimates from DELTA were unacceptable (from discussion with the model team and results from the Phase 2 interviews;
2. analysis to determine exactly why the rent changes were so large;
3. a search for a rational basis by which to alter the results;
4. the altering of the results on the conclusions from (3).

Clearly (3) is a vitally important step if the model is to be more than a product of the modeller's own views. However, it is important to note that large changes in the input coefficients (sensitivities to accessibility) led to large changes in the results (as will be seen in the comparison of the B7 and R4 results in Appendix IV).

8.4.2 Links with the 'scale of understanding'

There are clearly links between this typology of the modelling process, and the level of understanding of the model that was outlined in table 2.2 (page 22). The process of deductive design clearly depends upon the model architect, i.e. an expert with the highest level of understanding. The process of implementation and mechanical analysis does not require such a high level of understanding, as the hypothesised relationships in the model are not under examination. In other words, one does not have to be an expert on the model in order to get the basic system running. In contrast, rational analysis and deductive fitting do require a high level of understanding (in the terms of the box scale, at least at the 'white' level) in being able to understand and explain results. There also needs to be communication between analysts at the different levels in order to determine when the mechanical analysis is complete.

The situation would be slightly different if the model system, at the start of the DELTA/START implementation, had already passed the 'mechanical analytical' stage. At this point a modeller with a basic understanding could still run the model, and there may well be a past database of runs with which to compare new tests. This eases the burden of the rational analysis, and also means that an analyst with perhaps a lower level of understanding could interpret the results. It is upon this rationale that a model could be handed over to the client, in order for the client to be able to understand his/her own strategy tests.

8.5 Results from DELTA/START

A large number of model tests were undertaken (categorised in table 8.5), which culminated in July 1996 with the 'B7' runs. The results of these tests were considered sufficiently plausible to be used in the Phase 2 interviews discussed in Chapter 10. It was realised that further fine tuning of the results would have been desirable, as the B7 results, although satisfactory, were far from ideal Some of the problems inherent in the results are discussed at the end of this chapter. However, these B7 results were used in order to complete the thesis within the available resources, and hence are described in this chapter. The next section (8.5.1) outlines the do-minimum, and compares the results to other forecasts for the region. Section 8.5.2 then discusses the impacts from the transport policies. The B7 tests discussed here are:

1 the do-minimum: which included a land use scenario based upon the current Lothian Structure Plan, and a transport strategy based upon the standard do-minimum from the JIF project;

2 the do-minimum plus road pricing set at £1.50 in 1991 terms[10];

3 the do-minimum plus light rapid transit E-W and N-S routes, with fares set equal to bus fares, and a two minute headway all day (this was the service level tested during the JATES and JIF projects);

4 the do-minimum plus both road pricing at £1.50 and the LRT system as above, called 'the combined' strategy.

For all these tests, a key issue is how they compare with other forecasts for all, or part, of the study area. The other forecasts which can be contrasted are:

- the land use forecasts provided by the LRC planners as part of the JATES project, and reported in Chapter 7 where they provided the do-minimum estimates for the LUCI model (these date from 1990, but are the only exogenous source of zonal population and employment forecasts available);
- the transport forecasts from the JIF study (although the tests in this strategy were focused upon options for the second Forth Crossing, the study area boundaries and strategies were common to the DELTA/START modelling; these are referred to as the 'JIF' results[11]);
- demographic forecasts undertaken for the structure plan. These figures were already used to guide the total forecasts of the transition model, and are not therefore discussed further.

A feature of the DELTA/START model is the large amount of data that is generated for each period that the model is run. This includes:

- the outputs available from the START evaluation package (trip summaries, trip km summaries, parking summaries and accessibilities by purpose);
- the outputs available from the START environmental evaluation package (noise, VOCs, nitrous oxides, carbon monoxide, accident casualties and fuel consumption);

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[10] 'terms' refers to the fact that all prices are entered into START at equivalent 1991 levels.

[11] Those JIF results reported here were undertaken at ITS as part of the 'OPTIMA' study (Shepherd, Emberger, Johansen, and Jarvi-Nykanen (1997:forthcoming).

- the outputs available from DELTA, (floorspace and rent changes by space category, population (including by person type and SEG), households (by SEG and type), and employment by sector);
- the outputs derivable from the DELTA databases, namely employment, household or population densities.

Presentation of all this data can be overwhelming. Furthermore, as the focus of this thesis is upon land use response from transport, emphasis is given to the variables that are likely to be responding to changes in the transport indicators. The following discussion of the impacts of transport on land use therefore focuses upon:

- broad indicators of the transport system (such as trip totals relative to the do-minimum and accessibility);
- the impacts on rents, and where appropriate, the impacts on the distribution of new construction;
- the impacts on the distribution of *activities*, i.e. households and population (with some reference to SEG) and employment.

The discussion of the results begins with an examination of the DELTA/START do-minimum estimates, followed by a comparison of these results to the JIF and LRC predictions. The impacts of the three strategies on land use activities are then presented, with reference to their transport impacts. Finally, the transport indicators are compared to the JIF forecasts.

8.5.1 The do-minimum DELTA/START test

As discussed above, the do-minimum test consisted of a set of likely transport policies that had previously been used in the JIF study. To simplify the modelling process, all of the do-minimum policies were implemented in the first year (1991) and maintained throughout the study period. This was a reasonable assumption, as several of the do-minimum strategies (for example 'Greenways' bus priorities) had already been implemented, and less certain large scale do-minimum projects (such as guided bus) were not included in this testing (in order to be comparable with the START/LUCI tests). Fares policies and parking charges were set to change to their do-minimum levels in the first period.

With no 'sudden' introduction of policies after the first period, it was expected that the do-minimum would show gradual shifts in the transport indicators over time, as the overall demographic and employment growth from DELTA was known to be relatively constant.

For the transport indicators, it can be seen that this is the case. Figure 8.7 shows the increase in trips by purpose over the 20 year study period. It is clear that the future trends perpetuate the existing pattern, with increases in all the trip purposes. Figure 8.8 shows the number of trips split by mode. The intensification of existing trends is evident here, with a rise in car trips at the expense of public transport. This growth in car use is especially acute given the low base year car ownership levels. Note that train has a low mode share, as in Lothian bus is very much the dominant public transport mode.

What is clear from both these graphs is the gradual nature of the trends. Other transport indicators, such as trip km, exhibit a similar progressive pattern, although trip km's rise faster than trips, as shown in table 8.6. This table also illustrates the decline in mode share of public transport relative to the private car. The indicators are given for 1997 and 2011 to be consistent with later tables examining the impacts of transport strategies.

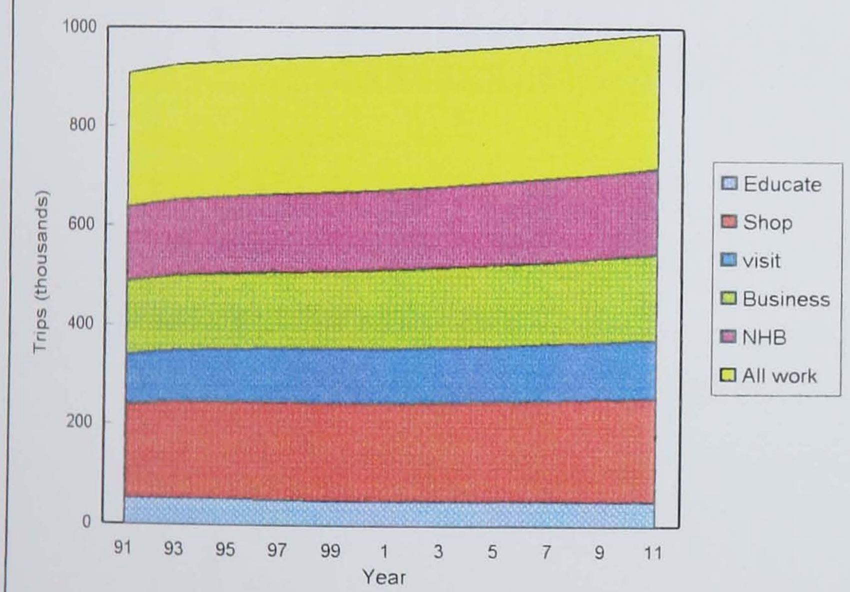


Figure 8.7: Do-minimum no. of trips by purpose
DELTA/START B7 DM1

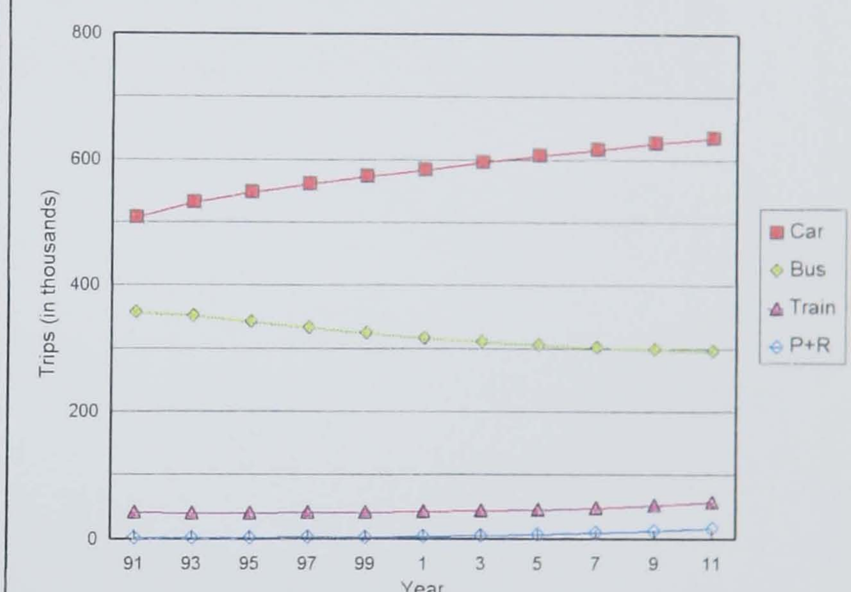


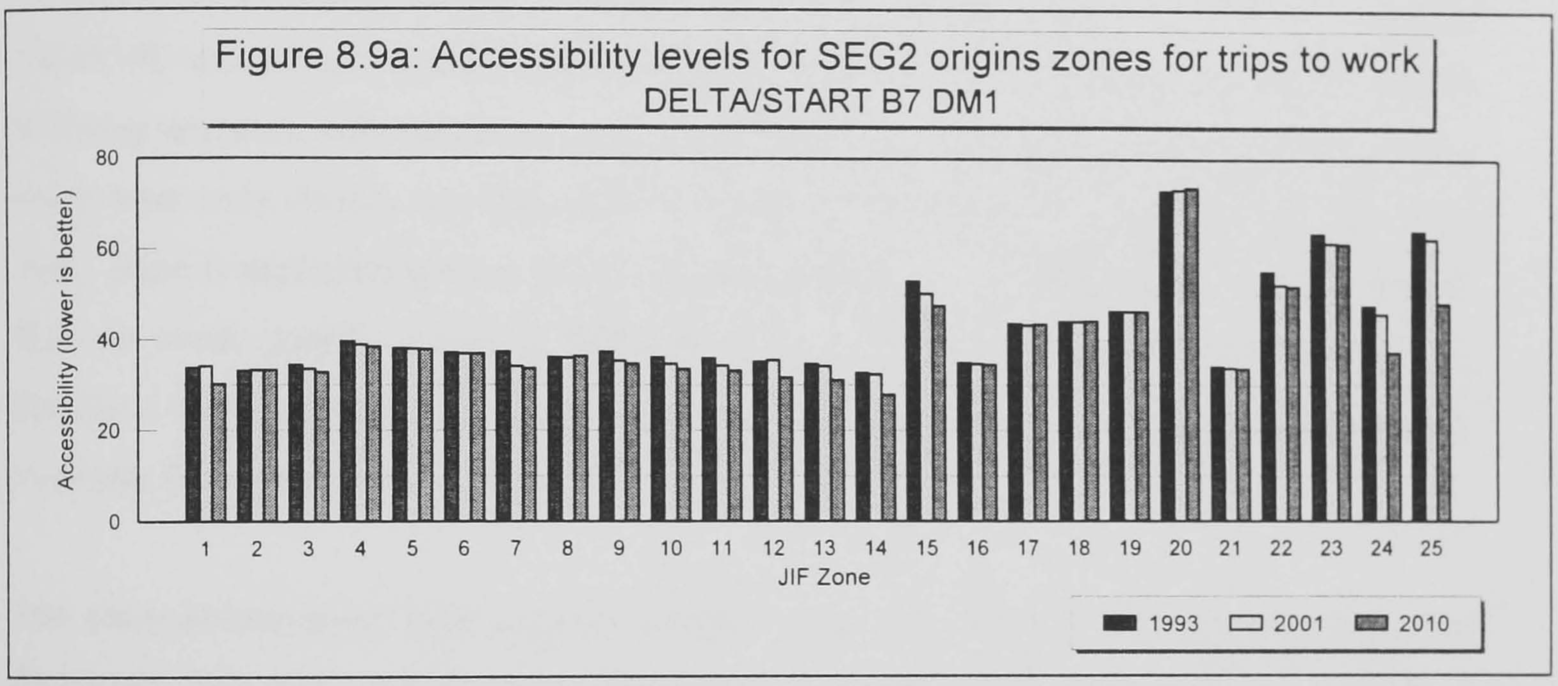
Figure 8.8: Do-minimum number of trips by mode
DELTA/START B7 DM1

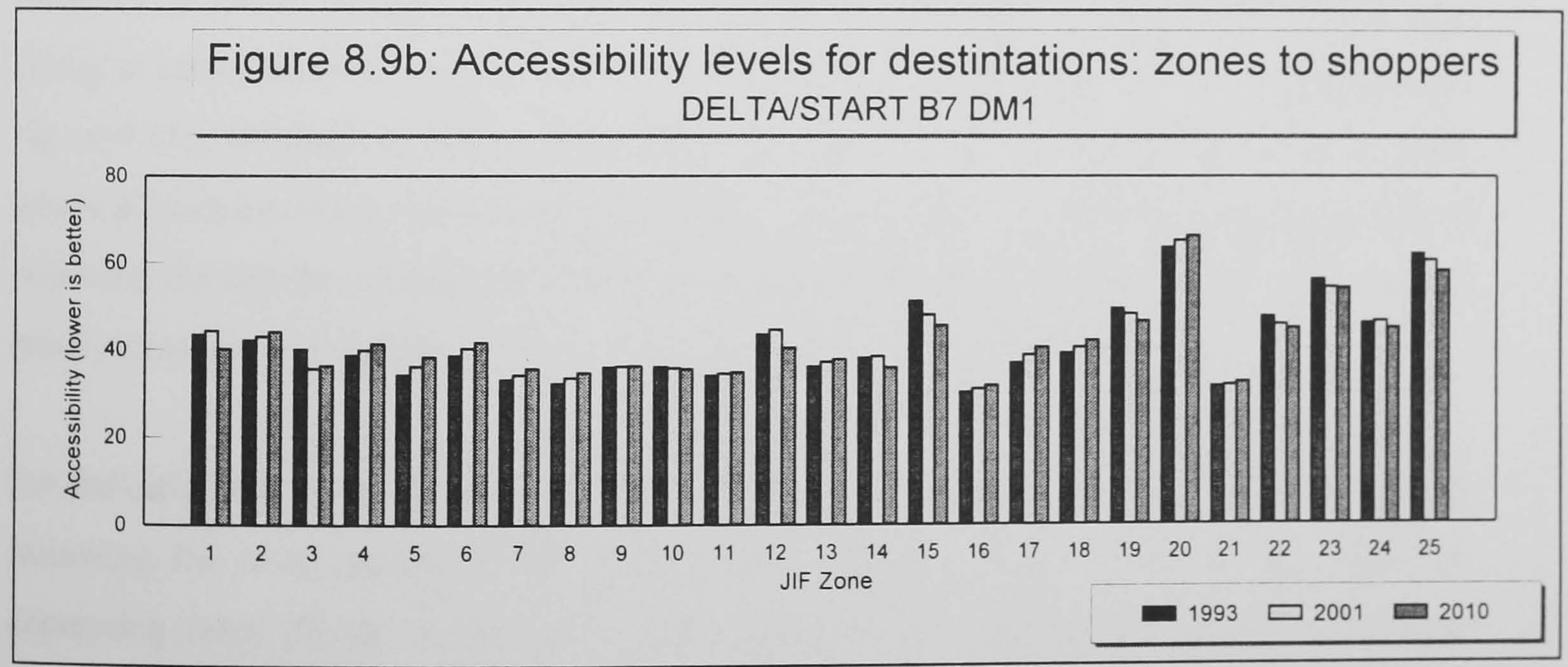
Table 8.6: Do-minimum transport indicators

(figures in '000s)	1991	1997	2011	% change (1997-2011)
Study area total trip km	10873	11928	14161	*+12%*
Total trip km by car	7352	8432	9872	*+17%*
Total trip km by bus	2390	2342	2248	*-4%*
Study area total trips	909	941	1009	*+7%*
Total trips by car	508	562	636	*+13%*
Total trips by bus	357	334	297	*-11%*
Mode share of car	*59%*	*60%*	*63%*	*+5%*
Mode share of bus	*41%*	*35%*	*29%*	*-17%*

The location of activities relates to the transport system via the accessibility and environmental indicators from START. Figures 8.9a and b show indicators for accessibility to work (an origin indicator), and retail to shoppers (a destination indicator). These charts show the trends for three years in the study period, and should be interpreted in terms of a lower figure being a 'better' accessibility. The resulting pattern for the accessibility to work shows a reasonably uniform level of accessibility within the city of Edinburgh (zones 1-14), and the outer districts having a worse accessibility. A noticeable trend is that by the end of the forecast period, the accessibility of Fife (zones 24 and 25) has markedly improved.

Figure 8.9: Accessibility indices from DELTA/START





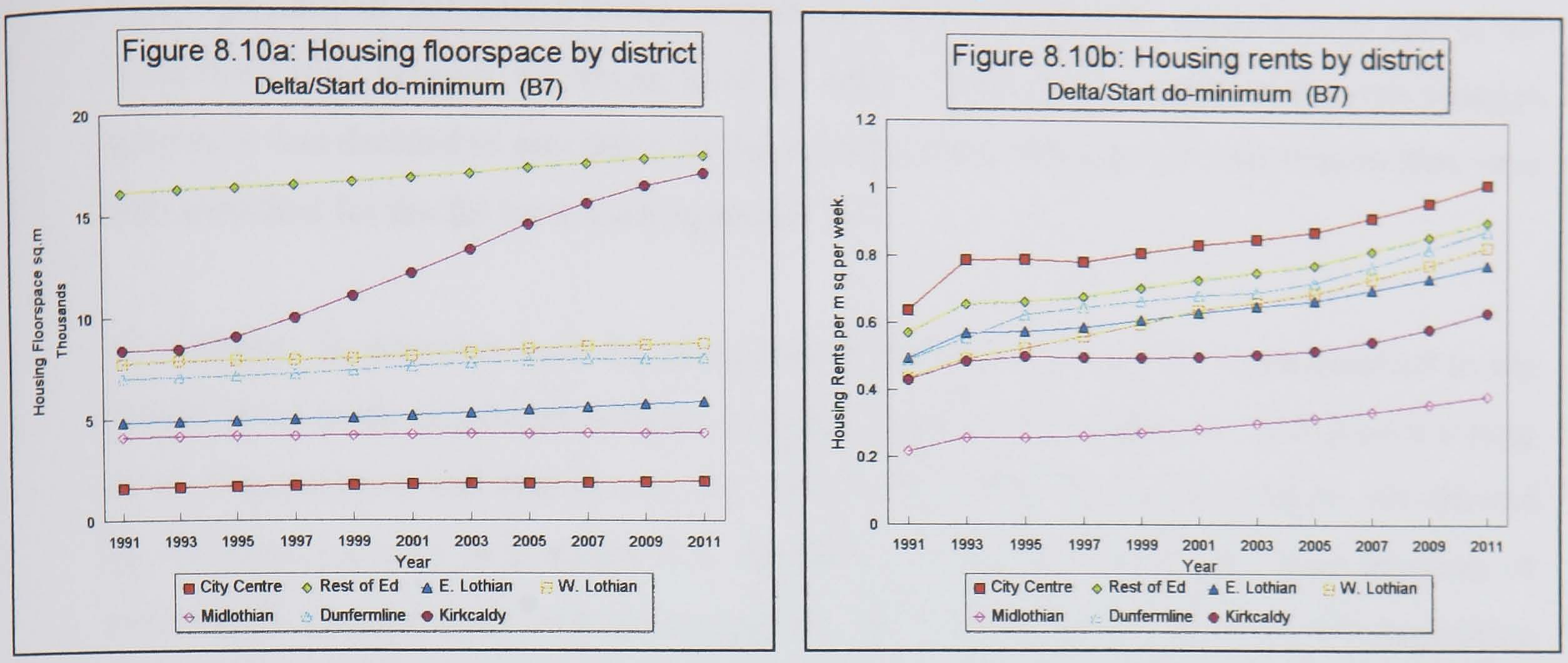
The accessibility for retail activities to shoppers (Figure 8.9b) is more complex, and shows the relative attraction (to retail) of centrally placed zones such as 16 and 21, as well as the city centre. Within both charts, it is interesting that the modal average accessibility index tends to improve over time, especially for access to work. The key reason for this is likely to be relocation of land use activities into a better mix of employment and population, as will be discussed below.

The changing pattern of rents over time is both an indicator of demand for a location, and also a key mechanism for allocating activities within DELTA. Rent levels are determined by the demand for floorspace by activities, the number that can locate being constrained by the available space. This interaction between demand and supply leads to some interesting trends. For example, figure 8.10 shows the floorspace and rent trends for the housing sector, by the study area districts. Presenting the districts loses the spatial detail in the model, but is useful for summarising the main changes that are predicted (Figure 5.1, page 81, outlined which JIF zones were in each district). Rents rise in all the districts (figures 8.10b), but by differing amounts, with the increase in rents highest within Edinburgh (despite the fact that these rents were already the highest in the study area). Figure 8.10a shows why this is the case; there is negligible growth in floorspace in the city centre, with most growth in Fife. In fact, so much growth occurs in Fife that this suggested an anomaly in the results. As discussed in Section 8.4, this was eventually traced to the data error in the file supplying available floorspace to Kirkcaldy.

The other sectors show differing rent trends, in part dependent upon differing supplies of floorspace. For retail, the structure plan places a constraint on available sites, and this is reflected by the drying up of new sites after the end of the century. This is part of a general policy to constrain retail decentralisation out of the city, a policy that seems successful from figure 8.11a, although in reality some retail floorspace growth would be expected in areas where population rises, such as West Lothian. These space constraints have the effect of reversing the downward trend in retail rents, and lead to high demand for floorspace as the retail sector tries to expand.

For the office and 'other' sector, the study period begins with large amounts of available land following the over capacity of the 1980's office sector 'boom'. This has the effect of depressing rents (figure 8.12b), and keeping them low, especially compared to the high observed rents to start with. Note that DELTA deals with floorspace as a continuous variable, rather than as discrete sites. This means that, with the office sector, the rents may be falling too far, as in reality, particular types of site may be in short supply (for example sites of a certain size, or suitable for computer equipment), even if there is a glut of space overall.

Figure 8.10: Housing rents and floorspace by district



* large rise in Kirkcaldy due to residential floorspace error; see page 194

Figure 8.11: Retail rents and floorspace by district

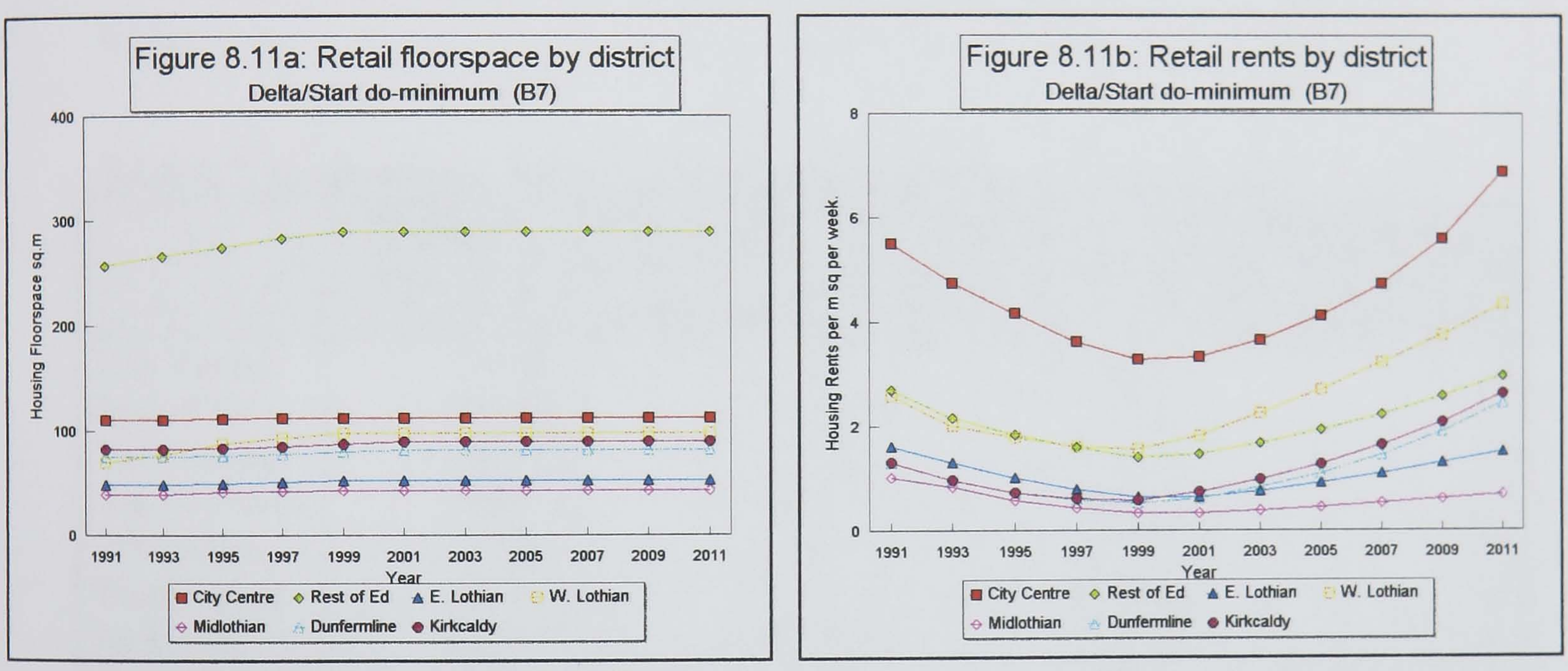
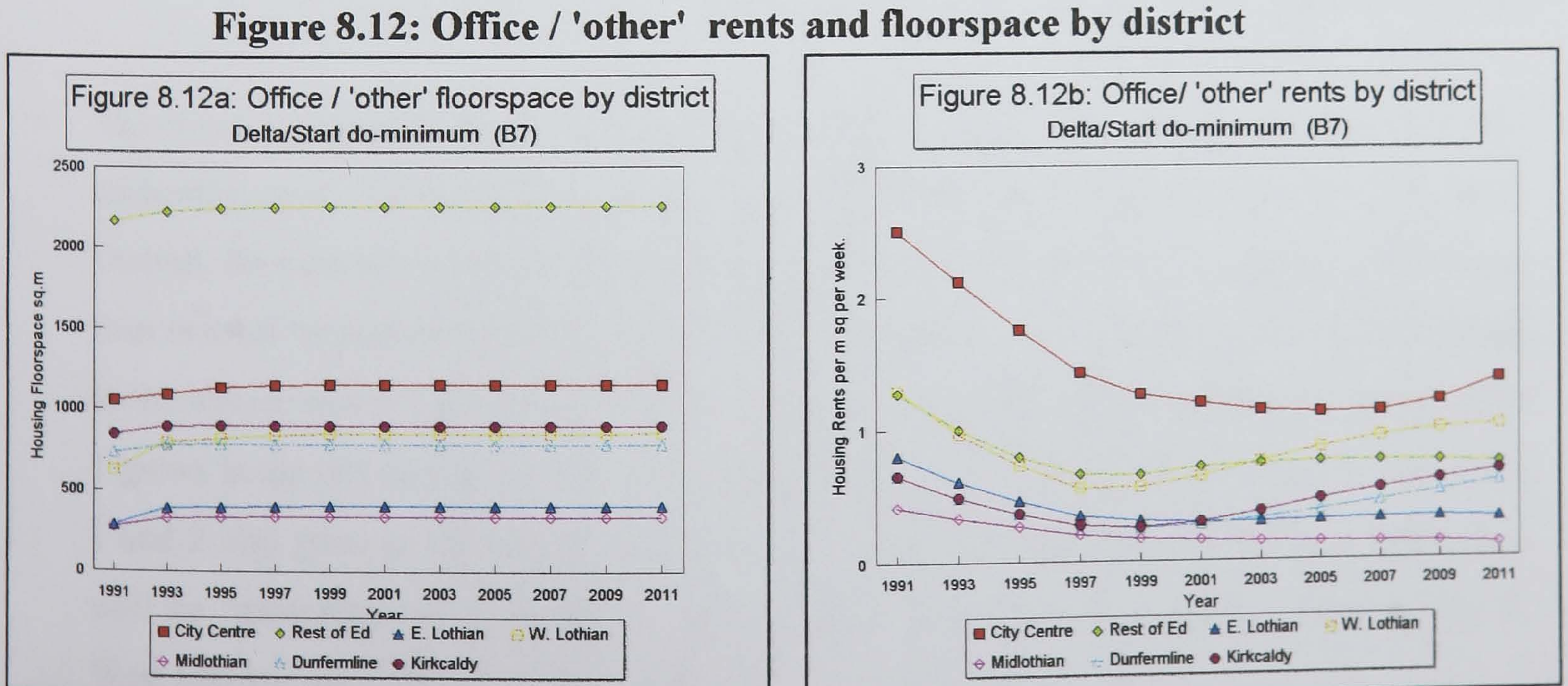


Figure 8.12: Office / 'other' rents and floorspace by district



At an early stage, it was considered that these rent levels seemed to change too much over time, especially in percentage terms, compared to what was thought reasonable as part of the deductive fitting process. However, with no other information to compare the rent changes against, it was decided to proceed with the model testing, although the rent sensitivities were later modified for the R4 tests (see Appendix IV).

The changes in activities over the study period are shown in table 8.7, summarised to the district level (with Edinburgh split into the city centre and outer area). This shows a clear trend of population and employment decentralisation. The population changes are skewed by the large increase in population in Kirkcaldy, a direct result of the large amounts of available floorspace there and the associated low rents. Note that there is still population growth to the west of Edinburgh. This is likely to be due to the high employment levels in West Lothian, although after 2005 this process slows as rents increase (figure 8.11b and 8.12b).

Table 8.7: Do-minimum land use trends for population and employment

	Population 2011	Population % change (1991-2011)		Employment 2011	Employment % change (1991- 2011)
City Centre	34257	-6		101935	-0
Rest of Ed	336498	-11		169626	-1
East Lothian	82499	-2		25018	+17
West Lothian	158735	+10		66016	+34
Midlothian	71741	-8		21780	+5
Dunfermline	141044	+6		47054	+8
Kirkcaldy	227936	+46*		53793	+7
Study Area	105710	+4		485222	+6

* excess growth due to error in Kirkcaldy data; see page 194.

The trends for the individual SEGs are also interesting, despite the discrepancy caused by the Kirkcaldy error. Table 8.8 shows that the total figures mask some large variations by SEG. Overall, the number of 'white collar' households (especially of SEG 1) continue to rise faster than manual worker households, reflecting the continued shift of employment in Edinburgh to the service sector. Ignoring Kirkcaldy, which has the highest growth for every group, SEG 1 grows in the city centre, probably being the only group able to afford the higher rents. SEG 1 and 2 also grow in the rest of Edinburgh, displacing people of lower SEGs, in what may well be 'gentrification' type effects. Where more floorspace is available, for example in West Lothian, then all the SEG groups grow.

Table 8.8: Household forecasts by SEG; percentage changes 1991-2011

	Total	SEG1	SEG2	SEG3	SEG4
City Centre	17.5	26.3	17.2	7.0	9.5
Rest of Ed	6.1	18.0	6.0	-2.7	-3.3
East Lothian	16.7	29.9	20.4	7.1	6.3
West Lothian	22.7	36.9	20.7	13.2	25.4
Midlothian	7.3	30.1	10.6	-2.4	-7.8
Dunfermline	19.4	33.0	23.3	8.9	13.8
Kirkcaldy*	80.3	81.0	94.4	60.6	81.6
Study Area	22.8	30.9	23.4	15.7	20.3

* excess growth due to error in Kirkcaldy data; see page 194.

8.5.2 Comparison of the transport do-minima: DELTA/START to the JIF model

The DELTA/START do-minimum results would not be expected to be identical to past JIF runs due to the influence of the dynamic land use feedback loop, and the differing land use data. However, given that the overall growth in the two transport models is similar, the 2011 forecasts would be expected to be broadly comparable. For the B7 test the general trends and results are similar, although there are important differences. Table 8.9 shows that compared to JIF-only, total study area trips in DELTA/START are lower for the dominant modes of car and bus, but higher for train and park and ride (which have a lower mode share). However, the trip km are greater for DELTA/START, which implies that fewer trips are being made, but over longer distances.

Table 8.9: Daily total of forecast year trips from JIF compared to DELTA/START (B7)

	JIF Do Minimum			DELTA/START % chg. from JIF	
	Trip km	Trips		Trip km	Trips
Car	9921.8	684.4		-0	-7
Bus	2511.0	347.1		-10	-14
Train	1247.3	44.5		40	31
Train P&R	52.1	3.8		473	358
Total	*13732.2*	*1081.8*		3	-7

There are two broad explanations for this difference in the trip making behaviour between the models; one rational, the other both rational and technical. Both stem from the changes in the distribution of activities. The former stems from the basic differences between the land use estimates from DELTA/START compared to the LRC planners' estimates:

1. the DELTA study area forecasts of employment and population are lower than the LRC forecasts, by 11% and 7% respectively;

2. there are large differences in the distribution of the growth, with most growth in DELTA occurring in Fife rather than in Lothian region;
3. for employment growth the Lothian predictions forecast most growth in the city itself, especially in the development areas in the south of the city, notably zones 5 and 9. In DELTA the growth is in the outer districts.

The fact that the study area population forecasts are lower in DELTA means that the average numbers of trips made per person are higher in DELTA/START than in JIF. This is coupled with the general observation that the land use scenario devised for DELTA/START tends to lead to more decentralisation and counterurbanisation than the Lothian planners' own forecasts, in part due to the large out migration to Kirkcaldy. This increased decentralisation explains the increased trip km found in DELTA/START, and may also rationally explain the rise in trips for singly constrained purposes, as increased use of cars outside Edinburgh may be likely if congestion in these outer areas is less severe, and outer area periphery trips are less well served by public transport.

However, if explanation is sought within the assumptions in the model, then it is possible that the increased trip rates could be due to the way in which START models trips. This requires some explanation. Within the external forecasting model there is a relationship between the trips originating in a zone (in the trip matrices), and the population in that zone. This creates an implicit 'trip rate' in the 1991 situation. In future years, if extra population moves into a given zone, it will take up the trip rate of that zone, implicit in the base data. This is acceptable if there is reason to believe that there are (modelled or non-modelled) factors that affect the spatial pattern of trip rates (e.g. zone where local shops allow walk trips for shopping rather than car use). However, clearly large numbers of people moving around the study area will affect the total trips produced, and this may be what is occurring in the do-minimum in DELTA/START. This is problematic if there are irregularities (i.e. errors) in the base pattern of implicit trip rates.

Although the do-minimum was unlikely to be a particularly plausible scenario (due to the over allocation of floorspace to Fife) nevertheless the direction of changes were sensible despite being lower than the LRC forecasts[12]. However, it should be noted that the model was set up so that activities seeking locations will take accessibility into account, and so the fact that transport policy does have an influence on land use should come as no surprise.

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[12] For more comparison of the B7 do-minimum to the LRC forecasts, see Chapter 9.

8.5.3 The impacts from LRT

LRT has a dramatic effect on accessibility due to the high level of service that was implemented, combined with a fares policy that matched bus fares. As a result accessibility improves within Edinburgh by around 30-40%, and this is especially large for the work purposes. The knock-on impacts of this improvement are an increase of 2.3% in trips made, (table 8.10) and a modal shift with LRT capturing 10% of the trips in the study area, mostly from bus. However, it is evident that the use of LRT changes over time. For example after its introduction in 1997, LRT's mode share falls, most likely as car ownership increases in the study area, and indeed car trip km and car trips rise almost to their do-minimum levels. This shows that LRT alone is not particularly effective at reducing car trips, as it takes the bulk of its patronage from existing bus users.

Table 8.10: Light rapid transit impacts; transport indicators

(Trips and trip km in '000s)	1997 absolute figures	2011 absolute figures	(1997 % chg. from Do-min)	(2011 % chg. from Do-Min)
Study Area total trips	949	1032	*0.9*	*2.3*
Study Area total trip km	11917	14112	*-0.1*	*-0.3*
Total trips by car	544	625	*-3.2*	*-1.8*
Total trips by bus	251	242	*-24.9*	*-18.4*
Total trips by LRT	108	100	*n/a*	*n/a*
Total trip km by car	8198	9871	*-2.8*	*-0.0*
Total trip km by bus	1880	1908	*-19.8*	*-15.1*
Total trip km by LRT	610	586	*n/a*	*n/a*
Mode share by car	*57%*	*61%*	-5.0	-3.2
Mode share by bus	*26%*	*23%*	-25.7	-20.7
Mode share by LRT	*11%*	*10%*	n/a	n/a

LRT has a complex impact on population and households. In broad terms, zones which have LRT running through them increase their share of the population, i.e. zones 5, 9 and 10, plus the city centre zones 1,2 and 12 (figure 8.13). There are also population increases for the unserved outer zones 20 and 23. Figure 8.13 clearly shows a ring of surrounding districts around the city that lose population to Edinburgh. This figure also shows that parts of the city not served by LRT also suffer a relative decline.

Figure 8.14 shows that the employment effects from LRT are equally pronounced. The dominant effect is centralisation of employment in zones 1,2,12, and lesser effects in zones 5 and 9, both of which have the LRT in them. Some of these gains are large, for example up to 30%, or +9000 jobs in zone 12. It is curious as to why this growth should be so high, although some explanation is afforded by the fact that with LRT, zone 12 has one of the best accessibility levels (both origin and destination) in the study area.

Population impacts from LRT		
JIF Zone	2011 LRT test zonal pop	% chg from 2011 do min
1	14600	16.3
2	11003	4.1
3	48339	0.6
4	37789	3.1
5	44860	12.1
6	19671	-3.5
7	28652	-0.3
8	27573	-14.3
9	23893	15.1
10	34200	6.7
11	25147	-0.3
12	14044	26.1
13	20114	1.1
14	14843	-2.1
15	75865	-4.3
16	6300	-14.5
17	35714	-9.9
18	28112	-12.4
19	41857	-6.0
20	44456	17.1
21	8672	-13.4
22	21330	3.2
23	64822	10.3
24	126738	-10.1
25	234124	2.7

Figure 8.13: DELTA/ START forecasts; study area map of impacts of LRT on population distribution (percentage change from do-minimum 2011)

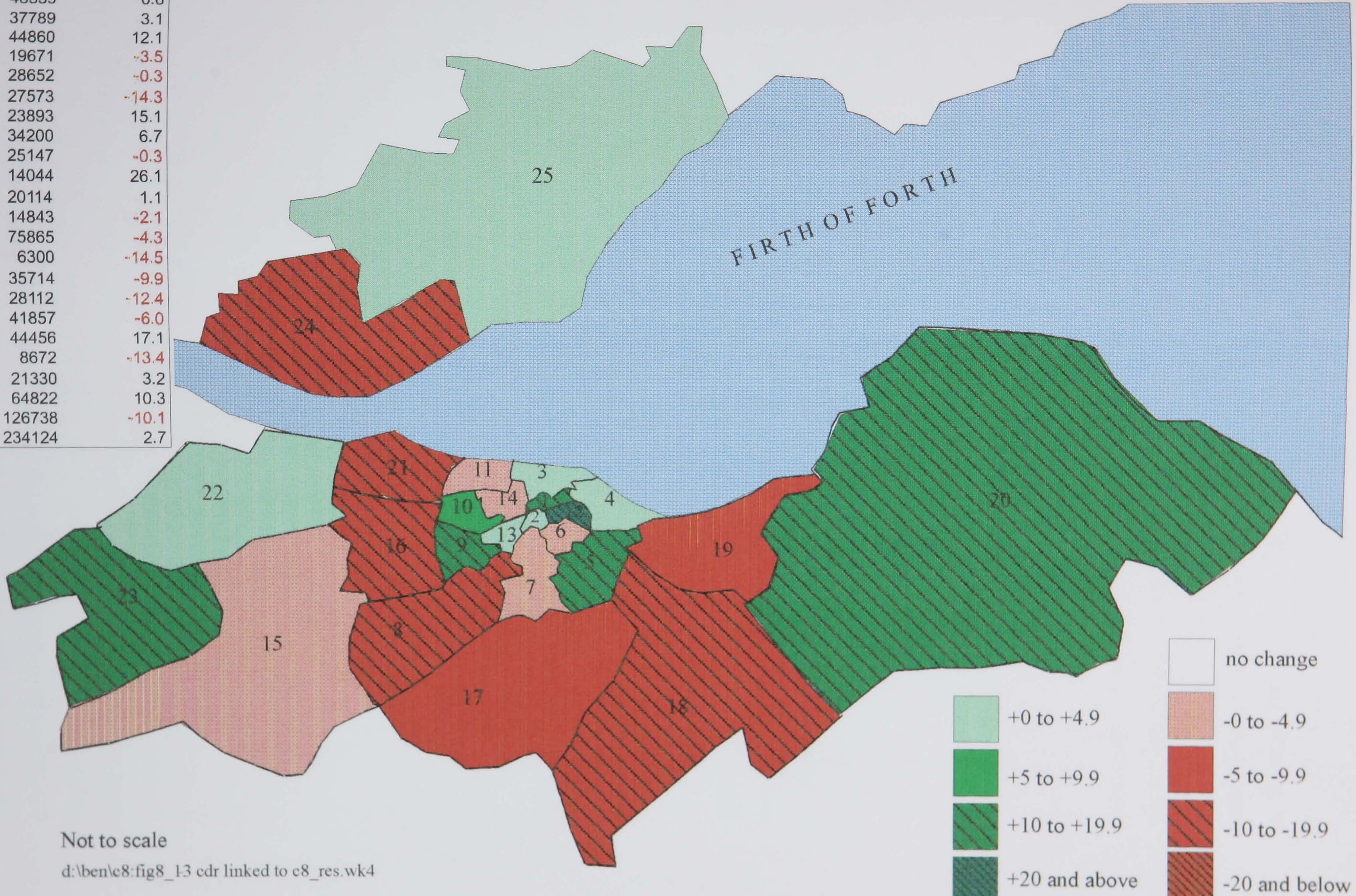

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Figure 8.14: DELTA/ START forecasts; study area map of impacts of LRT on employment distribution (percentage change from-do minimum 2011)

Employment impacts from LRT		
JIF Zone	2011 RP test zonal pop	% chg from 2011 do min
1	67154	12.0
2	14977	27.6
3	33065	-3.2
4	8915	-3.0
5	9407	5.5
6	7039	-6.0
7	10263	-6.3
8	3868	-7.8
9	18269	5.6
10	10442	2.9
11	11913	-7.2
12	39301	30.0
13	10894	-6.4
14	21485	-15.8
15	42004	-3.0
16	13283	-6.9
17	9810	-5.8
18	10528	-7.3
19	11417	-5.2
20	13277	2.4
21	2792	-7.8
22	6468	0.6
23	15659	-3.7
24	40956	-13.0
25	52038	-3.3

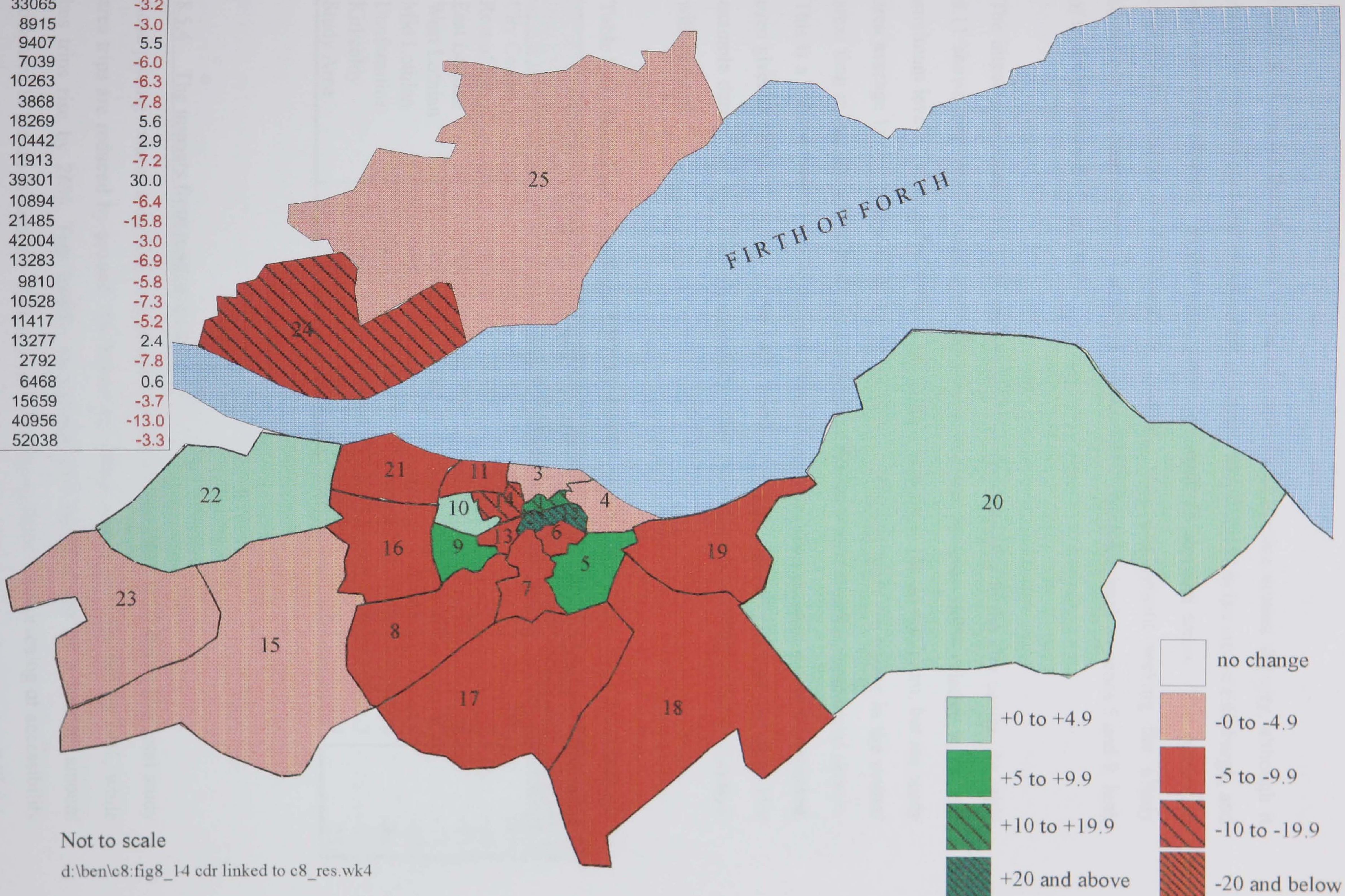


Figure 8.14 shows that there is a ring of employment decline around the city, although it should be remembered that employment is already very focused in the city of Edinburgh, and so percentage changes in the outer zones are small in absolute terms. The pattern of employment change in Edinburgh is complex, with employment seeking the highly accessible city centre, but still attracted to areas with floorspace, such as zones 5 and 9, both of which also benefit from LRT.

The impacts on rents from LRT are extremely large, especially in the city centre. As table 8.11 shows, city centre retail and office rents increase by over 100% relative to the do-minimum levels. Other zones suffer a fall in rents relative to the do-minimum, but the study area average is still higher than the do-minimum. Housing rents are higher in the central areas than in the rest of the study area, but not to the same extent as the commercial sectors. This is a good example of how the rent changes are larger than perhaps would be expected, even given the high frequency of the LRT. However, booms and busts in rents can occur (for example during the mid 1980's), especially when floorspace availability is not in harmony with demand.

Table 8.11: Resultant rents from LRT by district, and % differences from do-minimum

	Housing	Retail	Office/ other	Housing %	Retail %	Office/ other %
City Centre	1.10	14.04	4.44	8	104	226
Rest of Ed	0.91	2.69	0.32	0	-9	-56
East Lothian	0.83	1.39	0.08	7	-9	-75
West Lothian	0.87	2.82	0.23	4	-35	-77
Mid Lothian	0.33	0.61	0.02	-15	-13	-77
Dunfermline	0.81	1.49	0.08	-8	-39	-86
Kirkcaldy	0.63	2.46	0.38	-2	-7	-43
Study Area	0.81	4.04	1.00	-0	17	25

8.5.4 The impacts from road pricing

Road pricing causes a decline in trips and trip km by car. Table 8.12 shows that total study area trips are reduced by around 1%. However, within modes, car trips fall by 14%, while bus trips rise by 26%. Trip lengths on average still increase, but by a smaller amount compared to the do-minimum. Although not illustrated, there is a worsening of accessibility (for car based travel) within the cordoned area, and in other zones whose accessibility is largely determined by travel through or to the central area. There is also a large deterioration of the accessibility for all purposes in zone 16, which was thought to be spurious. This was traced to an error in the file of road charges on links, which was erroneously charging entry into zone 16[13].

Table 8.12 shows two sets of percentage changes from the do-minimum, firstly for 1997 (the year of implementation) and secondly for the horizon year of 2011. This shows how the most intense transport response for car use is felt at the time of the introduction of the system. However, the decline in public transport usage is greatly reduced over time, ending up more divergent in 2011 than 1997 from the equivalent year do-minimum. This points towards the road pricing charge having a continual beneficial effect on public transport patronage.

Table 8.12: Road pricing impacts; transport indicators

(Trips and trip km in '000s)	1997 absolute figures	2011 absolute figures	(1997 % chg. from Do-min)	(2011 % chg. from Do-Min)
Study Area total trips	921	997	*-2.1*	*-1.2*
Study Area total trip km	11762	14050	*-1.4*	*-0.8*
Total trips by car	474	544	*-15.5*	*-14.4*
Total trips by bus	399	374	*19.5*	*25.9*
Total trip km by car	7622	9065	*-9.6*	*-8.2*
Total trip km by bus	2997	2890	*27.9*	*28.6*
Mode share by car	*51%*	*55%*	-15.0	*-12.7*
Mode share by bus	*43%*	*38%*	22.9	*31.0*

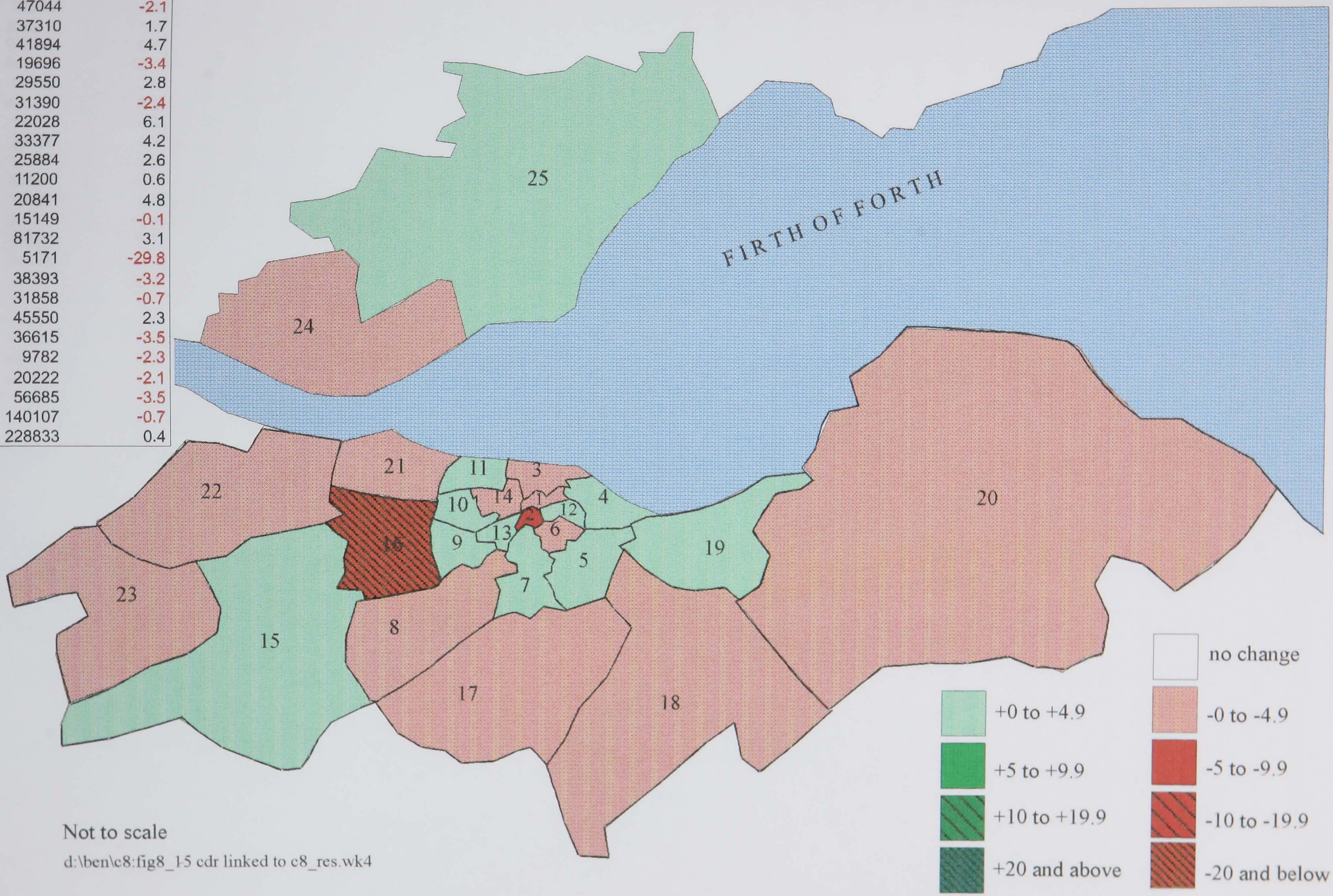
The impacts on population and households from road pricing are generally slight. Figure 8.15 maps the percentage changes in population from the do-minimum forecast year (2011). This shows generally a small effect on population (under 5%) affecting most zones. The zones within the cordon undergo a net out-migration while most outer city zones gain population, except 3, 6, 8 and 14. For 3, 6 and 14 this may be caused by the necessity to travel through the cordon frequently, although this does not apply to zone 8. The spurious worsening of accessibility in zone 16 (obvious on the map) leads to out migration that is large in percentage terms, but equates to around 2500 people, which is smaller than the positive impact on zone 15 in absolute terms.

For employment, figure 8.16 shows that road pricing has a strong and decentralising effect on the jobs in the city centre, with a loss of over 2000 jobs in zones 1,2,12 compared to the do-minimum. Notice however, that the New Town retains more employment than the older city centre areas, and that zones to the east and north also suffer employment losses.

[13] As this file was not available to be changed, all the tests with road pricing (including the combined strategy) include this error.

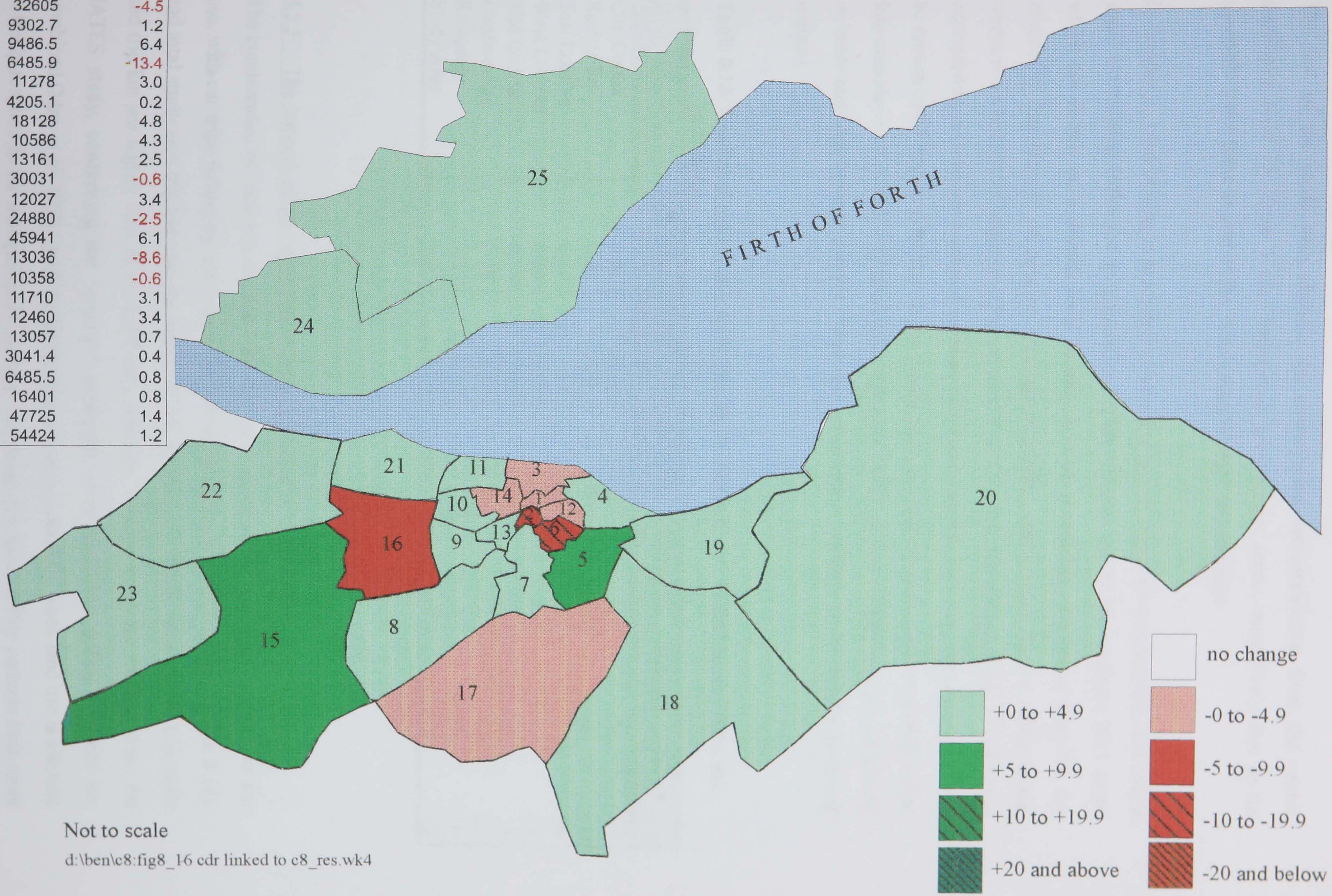
Figure 8.15: DELTA START forecasts; study area map of the impacts of road pricing on population distribution (percentage change from do-minimum 2010)

Population impacts from road pricing		
JIF Zone	2011 RP test zonal pop	% chg from 2011 do min
1	12519	-0.3
2	9893	-6.4
3	47044	-2.1
4	37310	1.7
5	41894	4.7
6	19696	-3.4
7	29550	2.8
8	31390	-2.4
9	22028	6.1
10	33377	4.2
11	25884	2.6
12	11200	0.6
13	20841	4.8
14	15149	-0.1
15	81732	3.1
16	5171	-29.8
17	38393	-3.2
18	31858	-0.7
19	45550	2.3
20	36615	-3.5
21	9782	-2.3
22	20222	-2.1
23	56685	-3.5
24	140107	-0.7
25	228833	0.4



Employment impacts from road pricing		
JIF Zone	2011 RP test zonal emp.	% chg from 2011 do min
1	58292	-2.8
2	10114	-13.8
3	32605	-4.5
4	9302.7	1.2
5	9486.5	6.4
6	6485.9	-13.4
7	11278	3.0
8	4205.1	0.2
9	18128	4.8
10	10586	4.3
11	13161	2.5
12	30031	-0.6
13	12027	3.4
14	24880	-2.5
15	45941	6.1
16	13036	-8.6
17	10358	-0.6
18	11710	3.1
19	12460	3.4
20	13057	0.7
21	3041.4	0.4
22	6485.5	0.8
23	16401	0.8
24	47725	1.4
25	54424	1.2

Figure 8.16: DELTA/ START forecasts; study area map of the impacts of road pricing on employment distribution (percentage change from do-minimum 2010)



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The rest of the study area absorbs the employment decentralisation from the centre, especially zone 15. Zone 5 also benefits in employment terms, most likely due to the available space there as part of the 'South East Wedge' development.

In summary, road pricing is predicted to have a negative impact on employment, and only a small centralising influence on population. This is borne out by the resultant 2011 rents, which are shown on a district level in table 8.13 as percentage differences from the do-minimum. The impacts on housing rents are negligible, and greatest for the office sector, where there is a strong negative effect on rents (-40%) within the cordoned area. The fall in accessibility is therefore predicted as being detrimental to the city centre. However, it should be remembered that employment in the model does not take environmental or quality issues into consideration, which may serve to mitigate the strong negative influences of road pricing on rents and employment density. However, even this is unlikely to reverse the predicted impacts.

Table 8.13: Resultant rents from road pricing by district, and % differences from do-minimum

	Housing	Retail	Office/ other	Housing %	Retail %	Office/ other %
City Centre	1.02	6.54	0.82	1	-5	-40
Rest of Ed	0.91	2.85	0.73	0	-4	1
East Lothian	0.77	1.55	0.39	-1	2	26
West Lothian	0.83	4.67	1.19	-0	7	18
Mid Lothian	0.38	0.65	0.11	-2	-6	4
Dunfermline	0.88	2.61	0.71	-1	7	22
Kirkcaldy	0.64	2.79	0.77	0	6	16
Study Area	0.81	3.42	0.77	-0	-1	-3

8.5.5 The impacts of the combined strategy (LRT and road pricing)

The combination of road pricing and LRT serves to increase the mode shift away from car use, with car trips falling by more than the individual strategy totals combined (table 8.14), and total study area trip km also the lowest of any of the tests. Both bus and LRT trip totals and trip km are higher than in the LRT-only strategy. This bears out the findings from the JATES study, concerning the 'synergy' produced when individual policy elements are combined (May *et al,* 1992), and shows that those conclusions hold when land use is allowed to freely respond to the transportation system. However, the accessibility patterns bear more resemblance to the LRT-only strategy than the road pricing strategy, indicating the dominant effect of LRT. Moreover the synergy is not great, and focused mostly upon the reduction of car trips and car trip km, where for the latter, the synergy benefit is a further 2% fall in car trip km.

As with the road pricing-only strategy, the impact on car use is greatest immediately after implementation, and falls off after this, although the overall impact is still larger than for the individual tests. This is shown by the 1997 and 2011 figures in table 8.14.

Table 8.14: Combined LRT/ road pricing impacts; transport indicators

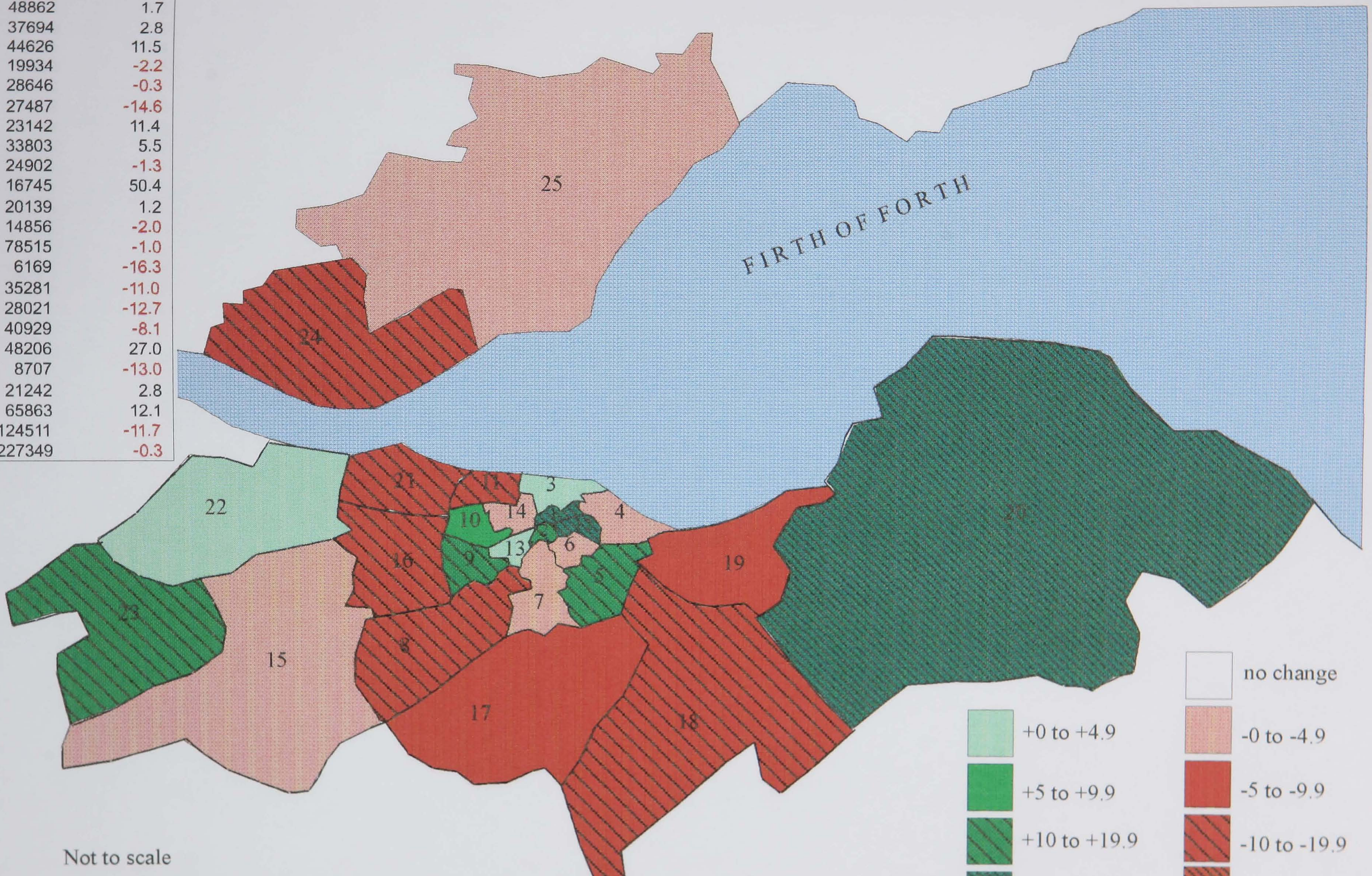
(Trips and trip km in '000s)	1997 absolute figures	2011 absolute figures	(1997 % chg. from Do-min)	(2011 % chg. from Do-Min)
Study Area total trips	928	1022	*-1.4*	*1.3*
Study Area total trip km	11702	13962	*-1.9*	*-1.4*
Total trips by car	455	531	*-19.1*	*-16.6*
Total trips by bus	307	314	*-8.0*	*5.8*
Total trips by LRT	114	105	*n/a*	*n/a*
Total trip km by car	7329	8862	*-13.1*	*-10.2*
Total trip km by bus	2380	2550	*1.6*	*13.4*
Total trip km by LRT	631	591	*n/a*	*n/a*
Mode share by car	*49%*	*52%*	*-18.3*	*-17.5*
Mode share by bus	*33%*	*31%*	*-5.7*	*6.9*
Mode share by LRT	*12%*	*10%*	*n/a*	*n/a*

The impact on activity patterns reflects the LRT strategy, but with city-centre impacts accentuated by the influence of road pricing (figure 8.17). Thus the centralisation of population in zones 1 and 12 is much greater than the LRT-only test, with a large increase in density. As with the LRT test there is a ring of decline in population around Edinburgh, as centralisation occurs, although zone 20 increases its population also as it did with the LRT-only run. For employment, figure 8.18 shows that the city centre zones increase their share of employment, to a greater extent than in the individual strategy tests. In general therefore, the distribution of impacts is a mix of the individual tests. For example zone 15 increases its employment, as it benefits from employment moving out due to road pricing, as it did in the road pricing-only strategy. In contrast those zones around the city centre generally lose employment, most likely to the LRT served city centre, despite the cordon.

The rents also show a greater increase in the city centre (for all space categories) than in the other tests (shown in table 8.15), in spite of the previous negative impacts on commercial rents from road pricing. It is thus evident that the negative impacts of road pricing are reversed when implemented with LRT, and the combined strategy produces a greater strengthening of the city centre relative to the other tests.

Population impacts from both policies		
JIF Zone	2011 RP test zonal pop	% chg from 2011 do min
1	15311	22.0
2	11776	11.4
3	48862	1.7
4	37694	2.8
5	44626	11.5
6	19934	-2.2
7	28646	-0.3
8	27487	-14.6
9	23142	11.4
10	33803	5.5
11	24902	-1.3
12	16745	50.4
13	20139	1.2
14	14856	-2.0
15	78515	-1.0
16	6169	-16.3
17	35281	-11.0
18	28021	-12.7
19	40929	-8.1
20	48206	27.0
21	8707	-13.0
22	21242	2.8
23	65863	12.1
24	124511	-11.7
25	227349	-0.3

Figure 8.17: DELTA/ START forecasts; Map of the impacts of both LRT and road pricing on population distribution (percentage change from do-minimum 2011)



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Employment impacts from both policies		
JIF Zone	2011 RP test zonal pop	% chg from 2011 do min
1	67238	12.1
2	16828	43.4
3	33731	-1.2
4	8709	-5.2
5	9301	4.3
6	7303	-2.5
7	10034	-8.4
8	3845	-8.4
9	17953	3.8
10	10305	1.5
11	11560	-10.0
12	40117	32.7
13	10874	-6.5
14	21096	-17.4
15	43780	1.1
16	12953	-9.2
17	9843	-5.5
18	10580	-6.9
19	11350	-5.8
20	13500	4.1
21	2753	-9.1
22	6347	-1.3
23	15531	-4.5
24	39704	-15.6
25	49981	-7.1

Figure 8.18: DELTA/ START forecasts: Map of the impacts of both LRT and road pricing on employment distribution (percentage change from do-minimum 2011)

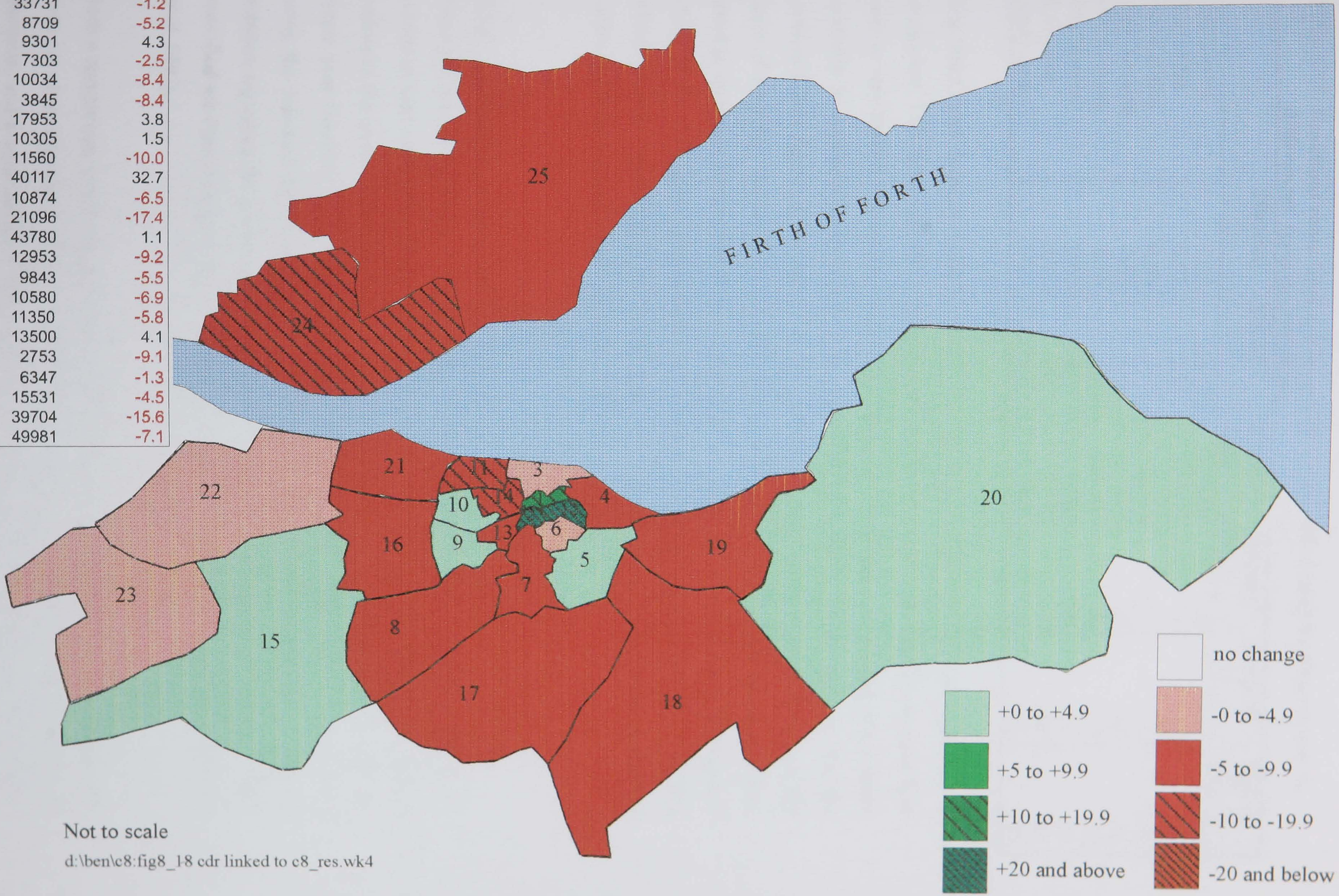

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Table 8.15: Resultant rents from combined LRT and road pricing by district, and % differences from do-minimum

	Housing	Retail	Office/ other	Housing %	Retail %	Office/ other %
City Centre	1.17	15.05	4.87	15	119	258
Rest of Ed	0.91	2.66	0.27	0	-10	-62
East Lothian	0.86	1.49	0.07	11	-2	-78
West Lothian	0.88	2.91	0.24	6	-33	-76
Mid Lothian	0.36	0.56	0.02	-8	-19	-77
Dunfermline	0.80	1.27	0.06	-10	-48	-91
Kirkcaldy	0.61	2.02	0.23	-4	-24	-65
Study Area	0.81	4.11	1.04	-0	20	30

The 'third order' impacts on the patterns of new development have not been addressed in this discussion. This is because the supply of available floorspace for residential and retail land uses is very limited throughout the forecast period, to the extent that all land that is made available is developed immediately. This means that regardless of the transport test, the patterns follow figures 8.10a and 8.11a. For the **office sector**, where available floorspace has more of a surplus, the pattern is different. Here, the increased accessibility of the combined strategy increases the profitability of development, with the result that more development occurs in the study area overall (from a 12% increase in the do-minimum 1991-2011, to 20% with LRT and road pricing). This development is concentrated to a large extent in the city centre and West Lothian, i.e. the zones benefiting from the LRT.

8.5.6 Comparison of the dynamic model impacts with the JIF model

From the discussion above, it is clear that DELTA/START predicts changes to the future pattern of land uses, as the urban system responds to the changing accessibility. This section addresses the issue of whether these changes of land use cause significant differences in the future year transport indicators between the DELTA/START tests, and comparable tests using the standard JIF (transport only) model. This will assist in discussions with the planners regarding the importance of altering the trip generation patterns over time. The JIF tests used are from a larger dataset of runs used for the OPTIMA research project (Shepherd *et al*, 1997).

Such a comparison is not straightforward as the 1991 situations for JIF and DELTA/START were not always the same. For example, DELTA/START used more up to date employment forecasts, and a more detailed disaggregation of the population. Furthermore, the trends in the do-minimum, while broadly comparable, are not identical, (due to the inclusion of the land use loop).

Note that only one JIF land use scenario is used for the comparisons. The reason for this is that only scenarios which re-arrange land uses would be appropriate for comparison with DELTA/START, not those which alter the overall population or employment forecasts (these would also constitute different scenarios in DELTA). Only economic scenarios existed for JIF, and to create an alternative to the trend would have required further resources from the consultants. In addition to this, the scenario approach of alternative land use patterns does not attempt to explicitly deal with transport impacts on land use, and requires pre-judging any impacts. This is no substitute for explicitly modelling these relationships.

These issues aside, examination can still be made of the relative percentage changes in the transport indicators for the horizon year. This is done in table 8.16, which gives a number of transport indicators and the percentage changes from the forecast year do-minimum for the LRT and road pricing strategies.

Table 8.16: Comparison of JIF and DELTA/START (D/S) forecasts

(Trips and trip km in '000s)	Road Pricing JIF % chg. from do min	D/S % chg. From do min	LRT JIF % chg. From do min	D/S % chg. from do min
Study Area total trips	-1.5	-1.2	+0.5	+2.3
Study Area total trip km	-0.8	-0.8	+0.8	-0.3
Total trips by car	-9.9	-14.4	-2.5	-1.8
Total trips by bus	+14.4	+25.9	-26	-18.4
Total trips by LRT (actual figure: `000kms)	n/a	n/a	(111.7)	(100.4)
Total trip km by car	-6.3	-8.2	-1.9	-0.0
Total trip km by bus	+17.1	+28.6	-20.8	-15.1
Total trip km by LRT (actual figure `000kms)	n/a	n/a	(704.8)	(585.7)
Mode share by car	*58%*	*55%*	*62%*	*61%*
Mode share by bus	*37%*	*38%*	*24%*	*23%*
Mode share by LRT	*n/a*	*n/a*	*10%*	*10%*

For the impacts of road pricing, the overall study total indicators from table 8.16 are very similar (total trips and trip km). However, the trips by mode are strikingly different, with the dynamic model estimating larger impacts on car trips than JIF. In other words there is a greater shift to public transport in the dynamic model, as shown by a 26% increase in public transport trips, and lower car mode share compared to JIF. Thus the impacts of road pricing on the transport system appear stronger once a land use response has occurred that is more suited to using public transport to avoid the charge, or avoiding the city centre altogether.

A similar pattern occurs for the impacts of LRT, although here for the study area there is a larger increase in trips in DELTA/START compared to JIF, the likely reasons for which (counter urbanisation and/or implicit trip rate issues) were discussed at the end of section 8.5.2 (page 206). The other most obvious change from the JIF results is the lower detrimental impact on bus patronage (and bus trip km), and the lower use of the LRT overall. This may also be due to the different patterns of land use, perhaps being more suited to bus patronage than LRT, especially if they require cross Forth movements.

For both policies, the overall mode shares are similar, the largest difference being the large predicted impact of road pricing on car mode share discussed above. Despite this, on a more disaggregate level there are some interesting differences in the travel matrices. To illustrate this the final total trip matrices for the road pricing scenario are shown in table 8.17, for trips destinating in the central area.

Table 8.17: Central area summary; comparison of JIF and DELTA/START road pricing forecasts

Road Pricing: trips destinating in central area	JIF % chg. From do min	D/S % chg. From do min
Car trips	*-23.8*	*-27.6*
Bus trips	*+20.9*	*+22.0*
Shopping purpose (all modes)	*-5.6*	*-5.7*
Work purposes: SEG1 (all modes)	*-0.2*	*-1.1*
Work purposes: SEG4 (all modes)	*-0.2*	*-3.9*
Non home based trips (all modes)	*-8.7*	*-11.4*
Total trips	*-3.3*	*-5.2*

Source: Ben_eval/SPS_eval: d:\data\start

This table shows that the impact of road pricing on trips in the dynamic model is greater than predicted in JIF alone. The greatest impact is on car trips, as would be expected, but within DELTA/START it can be seen that the impacts between purposes also differ to a greater extent than the JIF forecasts. Particularly interesting are the differing impacts between work trips by SEG, where the lower SEGs (manual and skilled manual) suffer a larger decline than the professional and managerial sectors, due to the differing distributions of their workplaces. This is in spite of the fact that the only differences between SEGs in START are the base origin-destination patterns and their car ownership levels. In other words, each SEG will respond to a rise in costs in the same way.

Also for the road pricing strategy, table 8.18 illustrates in more detail the transport matrices produced by DELTA/START. This shows that they do indeed differ from those produced by the standard JIF transport model. The table gives the difference (for total trips) between the percentage change from the 2011 road pricing forecast (from 2011 do-minimum) for DELTA/START relative to JIF. In other words, it shows how much the impacts on trips of road pricing differ between the two models.

The bottom right hand corner of the matrix gives the overall difference between the two runs, which shows that on a study area level, the overall effect on total trips is reasonably similar. The most obvious difference is the impacts on zone 16, where trips forecast in DELTA/START are much lower than in JIF, due to the error that is applying a spurious charge to this zone.

However, several other observations from this matrix show the influence of changing land uses. Firstly the DELTA/START model shows a fall in intrazonal trips within the cordoned area relative to JIF. This is likely to be caused by the displacement of activities from the city centre, and means that the transport and environmental benefits of road pricing within the cordon (in terms of reducing traffic), are being understated in the JIF transport-only model.

Secondly, the greater effect on the 'old town' of Edinburgh, in terms of losing trips, i.e. zones 2 and 12. This suggests that road pricing hits this area hard, displacing people and perhaps may be jeopardising the regeneration policies in these zones. This compares to the less severe impacts on trips in the New Town (zone 1). Thus, in terms of transport indicators, it also suggests that more emphasis should be placed on reducing trips in the new town area.

Thirdly, the increase in trips to and from zones 5, 9, 10 and 11 is most likely to be caused by displaced activities from within the cordon (indeed this is the pattern shown in figures 8.15 and 8.16 on pages 212 and 213). These inter-urban trips illustrate a changing trip distribution towards car use, as they are likely to be unsuited to public transport routes. Thus, there is a danger that road pricing could simply be shifting congestion to elsewhere within the city.

In summary there are differences in the predictions between the two models, that are interesting and important. DELTA/START tends to predict a greater impact of reducing car travel from road pricing, and less of an impact on bus from the LRT. However, of more significance than this is the differing horizon year forecast travel matrices, which not only will affect the overall results, but may lead to differing demands and pressure points on the transport network.

Table 8.18: Road pricing total trip matrix; comparison between DELTA/START and JIF road pricing impacts

(differences of JIF road pricing (% change from do-minimum) from DELTA/START road pricing (% change from do-minimum))

Origin \ Destination	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
1	-1.3	-6.1	-0.6	0.5	2.8	-3.5	2.4	-1.8	4.4	2.4	1.2	-2.4	2.6	-1.0	0.2	-16.8	-2.4	-0.6	1.1	-1.7	0.5	-0.6	-0.7	2.2	-0.8	-0.8
2	-5.9	-10.5	-5.4	-4.4	-1.7	-6.5	-2.6	-6.5	-0.3	-1.2	-2.8	-8.4	-2.0	-5.3	-5.0	-15.4	-7.0	-7.1	-3.3	-7.2	-8.1	-6.6	-6.2	-5.0	-5.5	-5.6
3	-0.8	-5.2	1.5	2.5	5.2	-2.1	4.2	-0.9	5.8	5.0	3.7	-1.1	5.0	0.2	1.2	-15.4	-1.5	0.4	0.6	-0.4	2.5	0.9	-0.6	2.3	0.6	0.5
4	0.5	-4.2	2.8	3.0	5.4	-0.3	4.7	-1.3	7.1	4.5	6.7	-0.9	5.8	1.7	4.1	-13.1	1.2	0.8	2.3	-0.7	1.3	2.6	-0.8	1.8	4.6	1.6
5	2.9	-1.9	4.9	5.5	6.0	2.8	6.6	3.1	7.9	7.5	9.2	1.9	8.7	3.1	3.0	-6.8	3.3	3.9	5.1	3.7	4.1	0.6	1.5	5.4	3.9	3.8
6	-3.7	-5.7	-2.0	0.0	2.5	-3.6	0.3	-3.1	2.1	3.0	2.2	-3.5	1.1	-2.3	-1.8	-12.4	-3.3	-3.0	-0.9	-4.0	-3.9	-0.4	-3.7	-3.6	0.1	-2.0
7	2.4	-2.5	3.8	4.4	5.9	0.2	4.6	1.4	7.2	6.1	8.4	1.4	6.5	2.6	4.4	-11.4	2.1	2.9	2.4	0.3	4.3	1.0	-0.3	5.1	4.1	2.7
8	-1.2	-5.8	-1.2	0.2	2.7	-3.0	1.6	-1.3	2.3	3.7	3.7	-4.7	2.8	-0.4	3.8	-16.7	-1.6	1.2	-0.1	-4.6	-0.7	-0.5	-2.0	-0.3	-1.3	-0.9
9	5.0	-0.4	5.4	6.4	9.2	1.0	7.4	2.4	6.7	5.9	6.4	4.6	7.4	3.5	4.8	-17.1	2.9	7.1	10.5	6.8	6.2	2.0	2.6	4.0	4.4	4.2
10	2.6	-2.0	4.8	5.3	9.0	2.4	6.3	3.5	6.0	4.9	5.4	2.7	6.3	3.3	3.9	-15.6	4.4	3.5	-0.3	5.8	4.6	3.3	1.7	4.2	5.3	3.3
11	1.2	-4.1	4.3	5.1	9.2	2.8	7.5	2.9	6.8	5.3	4.3	1.0	7.9	2.9	4.9	-17.3	4.2	0.8	5.8	1.6	3.8	2.9	0.8	7.2	5.9	3.1
12	-2.8	-8.6	-2.5	-1.4	0.8	-4.6	0.3	-5.2	1.6	0.8	-0.9	-5.6	0.5	-3.1	-2.6	-13.9	-4.2	-2.5	-1.5	-4.5	-2.8	-1.9	-0.3	3.3	-4.4	-2.6
13	3.0	-1.7	4.7	6.2	9.0	1.1	6.9	2.5	7.6	6.4	9.2	1.6	6.5	3.5	4.2	-10.2	2.6	2.8	3.5	5.2	4.6	2.1	1.2	1.2	6.3	3.6
14	-1.1	-5.2	0.0	1.3	3.6	-3.3	2.5	-1.2	3.3	3.1	2.5	-1.8	3.2	-0.7	0.6	-17.0	-0.6	1.3	-0.2	0.5	-2.3	-0.9	-0.8	0.8	0.5	-0.5
15	-0.5	-5.0	1.2	4.6	4.4	-3.1	4.0	3.3	4.1	3.9	5.2	-1.9	3.6	0.8	12.2	-7.5	0.8	1.9	5.3	0.7	2.2	4.2	7.8	2.1	3.2	2.3
16	-17.5	-17.9	-15.5	-15.2	-10.0	-14.2	-11.9	-16.4	-17.1	-15.0	-16.7	-15.8	-10.0	-16.7	-9.5	-27.4	-16.8	-13.0	-15.3	-17.2	-10.3	-16.5	-15.2	-14.9	-14.7	-15.2
17	-2.8	-5.7	-1.2	1.8	3.2	-2.3	2.8	0.2	2.6	4.1	5.7	-4.2	3.4	-1.0	0.5	-17.6	-1.4	0.0	1.2	-3.4	0.0	0.9	-1.0	-1.8	0.3	-0.6
18	-0.9	-7.7	1.1	1.5	3.3	-3.0	2.4	2.0	5.4	2.3	1.2	-2.6	2.1	2.3	2.6	-12.7	-0.3	0.1	2.2	1.5	0.5	-1.4	1.1	-0.6	0.5	0.1
19	0.9	-3.5	1.5	2.0	5.4	0.4	0.7	1.1	9.4	0.4	7.5	-2.2	6.9	-0.8	3.8	-18.1	1.8	2.9	2.4	1.4	-2.4	0.3	0.5	-2.4	2.5	0.9
20	-1.9	-7.6	-0.4	-0.4	2.9	-3.8	-0.7	-4.7	5.6	6.3	3.0	-4.2	6.5	-0.7	1.1	-14.4	-3.4	4.3	0.3	1.9	-1.9	-0.7	0.0	1.6	1.6	-0.4
21	-0.4	2.8	3.9	3.0	2.4	-2.2	5.0	-1.1	6.0	4.3	0.2	-2.2	2.3	0.3	-3.9	-15.3	1.0	0.1	-7.1	-1.5	-2.6	5.9	-3.4	2.2	1.3	0.0
22	-1.1	-6.7	0.8	2.2	1.5	-2.0	2.2	0.4	2.7	3.1	3.4	-0.3	3.2	-1.5	-0.9	-13.5	1.3	-0.4	1.1	0.3	7.0	-10.6	-2.4	0.2	1.4	-0.3
23	-1.2	-5.7	-0.4	0.3	1.1	-2.8	0.2	-1.4	2.5	2.1	1.3	-1.1	0.6	-0.4	3.2	-13.8	-1.4	0.2	-0.3	-0.4	-10.3	-4.0	20.0	1.5	0.5	-0.4
24	2.7	-0.8	3.3	-0.9	7.3	-2.3	4.0	1.6	4.2	3.2	7.4	2.9	3.0	-0.1	2.3	-17.6	-0.7	-1.0	0.7	1.2	2.7	0.2	1.5	3.0	-0.1	1.1
25	-0.2	-4.1	1.3	5.3	4.9	-0.2	3.4	-1.7	4.5	4.4	5.8	-2.9	3.1	2.1	2.9	-16.6	0.3	2.5	-6.0	1.0	0.7	1.5	0.4	-0.3	-4.5	0.3
	-0.9	-5.0	0.6	1.6	3.8	-2.1	2.6	-0.9	3.9	3.1	3.3	-2.0	3.5	-0.3	1.6	-14.9	-0.7	0.4	0.4	-0.5	-0.0	-0.6	0.1	0.8	0.6	-0.1

Differences in percentage changes.

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8.5.7 Discussion: the reliability of the DELTA/START results

From the results outlined above, it is clear that the land use response is leading to significant changes in the horizon year land use patterns. However, the reliability of these results needs to be examined. The following points are relevant:

- it is known that the model processes are working within tolerable limits. For example, in a 'no change' run, static results over time are produced;
- it is known that if transport only changes are implemented, then a gradual increase in trips and trip km arises, uniformly for each two year period. This is predictable given the steady increments given to the transport strategy data files;
- it was found that with a land use and transport do-minimum, then the results were similar to the JIF only runs, but with a lower number of trips being produced, partly due to the lower demographic predictions being generated by DELTA. The distribution of impacts is biased by the extreme growth in Kirkcaldy. If this was lower then greater growth would be expected in West Lothian, as was found in later testing outlined in Appendix IV.

These tests give some confidence that the model was capable of sensible results, and that the model processes were working correctly. However, various issues cloud the reliability of the results, and place their use firmly within a research context only. Firstly, an examination of table 8.9 indicates that there is likely to be an error occurring in the train P&R matrix calculations, due to the high (albeit relatively insignificant) growth that occurs. More serious was the road pricing error for zone 16, evident in table 8.18. However, both were easy to spot, and are good examples of how rational analysis can highlight errors when results do not meet expectations.

However, the error in the transition model could not be easily discerned in the outputs of the model, as the household forecasts (on the aggregate level) met the modellers' deductive expectations. This illustrates how even thorough error checking is likely to let through minor errors in a complex model.

Furthermore, the model sensitivities require more exploration before the model can be termed reliable. For example the large rent changes were likely to be due to over sensitivity of activities (especially employment) to changes in accessibility. Finally, the setting up of the land use scenario and 1991 database perhaps required more detailed consideration than resources permitted for this study allowed. There is clearly room for improvement in this database, especially with regard to Kirkcaldy, and also related to the agreement between the forecasts from the model and the LRC planners' own future estimates.

8.6 Conclusions

This necessarily lengthy chapter has summarised a large research effort. It has outlined the structure of the DELTA/START model system, and has described the main tasks undertaken during model implementation. This discussion has only alluded at the complexity of the model, but has included many of the key decision processes and assumptions that were made. The sensitivity of the model outputs to the assumptions in the input data have been stressed, as has the fact that for this implementation, much of the data was estimated on the basis of the consultants' judgement, rather than detailed cross sectional or longitudinal calibration.

A typology that compartmentalises the modelling implementation process has been proposed, based on the experiences gained during working with DELTA/START. This typology suggests that the bulk of the implementation requires a great deal of understanding of the model design and data requirements, especially when seeking to determine whether the first model predictions are valid or not. The difficulty in isolating errors has been examined, and divided between mechanical errors, and 'rational' errors that can only be found by careful 'deductive' examination of the model's forecasts. These problems begin to point to the need for a research tool to search for errors and assist in the explanation of results, and this is discussed further in Chapter 11.

The results from the B7 runs have been outlined in some detail. Although these were not the final results undertaken using the model for this research (further results are discussed in Appendix IV) the B7 results outlined in this chapter were discussed with the study area planners. As will be outlined in the next chapter, the fact that these results leave room for improvement does not invalidate them in terms of the aims of the Phase 2 planner interviews. This is especially the case given that while the do-minimum may still have some mechanical errors within the dataset, in comparisons of the impacts of transport on land use, the model has given some sensible results. These illustrate well the kinds of results that the model can produce, and the model processes underlying them.

It has also been shown that the forecasts from the DELTA/START model will differ, in some cases significantly, from the JIF transport-only forecasts. This applies both to the forecast land use pattern and also the transport indicators that result. For road pricing it appeared that the fall in car use could be maintained once the land use patterns adjusted to public transport routes. For LRT the strong centralisation effects for both employment and population compounded the strong negative effects on bus patronage. This suggests that for transport policies that involve radical impacts on accessibility, modelling land use response is important both for the land use and transport impacts.

The next chapter compares the DELTA/START results to those from the Delphi and LUCI/JATES methods, in order to come to some initial conclusions regarding the overall significance of transport impacts on land use for strategic planning in the study area.

CHAPTER 9
A COMPARISON OF THE THREE METHODS

9.1 Introduction

This chapter undertakes a comparison of the methods and their results. It then compares the results to the other sources of information on transport impacts on land use discussed in earlier chapters. Implications for the study area and conclusions are then drawn.

9.2 Comparison of the Delphi, LUCI and DELTA/START approaches

9.2.1 Comparison of the methods

The three methods for forecasting transport impacts on land use attempt to represent different places on the spectrum of forecasting methods that are available for spatial planning. The Delphi is a method of formalising the pool of expert knowledge on land use impacts that exists within the public and private sector; focusing opinions into quantitative responses. The LUCI model is an extremely simple modelling approach that takes the accessibility outputs of any standard transport forecasting model, and gives indicators of land use response. Finally, the DELTA/START model is a more complex modelling system that attempts to model more accurately the dynamics of the land use transport system over time.

The main features of the methods are summarised in table 9.1 overleaf. This summarises what should be obvious from the last three chapters, namely that of the three, DELTA is the most complex attempt to model transport impacts on land use, considering environmental factors from transport rather than just generalised cost, and produces the most detailed outputs. However the cost for this is a longer implementation time, a more laborious model running process (relative to the LUCI model), and a greater level of expertise is required to check the plausibility of the forecasts. The LUCI model can be seen as a simple version of the DELTA location submodel, with all the other submodels in DELTA effectively 'switched off', and only run once. As implemented in this study it is simply a spreadsheet, with the only run-time coming from the independent transport model that provides the accessibility indices.

In contrast to these two, the Delphi approach does not use a mathematical model at all, or even any explicit accessibility measure. Instead it relies upon the judgement of its panel. As such, while the models are clearly deductive, the Delphi approach makes use of the mental models of the panel members, which has the effect of concealing a clear explanation for its results. It is more of an inductive approach, and a completely independent source of evidence from the generalised cost based models.

Table 9.1: Summary features of the three methods

	Delphi	LUCI Model	DELTA/START
Method features	Use of a panel of experts, anonymous to each other. Iterative questionnaire sampling to reach a group consensus. No explicit accessibility measure used.	Hedonic analysis of components of housing value. Land use supply ignored. Logit model allocates activities on basis of changes in accessibility only.	Representation of floorspace supply, rent mechanisms, household transitions, trends in quality of urban fabric, employment change. Various factors influence activities' location choice.
Total elapsed time for this implementation	Nine months for design plus two rounds of questionnaires.	Consultants took six to eight months, 30 person days minimum.	18 months, future applications likely to be under one year.
Problems encountered	- Sample selection. - Only limited questions can be asked without very lengthy questionnaire.	- Obtaining zonal data, especially rents.	- Obtaining base year data, new model meant many mechanical and analytical errors.
Format and type of results.	- 9 zone study area. - Percentage change estimates of rents and population change.	- 23 zone (no Fife) population and employment re-distribution.	- 25 zone population, employment, household distribution, rents, new development, area quality.
General strengths	- Robust use of expert opinion and professional judgement	- Fast and can be used with any accessibility outputs. - Can add further complexity: e.g. floorspace supply.	- Simulation of key relationships considered relevant. - Dynamic over time.
General weaknesses	- Potential for sample self selection. - Potential for strategic bias. - Little explanation of results. - Uncertainty of estimates without control totals.	- Only takes accessibility into account. Nothing else assumed to change - No rent feedbacks - No time element, 'instant' changes. - No dynamics.	- Complex and time consuming to implement and test strategies. - Interpretation of results complex.
Theory base:	- Inductive : panel bring own mental models to address questions.	- Deductive. - Random utility theory.	- Deductive - Random Utility theory - Individual submodels

In terms of the comparability of the forecasting, a weakness of this Delphi was the fact that initial base year population and rent specifications by zone were not supplied to the panel. An option to include these in the information pack was rejected due to the additional data burden that this would have placed on the respondents. The Delphi therefore relies upon the panel having a common grasp of the current situation in the study area. It is also not constrained to the study area control totals used in the other methods. The LUCI model is incapable of making its own land use forecasts, and furthermore, operates with no time element. DELTA, although containing a household transition model, does not claim to be a demographic forecasting model. Instead it is intended to utilise external (usually study area wide) forecasts of population and employment to act as control totals. All these factors illustrate that the techniques are specifically suited for determining the impacts of transport on land use, rather than general urban forecasting *per se*.

All reasonable efforts were made to ensure that the strategies examined by the methods were comparable, although in the event it proved impossible to give the models identical base data. Most obvious here is the lack of a common accessibility base between the LUCI model and DELTA. Furthermore, the fundamental difference between the 'scenario' approach for LUCI, compared to the 'own forecast' approach of DELTA/START, meant that the horizon years were certain to be different. It is clear therefore that each method used its data in different ways, generating forecasts with differing base assumptions. This makes any comparison more complex, but it was not felt that this would detract from the ability to draw general comparisons between the methods.

However, these differences, both in methodology and base data meant that different findings were to be expected from the different tools. Of the three methods, the outputs from DELTA/START were expected to be the most complex to interpret (given the dynamic relationships considered), especially as the Kirkcaldy error meant that the results were likely to be biased towards Fife. This is the case compared to the LUCI model, where only one variable (accessibility) is changing. The Delphi would be expected to offer the most simplistic forecasts, given the limit of the range of factors (and their interactions) that the panel can consider in deriving their forecasts.

9.2.2 Comparison of the results

A summary table of results is given in table 9.2, with a focus upon impacts in the city centre. The first point to note is the much wider range of results available from DELTA than the other methods. However, there is no conceptual reason why any of the methods could not be applied to obtain the full set of results. For the LUCI model this would involve incorporating a rent feedback into the model. This has in fact been undertaken, in a generic and more complex version of the LUCI model, as discussed in Roberts and Simmonds (1995). For the Delphi it would involve further questions on housing prices and employment. The key constraint here would be questionnaire length and obtaining a suitable panel. Thus all of the methods can potentially be used for the examination of a wider range of transport impacts on land use than the ones produced in this study.

Even a brief glance at table 9.2 reveals that the methods predict some very different results, although the study area totals are broadly similar, especially for population predictions. However, the do-minimum estimates for the city centre show two clear discrepancies. Firstly there is higher growth forecast for the study area and city by LRC (in LUCI) relative to the Delphi and DELTA/START. For the Delphi the relatively small changes are a feature of all the results. For DELTA/START the low city centre estimates are caused by the relocation to Fife outlined in Chapter 8. Secondly, the large rent differences are also illustrative of the discussion in Section 8.6.2, that in DELTA/START changes in demand seem to have overly large influences on the rents.

Table 9.2: Comparison of the results from the three methods

	DELPHI	LUCI (LRC)	DELTA
Do-Minimum Forecasts (% chg. 1991-2011)			
Study area population growth	+2.8%	+5.9%	+4.8%
Study area employment growth	N/A	+13.1%	+4.5%
City centre population growth	+2.4%	+15.6%	-6.1%
City centre employment growth	N/A	+15.2%	0%
City centre retail rent growth	+7.7%	N/A	+25%
City centre office rent growth	+3.4%	N/A	-46.0%
City centre housing rent growth	N/A	N/A	+60.0%
LRT impacts: difference of strategy (1991-2011) to do-min change (1991-2011)			
Impact on city centre population	+0.9%	+11.2%	+15.7%
Impact on city centre employment	N/A	+8.2%	+13.1%
Impact on city centre retail rents	+4.5%	N/A	+130.0%
Impact on city centre office rents	+3.2%	N/A	+123.0%
Impact on city centre housing rents	N/A	N/A	+13.0%
Road Pricing impacts: difference of strategy (1991-2011) to do-min change (1991-2011)			
Impact on city centre population	-1.3%	+1.5%	-1.9%
Impact on city centre employment	N/A	-6.8%	-3.4%
Impact on city centre retail rents	-6.9%	N/A	-6.3%
Impact on city centre office rents	-8.8%	N/A	-21.4%
Impact on city centre housing rents	N/A	N/A	+1.2%
Combined strategy impacts: difference of strategy (1991-2011) to do-min change (1991-2011)			
Impact on city centre population	-0.6%	N/A	+27.0%
Impact on city centre employment	N/A	N/A	+21.0%
Impact on city centre retail rents	-2.7%	N/A	+148.0%
Impact on city centre office rents	-5.2%	N/A	+140.0%
Impact on city centre housing rents	N/A	N/A	+24.0%

Note: Delphi figures are averages of the zonal means, and the shaded numbers are the Lothian Regional Council Estimates. Note also that DELTA figures suffer from Kirkcaldy error (see page 194/202).

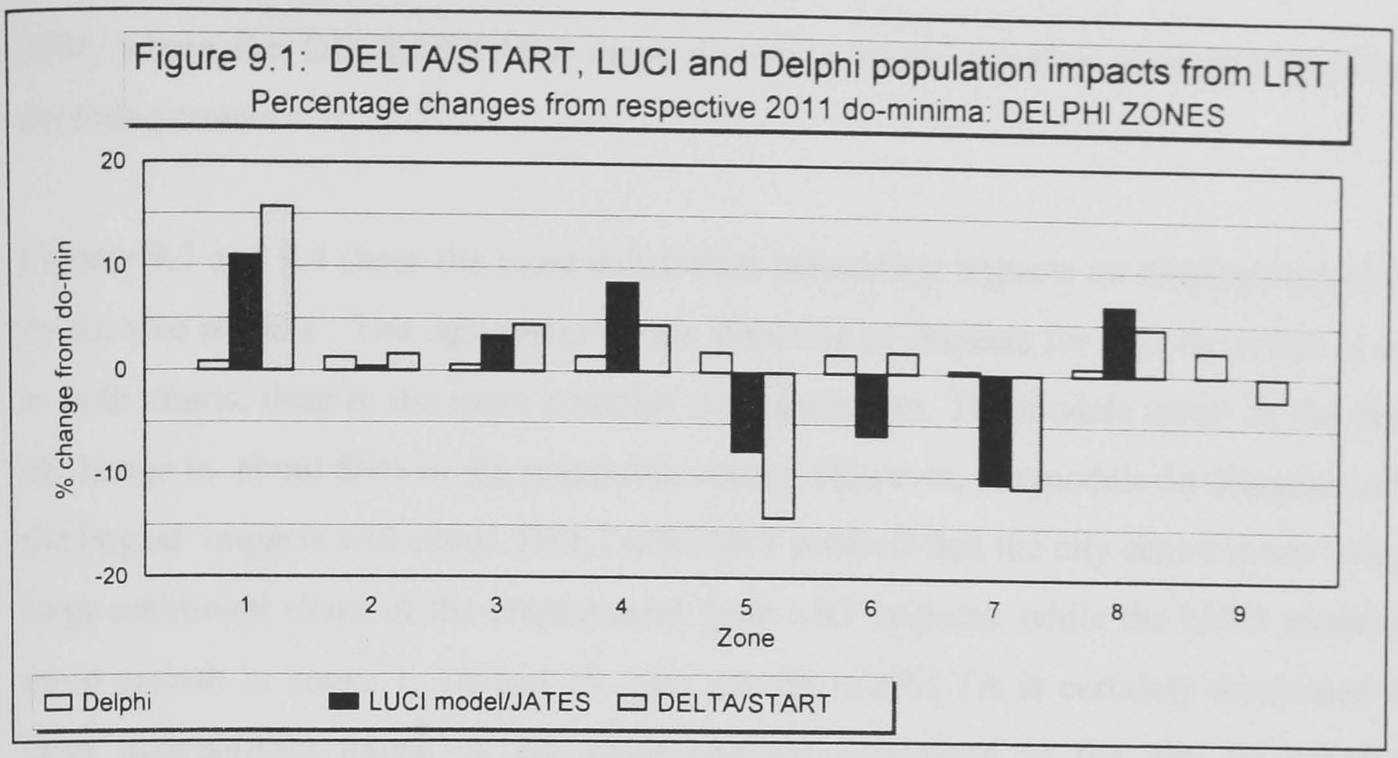
The impacts of the transport strategies in table 9.2 are interesting. The models estimate much greater impacts from the LRT than the Delphi, perhaps because the accessibility benefits were not perceived as significant by the panel. All the methods predict an activity centralising impact from LRT on the city centre, and both models produce reasonably similar results for population and employment impacts, as shown in table 9.2. In fact, while the models did agree on the impacts on the city centre, there was more disagreement on the distribution of impacts on the other zones within Edinburgh and the outer districts. More obvious are the differences in magnitude of the rent changes between DELTA and the Delphi, as mentioned above.

This contrasts with the impacts from road pricing. Although the effect is largely to reduce or slow down growth in the city centre, especially in terms of the influence on rents, the LUCI model does predict a small increase in city centre population, as does DELTA/START in terms of housing rents. In the latter however, this effect does not appear sufficient to actually alter the number of residents in the city centre. The negative impacts on employment and commercial rents are similar for both the Delphi and DELTA/START.

From the combined strategy the most obvious observations from table 9.2 are the large rent changes associated with DELTA compared to the Delphi results (similar to the differences in the LRT results). In addition, while the Delphi panel predicted that the influence of road pricing depressing city centre rents would prevail in the combined strategy, DELTA predicts that the LRT influence would dominate. This could be due to over concern for road pricing impacts in the Delphi.

The distribution of impacts can be seen more clearly in figures 9.1 to 9.4. Note that only in DELTA/START can the changing distributional impacts over time be assessed, as discussed in section 8.5.1 (pages 199-200). Therefore the results compared here are the horizon year forecasts, primarily for the data that has been mapped in previous chapters.

Figure 9.1 shows the impacts of LRT on population for each method, aggregated to the nine Delphi zones for comparative purposes. This chart displays the low responses of the Delphi relative to the other two methods. In addition there is consensus on the direction of change for the city (Delphi zones 1-4), but disagreement on the outer zones. DELTA/START shows the greatest centralising influence of population and also the greatest decrease in Midlothian (Delphi zone 7) and western Edinburgh (Delta zone 5).



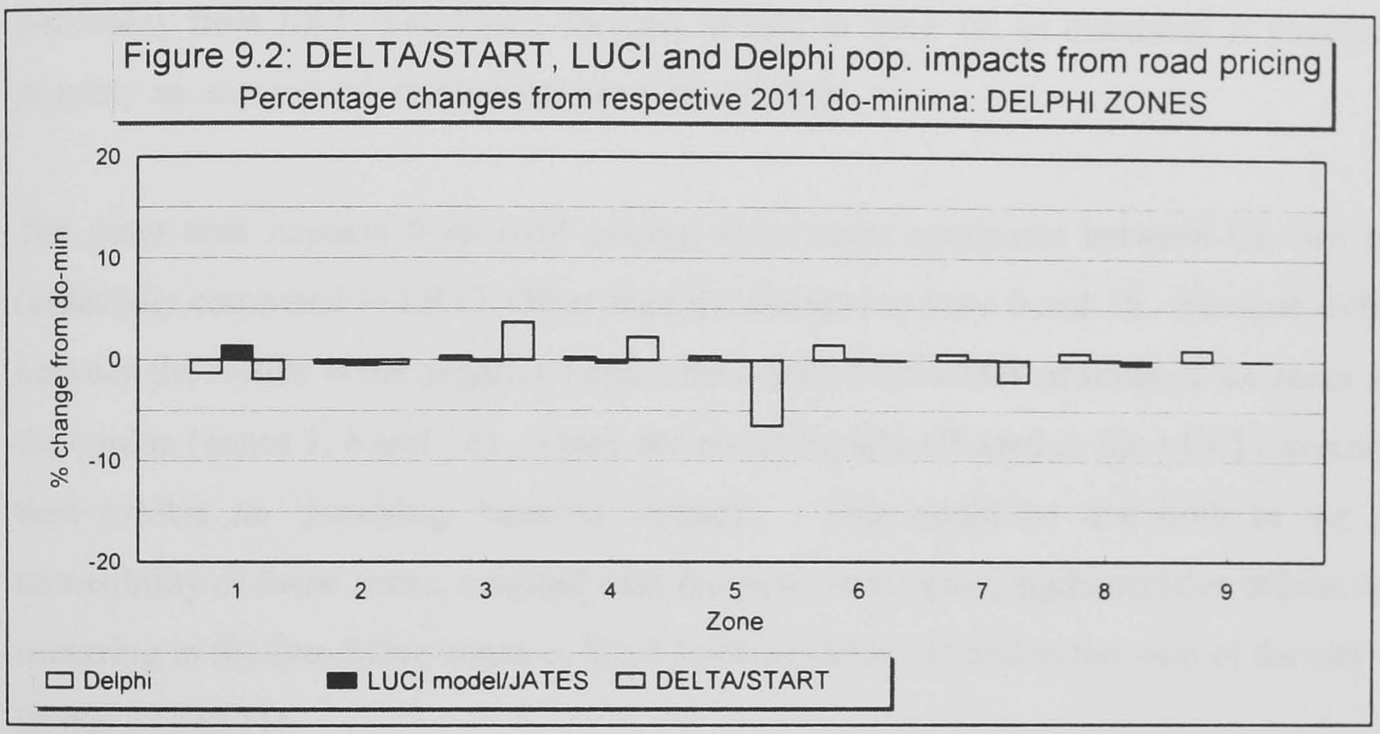


Figure 9.2 shows the zonal population data for the road pricing strategy. Here the much lower impacts from road pricing (compared to LRT as shown in figure 9.1) are evident in from all the methods, but especially from the LUCI model. DELTA/START and the Delphi both predict a decrease in the city centre population, while the LUCI model predicts a small rise. The latter can only be due to the small accessibility increase. However the DELTA/START results (where in fact accessibility in 2011 in the central area has declined from 1991) are caused by the dynamic land use response altering accessibility over time; in other words the accessibility index declines as both the cordon charge increases generalised costs, and activities move out of the cordoned area.

For both policies, the impact on the distribution of activities appears more complex in DELTA/START than in LUCI, as would be expected from the more complex interactions included in the dynamic model. For example, this is evident from a comparison of population impacts from Chapter 7 (figure 7.6, page 154) and Chapter 8 (figure 8.13, page

208), where the DELTA/START maps display a more complex pattern of growing and declining zones.

Figures 9.3 and 9.4 show the more substantial percentage impacts on employment estimated by the two models[1]. The agreement on the direction of impacts for the city centre is evident in both charts, despite the more complex disaggregation. The models agree on the direction of change in about 80% of the remaining zones. However, the models do disagree on where the largest impacts will occur. DELTA/START predicts that the city centre zones will gain a large additional share of the employment from LRT impacts, while the LUCI model places more growth in zones 1, 16 and 19. The growth in DELTA is certainly dominated by the large accessibility gains, as the environmental conditions in the city do not improve noticeably from LRT. The LUCI forecast impact in zone 19, as discussed in Chapter 7, is possibly an unresolved 'mechanical error' in JATES.

The outer area impacts from road pricing show more agreement between the two models (especially compared to LRT). Other than the changes to zone 6 and 16, the main difference between the results is the negative impact from DELTA/START in some of the zones around the cordon (zones 3, 6 and 14), which are not adversely affected in the LUCI estimates (but then exhibit no 'boundary benefits' either). This could be due both to the poorer accessibility of these zones, coupled with the positive business agglomeration effects that are occurring in the benefiting zones in West Lothian (zone 15) and to the west of the city centre (zones 10 and 11).

Clearly the differences in these estimates show the uncertainty that surrounds calculating quantitative estimates of transport impacts on land use. The rent results in particular give some cause for concern as they are so different between DELTA and the Delphi. It is likely that DELTA is allowing too great a change in the rent. For the Delphi the low level of the impacts may represent incorrect assumptions by the panel, but they are more likely to correctly reflect the past experience with regard to aggregate average rent changes. Clearly to verify this, there is a need here for some empirical study of rent changes over time, an issue discussed again in Chapter 11 (as part of the requirement identified for a better empirical framework of land use response). Thus, although the differences in some of these results are explainable, the downside is that in presenting these results to third party planners, they may well be more concerned with which do-minimum forecasts they find

[1]The Delphi did not attempt employment estimates.

more acceptable, rather than the methods themselves, or the relative changes between the do-minimum and the strategies.

Figure 9.3: DELTA/START and LUCI employment impacts from LRT
Percentage changes from respective 2011 do-minima

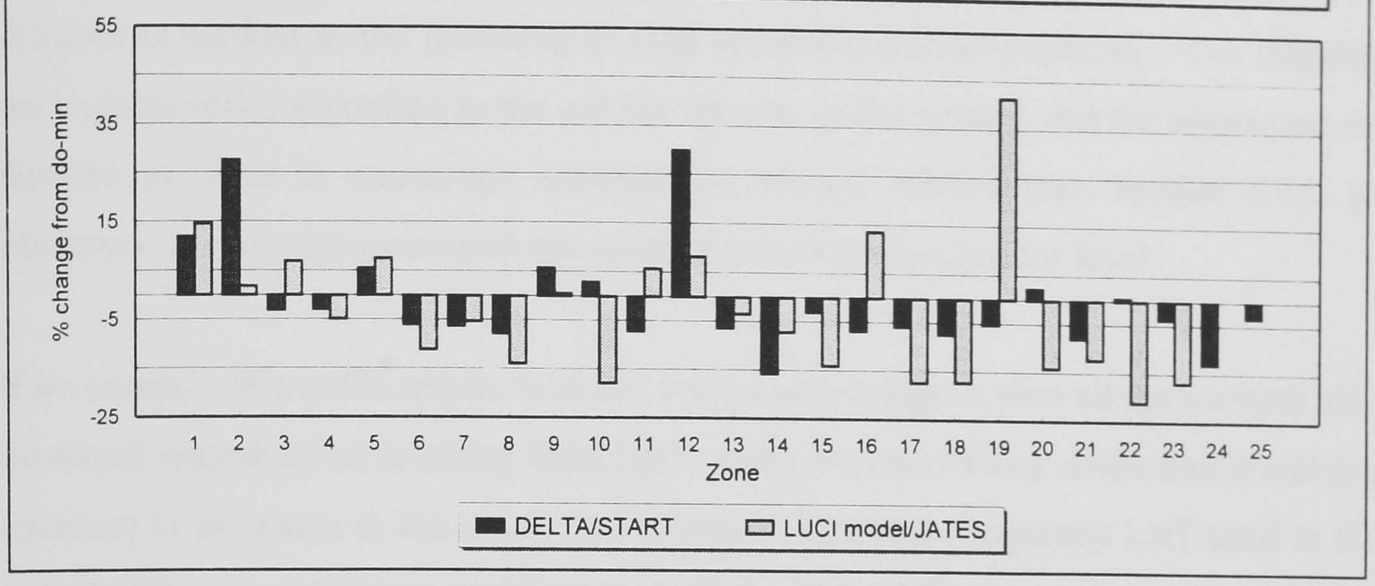
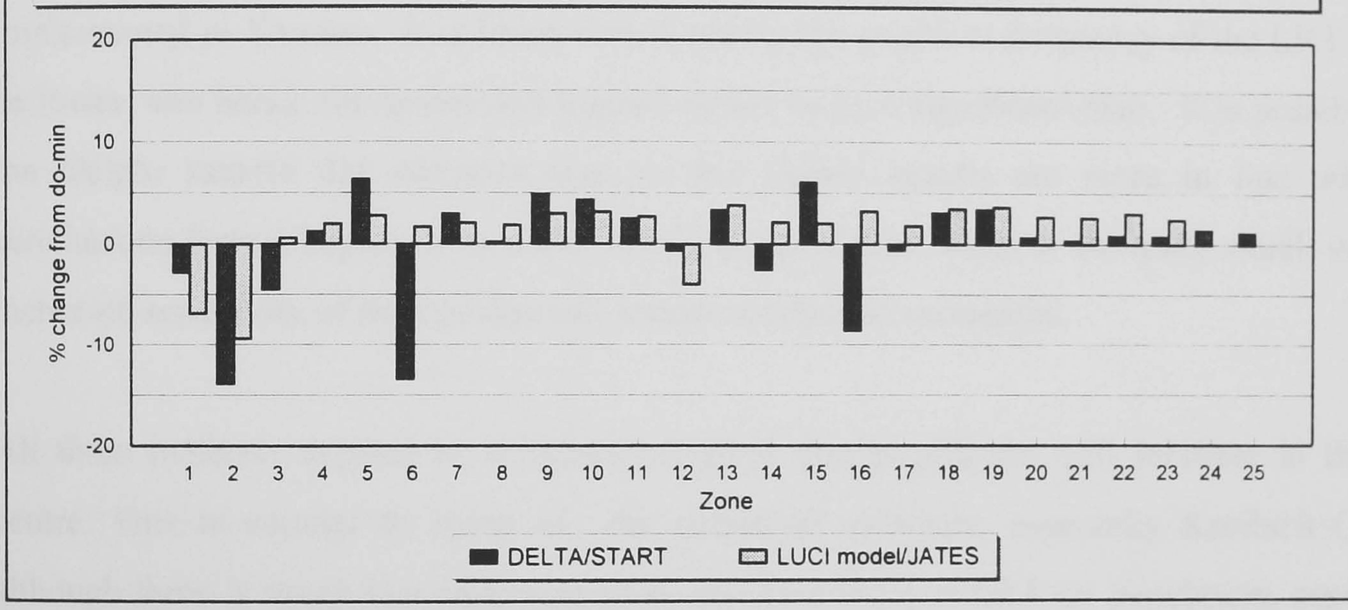


Figure 9.4: DELTA/START and LUCI Employment impacts from road pricing
Percentage changes from respective 2011 do-minima



9.3 Comparison of the three methods against other sources of evidence

The comparison of the estimates predicted for Edinburgh and its surrounding region with the evidence discussed in Chapter 3 will inevitably be broad brush. The reason for this is that most empirical results tend to focus upon the city centre impacts of LRT or road pricing, examining the policies in terms of their potential regenerative effects on city centres. Edinburgh's city centre is not in marked decline, although it is facing stiff competition from new retail and office facilities elsewhere in the region (as discussed in Chapter 5). This makes these types of policy relevant, especially in the light of the severe traffic congestion and transport related environmental pollution that the city suffers.

9.3.1 The impacts from LRT

The empirical evidence for LRT is varied, but Chapter 3 concluded that with city centre focused rail lines there is generally a centralising influence on economic activities and a decentralising influence on residences, especially of the higher SEGs. The commercial sectors tend to be more responsive than residential land uses. However, the influence of LRT is never as marked as the influence of high accessibility road locations. The magnitude of the impacts varies according to the service features of the system, and the supporting policies that are in place to encourage development around stations (see Section 3.4.1, p. 31). Moreover, the impacts examined are mostly focused on the corridor level.

If we compare this to the results from the three methodologies, then all the methods show the increased centralisation resulting from LRT, either in terms of city centre rent levels (a proxy measure) or increases in the density of activities. The high frequency LRT used in START and JATES means that the employment/commercial benefits here are much greater than the empirical evidence would suggest, greater even than the combined policy package implemented in Toronto. It is likely that in reality the practical frequency of the LRT would be lower, and hence the associated impact would be less significant also. It is possible that the Delphi sample did consider this, as the Delphi results are more in line with the conclusions from Chapter 3. In other words the predicted impacts are quite small, with an increased sensitivity of the commercial sectors relative to residential.

All three methods applied to Edinburgh predict that population will increase in the city centre. This is counter to some of the empirical evidence, especially Kreibich (1978), although there is much less empirical study on the effects of LRT on population, especially on topics such as gentrification, where the suitability of floorspace is a key issue. The Lothian Structure Plan (LRC, 1994b, para. 4.68) comments that there is limited scope for further additional floorspace in Edinburgh, but considerable scope for subdivision within the city (para. 4.71). Thus further population centralisation would be possible[2]. However as neither model matches the dwelling type to the potential occupier, the forecasts may be greater than the possible supply.

With regard to impacts in the outer areas, a general finding from Chapter 3 is that suburban residential values rise within a given proximity to a station. This would be shown on the strategic scale by rent increases in zones with LRT stops, which does occur (but not

[2]Note that the form of the accessibility index in DELTA/START and JATES means that an improvement in city centre accessibility makes the city a more attractive place to live in order to get to other locations in the study area.

consistently) in all three methods. This is more obvious in the LUCI model, which is only responding to accessibility. However, the strategic zoning (especially for the Delphi) makes detailed analysis, especially around stations, impossible. This is a particular problem as the empirical evidence of the impact on rents tends to show relatively localised impacts. The Delphi panel therefore had the difficult task of estimating the average impact across the whole zone.

Finally, an issue that was discussed in Chapter 3 was the role of LRT in the generation of absolute additional economic activity, rather than redistributional impacts. Clearly this will depend upon the size of the study area. The study area examined here, being divided into districts, could mean that planners in a given district are concerned with growth in 'their patch' rather than viewing it as redistribution within the study area. In terms of employment, the study area totals are fixed in both models, and migration cannot automatically respond to the economic conditions within the study area. However, it was found in both the Delphi and the DELTA model that the average study area rents were higher with LRT, especially in the commercial sectors, by up to 25% (see tables 8.11, page 210). This is an indication of high demand and land capitalisation, but is not of itself sufficient to say that additional economic activity has been attracted to the study area. Analysis of this type would require a wider regional economic model.

9.3.2 The impacts from road pricing

There was much less empirical evidence concerning road pricing. The Flowerdew and Stevens (1994) study has already been discussed in Section 6.9.3 (see page 133). The remaining evidence is from other modelling studies, notably the LASER model undertaken for the London congestion study (May *et al,* 1996). The LASER model estimated growth in commercial rents within the cordoned area, if only by a small amount. It seems that the Delphi panel are predicting larger impacts on the commercial sectors than the LASER model predicts for London, i.e. 5-8% compared to 1-2%. The DELTA/START model produces much higher rent impacts, with opposite directions of change, i.e. a decrease in commercial rents of -5% in retail and -40% in office (the latter being due to large amounts of available floorspace).

In terms of the impact on population, table 9.3 provides equivalent results to the LASER results (shown in table 3.8, page 44). LASER predicted no observable overall change, but this masked a net effect of professional households displacing unskilled workers, in other words continued gentrification. For Edinburgh, DELTA/START predicted a similar influx of professional people into the city, and an out-migration of households from the lower

SEGs, who generally move into the surrounding areas. Note that the out-migration is larger for the lower SEGs, suggesting that the increase in city centre rents may be forcing out those on a limited budget. Thus DELTA/START predicts a similar pattern of influences on population by SEG as LASER, but generally with a larger proportional displacement of the lower SEG households.

Table 9.3: DELTA/START: forecast percentage changes from do-minimum by road pricing; households by SEG

	SEG1	SEG2	SEG3	SEG4	Total
City Centre	3.8	0.7	-5.6	-10.4	-0.5
Rest of Edinburgh	0.1	0.4	0.5	1.7	0.5
East Lothian	-0.2	-1.0	1.7	0.4	-0.1
West Lothian	-0.0	-0.6	0.8	0.6	0.1
Midlothian	0.6	-0.2	-2.7	-3.6	-1.1
Dunfermline	-0.9	0.4	-1.0	-1.9	-0.7
Kirkcaldy	-1.4	-0.2	0.3	0.7	-0.1

The effects on the different employment sectors in DELTA/START are shown in table 9.4. Comparison of this table with table 3.7 (page 43) shows that these forecasts are very different from the LASER model. Although the sector disaggregation is slightly different between the two models, the strong negative impact of road pricing on Edinburgh city centre is evident. This occurs with DELTA even in the retail and professional services sectors, which LASER forecasts would centralise in London. The LUCI model estimates support the DELTA estimates for Edinburgh. Nevertheless, the Edinburgh findings must be taken with caution, especially the DELTA results, which have not been used on any other city dataset[3].

Table 9.4: DELTA/ START: percentage change from do-minimum due to road pricing; employment by sector

	Metal and vehicle Engineering,	Other Manufact.	Constru -ction	Retail/ Dist.	Trans- port	Financial Services	Other Services
City Centre	-2.3	-1.8	-2.1	-3.1	-3.2	-2.2	-4.0
Rest of Edinburgh	-0.2	-0.1	0.3	-0.8	-3.0	1.2	0.1
East Lothian	-0.4	-0.3	-0.2	2.3	4.0	2.8	1.7
West Lothian	0.2	0.2	0.1	2.0	3.3	1.9	0.8
Midlothian	-0.5	-0.5	-0.3	1.8	3.6	2.5	1.2
Dunfermline	-0.1	-0.0	0.1	1.8	4.0	2.9	1.7
Kirkcaldy	0.0	0.1	0.2	2.9	4.7	3.5	2.4
Total	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*

[3]This may soon change: DELTA/START is being applied to the Greater Manchester Region (Local Transport Today, 1997).

These differences between the predicted employment impacts of road pricing between the LASER and the DELTA/START model are particularly interesting. LASER estimates that the impacts on London will be marginally beneficial to employment, while DELTA START and LUCI predict negative impacts on employment. Several reasons can be postulated for these differences. Firstly, explanation should be sought within the model structures and output indicators themselves, with the models applied to the other city dataset to determine whether this is a feature of the model or the city. A key issue here is whether activities respond to identical transport changes in the same way in both models. If they do not, then logical reasons for any differences must be determined.

If, after this investigation, the results still stand, then the accessibility indicators need to be examined. For example the changes in accessibility may well be negative for Edinburgh and positive for London if the mitigation of congestion exceeds the user charge (in terms of the changes in generalised cost) in one but not the other. This is influenced by physical city factors such as urban size and morphology. Such analysis is beyond the scope of this research but is discussed further on page 279. Without further analysis, the conclusions in Chapter 3 (page 48) still stand; that there is still uncertainty as to what impacts will occur. However, an additional conclusion from the above analysis is that the impacts may not be uniform or even consistent between different cities.

9.4 Consequences of these findings for Edinburgh and Lothian

What implications do these forecasts have upon the implementation of these hypothetical strategies in Edinburgh? Although the magnitudes of the estimates vary, LRT is likely to have a centralising influence on population and economic activity in the city, hence strengthening the city centre. This of course will rely upon the existence of supporting factors, notably a supply of suitable residential and commercial floorspace. The downside of this is that overheating of the city centre may occur as space in the city runs out, and activities would be more reluctant to move into the areas of the city identified for regeneration, particularly JIF zones 5, 6 and 7. It is also likely that there would be an increased mismatch between the housing allocations identified in the structure plan and the demands of the market, which would need to be addressed.

The road pricing results may cause some concern for planners. The economic impacts of road pricing on the cordoned area appear negative from all the methods, with a decline in rents, development in the city centre and activities. Given that all the methods support this contention, it has a certain credence, and highlights the importance of examining the wider impacts, rather than simply relying on the transport benefits that road pricing is predicted to bring. However, from a modelling perspective it would be desirable to apply the DELTA/START package to Greater London, or MEPLAN to Edinburgh, to determine that the results as presented here are a feature of the study area, not the model.

Given the nature of the outer districts after local government reorganisation, it is suggested by the results that they (West Lothian and Fife especially) could expect some 'leakage' of commercial activity into the City of Edinburgh if the LRT scheme is opened. However, parts of East Lothian and West Lothian possibly may benefit from park and ride as modelled in LUCI and DELTA/START. With road pricing, the districts can expect to benefit by a small amount, especially West Lothian, but most activity appears predicted to remain with the city limits.

One other point that has not been discussed so far, but is evident from the DELTA/START and Delphi studies, is that the combined strategy goes some way to dissipate the 'negative'[4] impacts of road pricing. Thus it is very much the case that public transport improvements and road pricing should be seen as complementary in terms of their impacts on land use, as well as for the financial and transport reasons outlined in May *et al* (1992).

Finally, the precise nature of the transport policies will change the scale of the impacts. For example a lower frequency LRT service would limit its positive impacts, and a city centre residents' exemption from the road pricing charge may encourage further population centralisation. All these factors would need to be modelled in a series of Delphi exercises or model runs, both on the strategic, and then on the more local scale. A series of forecasts makes more obvious the complexity of the issues that are involved, preferably with a range of economic growth scenarios. Thus the limited runs undertaken in this research serve to illustrate the issues, rather than address them in depth.

9.5 Conclusions

This chapter has compared the model methods and results, and discussed the consistency of the findings both in terms of how they compare to each other, and how they relate to other sources of evidence. The following conclusions can be drawn:

[4]'Negative' here means a loss of employment and a decline in rents relative to the do minimum.

The methods vary a great deal in their complexity and detail. The main common element is that they are all most appropriate to the strategic scale. Thus they are designed to give the strategic planner a first impression on the direction and magnitude of likely impacts, and the interactions that will occur. They are not sufficient alone to inform detailed policy decisions. However, they should determine whether further more detailed study should be undertaken.

There are differences in the magnitudes and even some directions of results, between all three methods. The general pattern is that they agree on the impacts on the city centre, but are less united on the impacts elsewhere. The impacts from the dynamic model are generally more complex than the Delphi or LUCI forecasts. The Delphi results are of a lower magnitude than the model results. This is likely to be due to the panel's perception of average rent changes over time, and would need to be empirically validated by time series average rent data. However, given the much higher changes in DELTA rents, it would seem sensible to lower these sensitivities to produce changes more similar to the Delphi forecasts.

This situation is not helped by some large spurious results in both the computer models. This often left the researcher examining the results in terms of mechanical, rather than rational terms, i.e. looking for explanation in faulty data rather than modelled processes. It is also the case that the newness of the DELTA/START model counts against it, as there is uncertainty about what features are inherent in the model, or are features of the study area. The lack of totally consistent input data is also a limiting factor in any comparison.

Nevertheless, all of the methods produce results that are significant to Edinburgh and its surrounding region. Both policies have impacts on land use, especially important in the city centre, but also relevant to the landward districts. There are implications for road pricing in terms of its detrimental influence on rents and business activity, and for LRT in terms of how it may encourage population demands in areas not desirable in the structure plan policies.

However, the key reason for these results being important is that they show a complex series of land use and transport interactions, showing the wider influence of transport policy, and revealing impacts with a clarity that cannot be ascertained by intuitive reasoning alone.

CHAPTER 10
ATTITUDES TOWARDS THE METHODS: THE PHASE 2 PLANNER INTERVIEWS

10.1 Introduction

This chapter presents the interviews undertaken with a sample of planners regarding the results of the methods applied in Chapters 6 to 8. The aims of these interviews were to determine the perceived value of the methods and their results, as discussed in Chapter 1, namely:

- do the planners have comments on, preferences for, or objections to, the methods used?
- do the planners believe and/or accept the results?
- do the results encourage planners to conclude that transport's influence on land use should be more systematically analysed and incorporated into strategic planning?

This chapter begins by discussing the methodology for the Phase 2 interviews. Summary results are presented, and the chapter concludes with a discussion addressing the above questions.

10.2 Phase 2 interview methodology

10.2.1 Rationale for interviewing

The aims outlined in section 10.1 can be recast as follows:

1. to determine the relevance and usefulness of these types of outputs and results to strategic planning, and to isolate what kinds of planning they are most useful for (note that this applies to the type of output, rather than the actual results produced);
2. to assess the planners' views on the validity of the methods and how much understanding of the methods the planners had already, or felt they would need to have to make good use of the results;
3. to discuss the plausibility of the results themselves, and examine how this influenced the appreciation of the methods;
4. if the results were plausible, to discuss whether this influenced planners' judgements on the importance of the impact of transport on land use.

This kind of research is relatively novel in transport planning, as it is rare to obtain planners' comments on methodologies and results in a comparison of different methods for a common geographical area. It was realised at the outset that these issues are complex and detailed, and that there would not be a large pool of planners familiar with them. Therefore in-depth interviews with the relevant planners would be the best method to explore their views and gain the necessary insights. These interviews were more complex than the previous 'Phase 1' interviews discussed in Chapter 4, as they required the planners to examine the method results in advance of any discussion. This would not only require a more carefully structured interview, but would involve considerable time inputs from the planners. There was a concern that planners would have insufficient spare resources to assist in such detailed interviews.

Furthermore, within the study area, not only would the available sample of planners be small, but local government re-organisation in 1996 meant that several planners had changed positions (or councils), and the original Lothian Regional Council was now defunct (see Chapter 5). This meant that there was no clear strategic authority within which planners could be sought, nor were the roles of the planners in the new unitary district councils completely settled. There were plans for the district authorities to form a voluntary strategic planning alliance, but no clear idea of how this was to be done. As a result, this may seem to have been an unfortunate time to undertake these interviews. However, several advantages were also conferred, in that interviewing at this point allowed comparisons to be made between strategic planning before re-organisation and the prospects after it.

The method finally decided upon and implemented was as follows:

1. a sample of planners from the study area were identified and asked to participate;
2. in conjunction with the CASE consultancies, the steering group[1] were presented with the methods and results of DELTA/START;
3. the results from the methods were summarised in a concise and clear format as an 'information pack';
4. a questionnaire outlining the issues to be discussed in the interview was prepared;
5. in advance of the interviews, the information packs of results were sent to the planners, with the questionnaire;
6. using the questionnaire as a structure, the interviews were undertaken.

[1]The steering group was a small group of planners who gave comments on the development of DELTA/START. These same planners also comprised four of the six planners in the Phase 2 sample.

In common with Phase 1, the interviews were taped and the transcripts used for the subsequent analysis. Thus the key difference between these interviews and the Phase 1 interviews was that the planners were asked to discuss actual results and impacts. The above points are now discussed in turn.

10.2.2 Selection of the sample of planners

There were seven planners in the original Regional Council or Scottish Office who had been interviewed as part of Phase 1. Of these, six were still involved in strategic planning and, of these six, five agreed to take part in the research. An additional planner was also approached, who was part of 'Corporate Research' at The City of Edinburgh Council (CEC). This gave a sample size of six, as summarised in table 5.3 in Chapter 5 (page 93).

The issue of whether this sample size was sufficient was given considerable thought. The sample size within the study area could not be increased easily, although representatives from Fife or the other Lothian districts could have been found. However, the key planners with strategic experience were in the sample, and it was quickly established during the interviews that The City of Edinburgh Council was likely to take the lead in strategic issues. The inclusion of planners from Fife District Council was considered, but ultimately decided against due to study resources, the lack of applicability to Fife of the LUCI results, and the floorspace error in Fife in the DELTA/START B7 tests.

This left the possibility of interviewing strategic planners in a different region of the UK, to act as a 'control' for the interview results obtained from the Lothian planners. This initially attractive idea suffered from the problem that the control-group planners would not be able to comment on the plausibility of the results, as they would not be familiar with the study area trends. This may also detract from the planners' interest in the exercise; after all, a specific study area was used precisely to avoid this problem. However, the planners in the control-group might still have been able to comment on the usefulness of the type of results, and on the methods themselves. To this end planners in Avon were contacted, due to their familiarity with START based model applications. However, responses were unenthusiastic and therefore ultimately this avenue of investigation had to be abandoned.

10.2.3 The steering group: presentation of the DELTA / START results

Chapter 5 (section 5.3.2 page 95) reported that several planners had been brought together as an informal 'steering group' to comment on aspects of the DELTA/START development, and that three group sessions were held, the first two of which were reported in Chapter 5. The third and final steering group meeting was held at the Scottish Office and included the relevant staff from the CASE consultancies. Note that at these meetings the author attempted to observe the proceedings and assist only where necessary, in order to not to appear to be 'selling' the model. The lead roles therefore were taken by the consultants.

The aims of the steering group (for the purposes of this thesis) were to:

1. provide some indications of the form of the output that the planners found most relevant, which would determine the nature of the 'information pack';
2. provide an initial gauge of reaction towards the DELTA/START model results, and its policy relevance;
3. allow the subsequent interviews with these planners to focus upon the method and results, rather than the structure of the DELTA/START model.

The presentation consisted of a brief outline of the structure of DELTA, and then a summary of the implementation of the land use model. This involved; firstly, a discussion of the importance of the 1991 'observed' database, secondly, the choice of model parameters based upon reported research findings, and thirdly, the types of validation undertaken, focusing upon general sensitivity tests.

Following this, the main results as described in section 8.5 were outlined, focusing mostly upon study area or district level trends over time. Throughout the presentation, the novel nature of DELTA/START, compared to JIF alone, was stressed by the consultants, especially the point that land use and transport are allowed to influence each other over time. It was also stressed that the results presented to the planners were just a selection of the total range of outputs, that these were initial results only, and much more could be undertaken to refine and validate the model.

A discussion regarding the model and its results ensued. The main conclusions from this (in terms of the aims outlined above) were as follows:

With regard to the **form of the information pack** (for the subsequent Phase 2 interviews), the comments regarding the data format focused upon the need for more actual figures, rather than just graphic output, to aid interpretation. Secondly, there was a desire to see more distributional impacts, rather than study area totals. Thirdly, there was some enthusiasm to see household changes split by SEG, or employment split by sector. A more general comment raised by a planner at the City of Edinburgh Council (CEC) was to see the results for Edinburgh, rather than for the entire study area. Finally, the planners generally agreed that they would like to see the full range of different outputs, rather than one or two indicators. These points were taken into consideration in the development of the information pack. None of the planners objected to, or appeared concerned about, the proposed form of the Phase 2 interviews.

With regard to the **advantages of the method**, it was clear from some of the planners' initial comments that not all of them saw the advantages of the 'iterative' land use transport model compared to the 'single jump' START model. This may have been because many of the transport results that had been presented were in formats similar to existing START outputs. Partly this was due to the nature of the presentation, which did not seek to overtly compare DELTA/START to JIF results (in contrast to Chapter 8). In addition, the generally linear growth patterns in DELTA/START (as shown for example in figures 8.7 and 8.8; page 200) probably did not appear dynamic or novel for the planners, and may not have accorded with their own mental models of how they expected their region to evolve. Different data with greater variations (such as household types for a zone over time) should perhaps have been presented to illustrate the greater changes in the individual activities that the model could represent.

The planners were also concerned with the **reasonability of the results**. For example on the land use side, the planners wished to know how the land use forecasts from DELTA compared to the forecasts in the LRC Structure Plan, and also whether the model considered the total amounts of land in a zone, and how that is split between land uses. There was concern here that because the estimates do not accord exactly with the Structure Plan, the planners may conclude that it could not replicate those estimates, whereas with more resources this should be possible.

Some questions on technical issues were also asked by the planners seeking to determine how similar in design the DELTA model was to previous Lowry type land use models (as discussed in Chapter 2). Another technical issue addressed was the flexibility of the zoning system, which was agreed to be a limiting factor in all land use transport models. There was certainly a feeling among the district planners that in the future they would desire a more detailed zoning system within their own district. Finally, the question was asked whether the number of variables in the DELTA/START system was too high, and whether there were too many aspects that could be manipulated, both of which imply that the interpretation of the results would become overly complex. The number of variables in the model was defended by the consultants, who commented that the aim was to make the assumptions in the model more explicit, by modelling more of the aspect felt to be important in land use and transport interaction, rather than assuming that they did not change[2].

With regard to what the planners actually thought of the results, the Lothian planners commented that the focus in the presentation on total study area growth (which included Fife) was of little meaning to them, as it was not a unit that they worked with. This highlighted the importance of obtaining the views of the planners on the appropriate spatial scales for data aggregation. The over-sensitivity of the rents and the problems with the Fife data were mentioned at this meeting. The planners found the changes in outputs due to the transport strategies plausible. The road pricing impacts prompted a discussion regarding whether the cordon charge effects on business profits would simply be passed on to customers. If this is the case then the land use impacts on the business sector may be less detrimental than the model was predicting, and perhaps worse for the retail compared to the office sector (as shoppers may be deterred from driving into central Edinburgh, and therefore drive elsewhere to shop).

The meeting concluded with several Edinburgh district planners commenting that they saw land use incorporation as a positive aspect. However, they added that whether the additional cost of such a model could be justified was uncertain in the current local authority climate.

In summary, this 'steering group' meeting highlighted the importance of discussing results with local area experts; as they approach the results from a different perspective and are more focused upon study area issues. It is fair to say that in general the planners appeared cautious and critical of the results, questioning the validity of the results, and the processes in the model. It was also the case the some of the planners saw the model as still primarily a transport model. However, this meeting raised some interesting issues, especially concerning the spatial scale and form of the outputs, that were discussed further in the one to one interviews.

10.2.4 Preparation of the information pack

The next step was to prepare the results in a format suitable for the planners. The results had to be concise in order to maximise the chances that the planners would have time to examine them. However, this had to be balanced with the fact that at the steering group, the planners wanted to see a full range of the model outputs. Furthermore, a balance between tabular and graphical output had to be found, as well as a way of keeping the different methods distinct.

[2] As is assumed in simpler methods such as the LUCI model.

After careful consideration, it was decided to include in the information pack:

- a zone map;
- a brief description of each method on one side of A4;
- the do-minimum forecast population data for 1991 and 2011, in bar chart and tabular format, with additional bar charts showing the percentage and absolute changes by zone (DELTA results also included 2001 data);
- the do-minimum forecast employment data for 1991 and 2011, for LUCI and DELTA (plus 2001), in the same formats as the population data;
- for the road pricing and LRT (individual) strategies, population and employment changes from the do-minimum, with tabular outputs plus bar charts of absolute and percentage changes by zone;
- for the Delphi and DELTA; rent changes between 1991 and 2011 for the do-minimum, and then the percentage changes from the do-minimum for the LRT and road pricing strategies.

The method-summary and results for each method were printed on different coloured paper. The Delphi (yellow pages) and the LUCI model (blue pages) results each consisted of five sides, the DELTA (grey pages) section was longer, at eight sides. A sample information pack is presented in Appendix III. Note that in selecting these results for presentation, much information had to be omitted. This included any more detail of changes over time, (graphs of which had been presented at the steering group presentations, and therefore it was hoped that the planners in the steering group would be familiar with the range of results possible). The other major omission was the dropping of the combined strategy, which although interesting, was not in the LUCI set of results, and did not further the aims stated in section 10.1. Comparative data between the methods (such as used in figures 9.1-9.4 in Chapter 9) was also not provided, in order to keep the methods as distinct as possible in the planners' minds.

Three other issues needed to be addressed. The first was the treatment of the Delphi results which were on a coarser, 9-zone system compared to the other methods. Two options were available here, either to aggregate the DELTA and LUCI results into the 9-zone system, or alternatively, to disaggregate the Delphi into 25 zones, maintaining the percentage changes for each disaggregated zone. The former method was deemed the more suitable. This was primarily because the disaggregation of the Delphi means making assumptions concerning what the sample believe would happen on a finer spatial scale. This is clearly unsatisfactory. However, this zonal aggregation conflicts with the views expressed at the steering group regarding a desire for finer spatial disaggregations. In the event therefore, the 25 zone LUCI and DELTA/START results were sent to the 'steering group' planners, and all the planners were sent the 9-zone results, and the planners then asked to consider which ever they wished (Appendix III contains the 9-zone information pack).

The second issue was the treatment of the non-steering group planners. For these the 9-zone results were used due to their ease of interpretation. Otherwise, the non-steering group planners were treated in the same way as the steering group planners, although their initial covering letter contained more explanation. A third issue was the treatment of Fife. Following the comments from the steering group, it seemed sensible to exclude Fife from the study area totals, especially as it was not included in the LUCI results. However, Fife was not dropped completely from the results, as it was part of the study area for the other methods, and indeed consumed much of the growth in population in DELTA/START.

Finally, further results of impacts by SEG and accessibility outputs (for DELTA), and comparative bar charts (figures 9.1-9.4) were taken to the interviews to be presented and discussed if necessary, but were not circulated in advance so as not to overburden the planners.

10.2.5 Design of the interview structure and questionnaire

A questionnaire was thought desirable in order to structure the interviews. Furthermore, it was hoped that by thinking about the questionnaire in advance, the interview itself could progress faster and focus on the main issues of interest. The questionnaire was collected at the end of the interview.

The questionnaire was divided into four sections corresponding to the aims given in section 10.2.1. The full questionnaire was printed on green paper, and is given in Appendix III. To assist the planners in completing the questionnaire, spaces were left to write down notes. For other questions, a rating scale was used based upon an ordinal seven point scale. It was hoped that such a scale would make the planners' comments more comparable. However, as will be discussed, this aim met with mixed results.

Section 1 concerned the usefulness and relevance of the outputs to current strategic planning, asking whether the estimates provided were useful to the planners or not, and if so, seeking specific applications. It then asked whether it was considered that these results would influence the transport planning process. Finally it asked about the nature of the outputs more specifically, requesting the most appropriate format for the results.

Section 2 then considered the validity of the methods, firstly setting a context by asking the planners to give an estimate of their familiarity with the methods. Then a rating scale was used to ask how much understanding of the techniques the planners thought was required for acceptable interpretation. Note this question is complex, as the scales are not directly comparable (e.g. clearly understanding all of DELTA/START requires more knowledge than full understanding of the Delphi). Finally the section addressed the issue of confidence in the methods.

Section 3 asked about the plausibility of the results, firstly for the do-minimum, and then for the road pricing and LRT strategies. These questions again used a rating scale, but this time centred around zero, with positive numbers for agreement, and negative numbers to signify disagreement.

Section 4 asked some closing questions to indicate the planners' views on the significance of transport impacts on land use. It did this by asking planners to rate the relevance of transport impacts on land use to four aspects of planning, (1) economic appraisal of transport policy, (2) strategic economic planning, (3) trip generation impacts, and (4), understanding the benefits of integrating land use and transport policy. Finally, space was left for additional facets of planning the planner felt had a relevance for transport impacts on land use.

10.2.6 Interview implementation

The questionnaire and information pack was discussed in depth with members of the collaborating consultancies, as no formal piloting was possible (as the sample was so small). The six interviews were undertaken in July and August 1996, taking an average of two hours each. All of the planners had considered the questions in advance. The Scottish Office (SO) planners wished to be interviewed together, although their independent views were sought when possible. The SO planners had also not completed the questionnaire in advance, but did so during the interview, with the exception of the questionnaire Section 3, as will be discussed below.

10.3 Findings from the Interviews

The main points from the interviews are examined below, with the tables reflecting the rating scores that the planners gave. This was often two adjacent points on the scale, rather than one, which probably reflects both the arbitrary nature of the scale and the uncertainty of the planners regarding some of these issues. Where there are two planners from the same department, (who gave individual scores), both scores are given in a split box.

10.3.1 Relevance of the outputs to strategic planning

Question 1.1 asked whether the planners felt that the outputs from the methods were relevant to the work that the planners currently did. As shown in table 10.1, the ratings are not uniform. The view from the SO was that the results were relevant, but not to the work that they actually do. They are more concerned with strategic policy development, rather than using any quantitative results themselves. The low score from WLC was explained by the fact that few large transport schemes are on their agenda at present.

Table 10.1: Responses to question 1.1; relevance to planning

Question 1.1: *Are the outputs of this kind relevant to the work that you currently do?*	Score *(7= very relevant, 1= not relevant at all)*	
Scottish Office Planners (SO)	2-3	
CEC Corporate Strategy (City of Edinburgh Council)	5-6	6-7
CEC Corporate Research	6	
West Lothian Council Planning Services (WLC).	2-3	

It was the planners at CEC (City of Edinburgh Council) who said that the results were of more relevance to them, as shown by their scores. They felt that the merging of their planning and transport (engineering) departments, coupled with policy guidance such as PPG13 made examining land use and transport together very relevant, although they did have reservations, as will be discussed below.

Question 1.2 asked for specific applications where transport impacts on land use would be important. The applications mentioned were primarily in 'what if' testing, of the impacts from potential policies. Relevance in developing structure plan policies was also mentioned, especially examining the regeneration potential for specific districts of Edinburgh. A CEC planner mentioned that an area of interest would be in examining how great increases in accessibility would have to be to invoke development, in other words, examining the relationships at a more theoretical level.

The general response to question 1.3, asking about how such information may influence the decision making process, was somewhat defensive. Planners commented that land use planning decisions were taken '*with transport in mind*' (Int. 4c). An example given was the focus on the SE Wedge resulting (in part) from the conclusion in JATES that there was spare transport capacity in this area. There was a common view that was neatly summarised by one planner as:

> *'models will never have a revolutionary influence on policy, but rather tend to support or refute arguments developed elsewhere'* (Int. 3c),

which tended to dampen some responses to this question, as shown in table 10.2. It is interesting that this statement was also one of the central findings of Forster (1996). One SO planner commented that plans today are often put together without forecasts of transport impacts on land use, and that he wondered whether they were noticeably worse than plans produced from forecasts that had considered land use and transport together.

A further issue here was that even if significant impacts on land use were forecast from a transport policy, the policy would be likely to go ahead if other transport related issues dominated. In other words, the importance of predicted transport impacts on land use may be outweighed by other transport or economic arguments. However, they recognised that there is still benefit here in having an understanding of what the impacts are likely to be, for example so that attempts could be made to mitigate undesirable impacts.

Table 10.2: Responses to question 1.3; influence on policy

Question 1.3: *Would information of this kind influence the decision making process for transport schemes / policy?*	Score *(7= very much so, 1= not at all)*	
Scottish Office Planners	2	
CEC Corporate Strategy (City of Edinburgh Council)	4	6
CEC Corporate Research	6	
West Lothian Council Planning Services.	5	

Question 1.4 asked about the level of detail required to maximise the usefulness of the results. Most planners thought that the 9-zone system was too coarse even for broad policy development, and all the 'steering group' planners used the 25-zone results. However, there was also the comment that any more than 25-zones would be too many for easy or rapid assimilation. However, it was also true that the more technically minded the planner was, the more detail was sought. Most of the planners commented that the analysis of the impact would depend upon the zone system and size, and a coarse zoning would lose more localised impacts.

Zone boundaries were also discussed. For example the WLC planner commented that zones oriented on transport corridors were of most relevance to the districts surrounding Edinburgh. The rigidity of zoning systems was seen as problematic as 'what if' testing may well wish to alter the size or boundaries of the zones to examine different impacts. The quoted example was the 'South East Wedge', (JIF zone 5), which the planners may wish to subdivide further. Geographic Information Systems (GIS) were advocated by the Corporate Research planner at CEC as the way to overcome this limitation.

Disaggregations by SEG or SIC were generally dismissed by the planners as being over complex for the issues that strategic planning had to deal with[3]. How much of this was due to fact that this was *'an unknown level of sophistication'* (Int. 3c) is debatable. However, aggregation was often favoured (especially in presentation) *'for the sake of simplicity'* (Int. 4c). Again, the more technically minded the planner, the more interest there was in greater detail in the results. In terms of the issue of intermediate years, the interviews reinforced the views from the steering group meeting. The horizon year (for the structure plan or forecast period) was ultimately the year of interest. Intermediate years, while interesting, were not seen as essential.

The planners were asked about the additional outputs from DELTA, particularly the rent data. They were generally unenthusiastic about these, commenting that, other than in economic appraisal (which has strict guidelines about what can and cannot be included; and anyway cannot easily deal with changing land uses), it was the distribution of activities that was ultimately of most interest.

However, it should be noted that despite these comments, one planner said that the activity impacts from the transport strategies did make more sense when examined in conjunction with the impacts on rents. Thus although the rent data appears not to be of direct policy interest to the planners, it is useful in the explanation of the results. The same comments were made regarding the accessibility distributions, which were potentially useful (1), in helping the planners interpret results, and (2), as an indicator of 'system performance', but were perceived as too complex to be used in public consultation. The use of accessibility was also limited by the coarseness of the spatial zoning, another area where GIS may offer a potential way forward (if point based accessibility measures are possible).

10.3.2 The validity of the methods

Question 2.1 asked for the familiarity of the planners with the methods. Two of the planners had experience of Delphi techniques outside this research project, although none had seen it used in this context. Those planners familiar with JATES knew of the LUCI model, and that its findings generally reinforced the JATES transport strategies. No planner claimed to

[3] It is of course possible that the strategic planners were not keen to deal with the distributional or social equity issues that such analysis would imply.

be familiar with DELTA beyond a basic understanding of the submodels (nor really could they be, given the information that was provided: see Appendix III). In summary, as table 10.3 shows, the LUCI model was given as the best understood, probably due to the JATES work.

Table 10.3: Responses to question 2.1; previous experience

Question 2.1: *How familiar are you or your department with these techniques?** Score *(7= very familiar, 1= not familiar at all)*	Delphi		LUCI		DELTA/ START	
Scottish Office Planners	2		2		2	
CEC Corporate Strategy	4	5-6	5	5-7	4	3
CEC Corporate Research	4		7		5	
West Lothian Council Planning Services.	4-5		5		5	

* the table shows the personal scores

Question 2.2 then asked about how much understanding of the technique would be required for acceptable interpretation of the results. As table 10.4 shows, not all the planners felt that this was an easy question to answer, especially if they were not familiar with the technique. However, the responses do show that the planners believe that a proficient understanding is required, in other words enough to be able to ask *'searching questions'* (Int. 1c).

Table 10.4: Responses to question 2.2; understanding

Question 2.2: *How much understanding of the techniques is required for acceptable interpretation?* Score *(7= full understanding, 1= none at all)*	Delphi		LUCI		DELTA/ START	
Scottish Office Planners	-		-		-	
CEC Corporate Strategy	5-6	5	5-6	5	5-6	5
CEC Corporate Research	-		4		6	
West Lothian Council Planning Services.	5		5		5	

Note: '-' implies that no response was given.

Most of the planners commented that they would never receive results without the consultants' own interpretation of them. Although the CEC Corporate Research planner said that this analysis would then be *'reworked'*, the impression was that it was the consultant who came to the initial conclusions regarding the significance or otherwise of the results. That aside, the planners said that a proficient understanding was required in order to be able to give well founded advice to the councillors. This meant that the information packs, with no discussion about the results, were untypical of the results that planners would receive. A CEC planner gave the Delphi no score on the basis that the method precludes the possibility of explaining the results.

The SO planners did not feel able to give scores for question 2.2, and hence the discussion focused upon the ways that a planner's confidence in a method is acquired. This may be via empirical validation of a model's predictions, or a well tried and tested method whose sensitivities and assumptions are well known. However, more than this, confidence can depend upon the marketing and reputation of the consultant implementing the model. The impression was given that a reputable consultant can more easily adopt a *'black box'* methodology (Int. 1c). Within a given method, every forecast or impact would have informal 'confidence bands', indicating the belief that the planners place in the results. Thus just because there is confidence in a method, does not mean that all the impacts are seen as equally reasonable.

Question 2.3 built upon this by asking how confident the planners would be in accepting the forecasts from each of the methods. The responses are shown in table 10.5, and appear higher than the comments from the planners would suggest. On average, the Delphi scored the lowest, as the planners felt that the method was too subjective, too much of a 'black box' and open to strategic bias (see below). However, the more senior planners considered the results of expert opinion to be useful for informing policy, likening it more to market research than to quantitative estimates of change.

Table 10.5: Responses to question 2.3; confidence

<table>
<tr><th>Question 2.3: How confident would you be in accepting the forecasts of each method?
Score (7= very confident, 1= not confident at all)</th><th colspan="2">Delphi</th><th colspan="2">LUCI</th><th colspan="2">DELTA/ START</th></tr>
<tr><td>Scottish Office Planners</td><td colspan="2">4</td><td colspan="2">5</td><td colspan="2">5</td></tr>
<tr><td>CEC Corporate Strategy</td><td>4</td><td>4</td><td>5</td><td>4</td><td>5</td><td>4</td></tr>
<tr><td>CEC Corporate Research</td><td colspan="2">3</td><td colspan="2">4</td><td colspan="2">5</td></tr>
<tr><td>West Lothian Council Planning Services.</td><td colspan="2">6</td><td colspan="2">6</td><td colspan="2">6</td></tr>
</table>

The two models obtained similar scores. The CEC corporate research planner felt that the simplifications in LUCI were too limiting and that this reduced his confidence in it. The others were just as likely to accept the results from one as the other, provided that they had confidence in the calibration and method. However, they were more likely to gain confidence in a method where explanation for the results could be obtained.

On the other hand, some reservations were expressed concerning the complexity of DELTA/START, partly because it may inhibit interpretation of the results, and partly due to the extra costs of implementing such a model. After all, one planner added, if an indication of the trends is sufficient, is the extra complexity worthwhile? However, the level of accuracy (or certainty) required in a forecast was one element that the planners were very unsure about, and is likely to vary depending upon the study in question.

Perhaps the main point from question 2.3 was that faith in a technique does not vary greatly on the basis of the technique itself (i.e. the scores in table 10.5 are reasonably constant across methods), but upon who is implementing the methods, and the confidence of the planners in them. Furthermore, it was clear that more empirical evidence is required to convince planners of the circumstances where transport really does influence land use, to compare with the forecasts from the predictive methods.

Questions 2.4 and 2.5 asked the planners to give their views as to the weaknesses and improvements they would like for each method. The list of weaknesses was the longest for the Delphi. The planners thought that it was open to subjective bias, especially if the sample were drawn from a single profession, and over simplification, where the Delphi panel may only concentrate on a single dominant issue (for example the impact of road pricing on the city centre, and ignoring outer area effects). Doubt was also expressed about the ability of any panel member to interpret such large amounts of data. Hence this would limit the complexity of the issue that a Delphi could deal with. Finally, the Delphi offered no explanation for its predictions. In summary, the following view was common, that they *'would not accept the Delphi estimates without further supporting evidence'* (Int. 3c).

The improvements that would increase confidence of the planners in the Delphi method would be their involvement in the questionnaire development, and in the selection of the panel. One planner commented;

> *'if the people and the questions were right, we would probably place quite a lot of confidence in it'* (Int. 1c).

The LUCI model was criticised as being too simplistic, in that so many factors are held constant. The DELTA/START model was seen to be weak primarily as the planners did not feel as though they had a thorough understanding of the complex model. Several also felt that they did not understand the treatment and assumptions concerning land use policy. It was clear that if the planners felt uncomfortable with the model or its assumptions, they would be less likely to use it. As one said;

> *'people in my line will not be satisfied if they have a complex model which they cannot understand'* (Int. 2c).

For both models, the methods to increase the planners' confidence involved increasing their understanding of the processes in the model, and being able to validate the results. The theoretical basis of the models was not questioned, in that the planners felt that if the relationships were plausible (and more importantly the results sensible) then conceptual objections are unlikely. This accords with the conclusions of Bell (1994), that a working model that produces plausible results is more important than having a perfect theoretical base[4]. Coupled with this was the issue of client control over the model, in other words the ability of the client to use the method once the consultant has finished. Some planners held the view that the more control was passed to the authority, the greater the confidence required in the technique, but that ultimately more understanding will be gained from the planners ability to do their own tests.

The issue of calibration was discussed in several of the interviews, as a means of building confidence. The general view was that planners needed some evidence that a model had been calibrated, preferably locally. For example one planner commented that another model applied in Lothian but using parameters (and possibly results) derived for the USA was not particularly well received. As calibration of either model for this research was not discussed in detail, this failing may have contributed to the lack of confidence of the planners in the techniques.

An important process for improving confidence in the methods relates to how far the planners have been involved in the model development. This was part of the purpose of the steering group meetings, and given the responses to question 2.4, three meetings were clearly insufficient. Question 2.6 therefore asked the steering group planners to clarify the level of involvement that they would desire. The results are shown in table 10.6, and show that more involvement was required, the amount directly proportional to the complexity of the method. The upper limit of involvement was more difficult to determine, the planners commenting that in a 'real' steering group, the meetings would be closer together (rather than every six to nine months as in this research). It is also likely that the planners would have more of an interest and involvement in work they themselves had commissioned.

[4] However, it must also be true that a sound theoretical base allows the rational interpretation of results, as much as the structure of the modelling system.

Table 10.6: Responses to question 2.6; involvement

Question 2.6: *Compared to the 3 group meetings for the DELTA/START development, how much more involvement is required?* Score *(+3 much more involvement, -3 much less involvement, 0 current situation acceptable)*	Delphi	LUCI	DELTA/ START
Scottish Office Planners	+2	+2	+3
CEC Corporate Strategy	-	-	+3
CEC Corporate Research	0	+1	+3
West Lothian Council Planning Services.	-	-	-

Note: '-' implies that no response was given.

10.3.3 The plausibility of the forecasts

This section was the least well answered by the planners. The SO and WLC planners did not attempt this section at all (unsurprising given their earlier comments about not usually having to do this type of analysis), but did offer some useful comments during the interviews. The estimates that were given by the other planners are presented in table 10.7.

Firstly, for the do-minimum results, the Delphi forecasts were criticised for their positive skew (i.e. no zones were declining). Most of the planners believed that population will decline in central Edinburgh due to a lack of space for new housing coupled with decreasing household size. The LUCI do-minimum estimates (which originated from LRC), were thought the most likely projections, which was not unexpected given that LRC planners had originally derived them. Throughout, the reasonableness of the DELTA/START results suffered due to the excessive growth in Fife, especially for the population predictions. Despite this, one planner commented that DELTA/START *'had the edge in terms of consistency'* (Int. 3c).

It was also the case that the planners with the 25-zone results (for DELTA/START and LUCI) were able to provide more precise comments and more detailed criticisms. Several discrepancies were highlighted, for example, a lack of growth of population in Musselburgh (in zone 19) compared to what was expected by the planners. Furthermore, zones 6, 7 and 8 all lost population in the forecasts, when these have been subject to heavy government investment to mitigate their deprivation since the early 1990s. One planner commented that these results could be seen as politically unacceptable, and hence unpublishable, as they show the policy having a negligible impact. In fact, this policy was not modelled within DELTA, (and indeed would only be applicable on the strategic scale if it was having a marked effect on the overall environmental quality in the zone).

Table 10.7: Responses to questions 3-1 to 3.3; plausibility

Question 3: *How strongly do you agree or disagree with the following forecasts:* Score *(+3 strong agreement, -3 strong disagreement)*	Delphi		LUCI		DELTA/ START	
DO -MINIMUM						
CEC Corporate Strategy	+3	-2	+3	+2	+2	-3
CEC Corporate Research	-1		0		-2	
LRT IMPACTS						
CEC Corporate Strategy	+1	+2	+3	-2	+3	-1
CEC Corporate Research	-1		-2		-1	
ROAD PRICING IMPACTS						
CEC Corporate Strategy	+1	+2	+2	+2	+2	-2
CEC Corporate Research	-2		0		-2	

As thought likely, the planners were more at ease discussing the do-minimum forecasts than the transport impacts on land use. However, with regard to the impacts from the LRT, the planners felt that both LUCI and DELTA/START predicted percentage changes larger than they would have expected, although the direction of the changes accorded with their views. From discussion it was noted that the planners felt the DELTA/START impacts made more 'sense' than the LUCI results. One explanation given for this was that the rent graphs allowed some 'transparency', i.e. the impacts could be traced through the results. In addition, the more complex response from DELTA/START may appear more likely than the simplistic responses in LUCI. There is also the possibility that not providing the accessibility distributions prevented more explanation of the LUCI estimates. Considerable discussion with several planners focused upon whether the LRT centralising influence on population to the city centre was reasonable, given the available housing supply within the city.

With regard to road pricing, the planners generally commented that they found these results easier to interpret than the LRT results, probably due to the focus on the city centre. As could be seen from table 10.7, the LUCI model forecasts from road pricing were seen more favourably than the other methods. The Delphi forecasts were generally accepted, as they also accorded with the planners views, although one planner was concerned that strategic bias may be an issue here (thus lack of explanation for the results again appearing a problem). From the DELTA/START results, the strong response in zone 16 (losing population) was at odds with the perceptions of the planners: This zone is one of the most affluent in Lothian and would expect to absorb some of the employment that does not locate in the city centre. However, the general growth of West Lothian compared to the south and east as a result of road pricing was found acceptable. Several planners commented that further examination of road pricing for Edinburgh would probably be targeted at the social and economic impacts of road pricing, rather than the performance of the transport system.

It is clear that in discussing plausibility, the forecasts could not be separated from the methodological issues of transparency and explanation, both a function of the theoretical underpinning of the method. Thus DELTA/START was able to show an advantage over the other methods. However, note that rent feedbacks can be added to the LUCI model, providing something of a 'half-way house' of complexity between the two modelling systems.

10.3.4 The importance of examining transport impacts on land use

The final questionnaire section (4) addressed the issue of the importance of transport impacts to strategic planning via a discussion of its potential uses. The results are presented in table 10.8. The first issue (the additional costs or benefits of transport policy), implies extending the remit of transport impact studies into land use and activity patterns, and examining additional impacts such as rent capitalisation[5]. The scores are not particularly high, reflecting the planners' views that they rarely dealt with economic matters, and transport (either road or public transport) appraisals were governed by tight time scales and very strict criteria for assessment. The CEC planners implied that change would have to come from the national level. However, examination of the comments from the SO planners revealed that the central government planners themselves did not rate this application as particularly important.

The ability to examine the potential evolution of the urban area was seen as more relevant by most of the sample. However, this question was seen as a little unfocused, as urban evolution would usually be studied as part of the pursuit of other goals, for example structure plan derivation, or environmental assessment. The rise to prominence of sustainability as an objective for the region was the underpinning rationale for an interest in using land use and transport to reduce traffic growth.

Impacts on trip generation were seen as more important by the transport (as opposed to the land use) planners. Those in the CEC commented that if JATES was re-commissioned they

[5] Note this was not intended to imply that rent capitalisation can be used in economic appraisals, as in most cases capitalisation would be considered double counting the primary transport benefits. However, rent capitalisation does have equity and distributional significance.

would want a fully dynamic land use transport model, partly to take this factor into account. However, the planners did not ask whether the comparison of JIF with DELTA/START yielded significantly different trip distributions, but did seem to consider that they would be different (as indeed they are). Whether these trip distributions could be captured via a standard JIF model used with a range of scenarios was discussed as an alternative possibility, but this of course would not assist in determining the impacts of transport on land use. Furthermore, one planner commented that in JATES, there appeared to be little interaction between land use and transport, in that the transport indicators under different scenarios were not that dissimilar, a result which LRC felt to be somewhat counterintuitive.

Table 10.8: Responses to question 4; significance and importance

Question 3: *Please rate the importance of these tasks to strategic planning in general:* Score *(7 - very important, 1 - not important at all)*	Scottish Office Planners	CEC Corporate strategy planners		CEC Corporate Research planner	West Lothian Council planner
(1) To examine the additional benefits or costs of transport policy (e.g. land capitalisation)	3-4	3	5	6	3
(2) To examine the implications for urban form and economic development from transport policy	5	7	5	4	5
(3) To examine the changes to transport demand as a result of the patterns of trip generation.	6	5	6	5	5
(4) To understand the potential benefits of integrating land use and transport policy.	6-7	7	5	5	5
(5) Other: (suggestions from the planners)					
- derivation of the structure plan (justification for policy)	-		5	-	5
- assessment of the sub-regional four CEC development areas	-	6	6	-	-
- location of new settlements	-		4	-	-

Equally important was the broader issue of using transport impacts on land use to contribute to integrating land use and transport planning, a view especially prevalent within CEC and WLC where the planning and transport departments had been merged as part of re-organisation.

The other uses for assessing transport impacts on land use were largely concerned with the use of a dynamic land use transport model to address the key planning issues within

Edinburgh. Thus specific issues such as ways to improve the four 'focus areas'[6] within Edinburgh, or the placement of a new town were discussed. Within West Lothian, the issue mentioned was determining ways to prevent 'leakage' of population and employment out of the district. Both the SO and CEC mentioned the importance of having a hierarchy of models, with the more detailed models overcoming the limitations of the coarse zoning from the methods discussed at the interviews, and the strategic models used to highlight general policies, impacts and directions of change.

10.4 Discussion

This section uses the interview findings from this chapter and Chapter 4 to address the aims presented in Section 10.2 page 240, and in doing so, draws together the essential conclusions from the interview work.

Firstly, it is useful to review the success (or otherwise) of the interview technique. Without a doubt, the interviews obtained some interesting findings from the planners, in considerably more depth than was possible from the steering group sessions. Furthermore, more direct comments on the methods were possible because working examples had been presented. This was felt to justify the large effort involved in this 'in-depth case study' approach.

However, these results also revealed that in this exercise the planners were asked to undertake a task quite different from normal planning. The main reason for this was that the information pack gave only the raw data, asking the planners to come to their own conclusions as to the key trends and important results. This appeared at odds with standard practice, where a written discussion would accompany any commissioned forecasts. However, for this research it was desirable for each planner to reach individual conclusions about the results.

The scoring system was useful in terms of eliciting more precise views from the planners, and providing general grounds for comparison between the different interviews. However, as it is unknown if all the planners would give exactly the same score if given the same conditions, it is difficult to use these results for detailed comparisons. Evidence that the scores should be used with caution came from the fact that the planners' comments were

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[6]Four areas identified by CEC as either requiring regeneration or environmental improvement. These are the City centre, Leith (Waterfront), the Airport and the SE Wedge.

generally consistent with each other (i.e. there were few issues on which planners held opposing views), while this is not immediately apparent from the range of scores given (for example question 2.1, page 252).

The other potential weakness of this methodology is in generalisation, and the representativeness of the sample. The views of the planners in Lothian have found to represent a cross-section of opinion, but be relatively homogeneous towards the methodological approaches. However, how would the views of these planners compare to those in the rest of the UK? In considering this, it is problematic that most of the sample were from a department known to have an active interest in land use and transport issues (as was the majority of the sample in the Phase 1 interviews). In more traditional planning departments, less attention may be paid to assessing transport impacts on land use. However, the cross section of technical and policy planners is likely to be similar in many departments. Certainly the views from the planners in the Phase 1 interviews suggested that thinking on appropriate methods and current objectives is similar among planners in many urban areas.

Thus although confident generalisation is not possible, these types of views are likely to be commonplace among planners, and applicable to other growing urban areas facing the transport and land use issues discussed here and in Chapter 5. This includes practically all growing regional centres such as Leeds, Bristol, Manchester and Cambridge. In London the issues are more complex due to the larger urban scale (as seen in the comparison between the LASER and DELTA/START results), but the potential of the methods would appear just as relevant. Planners in declining urban areas are less likely to find these methods justify their costs, although management of decline is as important as management of growth.

The personalities of the planners have an important bearing on the results, especially towards the use of quantitative models in planning and their views on the particular needs of their district. This applies not only to the responses to the questions, but also to the formulation of policy for the urban area. It is important that the planner is seen in these discussions as a formulator of policy and key advocate of policy initiatives, with considerable scope to determine policy.

10.4.1 The relevance and usefulness of the methods to forecasting transport impacts on land use

The first issue to address is the relevance of transport impacts on land use to strategic planning. The Phase 2 interviews have established that the relationship between land use and transport is of interest to most planners, even if they have doubts about the certainty of the impacts. It was the planners at the district level for urban areas who were most interested in how transport may influence land use development and activity patterns, especially how it would affect the success of other planning policies.

Once it is decided that the impacts of transport policy on land use will be examined, the issue of how to establish impacts becomes important. By presenting the Phase 2 planners with a variety of outputs, the indicators that the planners were interested in became apparent. It was clear that both land use and transport planners essentially divided the indicators into those considered as:

- essential (such as activity distributions, and transport performance indicators);
- useful for study within the department (accessibility and rents);
- superfluous to the planners' needs (forecasts every 2 years);
- of uncertain value (divisions by SEG or household type).

Clearly there is a balance here between what data is required by the method (for example land use models generally need to use SEG or SIC divisions to isolate differing location preferences), and what forms an impact indicator. However, this raises another issue, of what data the planner thinks he/she needs to have, compared to the data the consultant thinks the planner ought to know. Finally, the interviews also revealed a 'spectrum of need' for information, between the technical planners who want more detail and information on assumptions, compared to more senior planners, who required the substantive conclusions from the models and more concise outputs. The consultants and methods must be sufficiently flexible to cater for these different needs if necessary.

After suitable indicators are selected, the key consideration for examining transport impacts on land use is the spatial scale of analysis. It is clear that there is a balance between the number of zones it is possible to assimilate, and a useful level of spatial detail. The 9-zone Delphi zoning was found to be too coarse, the 25-zone pattern was more useful, although its focus upon Edinburgh was obvious from the difference in zone sizes. This made it less relevant to the West Lothian planner. Choosing the spatial remit of a model has clearly been affected by local government re-organisation, with a desire for finer zoning and a more 'district' based approach. However, given the interactions of activities throughout the entire study area, any examination of activity location choice must consider both Edinburgh city itself and its economic, social and travel sphere of influence. It appears that fine zoning is necessary, even if it is aggregated in presentation. However, for the models, this implies moving away from an abstract representation of the transport network as currently embodied in START.

10.4.2 Confidence and understanding of the methods

The methods applied in this thesis demonstrate that land use response to transport investment is likely to occur, and can be significant in affecting the pattern of activities and travel movements. Moreover, as the planners acknowledged, the methods can demonstrate knock-on impacts, and complexities in the distribution of effects that are difficult to estimate intuitively.

However, it is also true that the methods gave a wide range of magnitudes of response, for reasons explained in Chapter 9. Given this situation, the planners were cautious about accepting the predictions of the methods, and commented that more certainty is required on the magnitude and distribution of the impacts. This is consistent with their comments from the Phase 1 interviews (Section 4.5.1 page 60), and they would generally look to empirical evidence to provide them with this certainty.

Thus, the Phase 2 planners were generally sceptical and cautious towards all the methods, the prime reason for this being a lack of confidence in the predictions. With hindsight, this is not surprising, given the following circumstances:

- the planners had little or no familiarity with the methods;
- the planners were aware that transport impacts on land use are difficult to estimate;
- they had little or no involvement in the method selection or implementation;
- there was little demonstration that the models were well calibrated, and a good 'fit' for the study area;
- the methods gave a range of predictions as to the impacts, and the DELTA/START forecasts contained some obvious errors (most notably the Kirkcaldy error discussed on page 194).

It can be concluded from the interviews that for such impacts to be considered with more confidence, there would need to be; (1) a series of successful past applications of the methods, (2) far more interaction between the planner and the consultant (or modeller), involving both discussion of progress and education in the model structure, and (3) faith in the consultancy or practitioner who is undertaking the work. A central problem for this research was that apart from the reputation of ITS and the Consultancies (which undoubtedly helped), not much more could be done to improve the planners' confidence in the methods.

given the time that they could spare to assist in this research. The concept of confidence is therefore an amalgam of technical and qualitative issues.

Related to this is the issue of complexity. Transport impacts on land use are a very complex phenomenon, while the methods applied range from the simple to the complex. It would be expected that the confidence in the accuracy of the prediction increases with the complexity of the method, as more relationships are incorporated.

However, Forster (1996) concluded that the accuracy of the prediction is not necessarily the most important aspect of a method (as discussed in Chapter 4, page 51). The findings from this research agree with this assertion to a certain extent, but it is also true that confidence is often related to the explanation offered by the modeller, and this in turn is a function of the theory and structure of the model. For example, the planners' criticism of the LUCI model was based upon its simplistic *ceteris paribus* assumptions, while the ability to trace impacts through rents and floorspace was seen as a positive feature of DELTA/START. Any method should offer a degree of explanation on a par with that demanded by the planners.

The Phase 2 interviews also concluded that planners feel that they require a good level of understanding of the processes that underlie the methods. This is especially the case if modelling methods are aimed at use directly by planners (for example, as part of the move towards decision support tools advocated by Southworth (1995), discussed in Chapter 2). Such an understanding would in part result from widespread application of the techniques to examine transport impacts on land use. Until use becomes more common, methods of assessing transport impacts on land use are in something of a chicken and egg situation (i.e. use will be limited until the methods are understood, but they won't be understood until the methods are used).

10.4.3 Plausibility of the forecasts

The third aim outlined in section 10.2.1 was to establish the opinions of planners regarding the plausibility of the forecasts. The questionnaire was designed so that the questions prior to this section would relate to the method, rather than to its forecasts. However, despite the known errors in the forecasts, it is still interesting to consider which forecasts the planners found acceptable, and which they did not.

From the do-minimum predictions, the planners tended to use their own forecasts (given as part of the LUCI model results) to judge the other two (as their baseline for the deductive fitting process). The uniformity of change from the Delphi was not seen as likely, as the planners were expecting some zones to grow much faster than others. This suggested that perhaps the Delphi should have had study area control totals, despite the extra complexity this would have imposed. Moreover, the discussions regarding the Delphi did not in general deal with the variance associated with the results (which if anything would further reduce confidence in the results). The DELTA/START do-minimum was seen as giving sensible relative results within Lothian, although the error that resulted in too much growth in Fife tended to cast doubt over the do-minimum forecast (but not over the tests of transport impacts on land use).

None of the planners seemed surprised by the predicted impacts of transport on land use. There was a general consensus that the impacts were in the direction expected, especially in the city centre, but the methods were showing a larger impact than they would have anticipated, especially LRT. This last point could be indicative of planners tending to underestimate the impacts that transport has upon land use. Alternatively, it is also possible that the methods (especially DELTA/START for LRT) are predicting a response that was too large. Although the DELTA/START results were viewed as unlikely in terms of the absolute magnitudes of change, it was clear that they were still useful for the *relative* impacts between different zones. Thus this is an example of how flaws in the results do not necessarily mean the results have no use in the policy process.

These findings relate to the topic of confidence. Although confidence is a wider issue than the focus upon transport impacts on land use which concerns this thesis, the exploration of how confidence in a forecast could be increased is still relevant. Certainly confidence would have been greater if the methods had a consistent do-minimum, and had not included any mechanical errors. It is clearly a vital (but elusive) goal that explanation for results (deductive fitting) is sought within the assumptions and relationships in the model, rather than in errors in the database or coding. However this process is assisted if initial forecasts can be compared to forecasts that the planners are familiar with, such as the do-minimum. This created a problem in comparing methods where the three do-minima were different. Furthermore, it was clear that the estimate of a transport impact on land use cannot be isolated from the do-minimum that it is being compared against.

Plausible results must come from a method in which there is confidence. However, only if results are deemed plausible, in either absolute or relative terms will the forecasts have an impact on the policy process. Thus it is vital that the task of establishing the plausibility of a result is an explicit part of the modelling process, ensuring that rational judgements have been taken.

10.4.4 The overall importance and future of transport impacts on land use in strategic planning

The conclusion to Chapter 4 (page 77) identified four reasons why transport impacts were not assessed in the UK. Briefly, these were; (1) a lack of policy requirement, (2) lack of policy significance, (3) ambiguous evidence as to possible impacts, and (4) a lack of familiarity with the techniques. Using the results from the Phase 2 interviews, these issues can now be addressed, by way of assessing the overall importance of transport impacts on land use.

Firstly, it is true that there is a lack of policy requirement, and this is unlikely to change in the short term. Unlike the situation in the USA, where examination of land use response is a requirement in law for many cities (under the CAAA), in the UK there does not appear to be the will to force formal incorporation of these impacts into strategic planning (although it can now be assessed in COBA). This is primarily because the main guidance note, PPG13, was only redrafted in 1994. Furthermore, the change of UK Government in May 1997, while significant in its act of combining the Departments of the Environment and Transport, has not proclaimed any intention to either revise PPG13, or overhaul the treatment of land use and transport in planning.

However, this does not mean that assessment of such impacts (or rather the potential to do so) will not increase on a study level basis. Two examples of this are the possibilities for using GIS based systems (Wegener and Spiekermann, 1995), and the increasing use of dynamic land use transport models in situations where transport only models may have been used in the past.

Secondly, it is clear these impacts do have a policy significance, illustrated by the planners stating that they would want to incorporate land use response in any future strategic modelling study. Answers to Section 4 of the questionnaire identified two main planning purposes where impacts are important; (1) impacts on the pattern of future trip generations, and; (2) sensitivity testing of the synergy between land use and transport plans. The former of these points relates to producing more reliable transport forecasts, the latter to fine tuning structure plan policies. To this a third could be added given the evidence collected from Chapter 3, but not expressed in the interviews; the potential of transport investment to regenerate urban areas, and encourage people back into cities.

With regard to point 3 from Chapter 4 (i.e. ambiguous evidence), the methods applied to the study area have all shown that impacts are likely, and will be significant in the city centre. Any ambiguity rests with the magnitudes of the impacts, especially to other areas of the city. Finally, in undertaking in-depth case study, it is felt that some progress has been made against (4), increasing planners familiarity with the techniques.

Of course, having the ability to examine transport impacts on land use does not dictate that it will be undertaken, as was found in the Phase 1 interviews. The planners at CEC expressed an interest in seeing further results from DELTA/START, but whether their interest is driven by the new model, rather than by wanting to examine transport impacts on land use, is difficult to say.

Given the recent (1994) revisions to PPG13, and its widespread (cross-party) political support, Government guidance on land use and transport is unlikely to be revised in the near future, even with the recent change of Government on 1st May 1997. This means that transport impacts on land use are unlikely to become the subject of UK planning guidance, although the new Labour administration has taken the important step of combining the former departments of Transport and the Environment (which may be a portent of greater interaction between land use and transport planning to come). However, there is still the likelihood that planners and consultants consider transport impacts on land use significant enough to incorporate into structure plan formulation and standard transport forecasting methodologies. In doing so, the accuracy of forecasts will be improved, and the comprehensive nature of planning increased.

10.5 Conclusions

The research presented in this chapter has taken the results from three methods and applied a qualitative methodology to assess the relevance, validity and plausibility of each method, using a sample of planners in a case study area. The comments from the sample were relatively homogenous (although this was more obvious in their comments than in their scores to the questionnaire). The findings now allow the questions posed in Section 10.1 to be addressed.

10.5.1 Comments on / preferences for /objections to the methods

It is generally true that even with this case-study approach, the planners remain generally unfamiliar with the techniques applied, and in a real application would desire more education on the processes within the methods.

The methods can analysed by their complexity. There needs to be sufficient complexity to represent the relationships considered important, and also to assist in the explanation of results. However, greatly increasing the number of variables represented for the purposes of increasing the accuracy of the forecasts was not viewed as necessary. For practical planner purposes there is a balance to be found so that complexity serves to maximise explanation.

Perhaps for this reason the planners tended to treat DELTA/START more seriously than the other methods, despite the mechanical flaws in its forecasts. The LUCI model was criticised for being simplistic, and unsuited to trip generation assessment or other analysis involving a temporal element. The Delphi is different in that it held value for the planners as a survey of opinion, rather than as a source of 'hard' data, as it offers little by way of transparency. Its use in assessing transport impacts on land use is therefore limited to macro 'overview' studies, in which it proved a useful source of independent comparative data. The planners noted that it is limited in the complexity of the responses or transport policies that it can deal with, and needs careful specification to avoid bias in the sample.

A second topic relates to the types of forecast indicator that the method can produce. Finer spatial disaggregations were preferred, but temporal disaggregations were not thought necessary. This highlights the general conclusion that the modeller must take care to present simple and representative results from those available.

10.5.2 Do planners believe or accept the results?

None of the planners denied that impacts were likely to occur, however there was uncertainty concerning whether the actual forecasts were plausible or not. An assessment of the reasonability of the results was of interest to the planners from the steering group and the Phase 2 interviews. Plausibility of results relates to confidence in the methods, and the preceding discussion has shown that confidence depends upon:

- prior knowledge by the planners of the methods and their successful application;
- a reputable modeller/consultant, in which the client has faith;
- education in the method, its assumptions and calibration;

- demonstration of calibration and validation;
- do-minimum forecasts that the planners agree with, as part of an explicit deductive fitting process.

As discussed in Section 10.4.2, the methods applied in this thesis could not easily meet these criteria, and so it is not surprising that the planners treated the results with a degree of caution. This research has shown that they are more likely to accept the results from a method where the process and assumptions are more transparent. In the case of forecasting transport impacts on land use, they felt that this was most true with the dynamic model, where the processes were more theoretically underpinned and matched processes in the real world.

10.5.3 Do the results encourage the planners to conclude that transport impacts on land use should be more systematically analysed and incorporated into strategic planning?

The Phase 2 interviews have served to address some of the uncertainties raised in the Phase 1 interviews regarding why it is important that these impacts should be studied. Furthermore, the planners' had positive comments; that treating transport impacts on land use more consistently can lead to strong benefits to the process of strategic planning.

Despite this, the planners commented that technical methodologies tends to contribute most to practical planning where there is already a consensus over a policy. Given that land use responses are often both complex and controversial, then no such consensus is likely to exist, especially for policies such as road pricing. However, this does not reduce the importance assessing the impacts as part of the comprehensive planning process.

Due to its recent revision, it is not likely that PPG13 will be amended in the short term to deal with transport impacts on land use in a more thorough manner. This places the emphasis upon planners and consultants to bring land use response into the planning process, even if land use response objectives are not explicit policy. Only through application and dissemination of findings will understanding of land use response increase.

CHAPTER 11
CONCLUSIONS

11.1 Introduction and approach

The premise of this study is that transport impacts on land use are rarely given formal or adequate consideration in the strategic planning process in the UK. Despite this there is considerable evidence to support the view that transport can markedly influence urban development. In order to evaluate the practical value in assessing transport impacts on land use, it was necessary to set the following four objectives:

1. an analysis of the **various impacts** that selected transport policies (in particular road pricing and LRT) can have upon land use;
2. an examination of the **current treatment** of transport impacts on land use in the UK structure planning system, and of the present attitudes of planners towards the importance of such impacts.

The findings from these objectives identified that there was a specific need to:

3. evaluate the **practical contribution of several contrasting methods** to forecast land use responses, in terms of their relevance, validity, and plausibility to practising planners, and hence;
4. determine the **overall significance** of assessing transport impacts on land use in strategic planning.

The research has comprised two distinct methodological approaches[1]. To meet objectives 2, 3 and 4 a qualitative in-depth interview-based method was adopted. This was selected as the most appropriate way of gaining insights into the attitudes of planners towards transport impacts on land use. Secondly, in order to meet objective 1, and to produce the forecasts for objective 3, a positivist quantitative approach was followed, which applied both inductive (Delphi), and deductive (DELTA/START and LUCI) forecasting methods. Overall, this methodology can be termed a 'meta method' in that it seeks to examine the context in which quantitative methods are used, and provide an explanation for their use.

[1] Supplemented by literature reviews where necessary.

The Phase 1 interviews cast a wide net, incorporating planners, consultants and academics from several areas in the UK (see Chapter 4). In addition, interviews were undertaken in the USA in order to gain an international perspective in a country where consideration of these impacts is further advanced than in the UK (also Chapter 4). Having reached initial conclusions for objective 2, the research focused upon a specific study area: Lothian region. This case study was selected as it is a growing and relatively self-contained urban area, with a range of interesting and controversial transport policies on the planning agenda (see Chapter 5). It was also suitable for practical reasons, including the availability of a transport model.

Three quantitative methods were applied to this study area, assisted by the CASE consultancies (Chapters 6 to 8). These were; (a) an application of the Delphi method, (b) a simple land use indicator model (LUCI), and (c) a more complex dynamic land use transport model (DELTA/START). These three methods represent different points on the spectrum of forecasting methods, from the cheap and simple to the expensive and complex. Each was used to examine the impacts of road pricing and light rapid transit (LRT) on the pattern of urban activities. This quantitative work provided some valuable insights into the model implementation process, as well as completing objective 1 with a comparison of the three methods against other sources of evidence of transport impacts on land use (Chapter 9). Returning to the qualitative methodology, the forecasts from the three methods were presented to the case study area planners, and 'Phase 2' in-depth interviews undertaken to meet the Objectives 3 and 4.

However, the qualitative methodology applied here has suffered from two weaknesses. The first is due to the inconsistencies between the three land use response methods applied. Most obvious was the lack of a common do-minimum forecast (i.e. to provide reference base for comparison), which diverted some attention away from the impacts on land use in the Phase 2 interviews. However, to have made the do-minimum forecasts more similar would have involved extensively altering the LUCI application, and increasing the scale of the Delphi exercise, requiring resources beyond those available for this study.

The second weakness is in being able to generalise from the results. Chapter 10 established that some generalisation was possible, as the planners tended to be relatively homogenous in their views. Also Edinburgh faces similar transport and land use issues to many other UK cities. However, without repeated studies of this type in other urban areas, generalisations must be made tentatively. This is certainly an area worthy of further research.

11.2 Key findings and conclusions

11.2.1 Objective 1: transport influences on land use: examples with LRT and road pricing

Analysis of how transport impacts on land use was necessary to provide a basis for comparison with the three forecasting methods, and to provide background information for the author when interviewing the samples. The evidence was examined in Chapter 3. This concluded that even in the short term (under a decade), impacts can occur if local circumstances (for example in the local economy and quality of the environment) are conducive. Transport will have a greater impact the more 'scarce', or worse, accessibility is. In studying the influence of transport, the central problem is in isolating the degree of impact attributable to transport from other contributing factors, a problem compounded by the long timescales over which such impacts can occur (see Chapter 3).

Both empirical and modelling studies often cite LRT as a factor that can influence land use development and contribute to urban revitalisation. However, it is usually only successful in this latter role when part of a package of urban initiative measures. For road pricing there is far less evidence (as there are far fewer applications), and also much less agreement regarding possible impacts on (city centre) urban vitality. The ultimate outcome is likely to depend upon economic conditions and the detailed aspects of the scheme.

These findings were supported by the impacts predicted by the three forecasting methods for the Edinburgh area. Chapter 9 concluded that both policies would affect the pattern of urban growth. The methods indicate that LRT would enhance the attractiveness of the city centre, drawing in activities from the rest of Edinburgh and Fife. It would also encourage population centralisation, or rather, slow the strong counter-urbanisation trends that are predicted in the do-minimum tests. The LRT impacts from the models were much larger than the empirical evidence would suggest. All of the methods forecast that road pricing would have the effect of making the city centre less attractive to employment, and therefore would dampen city centre commercial rents. However, DELTA/START predicted that over the long term the distribution of activities would also alter to better suit public transport provision, and produce a more 'sustainable' urban form.

However, beyond this general agreement, the methods produced diverging forecasts. The Delphi impacts were generally of a lower magnitude than the models, and the models themselves agreed more on employment than on population impacts. When the policies were combined, DELTA/START predicted that synergy between the strategy elements would further promote growth in the city centre, while the Delphi predicted that urban development would still be dominated (although to a lesser extent) by the more rent depressive effects of road pricing policy.

Clearly, if implemented, both these policies would have an impact that should be accounted for in the Structure Plan, due to the differing pattern of pressures that would be placed on the transport system, and the changing redistribution of activities (away from the patterns envisaged in the structure plan). Given that in a thriving economy such as Edinburgh, the impacts were likely to be significant, this made the prospect of the Phase 2 interviews to discuss these results all the more interesting.

11.2.2 Objective 2: current treatment, and attitudes towards transport impacts on land use

Before examining whether transport impacts on land use should, or could, be examined more formally, it is important to establish the present situation. Chapter 4 concluded that in the UK there was little planning policy guidance relating to how transport can influence land use. Moreover, recent 'land use transport' policy (such as PPG13), has very much concentrated on the sole objective of reducing travel via land use planning and development control. Interviews with those responsible for drafting such guidelines concluded that transport impacts on land use were severely under-represented in practical guidance.

In general, the Phase 1 interviews undertaken in the UK concluded that, in the absence of any guidelines, or any common methods, it was not usual to assess the influence of transport policy on activity patterns and urban development. Studies which were undertaken tended to be *ad hoc*, or focused upon identifying specific economic or development benefits from transport investment. This meant that studies were rarely comparable or consistent.

The reasons for this lack of assessment can be summarised from the Phase 1 sample as threefold. Firstly there is an underlying belief that such impacts from transport policy are of minor consequence only, and that any impacts which could potentially occur can be controlled by the structure plan itself via development control. Secondly, there was the view that predicting such impacts is subject to a great deal of uncertainty and planners are generally unfamiliar with the methods that can be applied, their cost or accuracy. Thirdly, there is a general lack of well publicised data concerning the circumstances under which transport policy can lead to significant impacts on land use.

As the modelling and empirical evidence for objective 1 shows, there are strong grounds to suggest that such impacts are not inconsequential, although the issue is confused as a result of the other factors which can influence land use response. Moreover, the sample interviewed in the Phase 1 interviews recognised this fact, and there was a general consensus that these impacts should receive more consideration. The main benefits in assessing land use response were as part of the initiative to better integrate land use and transport planning, the need to plan more sustainable urban forms, and the requirement to address the environmental externalities of transport systems.

The comparable work in the USA found greater acceptance there of the idea that land use response can cause major impacts on transport policy. This is primarily via altered trip distribution patterns contributing to traffic congestion. Furthermore, in the USA, estimation of transport impacts on land use is now required for urban areas that fail to meet air pollution standards. Modelling land use and transport together is becoming more common, and is seen as superior to discussion based, or Delphi approaches. However, the interviews there suggested that this study was primarily because of the legislative requirements, and did not examine how transport influenced land use for the purposes of land use planning.

11.2.3 Objective 3: the requirements of a practical method

The Phase 1 interview work in the UK revealed that a clearer specification of the most appropriate methods was required. 'Appropriate' was defined in terms of the relevance of the results to planners' requirements, confidence in the methods and the plausibility of the forecasts. The Phase 2 interviews addressed these issues (discussed in Chapter 10), and produced the most important findings from this research.

The analysis from the interviews concluded that planners accept that transport impacts on land use do occur, and that the available methods do offer indicators useful to strategic planning tasks. However, these must focus on the resulting distribution of activities, and development pressures, which are the key indicators, for both trip generation and development of the structure plans.

The application of these methods requires careful specification. For example zoning must strike the best balance between coarse aggregate zones and too many zones to comprehend. It is clear that the planners desired fine spatial detail, (aggregated if necessary for clarity in presentation). Thus the 9-zone system was too coarse, and 25-zones satisfactory for assimilation, but unrefined in the outer districts.

Chapter 10 concluded that the issues of confidence, transparency, complexity and theory were all interrelated. Moreover it is the interaction of these variables that determines the validity of the method.

It was concluded from the sample that increased complexity is likely to be the way forward. Ironically, this is not necessarily because it allows more accurate forecasts, but because more sophisticated methods offer a better explanation for any forecasts they produce. This was found both in the Phase 2 planners' comments, and also in the preference towards using models in the USA to meet the CAAA requirements.

In turn the transparency of a model is in part determined by the underlying theory. Thus although the planner may not rate the underlying theory as very relevant, for the modeller attempting to explain the results, a consistent behavioural or theoretical approach is vital. The ability to trace impacts over time through rents, accessibilities and location choices is attractive both to modellers and planners, and provides the explanation that is necessary to assist the deductive fitting process[2].

Therefore, the Phase 2 interview evidence shows that the concept of confidence is multi-faceted. In a technical sense it involves justifying the complexity of the technique, demonstrating that the model is well calibrated, undertaking rigorous validation and providing well reasoned and plausible forecasts. However, the interviews also revealed that qualitative issues, such as the reputation of the consultant or modeller, are very important, as is the perception of successful past applications, and the modellers' ability to 'market' a method. Most important of all, the planner must have a sufficient level of understanding of the concepts and assumptions in the model in order to be able to comprehend the results.

As was expected, the planners were relatively sceptical towards the plausibility of the forecasts presented to them. Chapter 10 revealed that, with hindsight, the key reason for this was that it was difficult to engender strong confidence in the techniques within the resources of the research. This meant that the forecasts were always judged on the basis of the underlying method, rather than the results *per se*.

For do-minima, the planners considered their own forecasts from the LUCI model the most plausible. However, they considered the DELTA/START estimates of impacts as more

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[2] The deductive fitting process was introduced in Chapter 8 as the means by which the plausibility of forecasts are judged, in the absence of data for any formal validation. See section 11.2.5.

plausible, due in part to having a series of linked indicators. The Delphi approach is different, in that it offers an independent source of forecasts for transport impacts on land use. This should be seen as complementary to any modelling venture, as it includes the benefits of professional judgement in a formal manner. The Delphi method also offers potential as a tool to assist in the calibration of more complex models.

11.2.4 Objective 4: the overall significance of transport impacts on land use

This thesis has argued and demonstrated that transport impacts are important, and merit inclusion in strategic examination of any major transport policy. It has taken the stance that the emphasis should be on how best to integrate transport and land use planning, not on whether there is sufficient evidence to do so. Strategic transport and land use planning should be seen as one combined task with common methods, not isolated disciplines.

Moreover, it has been seen from the Phase 2 interviews that the planners do not doubt that impacts occur, and that suitable methodologies for estimation of impacts exist. This would allow inclusion of land use response into urban transport forecasting, and sensitivity testing of structure plan options. It is in the interests of planners to consider these relationships if they claim to be aiming for a 'comprehensive' approach to rational planning, and fully integrating land use and transport planning.

However, it is unlikely that land use impacts will be incorporated into current government guidance (PPG13 being the obvious choice), due to recent revision of this document. It will therefore fall to planners and consultants to take the lead in incorporating land use response into planning studies.

11.2.5 Other findings

In addition to the main study objectives, two other topics investigated in this research have produced findings of particular interest. Firstly, the experience of implementing the DELTA/START model led to the typology of model development discussed in Chapter 8. This typology attempted to separate the 'mechanical analytical' aspects (i.e. those concerned with running the model and implementing the dataset correctly), from the 'rational analytical' aspects, (i.e. those concerned with explaining the results within the assumptions and data in the model). Within rational analysis is the process of 'deductive fitting', i.e. the qualitative decisions regarding whether the predictions of a method are plausible.

This typology proved useful in the Phase 2 interviews in determining what processes the planners needed to understand, and how they themselves undertook deductive fitting to determine the plausibility of forecasts. Moreover, as Chapter 8 concluded, the deductive fitting process itself should be a more explicit part of the modelling process.

The second topic was the use of the Delphi methodology to assist in the 'calibration' of DELTA/START, by reducing the sensitivity of employment to accessibility. This process is described in detail in Appendix IV. The use of expert opinion to fine tune a model is relatively novel, and may have potential for seeking independent estimates for the parameters in DELTA.

11.3 Topics for future investigation and concluding remarks

Through this thesis several areas of further investigation have been highlighted. Most importantly there is a need to establish a more comprehensive framework for understanding when and how transport impacts on land use will occur. This could be similar to the TRICS (TRICS Consortium, 1987) system, but instead of trip generation data, would provide a database of impacts, indicator variables, the circumstances in which they are likely to occur, and contributory factors. What defines this as a research topic is that analysis is required for the specification of the indicators and techniques. As transport impacts on land use cannot be observed, so the database would either; (1) present the 'raw' transport and land use data, and leave the user to decide upon what impacts are occurring, or; (2) present the results of analysis of impacts using common indicators. The most appropriate measures for indicating change could be further researched, building upon the Phase 2 interviews from this research. Carefully specified, such a database would offer a valuable tool to planners, organising the mass of information on transport impacts that exist and allowing clear and reasoned generalisations to be made.

In addition to this, there is a wider need to study the use of quantitative methods in comprehensive planning, and in particular to focus upon the inherent confidence in the methods that is required. Such research would follow naturally from this project, highlighting to modellers and consultants the non-scientific context in which their forecasting techniques are being used. The obvious approach would be to use a method similar to that used by Forster (1996), i.e. adopt a case study approach examining how planners choose a method in practice, and observe how the implementation of that method proceeded. This would allow the testing of ideas developed in this thesis, such as the necessary levels of understanding required by planners, and the determination of sensible forecasts via the processes of rational analysis and deductive fitting.

There is a great deal of scope of further research into the Delphi method. The Delphi designed in this thesis was intended to be an exploratory study (as outlined on page 101). Several lessons have been learnt that would assist in future applications of the Delphi for *use in strategic planning*. Firstly the discussion in the Phase 2 interviews on the most appropriate indicators placed the emphasis upon 'end state' measures such as population and employment, rather than market indicators (i.e. rents) as applied in the Lothian Delphi. Any future Delphi study would therefore require initial discussions to determine exactly what the planners require. This in turn would determine the expertise required from the Delphi panel, and hence its composition.

Secondly there is the issue of the most appropriate indicator scale. The simple percentage indicators used in the Lothian Delphi could be replaced with actual values and study area 'control totals'. This would clarify the base situation, and the size of the impacts that the Delphi panel are predicting, but would also require more careful analysis of the allocations of activities by the panel. Such a Delphi would become a larger and more complex survey as a result, and hence some form of incentive (preferably financial) should be considered for the participants.

Finally, it was discussed in Chapter 6 (page 132 and 134) that policy response bias may be an issue with Delphi surveys, especially for emotive policies such as road pricing. This could be reduced (or accounted for), if the panel were forced to give reasons for their estimates (rather than just given the option of giving reasons as in the Lothian Delphi). One way of accomplishing this would be to include questions asking for justification for each prediction given, (although given a constraint on the overall length of the questionnaire, this would reduce the number of predictions that could be sought).

In addition to the Delphi, several technical aspects of this research merit further work. The most interesting is in the potential use of GIS with land use transport modelling to allow more flexible and easily changeable zoning. This would address the concerns over zoning raised during the Phase 2 interviews, but would invariably involve more disaggregate land use modelling in order that fine zones or 'points', could be aggregated as required. This may require micro simulation disaggregate modelling, a technique not commonly used in practical planning in the UK (or indeed anywhere else). The main limitation here is likely to be the availability of data at fine spatial scales (especially confidential data such as employment by ward), and hence part of the research would involve determining what data is available, what is the minimum data a model would require, and how missing data could best be synthesized at a fine spatial scale.

Linked to this is the issue of assisting the modeller in the mechanical and rational analysis processes. An interesting topic here is the possible development of a 'wizard', or expert system; a piece of software that could trace the reasons for the results of a land use transport test back through the submodels and datasets, and hence greatly increase the speed of identifying mechanical or rational errors. At its simplest, this could be a utility that highlighted (or tabulated) the relevant data leading to a result. However, at its most elaborate this could (theoretically) be a system more complex than the model itself. This would work backwards, taking a question relating to a forecast (such as 'why is the growth in Fife so large?'), and tracing the sources to address the question. However, not only would this be a large programming task, it would also involve an extremely lengthy design process, and would be open to the analytical and mechanical errors discussed in Section 8.4 (page 191). For these reasons the most plausible initial system would be one in which zonal or temporal differences in variables would be compared against a do-minimum run, and highlighted for the modeller to then examine further.

Finally, there is clearly more research to be undertaken to clarify land use responses to road pricing within models. This would involve more research of the 'ISGLUTI' (Webster *et al*, 1988) type, i.e. testing several models against several city datasets with common road pricing policies. In terms of practically undertaking such work with DELTA/START, this would require undertaking more road pricing tests at differing price levels, and applying the model to a city where a MEPLAN model already exists (most obviously London). The central problem here is that to apply such a model from scratch is very costly, and hence most research applications use models developed for commercial applications.

This thesis has identified the contribution that assessing transport impacts on land use can offer comprehensive strategic planning. It has also defined the key elements that forecasting methods must have if they are to be of practical value to planners in helping them understand this complex relationship.

There is certainly some way to go before a practical understanding of land use response from transport is fully available. However, only as part of regular consideration in planning tasks will our understanding of these relationships increase. It is hoped that this thesis has served to increase the pace of momentum on this important issue.

11.4 One page summary of key study findings

1. The Phase 1 interview research found that there is no systematic examination on the impacts of transport policy on land use and activity patterns in the UK strategic planning system. Any study that does take place tends to be *ad hoc*, and not easily comparable with other studies. Use of 'formal' techniques is extremely limited.
2. In the USA, formal methods are being applied to meet air quality legislation. Interview research found that a variety of methods are being used, of which dynamic modelling is seen to be the most satisfactory, although Delphi-type and group discussion approaches are more common. The role of transport in influencing land use is widely accepted, given the lack of planning controls in the USA.
3. Application of three contrasting methods to the Lothian study area found that the significant impacts were predicted to occur following LRT and road pricing policies. These had clear implications for the city-centre objectives in the current draft structure plan. Moreover, the predicted impacts were consistent with those from the literature review of the empirical evidence.
4. Discussion of these methods and results with study area planners (Phase 2 interviews) found that:
   - the indicators of land use thought relevant by the planners are either already part of, or can be easily incorporated into, current methods. Indeed, some of the indicators were considered too detailed for structure planning purposes (e.g. data by two year time periods).
   - the key area of concern is spatial detail, where the 9-zone system proved inadequate, and the 25-zone system suffered from widely varying zone sizes. Strategic modelling needs to look for greater spatial disaggregation, perhaps via GIS;
   - the type of method applied was less important to the planners than having **transparency** (i.e. ease of explanation) in the results, and hence **confidence** in the validity of the method;
   - confidence was found to be determined by technical issues, such as calibration and successful past applications, but also by qualitative issues; the quality of education in the method, and the reputation of the model/modeller. Confidence is also engendered by the process of 'deductive fitting', and it was argued that this process should be more explicit in the modelling process.
6. From the Phase 2 interviews, it was concluded that dynamic modelling is best able to meet the 'transparency and confidence' criteria. This is due to its underlying theoretical and behavioural base and because impacts can be traced through the sub-models. However, this means that interpreting the results is complicated, and requires a very full understanding of the processes and assumptions in the model. Complexity is therefore a double-edged sword.
7. The Delphi method proved better suited to providing an initial overview of the impacts. It should be seen as a source of comparable (or even input) data, rather than a substitute for modelling. The LUCI method is attractive by its simplicity, but lacks power in explanation.
8. It was concluded that future research should focus upon obtaining systematic data on land use response, to assist in calibration, validation and increasing understanding of the relationships.
9. The views of the planners were much more focused in the Phase 2 interviews than in Phase 1. This indicates that the 'in-depth' case study approach to method assessment, as adopted in this thesis, provides insights that less focused interviewing fails to obtain.

REFERENCES

(Numbers in square brackets refer to sections in which reference is used)

Alonso W (1964) *Location and Land Use* Cambridge MA., Harvard University Press [2.3].

Amara R C and Lipinski A J (1972) 'Some views on the use of expert judgement', in *Technological Forecasting and Social Change*, Vol. 3 pp. 279-289 [6.2].

Anas A (1982) *Residential Location Markets and Urban Transportation: Economic theory, Econometrics, and Policy Analysis with Discrete Choice Models*, New York Academic Press [2.3].

Anas A (1985) 'Dynamic Forecasting of Travel Demand, Residential Location and Land Development: Policy Simulations with the Chicago Area Transportation/Land Use System', *Regional Science Association*, Vol. 56, pp. 38-58 [4.6].

Anas A (1994) 'METROSIM: a Unified Economic Model of Transportation and Land Use', (paper presented at the *Travel Model Improvement Programme Conference*, Dallas, Texas, February 1995) [2.4].

Anas A (1995) 'Capitalisation of Urban Travel Improvements into Residential and Commercial Real Estate: Simulations with a Unified Model of Housing, Travel Mode and Shopping Choices' *Journal of Regional Science*, Vol. 35, No. 3, pp. 351-375 [4.6].

Anderstig C and Mattsson L G (1992) 'Policy Applications of an Integrated Land Use Transport Model in the Stockholm Region', *Paper presented at the 6th World Conference on Transport Research, Lyons* [2.4].

Antwi A and Hennebury J (1995) 'The Land and Property Market Impacts of Transport Infrastructure Investments, paper presented at the seminar session: *Monitoring the land and property impacts of transport infrastructure: the South Yorkshire Supertram'* [6.2].

Association of County Councils (1994) *Towards a Sustainable Transport Policy (Second Edition)*, Scotia Press [4.3]

Atlanta Regional Commission (1995) *Atlanta Region Outlook* [4.6]

Bates J, Brewer M, Hanson P, McDonald D and Simmonds D (1991) 'Building a Strategic Model for Edinburgh', *Proceedings of Seminar D, PTRC 19th Summer Annual Meeting* PTRC, [2.4, 5.2, 7.2, 8.4]

Bedfordshire County Council Planning Department (1994) *'Structure Plan 2011'*, Consultation Draft [4.3].

Bell M G H (1994) 'The Jewels in the Crown of Transportation Science', *University Transport Studies Group 26th Annual Conference, University of Leeds* [2.3, 10.3].

Bonsall P W (1991) *'Feasibility of Measuring Responses to Highway Improvements'*, Contractor Report 200, Transport and Road Research Laboratory [3.2].

Bonsall P W (1993) *PLUTO: How the Model Represents Reality*, Working Paper 330 Institute for Transport Studies, University of Leeds [2.4].

Botham R W (1980) 'The Regional Development Effects of Road Investment', in *Transportation Planning and Technology* Vol. 6, pp. 97-108 [3.2, 3.3].

Brindley T, Rydin Y and Stoker G (1989) *Remaking Planning: the Politics of Urban Change in the Thatcher Years*, London, Unwin Hyman [3.4].

Buchanan M, Bursey N, Lewis K and Mullen P (1980) *Transport Planning for Greater London,* Saxon House, Farnborough [3.3]

Buck N, Gershuny J, Rose D and Scott J (1994) *Changing Households: The British Housing Panel Survey, 1990 to 1992*, The ESRC Research Centre on Micro Social Change, University of Essex, Colchester [8.3, 8.4].

Button K J (1993) *Transport Economics*, Edward Elgar Publishing [3.2].

Carlson D and Billen D (1996) '*Transportation Corridor Management: Are we linking transportation and land use yet?*' Report by the Institute for Public Policy and Management, University of Washington, Graduate School of Public Affairs [4.3].

Cavalli-Sforza V and Ortolano L (1984) 'Delphi Forecasts of Land Use: Transportation Interactions', in *Journal of Transportation Engineering*, Vol. 110, No. 3 [6.2].

Cervero R (1984) 'Light Rail Transit and Urban Development', *Journal of the American Planners Association*, Spring 1984 [3.4].

Cervero R and Landis J (1995) 'Development Impacts of Urban Transport: a US Perspective', in Banister D (ed.) *Transport and Urban Development*, ESRC, E&F Spon [3.2].

Cervero R and Seskin S (1995) 'An Evaluation of the Relationships between Transit and Urban Form', *Transportation Research Board, Transit Co-operative Research Programme: Research Results Digest* No. 7 [3.2, 3.3, 3.4, 4.3].

Christaller W (1933) *Central places in southern Germany*. English edition of *Die Zentralen Orte in Suddeutschland, Jena*, (1966) translated by C W Baskin, Prentice Hall [2.3].

Cisneros H G (1995) *Regionalism: The New Geography of Opportunity*, United States Dept. of Housing and Urban Development [4.6].

Commission of the European Communities (1993) *White Paper on Growth, Employment and Competitiveness,* Brussels [3.3].

Coombe D and Copley G (1993) 'Modelling Transport Packages', *Transportation Planning Systems* Vol. 1 No. 4 October-December, pp. 5-12 [5.2, 7.2].

Damm D, Lerman S R, Lerner-Lam, E and Young J (1980) 'Response of Urban Real Estate Values in Anticipation of the Washington Metro', *Journal of Transport Economics and Policy*, Vol. XIV No. 3 pp. 315-336 [3.2].

Davoudi S, Gillard A, Healy P, Pullen B, Raybould S, Robinson F (1993) '*The Longer Term Effects of the Tyne and Wear Metro*', University of Newcastle Upon Tyne, Contractor Report 357, Transport and Road Research Laboratory [3.2, 3.4].

de la Barra T (1989) *Integrated Land Use and Transport Modelling*, Cambridge University Press, Cambridge, England [2.3].

Deakin D, Porter C and Melendy L (1995): *A Survey of the Metropolitan Planning Organisations of the 35 Largest US Metropolitan Areas*, Institute of Urban and Regional Development, University of California at Berkeley [4.6].

Department of the Environment (1994a) *Sustainable Development: The UK Strategy*, London, HMSO, Cm 2426 [4.3].

Department of Environment (1994b) *Transport and the Environment: 18th Report of the Royal Commission on Environmental Pollution* HMSO, Cm 2674 [4.6].

Department of the Environment (1996) *Planning Policy Guidance Note 6: Town Centres and Retail Development* [4.3].

Department of the Environment and Department of Transport (1994) *Planning Policy Guidance Note 13: Transport* [4.3].

Department of the Environment and Department of Transport (1996) *PPG13: A Guide to Better Practice,* HMSO [4.3].

Department of Transport (1988) *Calculation of Road Traffic Noise*, HMSO [7.2].

Department of Transport (1989) *National Roads Traffic Forecast (Great Britain)*, HMSO [5.2].

Department of Transport (1994a) *'Trunk Roads and the Generation of Traffic'*, Report of the Standing Committee on Trunk Road Appraisal (SACTRA), HMSO [4.3].

Department of Transport (1994b) *'Trunk Roads and the Generation of Traffic'*, Response by the Department of Transport to Report by the Standing Committee on Trunk Road Appraisal, [4.3].

Department of Transport (1996a) *Transport: The Way Forward: The Governments Response to the Transport Debate* HMSO, Cm 3234 [4.3].

Department of Transport (1996b) *The COBA Manual (Version 10)*, HMSO [4.3].

Diamond D and Spence N (1989) *Infrastructure and Industrial Costs in British Industry, Department for Enterprise*, HMSO [3.3].

Dickins I (1987) *Rapid Transit and Land Use in North America*, Working Paper 22, Department of Planning and Landscape, Birmingham Polytechnic [3.2, 3.4].

Dickins I (1988) *An Introduction to Light Rail in Europe*, Working Paper 32, Department of Planning and Landscape, Birmingham Polytechnic [3.2, 3.4].

Dodgson J S (1974) 'Motorway Investment, Industrial Transport Costs and Subregional Growth: the M62 Case Study', *Regional Studies,* Vol. 8, pp. 75-91 [3.2, 3.3].

Dyett M, Dornbusch D, Fajans M, Gussman V, and Merchant J (1979) *'Land Use and Development Impacts of BART'*, Final Report No. DOT-P-30-79-09, United States Department of Transportation [3.2, 3.4].

Echenique M H, Flowerdew A D, Hunt J D, Mayo T R, Skidmore I J and Simmonds D C (1990) 'The MEPLAN models of Bilbao, Leeds and Dortmund', *Transport Reviews*, Vol. 10, pp. 309-322 [2.4, 3.6].

Environmental Resources Management, (1994) *Setting Forth: Environmental Appraisal of Alternative Strategies,* prepared for the Industry Department, Scottish Office [5.2, 6.8].

Environmental Resources Management, Oscar Faber TPA and The MVA Consultancy (1994) *Setting Forth: Strategic Assessment. Summary Report,* prepared for the Industry Department, Scottish Office [5.2].

Estates Gazette (1995) '*Focus on East Scotland and Highlands*' Issue 9528, July 15th, pp. 75-91 [5.2].

Evans A W (1973) *The Economics of Residential Location*, Macmillian [2.3].

Federal Ministry for Regional Planning, Building and Urban Development (1993) *Guidelines for Regional Planning: General Principles for Spatial Development in the Federal Republic of Germany* [4.5].

Flowerdew A D and Stevens R C (1994) *The Effects of Road Pricing on Land Values and Future Settlement Patterns,* Report to the Royal Institution of Chartered Surveyors [3.5, 6.9, 9.3].

Foot P (1982) *Operational urban models*, London, Methuen [2.3].

Forster A (1994) 'The Role of Integrated Transport Studies in Urban Transport Planning' *University Transport Studies Group 26th Annual Conference,* University of Leeds [4.6].

Forster A (1996) *The Contribution of 'Integrated Transport Studies' to the Process of Urban Transport Planning*, PhD Thesis, Dept of Civil Engineering, University of Leeds [4.2, 7.2, 10.4, 11.4].

Freilich R H and While S M (1994) 'The Interaction of Land Use Planning and Transportation Management', *Transport Policy,* Vol. 1, No. 2 pp. 101-115 [4.3].

Gardner K (1994) 'Land Use and Transport Interaction', *Highways and Transportation,* Vol. 41, No. 4 pp. 10-12 [4.5].

Gentlemen H, Walmsley D and Wicks J (1980) *The Glasgow Rail Impact Study: Summary Report*, Transport and Road Research Laboratory Supplementary Report 800 [3.2, 3.4].

Giannopoulos G A and Curdes G, (1992) 'Innovations in Urban Transport and the Influence on Urban Form. A Historical Review', *Transport Reviews,* Vol. 12, No.1 pp. 15-32 [2.2, 3.2].

Giannopoulos G A and Pitsiava-Latinopoulou M (1985) 'Some Findings on the Interaction between Transport and Land Use in Greece', *Transport Planning and Technology*, Vol. 10, pp 13-27 [3.2].

Giuliano G (1989) 'Research Policy Review 27; New Directions for Understanding Transportation and Land Use', *Environment and Planning A*, Vol. 21, pp. 145-159 [3.3].

Green R D and James O M (1993) *Rail Transit Station Area Development: Small Scale Modelling in Washington DC* , Amronk, New York [3.2, 3.4].

Grieco M (1994) *The Impact of Transport Investment Projects on the Inner City*, Aldershot, Avebury [3.2, 3.3, 3.4].

The Hague Consulting Group (1991) *Alternative Land-Use Modelling Systems: An International Review and Evaluation* [2.4].

Hall P (1966) *London 2000*, Blackwell [3.2].

Hall P (1989) *London 2001*, Blackwell [3.2].

Hall P (1992) *Urban and Regional Planning,* Third Edition, Routledge [4.2]

Hall P and Banister D (1995) 'Summary and Conclusions', in Banister D (ed.) *Transport and Urban Development*, ESRC, E&F Spon [3.3, 3.8].

Hall P and Hass-Klau C (1985) *Can Rail Save the City?* Gower, Aldershot [3.4].

Hansen W G (1959) 'How Accessibility Shapes Land Use', *Journal of the American Institute of Planners* Vol. 25, pp 73-76 [2.3].

Harrison F (1991) 'Land Values and Integrated Transport Systems', *Proceedings of 19th Summer Annual Meeting,* PTRC [3.3].

Hass-Klau C (1993) 'The Impact of Pedestrianisation and Traffic Calming on Retail', *Transport Policy* Vol. 1 No. 1 [3.2, 3.5].

Headicar P and Bixby B (1992) *Concrete and Tyres: The Development Effect of Major Roads: a case study of the M40*, report for The Council for the Protection of Rural England [4.3].

Horowitz A J (1994) *Highway Land Use Forecasting Model II+ Reference Manual*, AJH Associates, Milwaukee [2.4].

Hoyt H (1939) *The Structure of Growth of Residential Neighbourhoods in American Cities* Washington DC, Gov't Printing Office [3.2].

Hunt J D (1994) 'Calibrating the Naples Land Use and Transport Model', *Environment and Planning B*, Vol. 21 pp. 569-590 [2.4].

Hunt J D and Simmonds D C (1993) 'Theory and Application of an Integrated Land Use and Transport Modelling Framework', *Environment and Planning B*, Vol. 20, pp. 221-244 [2.4].

Jones S R (1981) *Accessibility Measures: a Literature Review*, Supplementary Report 967, Transport and Road Research Laboratory [2.3].

Keilman N, Kuijsten A, and Vossen E (1988) *Modelling Household Formation and Dissolution,* Clarendon, Oxford [8.4].

Kerrigan M and Bull D (1992) 'Made to Measure', *Surveyor*, 5th November [2.3].

Knight R (1980) 'The Impact of Rapid Transit on Land Use', *Transportation*, Vol. 9, pp. 3-16 [3.4].

Knight R and Trygg L (1977) 'Evidence of Land Use Impacts of Rapid Transit Systems' *Transportation* Vol. 6 pp. 231-248 [3.4].

Knox P (1987) *Urban Social Geography*, Longman [8.2].

Koenig J G (1980) 'Indicators of Urban Accessibility: Theory and Application', *Transportation* Vol. 9, pp. 145-172 [2.3].

Kreibich V (1978) 'The Successful Transportation System and Regional Planning Problems: An Evaluation of the Munich Rapid Transit System in the Context of Urban and Regional Planning Policy.', *Transportation* Vol. 7, pp. 137-145 [3.2, 3.4, 3.7, 9.3].

Landis J, Guhathakurta S and Zhang M (1994) '*Capitalisation of Transport Investments into Single Family Home Prices: a Comparative Analysis of California Transit Systems and Highways*', Working Paper 619, Institute of Urban and Regional Development, University of California at Berkeley [3.2, 3.4].

Law C (1995) 'The Metrolink Monitoring Study: Approaches To and Problems In Evaluating the Economic Impacts of Manchester's Metrolink', paper presented at *The Light Rail and Non-User Benefits Conference*, Sheffield [3.2, 3.4].

Law C and Dundon-Smith D (1995) *Metrolink and Greater Manchester Office Market - an Appraisal: Metrolink Impact Study,* Working Paper 13, Department of Geography, University of Salford [3.4].

Lee D B (1994) 'Retrospective on Large Scale Urban Models', *Journal of American Planning Association* Vol. 60 pp. 35-40 [2.4].

Linneker B J and Spence N A (1991) 'An Accessibility Analysis of the Impact of the M25 London Orbital Motorway on Britain', *Regional Studies* Vol. 26, pp 31-47 [3.2].

Linneker B J and Spence N A (1996) 'Road Transport Infrastructure and Regional Economic Development: the Regional Development Effects of the M25 London Orbital Motorway', *Journal of Transport Geography* Vol. 4 No.2 [3.2, 3.3].

Local Transport Today (1995) 'Interview: Putting things in their place: Eastman questions the new received wisdom on planning' Issue 169, 28th September p.12-13 [4.3].

Local Transport Today (1996) 'Scottish Office draft Transport NPPG criticised' Issue 192, 15th August p.3 [5.2].

Local Transport Today (1997) 'Greater Manchester partnership develops area strategy model' Issue 202, 3th January, p. 20 [9.4].

London Planning Advisory Committee (1994) *Advice on Strategic Planning Guidance for London* [4.3].

Lothian Regional Council (1992) *Moving Forward: a Transport Strategy for Lothian* [5.2].

Lothian Regional Council (1994a) *Lothian Regional Structure Plan: Report of Survey* [5.2].

Lothian Regional Council, (1994b) *Structure Plan: Written Statement Finalised Plan* [5.2, 9.3].

Lothian Regional Council Planning Department (1991) *Planning Handbook* [5.2].

Lowry I S (1964) *A Model of a Metropolis*, Rand Corporation, Santa Monica, CA [2.3, 2.4].

Mackett R L (1990a) *The MASTER model* Contractor Report 237, Transport and Road Research Laboratory [2.4].

Mackett R L (1990b) 'The Systematic Application of the LILT Model to Dortmund, Leeds and Tokyo', *Transport Reviews*, Vol. 10, No. 4 pp. 1-18 [3.6].

Mackett R L (1991a) 'A Model Based Analysis of Transport and Land Use Policies for Tokyo' *Transport Reviews,* Vol. 11, No. 1 pp. 323-338 [3.6].

Mackett R L (1991b) 'LILT and MEPLAN: a Comparative Study of Land Use and Transport Policies for Leeds' *Transport Reviews,* Vol. 11, No.2 pp. 131-154 [2.3, 3.6].

Mackett R L (1994) 'The Use of Land Use Transportation Models for Policy Analysis', *Transportation Research Board Conference,* January 1994 [2.2, 4.5].

Mackett R L and Nash C A (1991) 'Commuting', in Fowkes T and Nash C A (1991) *Analysing Demand for Rail Travel,* Avebury [3.6].

Martinez F (1991) 'Transport Investments and Land Values Interaction: the Case of Santiago City', *Proceedings of the PTRC 19th Summer Annual Meeting,* London, PTRC, pp. 45-58 [2.3].

May A D, Bristow A L and Shepherd S P (1997: forthcoming) 'Towards The Sustainable City: the Impact of Land Use - Transport Interactions' *PTRC European Forum (28th Summer Annual Meeting),* Brunel University [8.3].

May A D, Coombe D and Travers T (1996) 'The London Congestion Charging Research Programme: Assessment of the impacts', *Traffic Engineering and Control*, Vol. 37, No. 6 [3.6, 9.3]

May A D, Roberts M and Mason P, (1992) 'The Development of Transport Strategies for Edinburgh', *Proc. Instn. Civil Engineers: Transportation* , No. 95 pp. 51-59 [5.2, 7.4, 9.4].

Meyer M and E Miller (1984), *Urban Transportation Planning: A Decision Oriented Approach*, Mcgraw Hill, NY [4.3].

Moon H (1990) 'Land Use Around Suburban Transit Stations', *Transportation,* Vol. 17 pp. 67-88 [3.2].

Morisugi H, Ohno E and Miyagi T (1993) 'Benefit Incidence of Urban Ring Roads - Theory and Case Study of the Gifu Ring Road', *Transportation,* Vol. 20 pp. 285-303 [3.2].

Mullins J A, Washington E J and Stokes, R W (1989) 'Land Use Impacts of the Houston Transitway System', *Transportation Research Record* 1237 [3.2].

The MVA Consultancy (1991) *The Joint Assessment of Transport and the Environment Study (JATES),* Final Report to Lothian Regional Council, Edinburgh District Council and the Scottish Office [2.3, 5.2].

The MVA Consultancy (1993) *Integrated Transport Studies: START Program Suite User Guide,* Version 1.3 [7.2].

The MVA Consultancy (1994) *Setting Forth Strategic Transport Assessment: Final Report*. Prepared for The Scottish Office Industry Department. [5.2]

The MVA Consultancy (1995) *The London Congestion Charging Research Programme. Final Report*, Prepared for Department of Transport [3.6].

The MVA Consultancy and ECOTEC (1990) '*The Impact of Rail Electrification on House Prices in the South East*' [3.2]

Nelson A C and McCleskey M (1990) 'Improving the Effects of Elevated Transit Stations on Neighbourhoods' *Transportation Research Board* 1266, pp. 142-149 [3.2, 3.4].

Office of Science and Technology (1995) '*Technology Foresight: Progress Through Partnership. Number 5: Transport*, HMSO [6.2].

Ortúzar J de D and Willumsen L G (1994) *Modelling Transport, Second Edition*, Wiley [2.2, 2.3].

Parkinson M (1981) *The Effect of Road Investment on Economic Development in the UK*. Government Economic Service Working Paper 43 [3.2, 3.3].

Payne-Maxie Consultants (1980) *The Land Use and Urban Development Impacts of Beltways*, Final Report No. DOT-0S-90079, United States Department of Transportation [3.2].

Pivo G (1990) 'The Net of Mixed Beads: Suburban Office Development in Six Metropolitan Regions', *Journal of the American Planning Association*, Vol. 56, No. 4 pp. 457-69 [3.2, 3.4].

Planning (1997) 'Old Town Enjoys Subtle Art of Conservation' *Planning*, 28 February, pp. 22-23 [5.2].

Planning Week (1997) 'Transport Focus: Room For One More Inside', *Planning Week*, 23 January, pp. 15-16 [3.4].

Pooler J A (1995) 'The Use of Spatial Separation in the Measurement of Transportation Accessibility, *Transport Research A*, Vol. 29, No. 6 pp. 421-427 [2.3].

Potter P (1979) 'Urban restructuring, One Goal of the New Atlanta Transit System', *Traffic Quarterly*, No. 1 [3.2, 3.4].

Prastacos P (1986) 'An Integrated Land Use Transport Model for the San Francisco Region: Empirical Estimation and Results', *Environment and Planning A*, Vol. 18 pp. 511-528 [2.3].

Priest D E (1980) 'Enhancing the Development Impact of Rail Transit', *Transportation*, Vol.9 pp. 45-55 [3.4].

Putman S H (1994) 'Results From Implementation of Integrated Transportation and Land Use Models in Metropolitan Regions', *Paper presented at Seminar for Network Infrastructure and the Urban Environment: Recent Advances in Land use/Transportation Modelling*, Stockholm Sweden, [4.6, 4.7].

Putman S H (1995) 'EMPAL and DRAM Location and Land Use Models: An Overview', (paper presented at the *Travel Model Improvement Programme Conference*, Dallas, Texas, February 1995) [2.4].

Raji F A O (1987) *Accessibility Preferences in Residential Location Decisions: a Study of Home Buyers Reactions to Travel Time*, PhD Thesis. Department of Civil Engineering, University of Leeds [2.3].

Roberts M and Simmonds D C (1995) 'A Strategic Modelling Approach for Urban Transport Policy Development', paper presented to *7th World Conference on Transport Research*, Sydney [7.2, 9.2].

Robinson F and Stokes G (1986) *'Rapid Transit and Land Use: The Effects of the Tyne and Wear Metro'*, Centre for Urban Regional Studies, University of Newcastle upon Tyne [3.4].

Scottish Office Development Department (1996) *National Planning Policy Guideline: Transport and Planning*, Draft, [5.2].

Shepherd S P, Emberger G, Johansen K, and Jarvi-Nykanen T (1997: forthcoming) 'OPTIMA: Optimisation of Policies for Transport Integration in Metropolitan Areas: A Review of the Method Applied to Nine European Cities' *PTRC European Forum (25th Summer Annual Meeting)* [8.5].

Simmonds D C (1991) 'Development of Indicators of Land use Change', in The MVA Consultancy, *JATES Technical Appendices, Technical Working Paper 4* [2.4, 5.2, 7.3].

Simmonds D C (1994) 'The 'Martin Centre Model' in Practice: Strengths and Weaknesses', *Environment and Planning B, Planning and Design*, Vol. 21 pp 619-628 [2.4].

Simmonds D C (1995) *'Available Methods for Land Use/Transport Interaction Modelling'*, David Simmonds Consultancy (unpublished) [2.4].

Simmonds D C (1997: forthcoming) 'The Design of the DELTA land use modelling package' [8.4].

Simmonds D C and Still B G (1997) *'The Implementation of the DELTA/START Land Use Transport Model'*, Working Paper 494 ,Institute for Transport Studies, University of Leeds [8.3].

Simon D (1987) 'Spanning Muddy Waters: the Humber Bridge and Regional Development' *Regional Studies*, Vol. 21.1 pp. 25-36 [3.2].

Smyth A (1995) 'The Development of Long Term Land Use Guidelines and Public Transport Strategy for Belfast: Lessons for Medium Sized Cities', *Proceedings of the Institute of Civil Engineers: Transport*. Vol. 111, pp. 213-224 [6.2].

Southworth F (1995) *A Technical Review of Urban Land Use- Transportation Models as Tools for Evaluating Vehicle Travel Reduction Strategies*, Oak Ridge National Laboratory (ORNL), Report for United States Department of Energy, ORNL-6881 [2.4, 2.5, 10.4].

Still B G (1992) *Reducing Transport Impacts via Land Use Patterns: A Study Using Integrated Transport Models*, MSc Thesis, Dept of Civil Engineering, University of Leeds, [5.2, 7.2].

Still B G (1996) 'The Importance of Transport Impacts on Land Use in Strategic Planning' *Traffic Engineering and Control*, Vol. 37 No. 10 pp. 564-571 [4.1].

Taylor S J and Bogdan R (1984) *Introduction to Qualitative Research Methods: The Search for Meanings: Second Edition*. John Wiley [4.4].

Transportation Research Board, (1995) *'Expanding Metropolitan Highways: Implications for Air Quality and Energy Use'*, report by The Committee for Study of Impacts of Highway Capacity Improvements on Air Quality and Energy Consumption, National Academy Press [4.5].

TRICS Consortium, (1987) *TRICS (Trip Rate Information Computer System): A Trip Generation Database for Development Control: Information Booklet*, JMP Consultants Ltd [11.3].

U.S. Department of Transportation (1995) *A Guide to Metropolitan Planning Under ISTEA: How the Pieces Fit Together*, FHWA-PD-95-031 [4.3].

Underwood S E (1992) *Delphi Forecast and Analysis of Intelligent Vehicle-Highways Systems through 1991*. IVHS Technical Report ~92-17, University of Michigan Transportation Research Institute [6.2].

van Houten D (1989) 'Planning Rationality and Relativism', *Environment and planning B: Planning and Design*, Vol. 16, pp 201-214 [4.2].

Voith R (1993) 'Changing Capitalisation of CBD Oriented Transportation Systems: Evidence from Philadelphia 1970-88' *Journal of Urban Economics*, Vol. 33, pp 361-376 [3.2, 3.4].

von Thünen J H (1966) *Isolated State: an English edition of Der isolierte Staat*, translated by C M Wartenburg and edited by PG Hall, Pergamon (first German edition 1826) [2.3].

Wachs M (1985) 'Planning, Organisation and Decision Making: a Research Agenda' *Transport Research A*, Vol. 19 pp. 521-531 [4.2].

Walmsley D and Perrett K (1992) *The Effects of Rapid Transit on Public Transport and Urban Development*, Transport Research Laboratory, HMSO [3.2, 3.3, 3.4, 3.7].

Webster F V, Bly P H and Paulley N (eds.) (1988) *Urban Land Use and Transport Interaction: Policies and Models*, Report of the International Study Group on Land Use and Transport Interaction (ISGLUTI), Aldershot Avebury [2.4, 3.6, 7.3].

Webster F V and Paulley N J (1990) 'An International Study of Land Use and Transport Interaction', *Transport Reviews*, Vol. 10, No. 4 pp. 287-308 [3.6].

Wegener M (1982) 'The Impact of Systems Analysis on Urban Planning: the West German Experience', in Batty M and Hutchinson B, eds. *Systems Analysis in Urban Policy Making and Planning* Plenum Press [4.2].

Wegener M (1994) 'Operational Urban Models: State of the Art', *Journal of the American Planning Association*, Vol. 59, pp. 17-29 [2.2, 2.3, 2.4].

Wegener M (1995) 'Accessibility and Development Impacts', in Banister D (ed.) *Transport and Urban Development*, ESRC, E&F Spon [3.3].

Wegener M, Mackett, R L and Simmonds D C (1991) 'One City, Three Models: Comparison of Land Use Transport Policy Simulation Models for Dortmund, *Transport Reviews*, Vol. 11 No. 1, pp. 107-129 [2.4, 3.6].

Wegener M and Spiekermann K (1995) 'Freedom from the Tyranny of Zones: Towards New GIS Based Spatial Models', paper presented at GISDATA Specialist Meeting, *'GIS and Spatial Models: New Potential for New Models?'*, Friiberghs Herrgard, Sweden [10.4].

Williams H C W L (1977) 'The generation of consistent travel-demand models and user-benefit measures', in Bonsall P, Dalvi, Q and Hills P, (eds.) *Urban transportation planning: current themes and future prospects*, Abacus Press [2.3].

Williams I N (1994) 'A Model of London and the South East', *Environment and Planning B: Planning and Design,* Vol. 21, pp. 535-553 [4.5].

Wilson A G (1970) *Entropy in Urban and Regional Modelling,* London, Pion [2.3].

Wingo (1961) *Transportation and Urban Land,* Baltimore, John Hopkins Press [2.3].

APPENDIX I

THE DELPHI SURVEY

Covering Letter

Supporting Information

First Round Questionnaire

Second Round Questionnaire

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ITS

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0113 2335325

<<Date>>

«Contact»
«Company_name»
«Address1»
«Address2»
«Address3»
«Address4»

Dear «Contact»,

The Impacts of Transport Policy on Land Use Change in Edinburgh : A Survey of Expert Opinion.

I am writing to you to ask for your assistance in a survey, which forms part of a University research project examining the influence that transport policy may have upon property prices and population in Edinburgh and its surrounding region.

The survey is targeted at 'experts' in the property and development sector. Your name as a key specialist in this field was strongly recommended to me by Hugh Munro from The MVA Consultancy (who are partially funding this research). I would be very grateful therefore, if you would be willing to participate in the survey, firstly by spending a small amount of time (no more than 35 minutes), completing the enclosed questionnaire. Its prime aim is to elicit **your** professional judgement on property market issues.

I would hope that the results of the survey will be of interest to all participants. Analysis from the sample will reveal the collective estimates of the distribution and magnitude of growth expected in Edinburgh, and likely sensitivities of various markets to transport policies. This should lead to a better grasp of what the market is expecting in the near future. A report of the analysis of results will be sent to each participant. If this survey is successful a second questionnaire will be distributed to 'fine tune' the responses and give a chance for further comment.

Please note that your individual response will at all times remain confidential.

I hope that you are willing to participate in this survey of experts. Indeed, your contribution is vital if the sample is to be representative. The questionnaire, and full instructions for its completion are enclosed with this letter, as is a pre-paid envelope for return of the completed questionnaire. Please contact me on the above number if you have any questions concerning the survey.

Thank you in advance, and I look forward to hearing from you in the near future.

Yours sincerely,

Ben Still
Researcher: University of Leeds
de_v2let.doc

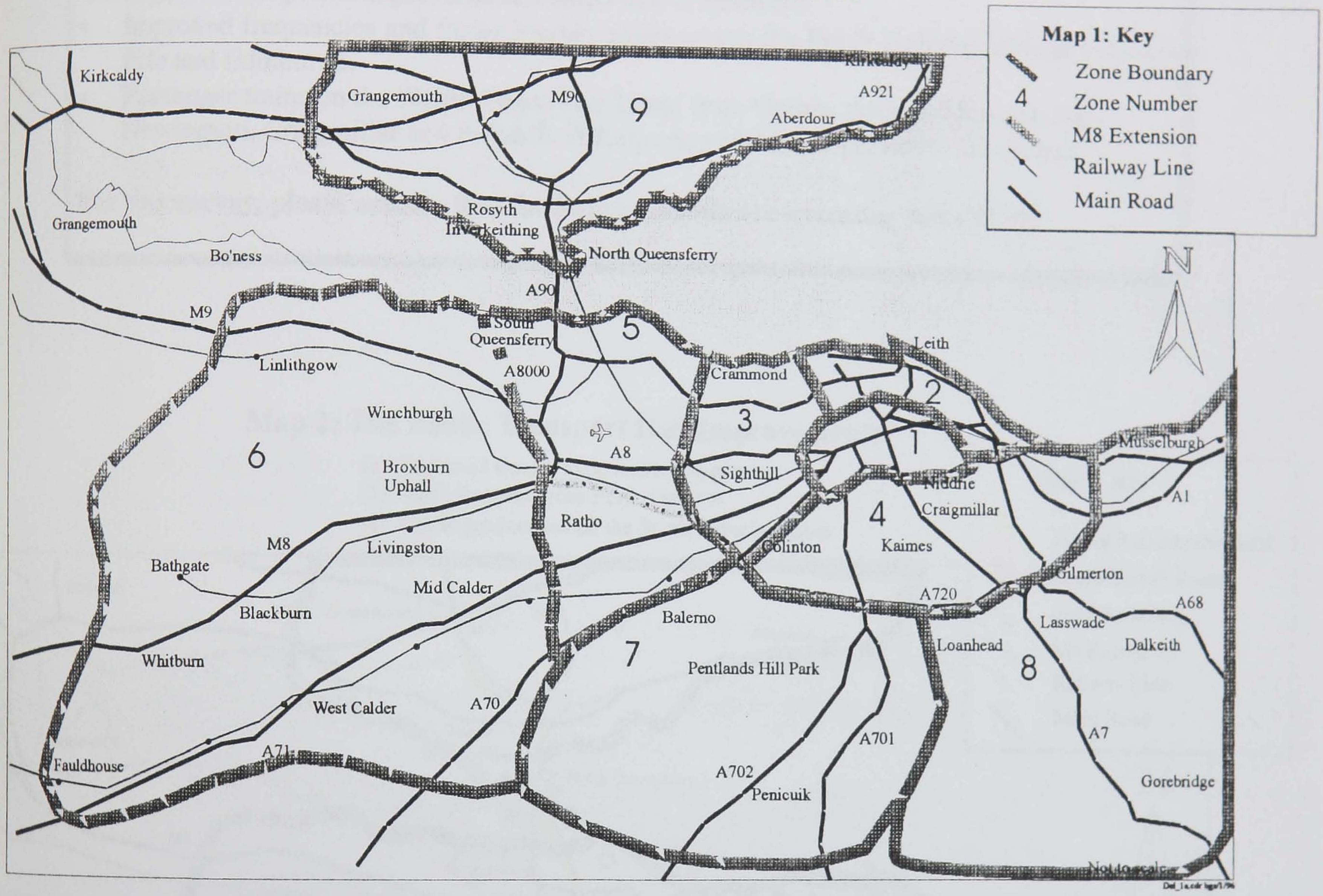
INFORMATION PACK

SUPPORTING INFORMATION

THE THREE TRANSPORT STRATEGIES

These notes are provided to give some information about the transport strategies used in the questionnaire. To complete the questionnaire, you must imagine what the impacts of each strategy will be on the study area, which is shown in **Map 1**. However, these strategies are **illustrative only**, and do not imply any commitment to the proposals from Lothian Regional Council or Edinburgh City Council.

Map 1: Lothian and Fife: Zone Divisions



For the purposes of underlying <u>transport and land use policy</u>, please make your own assumptions about what policies are likely to occur, and assume that these policies remain constant throughout the questionnaire.

<u>Map 1</u> shows the study area: Lothian and Fife, divided into 9 zones.

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Hypothetical Public Transport Improvements (Map 2)

There are two 'rapid transit' routes. These are shown on Map 2. The '**North-South**' route runs from Davidson's Mains, turning south at Inverleith through the city centre. At Newington, the line splits into 2 branches, one going to Burdiehouse, the other to Gilmerton.

The '**East-West**' route runs from the Airport to South Gyle, then east, through the city centre to Leith. The North-South and East-west lines cross in Edinburgh City.

The rapid transit system would be similar in appearance and quality to those already existing in Manchester and Sheffield. The normal operating frequency will be 12 an hour on each line.

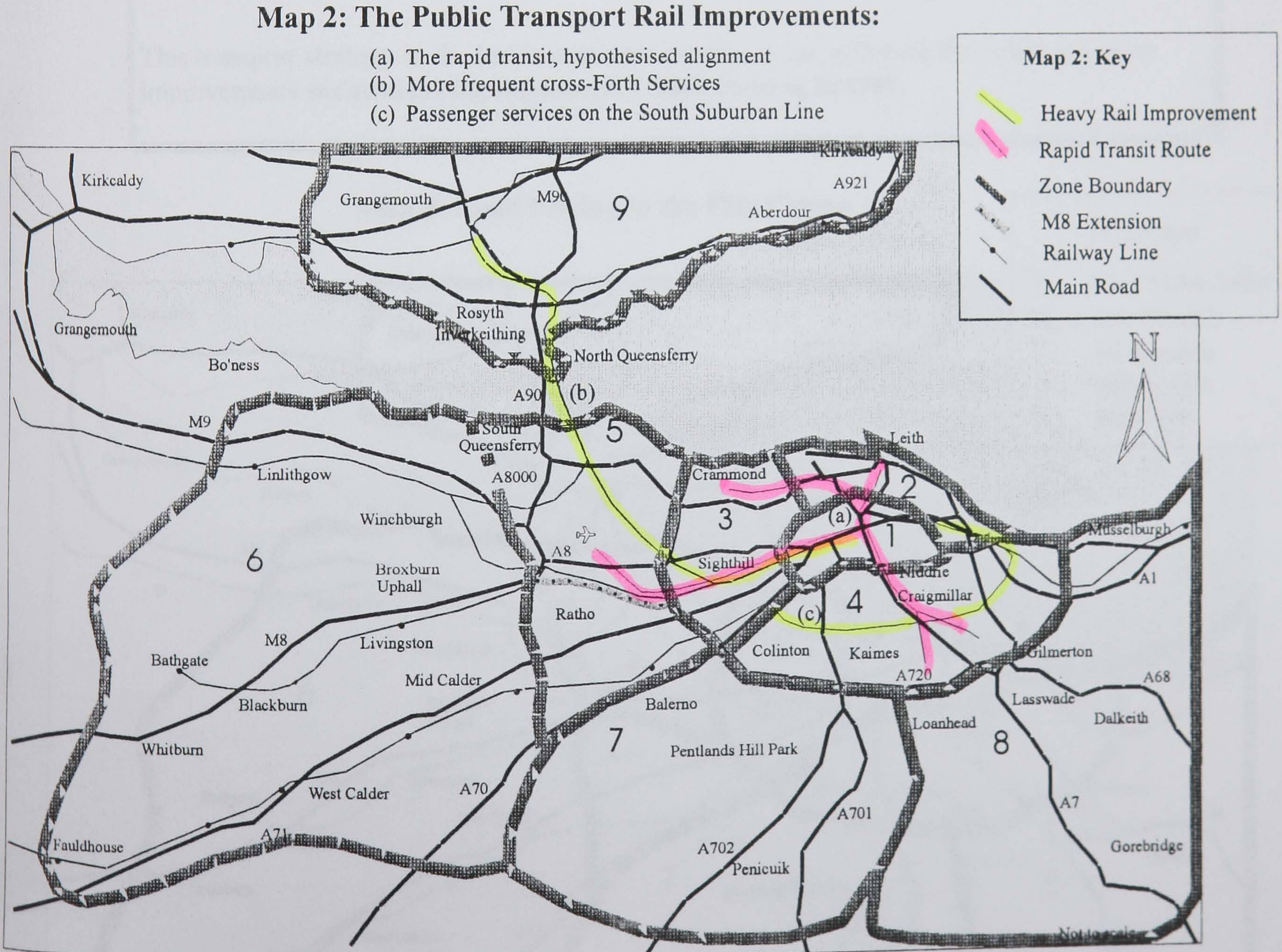
The regional rail system improvements consist of two elements:

- Improved frequencies and faster journey times across the **Forth Railway Bridge** between Fife and Edinburgh.
- Passenger trains on the '**South Suburban Loop**' from Gorgie, through Morningside, Newington, Craigmillar and Piershill. A frequency of 3 trains per hour will operate.

For this survey, please assume that the improvements are operating from 1997.

Map 2: The Public Transport Rail Improvements:

(a) The rapid transit, hypothesised alignment
(b) More frequent cross-Forth Services
(c) Passenger services on the South Suburban Line



A Hypothetical Road Pricing Policy (Map 3)

'Road Pricing' is additional charging on vehicles for using roadspace, especially when demands on roadspace are high.

The system assumed for Edinburgh is a simple 'cordon' charge, around the city centre (zone 1 of Map 2). This includes both New Town and Old Town. The charge will operate all day.

Cars and lorries crossing the cordon in either direction incur a charge of £1.70 (1995 prices) each time they cross. Buses, taxis and cyclists are exempt from the charge.

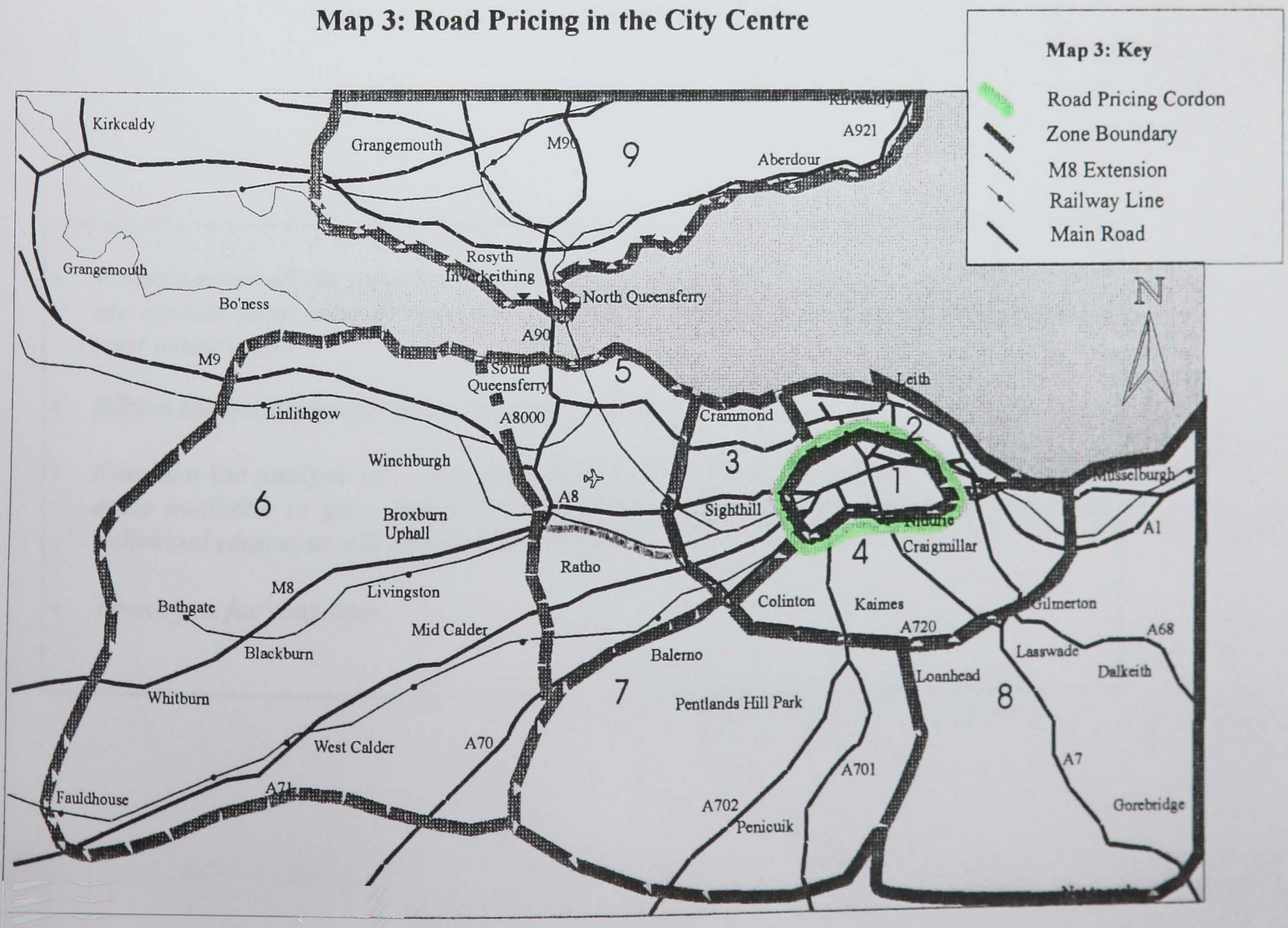
Please assume that the road pricing system operates effectively (i.e. drivers cannot avoid paying).

For this study, please assume that the system is operating from 1997.

The Combined Strategy of both Road Pricing and Rapid Transit

This transport strategy is the last two options combined, i.e. with both the public transport improvements and road pricing implemented, **both starting in 1997.**

Map 3: Road Pricing in the City Centre



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January 1996

REF: .PE........../................

THE IMPACTS OF TRANSPORT POLICY ON PROPERTY PRICES AND POPULATION IN LOTHIAN AND FIFE:
A STUDY OF EXPERT OPINION

SURVEY QUESTIONNAIRE

- ***Please answer all the questions in all sections, even if you feel that some of these topics are outside your area of expertise, or dealing with spatial scales not appropriate to your usual work.***
- ***Return the questionnaire in the envelope provided.***
- ***Note that the analysis of results from the panel of experts as part of this study will be made available to you, and will be used in a PhD research project. However, all individual responses will remain confidential.***
- ***Thank you for your time.***

Section 1: Questions about the Respondent: Property Experts

This first section asks questions about your areas of expertise within Lothian Region.

1a. How many years have you been professionally involved with the property market in Lothian region?

Years: [ ]

1b. Using map 1, which divides Lothian and Fife into 9 zones, please circle on the bar below which zones of the region you deal with in your professional capacity (you may circle more than one zone).

Zone	1	2	3	4	5	6	7	8	9	All

1c. Please indicate your familiarity with the following sectors by circling YES in the first column of the table below for those sectors in which you work, and NO for those in which you do not.

Then in the second series of columns please indicate how much of your time is spent with each sector that you have circled YES, by ticking the relevant boxes.

Property Sector	Involved? (circle)	Time Spent (as % of total time at work) 0-25%	26-50%	50%+
Residential	Yes / No			
Retail	Yes / No			
Office	Yes / No			
Industrial	Yes / No			

1d Please outline below the type of work that you do in the property sector (e.g. development, valuation, surveying)

....

....

Please turn over to section 2

Section 2: General Impacts from the Transport Policies

This section asks some general questions about your views on the impacts that three ***hypothetical transport policies*** *may have upon property prices and population distribution in and around Edinburgh. Details of the hypothetical policies are presented in the supporting information pack.*

2a Do you think that the transport policies described will have **any effect** on **property prices** in any zone at any time? (Please circle YES or NO, for each sector and transport policy).

Transport Policies as described in the information pack: ↓	Residential Property Prices	Office Property Prices	Retail Property Prices	Industrial Property Prices
Public Transport *(Map 2)*	YES / NO	YES / NO	YES / NO	YES / NO
Road Pricing *(Map 3)*	YES / NO	YES / NO	YES / NO	YES / NO
Combined	YES / NO	YES / NO	YES / NO	YES / NO

2b. In the boxes below, for each transport policy <u>independently</u>, please rank the 4 sectors from 1 to 4, from '1' (a transport policy having most effect on a sector relative to the others), down to '4' for the least impact.

Rank (1= greatest, 4= least)	Residential Property Prices	Office Property Prices	Retail Property Prices	Industrial Property Prices
Public Transport				
Road Pricing				
Combined				

2c. Do you think that any transport policy will have effects on overall **population distribution** in any of the zones shown on Map 1 for Lothian Region or Fife? Please circle YES or NO for each strategy in the table below.

	Public Transport	**Road Pricing**	**Combined**
Population Impact	YES / NO	YES / NO	YES / NO

Please turn over to section 3

This section again refers to the three transport policies used in section 2. See the enclosed sheet for details on completing this section.

Retail Property Price Impacts

A1: Your general estimates of retail property price changes in the next 10 years

Remember: exclude inflation!

Zone	1	2	3	4	5	6	7	8	9
% Impact (+ or - change in prices)									

Office Property Price Impacts

B1: Your general estimates of property price changes in the next 10 years.

Zone	1	2	3	4	5	6	7	8	9
% Impact (+ or - change in prices)									

Population Distribution Impacts

C1: Your general estimates of population changes in the next 10 years.

Zone	1	2	3	4	5	6	7	8	9
% Impact (+ or - change)									

Please remember that in the tables below, enter ***additional changes relative*** *to the top table. Also, please add an approximate time scale for the impacts that you estimate.*

Public Transport

A2: Retail property price impacts with public transport policy.

Zone	1	2	3	4	5	6	7	8	9
% Impact (+/- change in prices)									
Time scale (in years)									

B2: Office property price impacts with the public transport policy.

Zone	1	2	3	4	5	6	7	8	9
% Impact (+/- change in prices)									
Time scale (in years)									

C2: Population distribution impacts with the public transport policy.

Zone	1	2	3	4	5	6	7	8	9
% Impact (+/- change)									
Time scale (in years)									

Road pricing

A3: Retail property price impacts with the road pricing policy

Zone	1	2	3	4	5	6	7	8	9
% Impact (+/- change in prices)									
Time scale (in years)									

B3: Office property price impacts with the road pricing policy

Zone	1	2	3	4	5	6	7	8	9
% Impact (+/- change in prices)									
Time scale (in years)									

C3: Population distribution impacts with the road pricing policy.

Zone	1	2	3	4	5	6	7	8	9
% Impact (+/- change)									
Time scale (in years)									

Both Policies

A4: Retail property price impacts with both policies

Zone	1	2	3	4	5	6	7	8	9
% Impact (+/- change in prices)									
Time scale (in years)									

B4: Office property price impacts with both policies

Zone	1	2	3	4	5	6	7	8	9
% Impact (+/- change in prices)									
Time scale (in years)									

C4: Population distribution impacts with both policies

Zone	1	2	3	4	5	6	7	8	9
% Impact (+/- change)									
Time scale (in years)									

300

Please complete all the tables, even if the subject is outside your area of expertise.

Please turn over to Section 4

Section 4: Final Comments

Finally, please use the space below to outline any other comments. These may be:

- Reasons for your estimates of future change in Edinburgh and surrounding area.
- Other impacts that you think are important
- Comments on impacts on the residential or industrial sectors.
- Comments on the questionnaire itself.

In your comments, please remember to state which transport measure is related to the impacts you describe.

Please check that you have answered all the questions.

Thank you for completing this questionnaire. Your time in doing so is greatly appreciated.

Please use the prepaid envelope to return the completed questionnaire.

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FAX TO: 0113 2335334
Ben Still
Institute for Transport Studies
University of Leeds,
Leeds LS2 9JT

Ref:
Pages: 3

FROM: (Name)
(Company)
(Fax No)

Edinburgh Expert Opinion Survey: Additional Questionnaire

Thank you for undertaking this short follow up questionnaire. The tables are set out with your original response, the average estimates of percentage change for the sample as a whole, and a space for any new response. If you wish to revise your original estimate, please fill in the new estimate in the box provided. If you do not wish to change your response, please place a cross in the appropriate box. PLEASE USE BLACK INK.

The zone numbers refer to the zones shown on the accompanying map, which is identical to that in the original questionnaire. Please assume that all the hypothetical policies remain as before, and the supporting information is enclosed. Again, all responses remain confidential at all times.

The first 4 tables ask about impacts on Retail Property Prices

Table 1.1 Retail Property: Base Estimates of % Change over next 10-15 yrs.									
Zone	1	2	3	4	5	6	7	8	9
Your previous response									
Mean (% chg)	+7.9	+6.8	+5.8	+4.1	+4.1	+2.8	+1.6	+1.3	+2.1
Median(%chg)	+8	+3.5	+5	+4	0	+4	0	0	0
New estimate (% chg)									

Please place a 'X' in the box where you do not wish to change your previous response.

Table 1.2 Retail Prop: Estimates of Additional % Change Due to Public Transport.									
Zone	1	2	3	4	5	6	7	8	9
Your previous response									
Mean (% chg)	+5.2	+2.8	+1.5	+0.7	+0.5	+0.1	-0.2	+0.1	0
Median(%chg)	+5	0	0	0	0	0	0	0	0
New estimate (% chg)									

Table 1.3 Retail Property: Estimates of Additional % Change Due to Road pricing.									
Zone	1	2	3	4	5	6	7	8	9
Your previous response									
Mean (% chg)	-3.8	+0.8	+2.2	+1.6	+0.7	+1.8	+0.9	+2.1	+1.4
Median(%chg)	-3	+1	+1	+2	0	0	0	0	+1
New estimate (% chg)									

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Table 1.4 Retail Property: Estimates of Additional % Change Due to Both Policies

Zone	1	2	3	4	5	6	7	8	9
Your previous response									
Mean (% chg)	-2.3	+2.5	+3.4	+2.1	+1.2	+1.3	+0.4	+1.2	+0.7
Median(%chg)	0	+2	+3	+2	0	0	0	0	0
New estimate (% chg)									

The next 4 tables ask about the impacts on Office Property Prices

Table 2.1 Office Property: Base Estimates of % Change over next 10-15 yrs.

Zone	1	2	3	4	5	6	7	8	9
Your previous response									
Mean (% chg)	+3.5	+6.4	+10.1	+2.6	+4.2	+2.3	+1.0	+0.4	+2.1
Median(%chg)	+1.5	+5	+5	0	+2.5	0	0	0	+5
New estimate (% chg)									

Please place a 'X' in the box where you do not wish to change your previous response.

Table 2.2 Office Prop: Estimates of Additional % Change Due to Public Transport.

Zone	1	2	3	4	5	6	7	8	9
Your previous response									
Mean (% chg)	+2.9	+2.5	+2.5	+1.9	+1.7	+0.9	+0.5	+0.6	+0.9
Median(%chg)	0	+1	+1	0	0	0	0	0	0
New estimate (% chg)									

Table 2.3 Office Property: Estimates of Additional % Change Due to Road pricing.

Zone	1	2	3	4	5	6	7	8	9
Your previous response									
Mean (% chg)	-8.2	0	+3.5	+2.3	+2.3	+2.2	+1.8	+1.8	+2.6
Median(%chg)	-10	0	+3	0	0	0	0	0	+1
New estimate (% chg)									

Table 2.4 Office Property: Estimates of Additional % Change Due to Both Policies

Zone	1	2	3	4	5	6	7	8	9
Your previous response									
Mean (% chg)	-5.2	+2.2	+5.6	+3.5	+3.6	+2.7	+1.4	+1.9	+2.5
Median (% chg)	-5	+3	+4	+1	0	0	0	0	0
New estimate (% chg)									

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The final 4 tables ask about the impacts on <u>population distributions</u> of the transport policies:

Table 3.1 Population Distribution: Base Estimates of % Change over next 10-15 years

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Your previous response									
Mean (% chg)	+1.8	+3.9	+4	+5.2	+4	+4.7	+1.7	+3.6	+3.6
Median(%chg)	+1.5	+1	+2	+4	+5	+5	0	+3	+4
New estimate (% chg)									

Please place a 'X' in the box where you do not wish to change your previous response.

Table 3.2 Population Dist'n: Estimates of <u>Additional</u> % Change Due to Public Transport Policy.

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Your previous response									
Mean (% chg)	+0.9	+1.4	+1.1	+2	+2.1	+1.8	+0.4	+0.8	+2.5
Median(%chg)	0	0	0	+1	+0.5	0	0	0	+1
New estimate (% chg)									

Table 3.3 Population Dist'n : Estimates of <u>Additional</u> % Change Due to Road Pricing

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Your previous response									
Mean (% chg)	-2	-0.5	+0.4	+0.6	+0.6	+1.5	+0.7	+0.8	+1.1
Median(%chg)	-0.5	0	0	0	0	0	0	0	0
New estimate (% chg)									

Table 3.4 Population Dist'n: Estimates of <u>Additional</u> % Change Due to Both Policies

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Your previous response									
Mean (% chg)	-1.4	+1.8	+2.4	+3.3	+3.4	+3.0	+1.3	+2.0	+3.1
Median(%chg)	0	0	0	+1	+0.5	+1.3	0	0	+3
New estimate (% chg)									

Additional comments would be welcome. Please use a separate sheet.

Thank you for completing this questionnaire. Your assistance in this survey has been extremely useful, and is greatly appreciated.

Please return/fax the questionnaire even if you have not changed any responses.

 Please Fax Back to : 0113 233 5334 c/o Ben Still

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APPENDIX II

DELPHI RESULTS TABLES (FIRST AND SECOND ROUNDS)

Do-minimum estimates of change in the indicators over next 15 years

Table II.1 Retail property rents; do-minimum estimates of change

ROUND 1 Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean (% chg)	7.9	6.8	5.8	4.1	4.1	2.8	1.6	1.3	2.1
Median(%chg)	8	3.5	5	4	0	4	0	0	0
IQR (units of % chg)	3-10	0-9	0-10	0-5	0-10	0-5	0-5	0-5	0-5
SD (units of % chg)	14.7	12.4	8.3	7.5	6.4	6.5	3.4	5.4	5.3
ROUND 2 Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean (% chg)	7.7	5.6	4.5	3.6	3.4	3.2	1.7	1.3	2.1
Median(%chg)	8	5	5	4	0	5	1	0	0.5
IQR (units of % chg)	3-10	0-6	0-8	0-5	0-10	0-6	0-5	0-5	0-5
SD (units of % chg)	10.2	7.9	5.9	6.0	4.6	5.9	2.5	4.6	4.5

Figures rounded

Table II.2 Office property rents; do-minimum estimates of change

ROUND 1 Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean (% chg)	3.5	6.4	10.1	2.6	4.2	2.3	1.0	0.4	2.1
Median(%chg)	1.5	5	5	0	2.5	0	0	0	5
IQR (units of % chg)	0-10	0-10	2-16	0-5	0-10	0-5	0-3.2	-0.5-5	0-5
SD (units of % chg)	8.9	12.6	12.1	5.5	4.9	3.9	3.4	4.8	5.6
ROUND 2 Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean (% chg)	3.4	6.1	8.0	1.6	4.6	2.5	1.2	0.9	2.8
Median(%chg)	3	5	5	0	5	1	0	0	5
IQR (units of % chg)	0-10	1-7.5	3-10	0-4	0-9	0-5	0-5	-1-5	0-5
SD (units of % chg)	7.3	8.2	7.8	3.2	4.6	3.3	2.8	3.9	4.3

Figures rounded

Table II.3 Population distributions: do-minimum estimates of change

ROUND 1 Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean (% chg)	1.8	3.9	4	5.2	4	4.7	1.7	3.6	3.6
Median(%chg)	1.5	1	2	4	5	5	0	3	4
IQR (units of % chg)	-1.3-5	0-5	0-6.3	0-10	0-5	0-10	0-5	0-8.1	0-5
SD (units of % chg)	5.6	7.5	6.2	5.5	4.4	6.0	4.2	6.4	6.4
ROUND 2 Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean (% chg)	2.4	3.3	2.7	3.4	3.7	3.7	1.4	2.8	2.4
Median(%chg)	2	2	2	3	5	5	0	2	3
IQR (units of % chg)	0-5	0-5	0-5	0-5	0-5	0-7	0-4	0-5	0-5
SD (units of % chg)	5.2	4.8	3.8	3.2	3.4	5.2	3.3	5.7	4.7

Figures rounded

Predicted impacts from the transport policies

Table II.4: The impacts from LRT (public transport) ROUND 2

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Retail rents									
Mean (% chg)	4.5	1.9	1.0	0.2	0.2	0.2	-0.1	0.2	-0.7
Median(%chg)	5	0	0	0	0	0	0	0	0
SD (% units)	3.2	3.0	1.8	3.5	3.5	2.1	2.0	2.1	3.5
Office rents									
Mean (% chg)	3.2	2.2	2.0	1.3	1.7	1.0	0.5	0.6	0.7
Median(%chg)	2	1.5	2	0	0	0	0	0	0
SD (% units)	5.6	4.2	1.9	2.7	2.6	2.9	1.8	1.9	2.8
Population dist'n.									
Mean (% chg)	0.9	1.3	0.6	1.5	1.9	1.8	0.3	0.7	2.4
Median(%chg)	0	0	0	1	2	0	0	0	2
SD (% units)	1.5	1.8	1.4	1.7	2.7	3.1	1.4	1.8	2.8

Figures rounded

Table II.5: The impacts from road pricing ROUND 2

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Retail rents									
Mean (% chg)	-6.9	1.14	2.2	1.1	0.6	1.7	0.8	2.0	1.3
Median (%chg)	-5	0	0	0	0	0	0	0	0
SD (% units)	6.0	4.8	4.9	3.9	1.5	4.1	1.8	4.2	1.7
Office rents									
Mean (% chg)	-8.8	0.2	3.1	1.4	2.3	1.8	1.6	1.3	2.4
Median(%chg)	-10	0	2.5	0	1	0	0	0	2
SD (% units)	5.7	3.7	2.9	1.8	2.6	2.4	2.2	2.0	2.4
Population dist'n.									
Mean (% chg)	-1.3	-0.3	0.4	0.3	0.4	1.5	0.6	0.7	1.1
Median(%chg)	-1	0	0	0	0	0	0	0	0
SD (% units)	6.2	2.8	1.1	1.4	1.2	2.3	1.4	1.8	2.0

Figures rounded

Table II.6: The impacts from the combined policies ROUND 2

Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Retail rents									
Mean (% chg)	-2.7	2.2	2.9	1.8	0.9	1.3	0.4	1.3	0.8
Median(%chg)	0	2.5	3	1	0	0	0	0	0
SD (% units)	10	5.8	2.7	3.1	2.3	2.2	1.5	2.2	2.9
Office rents									
Mean (% chg)	-5.2	2.5	4.5	2.3	3.7	2.8	1.4	1.9	5.1
Median(%chg)	-5	2.5	5	1.5	3	1	0	0.5	0
SD (% units)	8.5	7.1	3.1	2.6	4.3	5.0	2.5	2.8	13.1
Population dist'n.									
Mean (% chg)	-0.6	1.13	1.3	2.3	3.7	2.9	1.1	1.8	3.4
Median(%chg)	0	0	0	2	2	2	0	1	4
SD (% units)	5.1	4.7	3.2	3.1	4.1	3.2	1.8	2.1	2.3

Figures rounded

APPENDIX III

THE PHASE 2 INTERVIEWS

INFORMATION PACK

(1) **The Delphi Survey**

(2) **The LUCI Method**

(3) **DELTA/START**

(4) **Questionnaire**

Background Information on Method 1:
Expert Opinion Surveys (The 'DELPHI' Method)

One way to examine transport impacts on land use is to ask professionals who have experience with land use and transport systems what they expect the impacts of transport policy to be. A survey of this type was undertaken for the Edinburgh region, utilising the expertise of **property and planning experts**, familiar with the region.

The method used was to ask a series of questions to determine:

1. *The general impacts of a road pricing policy and a public transport (rapid transit) policy on property prices in the office and retail sectors.*
2. *In which sectors the transport policies are likely to have most effect.*
3. *The distribution of impacts over the study area, for retail and office prices.*
4. *The distribution of impacts on patterns of population over the study area.*
5. *The timescales over which the impacts are likely to take place.*

After asking the experts these questions, their responses were summarised, and presented to the experts again. They were asked if, given these 'group' results, they wished to revise their estimates of change. This repeat sampling method is often called the '**Delphi**' forecasting method (after the Greek oracle). It provides a better **consensus** within the sample group, as each expert is aware of the general views of the group.

Note the following key assumptions:

- the method focuses upon the opinions of the experts, **without** examining the reasons for their opinions.
- the experts' views are **anonymous**, both from each other, and in the analysis of the results.

The Delphi method is dependent upon securing a sample of willing and able 'experts'. Research into the consensus of results finds that with around 15 or more experts, so long as they consist of a cross section of expertise, another sample is unlikely to lead to a very different result. Our sample had 27 respondents in the first round, and 20 in the second round. All the results presented are from the second round, unless otherwise stated.

Outputs: **Population % change (from 1996) by zone for future year.**
Retail price % change (from 1996) by zone for future year.
Office price % change (from 1996) by zone for future year.

Please note that the DELPHI survey used the 9 zone system that is presented in these results and shown in Map 1. The other two methods used a finer zoning system, that has been aggregated for presentation.

Delphi : Population Forecasts 1995-2010

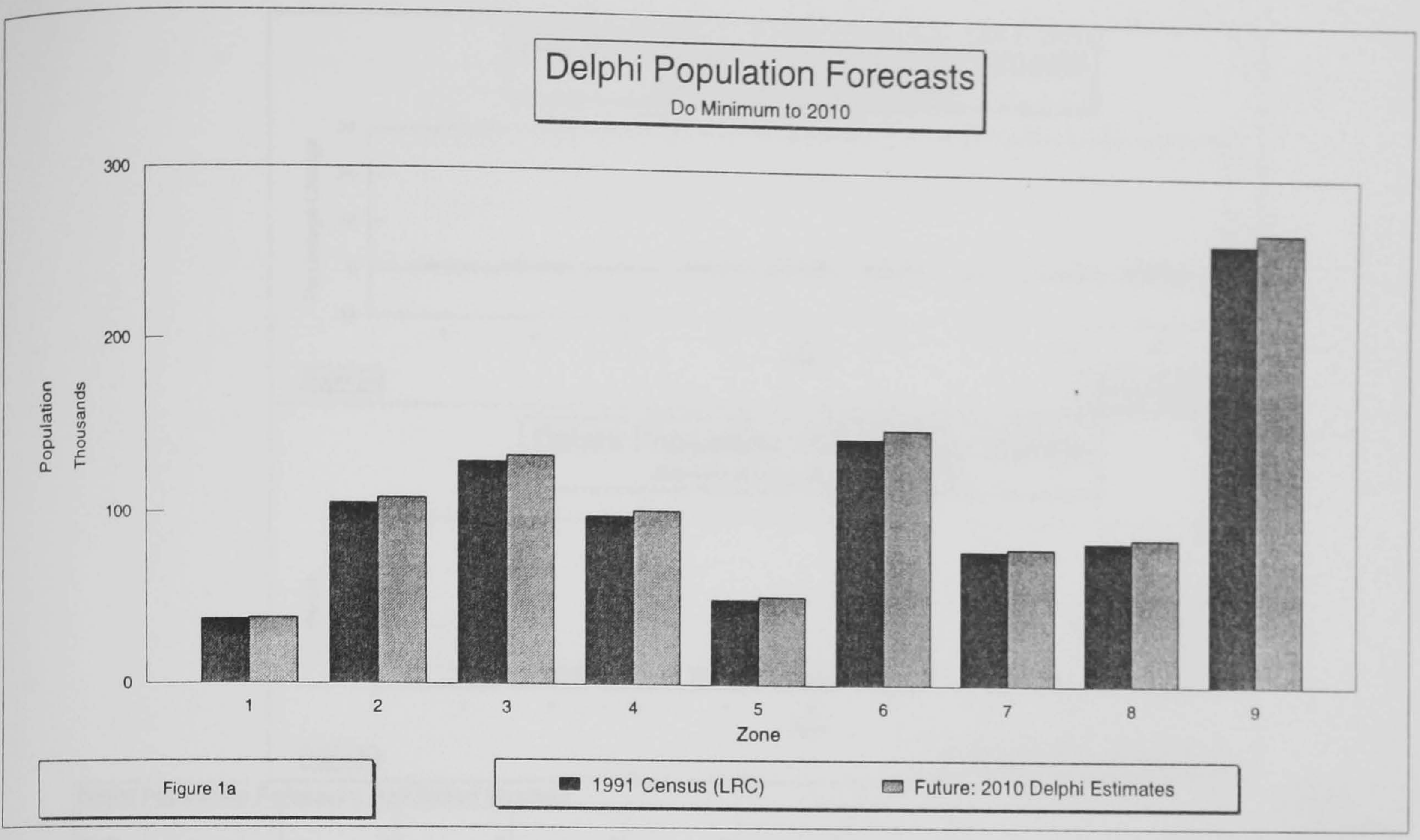


Figure 1a

Delphi Population Forecasts: Do-Min										
Zone	1	2	3	4	5	6	7	8	9	Totals (excluding Fife)
1991 Census	37269	104794	129477	98116	49256	144137	78845	84114	260663	726008
% Change	2.25	3.35	3	3.6	3.85	3.9	1.85	3.05	2.62	
2010 Estimate	38108	108305	133361	101648	51152	149758	80304	86679	267492	749315

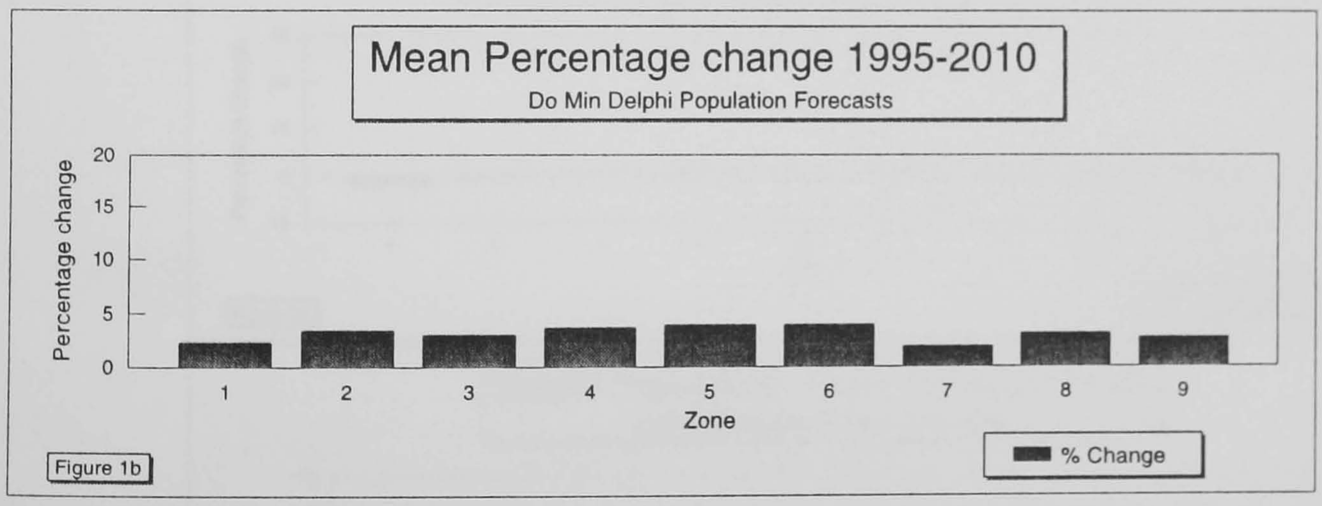


Figure 1b

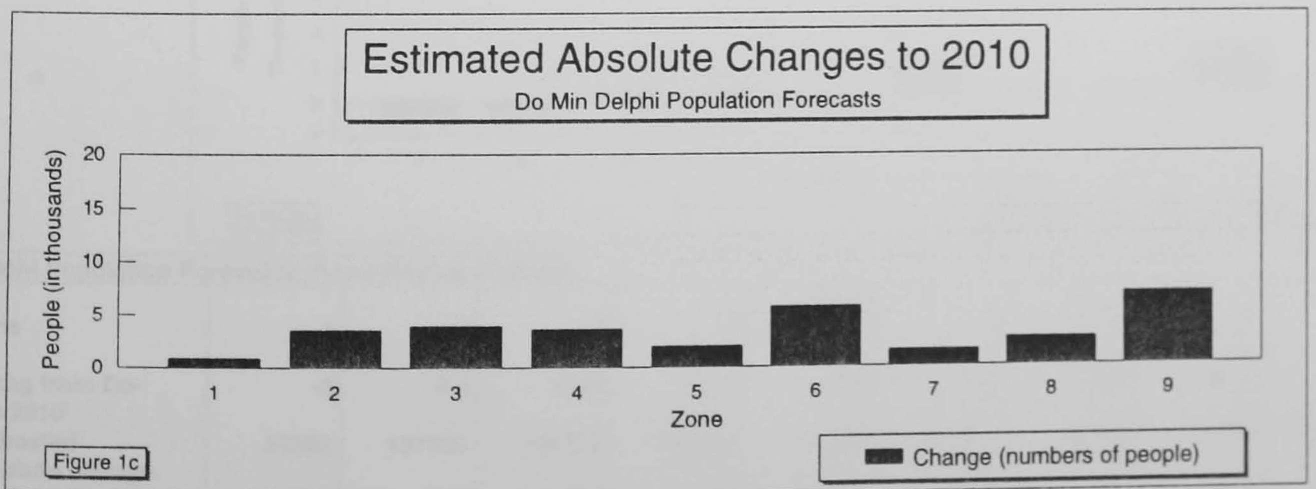
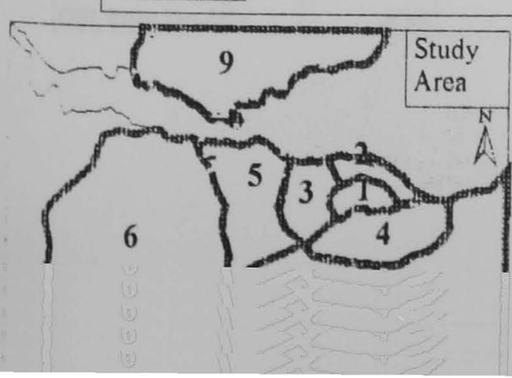


Figure 1c



Delphi : Transport Impacts on Population

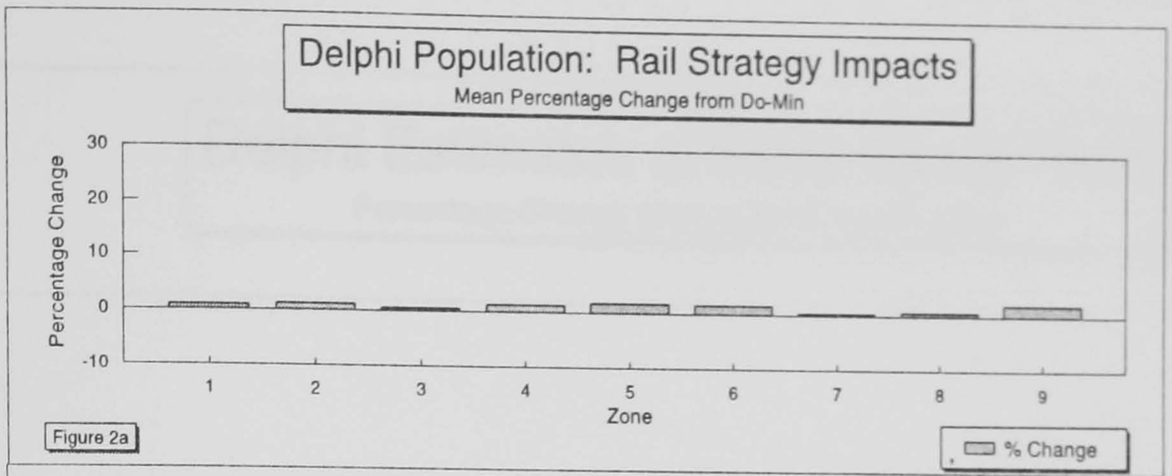


Figure 2a

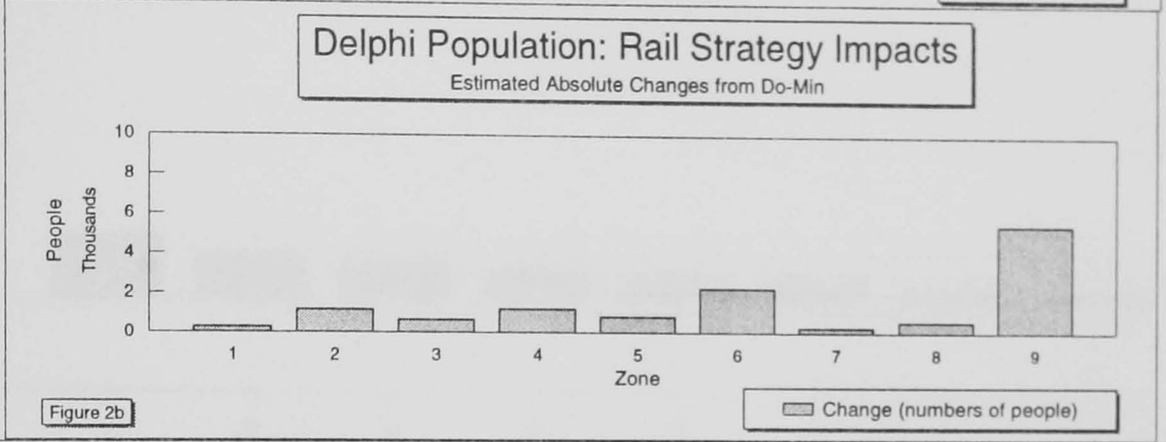


Figure 2b

Delphi Population Forecasts: Rail Based Strategy										Totals (excluding Fife)
Zone	1	2	3	4	5	6	7	8	9	
% chg from Do-Min 2010	0.72	1.11	0.5	1.22	1.67	1.56	0.33	0.67	2.11	
Estimated absolute change.	38376	109468	134009	102845	51975	152007	80564	87243	272992	756486
Diff from Do-Min	268	1163	647	1197	823	2249	260	564	5500	

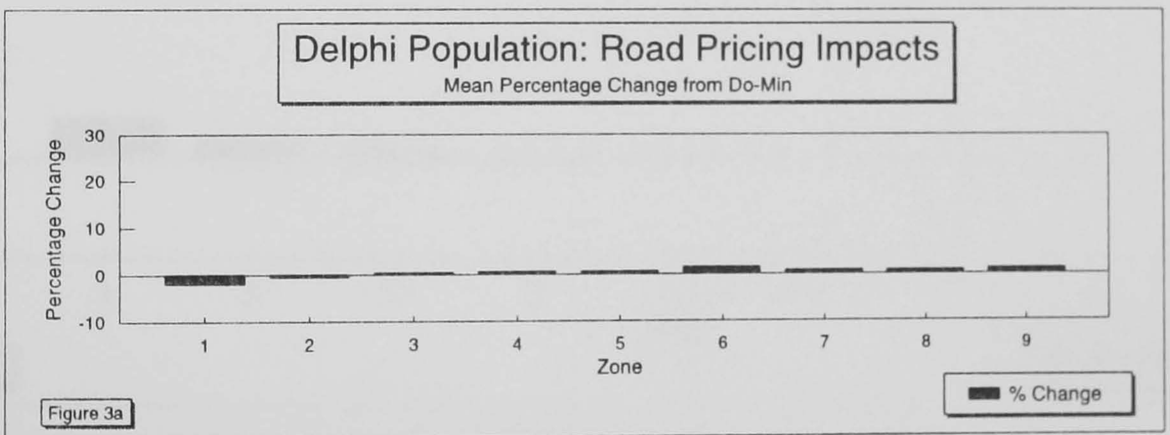


Figure 3a

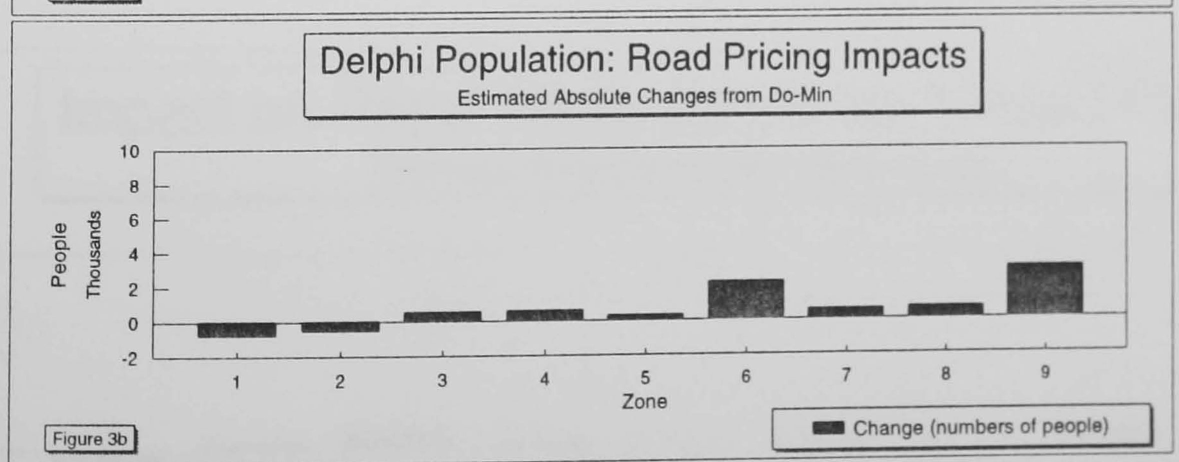
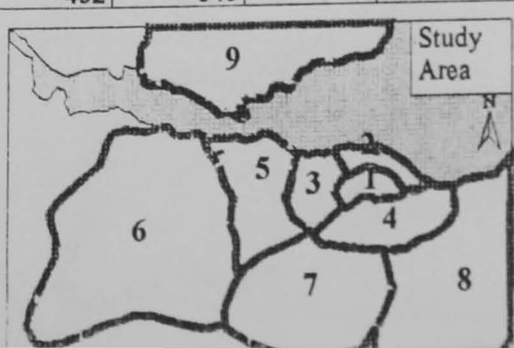


Figure 3b

Delphi Population Forecasts: Road Pricing Strategy										Totals (excluding Fife)
Zone	1	2	3	4	5	6	7	8	9	
% chg from Do-Min 2010	-2	-0.5	0.38	0.56	0.56	1.47	0.66	0.75	1.12	
Estimated absolute change.	37362	107781	133853	102198	51428	151877	80824	87310	270412	752633
Diff from Do-Min	-745	-524	492	549	276	2119	520	631	2919	



Delphi : Transport Impacts on Retail Rents

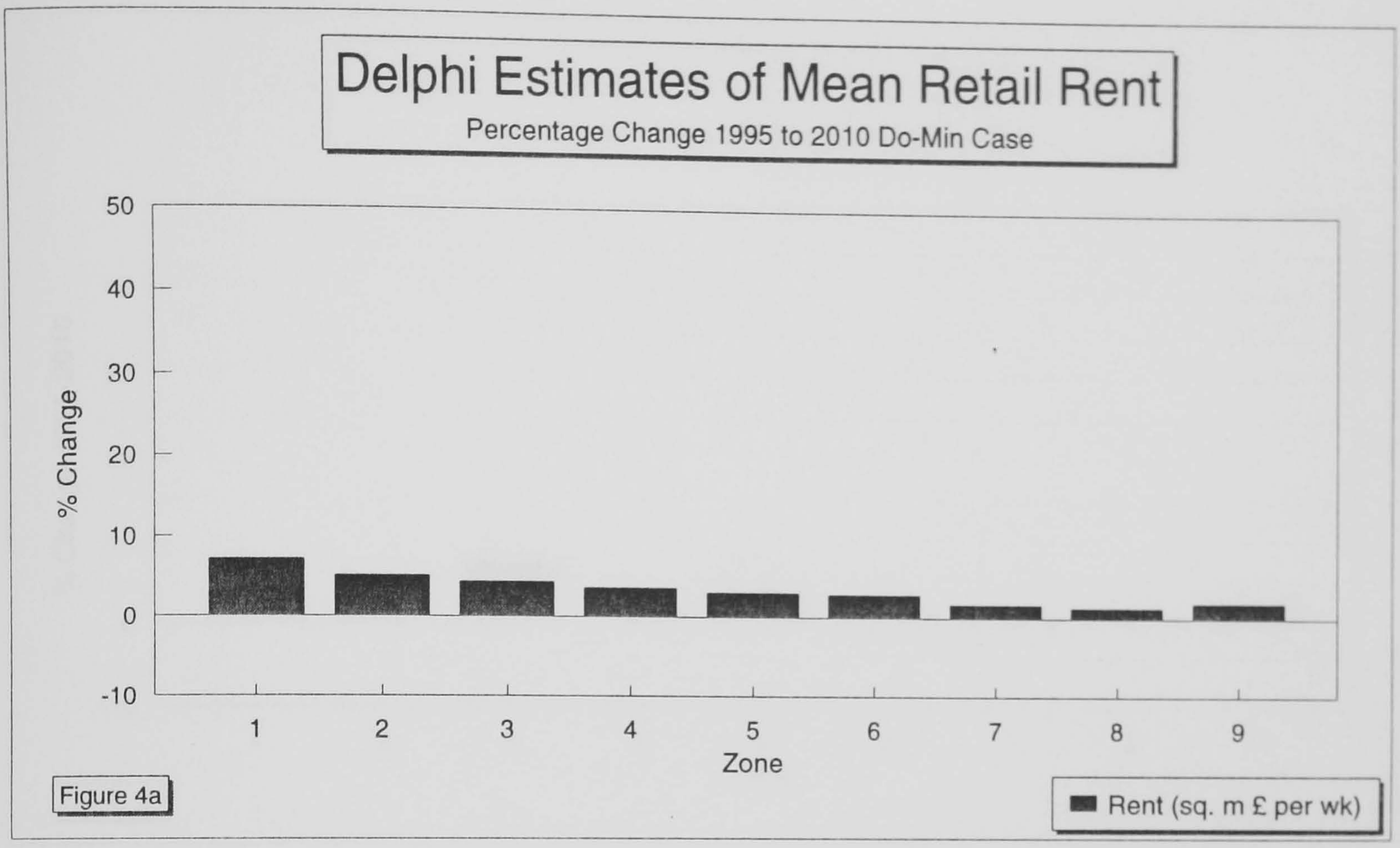


Figure 4a

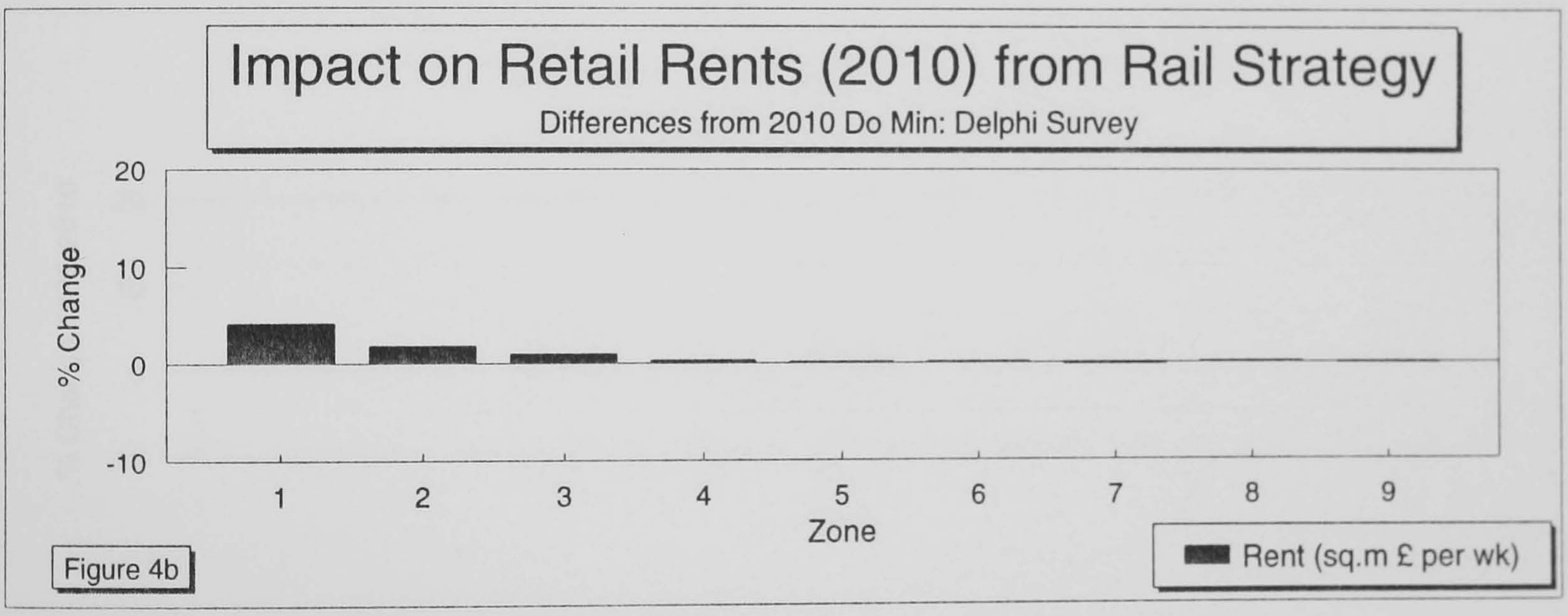


Figure 4b

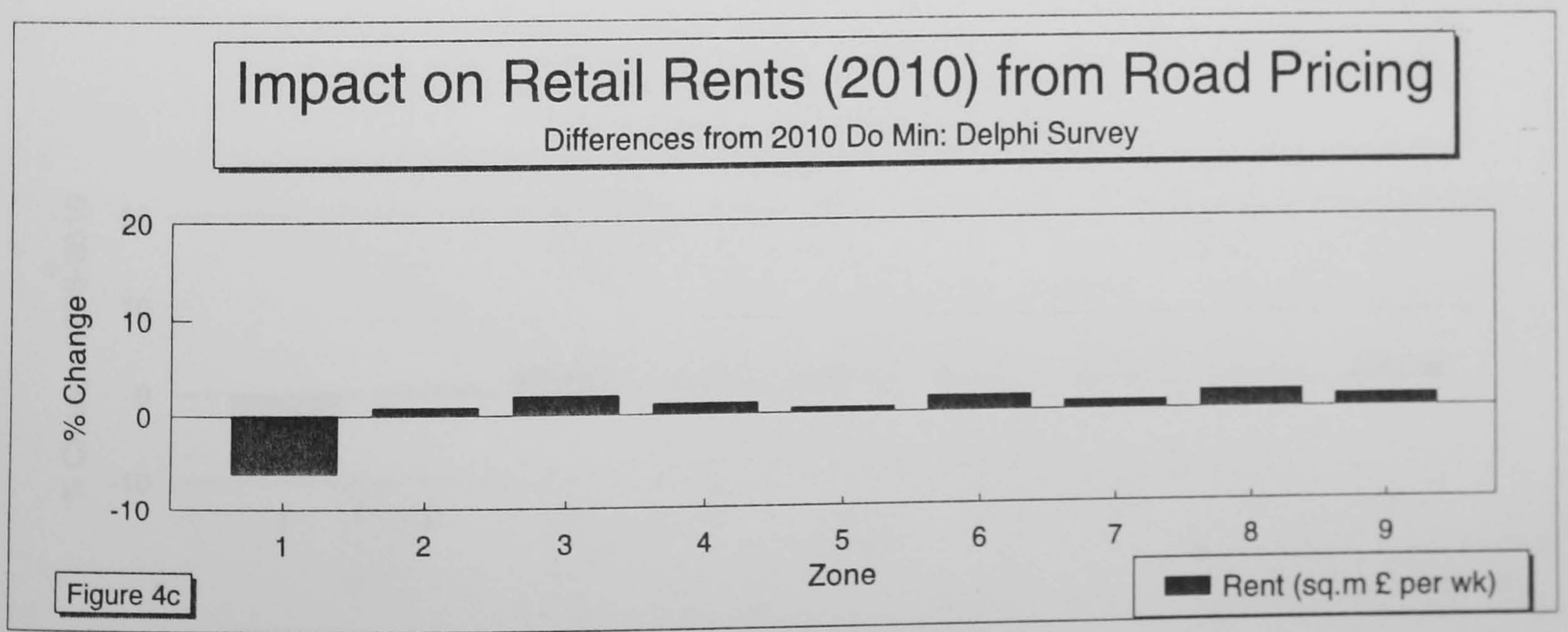
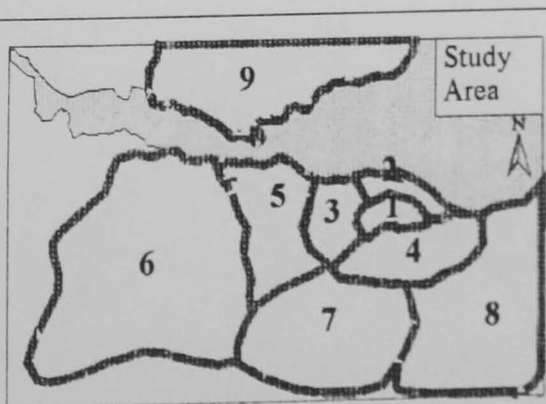


Figure 4c



Delphi : Transport Impacts on Office Rents

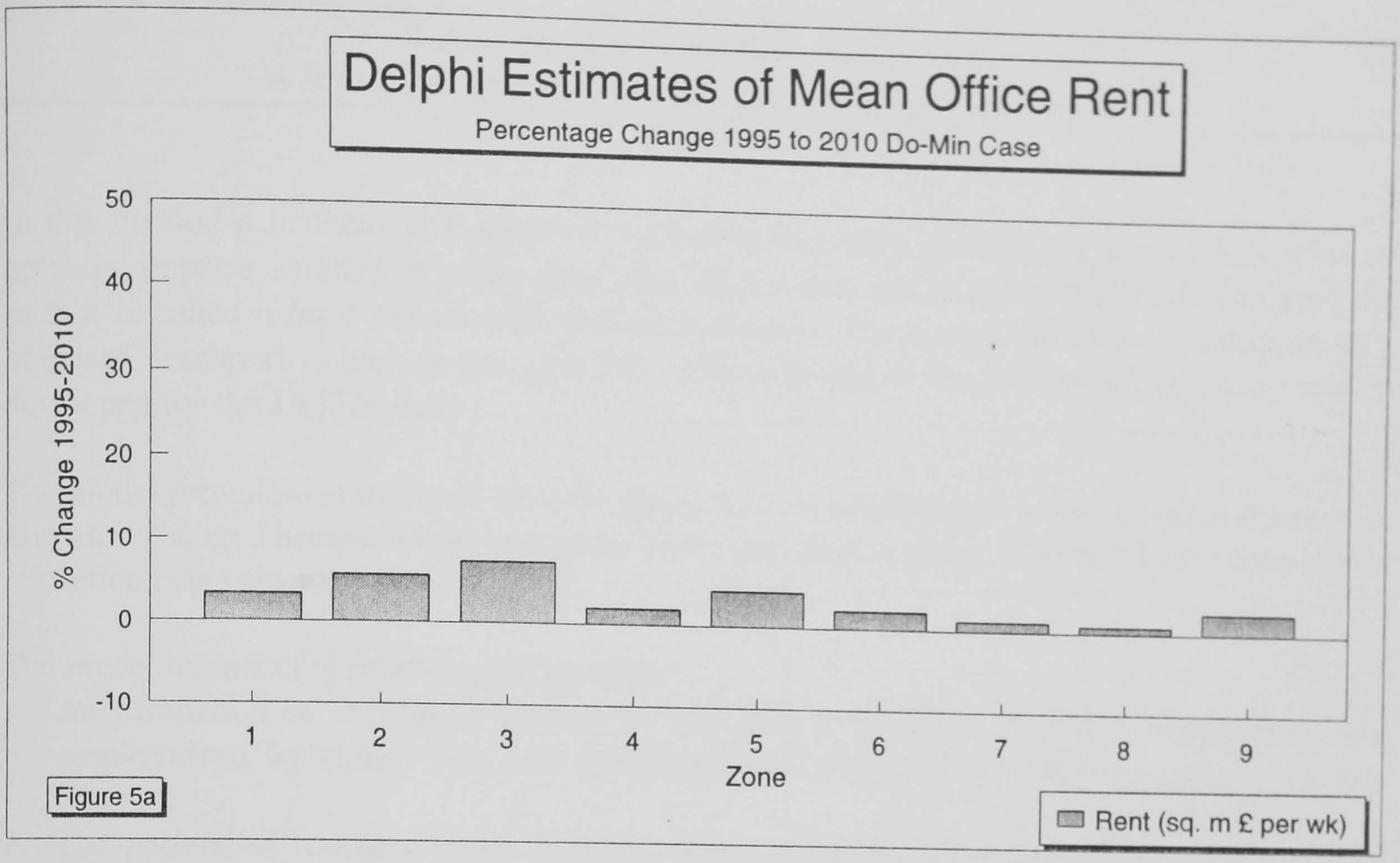


Figure 5a

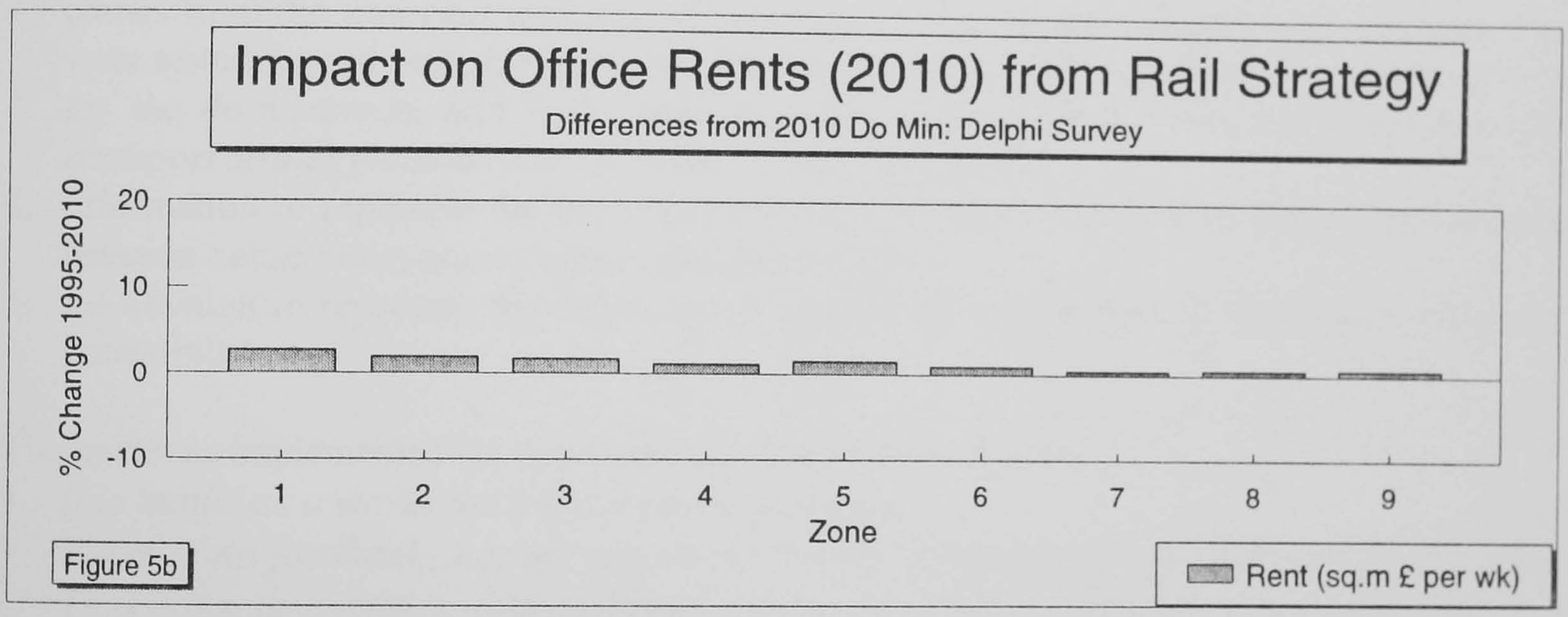


Figure 5b

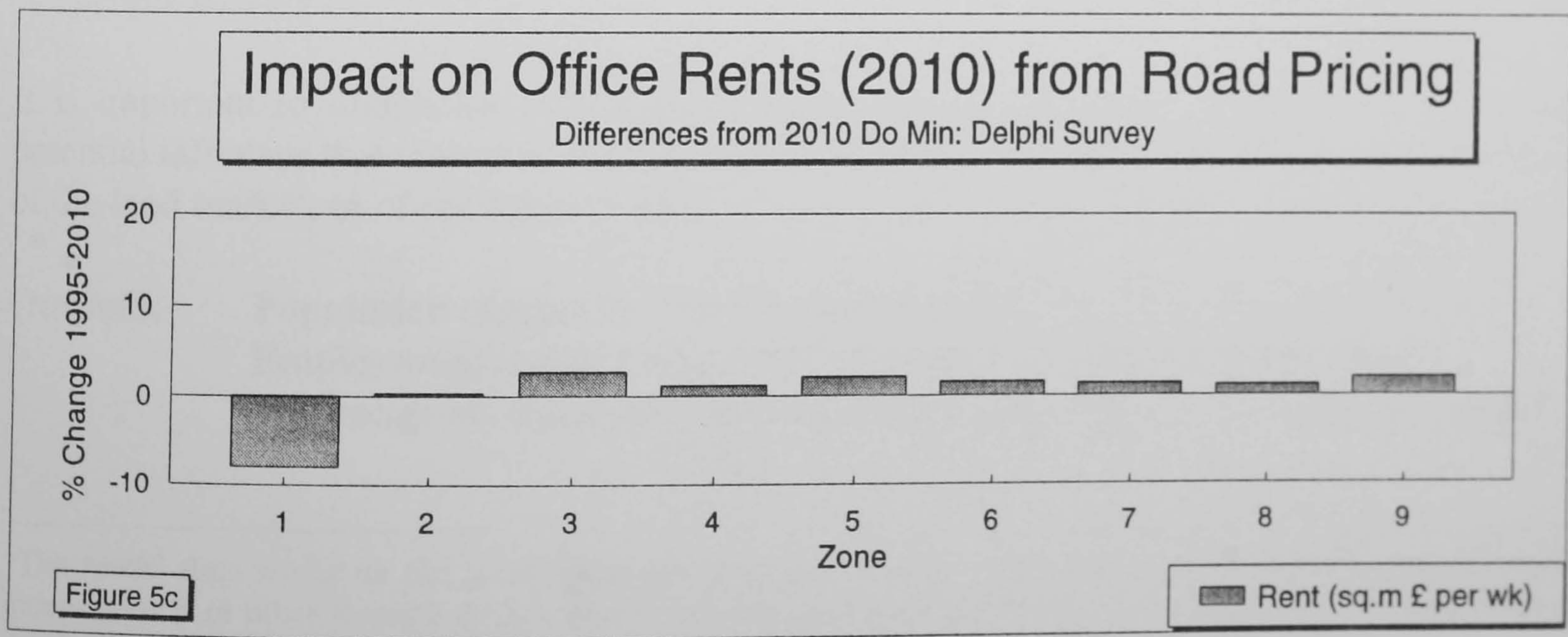
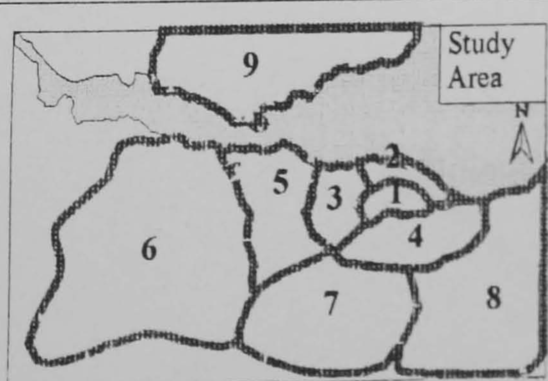


Figure 5c



Background Information on Method 2:
A Static Accessibility Model (The 'INDICATOR' model)

In this method a mathematical model is applied to the study area to provide an indication of potential impacts a transport policy may have upon a land use pattern **within** a future year. As such it is called a ***land use change indicator model***. The model works as an addition to a 'standard' transport model, in this case the existing model of the Edinburgh transport system developed for the JATES study.

The model provides estimates of how the population or employment would relocate themselves given the changed accessibilities as a result of the transport strategy. The only factor that affects relocation is the change in accessibility[1].

The model requires the following information:

1. An estimation of the future pattern of land use in the base case (i.e. **population and employment by zone**). This was exogenously produced by planners in Lothian Regional Council.
2. The pattern of transport costs between zones, produced as **accessibility** measures. This comes from the transport model (JATES), for the do-minimum and the two strategies that were tested: a road pricing strategy and an LRT strategy. *The same land use pattern is used for the do-minimum, and both strategies. The land use model then calculates how the transport strategy would alter the 'future' land use pattern.*
3. Information to represent the behaviour of the population, with respect to their preferences between house price, size of house, and accessibility.
4. Information to represent the behaviour of businesses, with respect to floorspace, price and accessibility.

The model as implemented for this study has the following features:

- *It is **'static'** as it works for a given future year only.*
- *There is no **feedback**, i.e. no constraints on the amount of space available in any zone. Thus if a zone becomes overwhelmingly attractive, nothing would prevent large numbers of people moving in.*

It is important to understand that the results are termed *indicators*, as they only show the potential influence that transport has upon location choice, via relocation. There is no modelling of the land market, or of change over time.

Outputs: **Population change by zone for future year.**
Employment (retail / other service) change by zone for future year.
Full range of transport / environmental outputs from the transport model.

[1]The model thus works on the assumption that transport impacts on land use can be isolated and examine independently of other location determinants, once the relative importance of accessibility has been determine during the 'calibration' of the model.

Indicator Model : Exogenous Population Forecasts 1991-2011

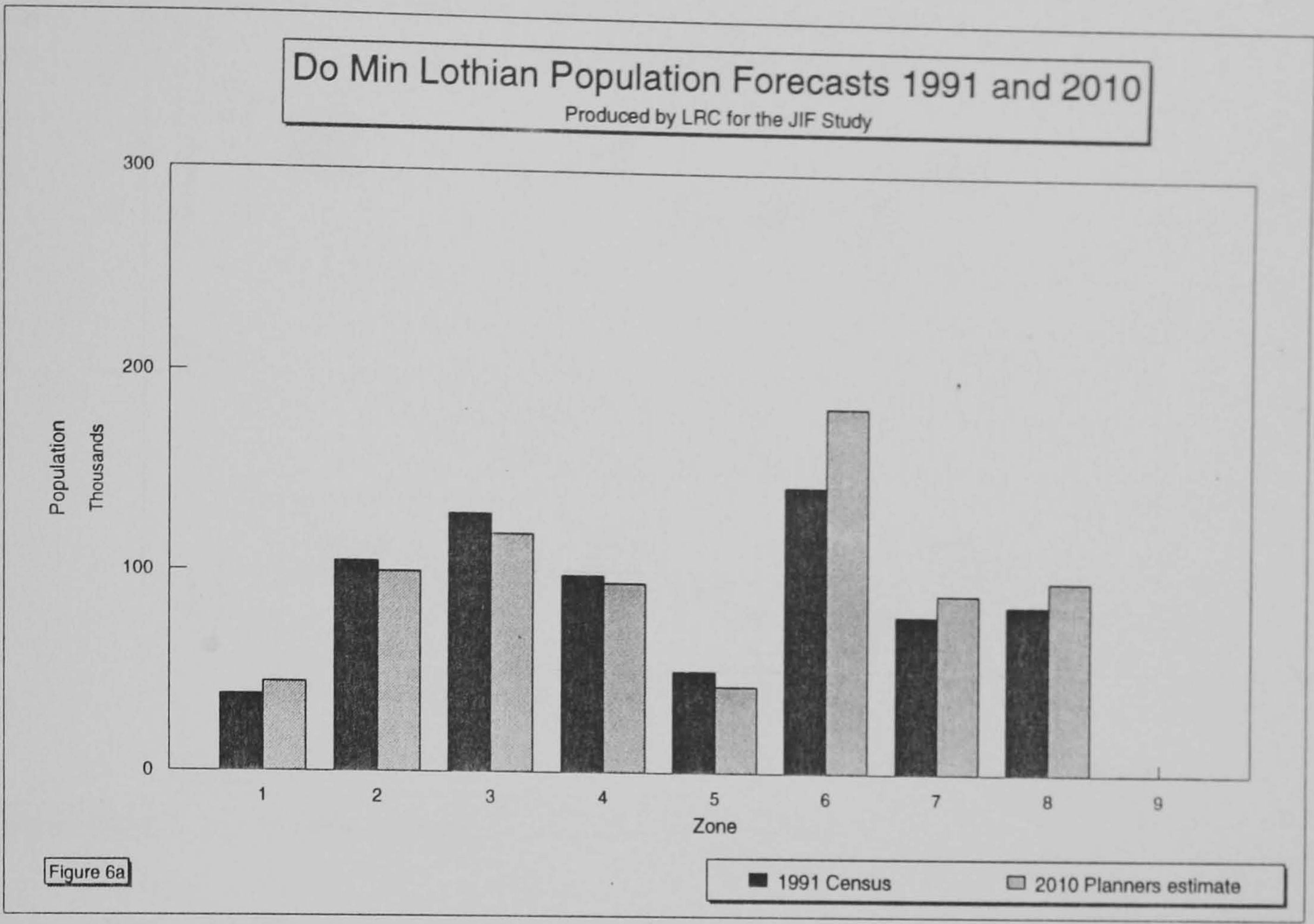


Figure 6a

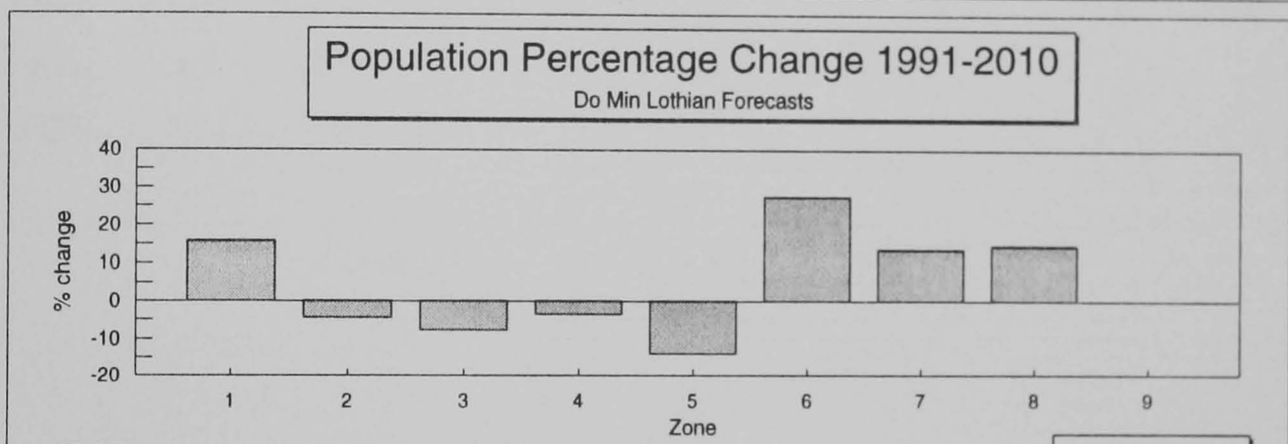


Figure 6b

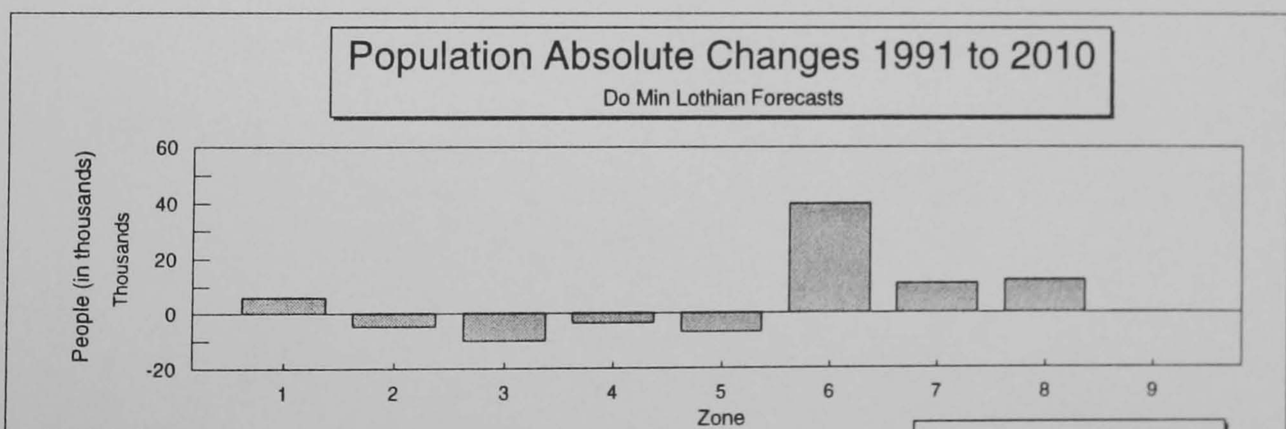
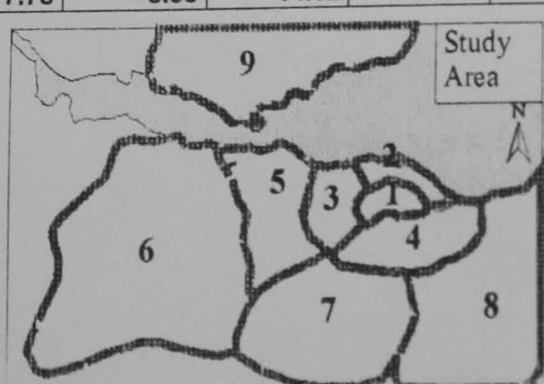
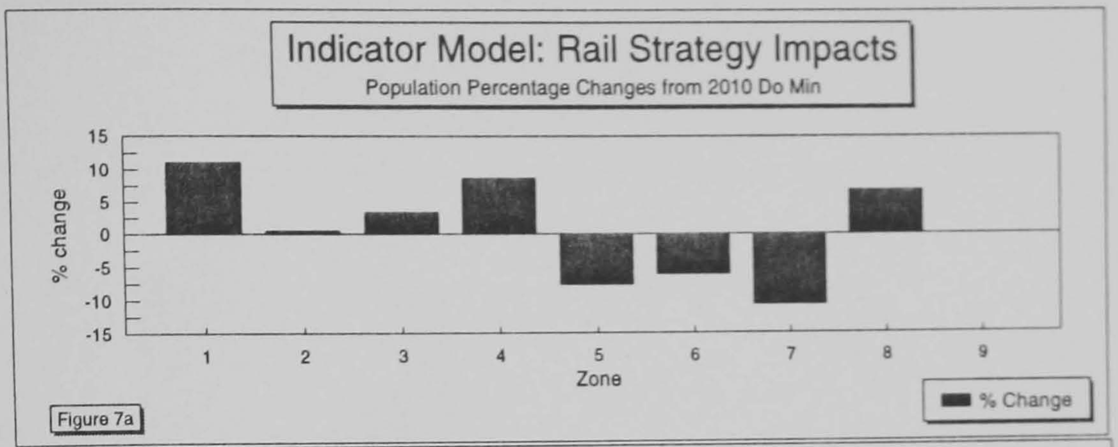


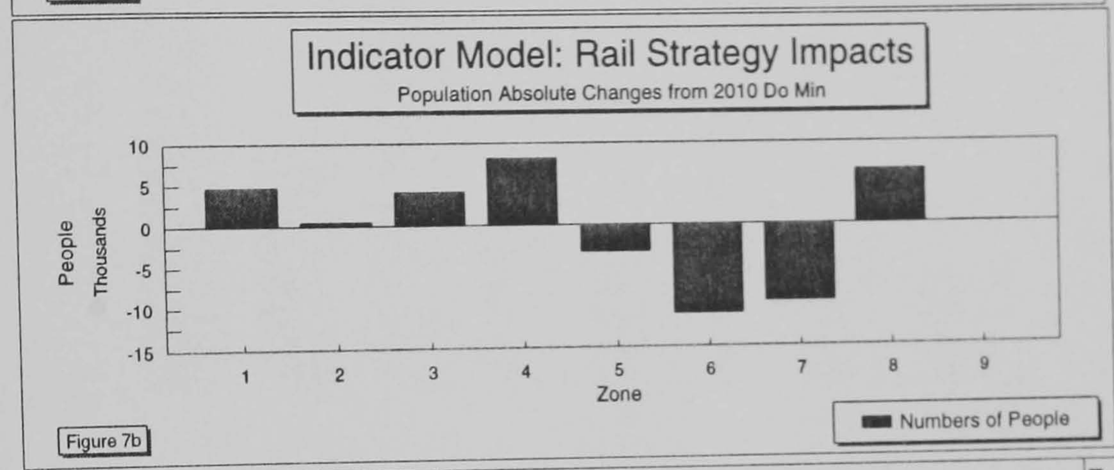
Figure 6c

LOTHIAN Population Forecasts: Do-Min										Total
Zone	1	2	3	4	5	6	7	8	9	
1991 Census	37269	104794	129477	98116	49256	144137	78845	84114	0	726008
2010 Estimate	43100	100200	119400	94600	42300	183700	89600	96300	0	769200
Absolute Change (from 1991-2010)	5831	-4594	-10077	-3516	-6956	39563	10755	12186	0	
% Change(91-10)	15.65	-4.38	-7.78	-3.58	-14.12	27.45	13.64	14.49		

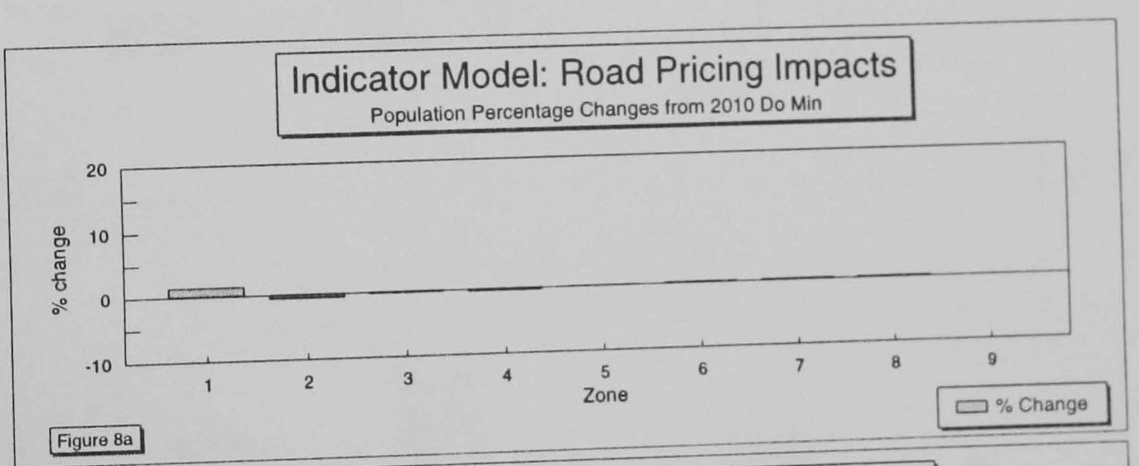


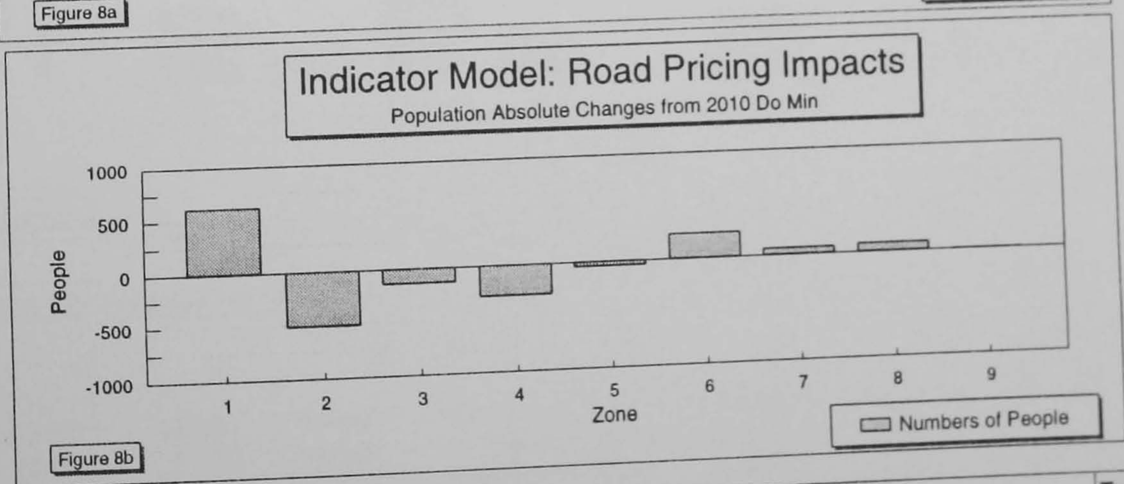
Model : Transport Impacts on Population



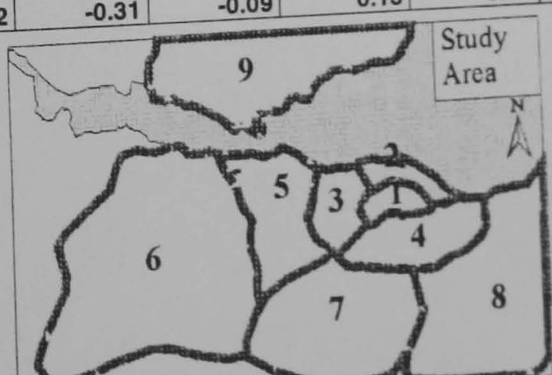


INDICATOR Model Impacts on Population distribution due to Rail Based Strategy										Total
Zone	1	2	3	4	5	0 6	7	8	9	
2010 Estimate	47863	100616	123472	102725	39069	172590	80053	102811	0	769200
Absolute Chang (from Do-Min)	4763	416	4072	8125	-3231	-11110	-9547	6511	0	
% Change	11.05	0.42	3.41	8.59	-7.64	-6.05	-10.65	6.76		





INDICATOR Model Impacts on Population Distribution due to Road Pricing Strategy										Total
Zone	1	2	3	4	5	6	7	8	9	
2010 Estimate	43711	99684	119261	94311	42261	183933	89659	96380	0	769200
Absolute Chang (from Do-Min)	611	-516	-139	-289	-39	233	59	80	0	
% Change	1.42	-0.51	-0.12	-0.31	-0.09	0.13	0.07	0.08		



el : Exogenous Employment Forecasts 1991-2010

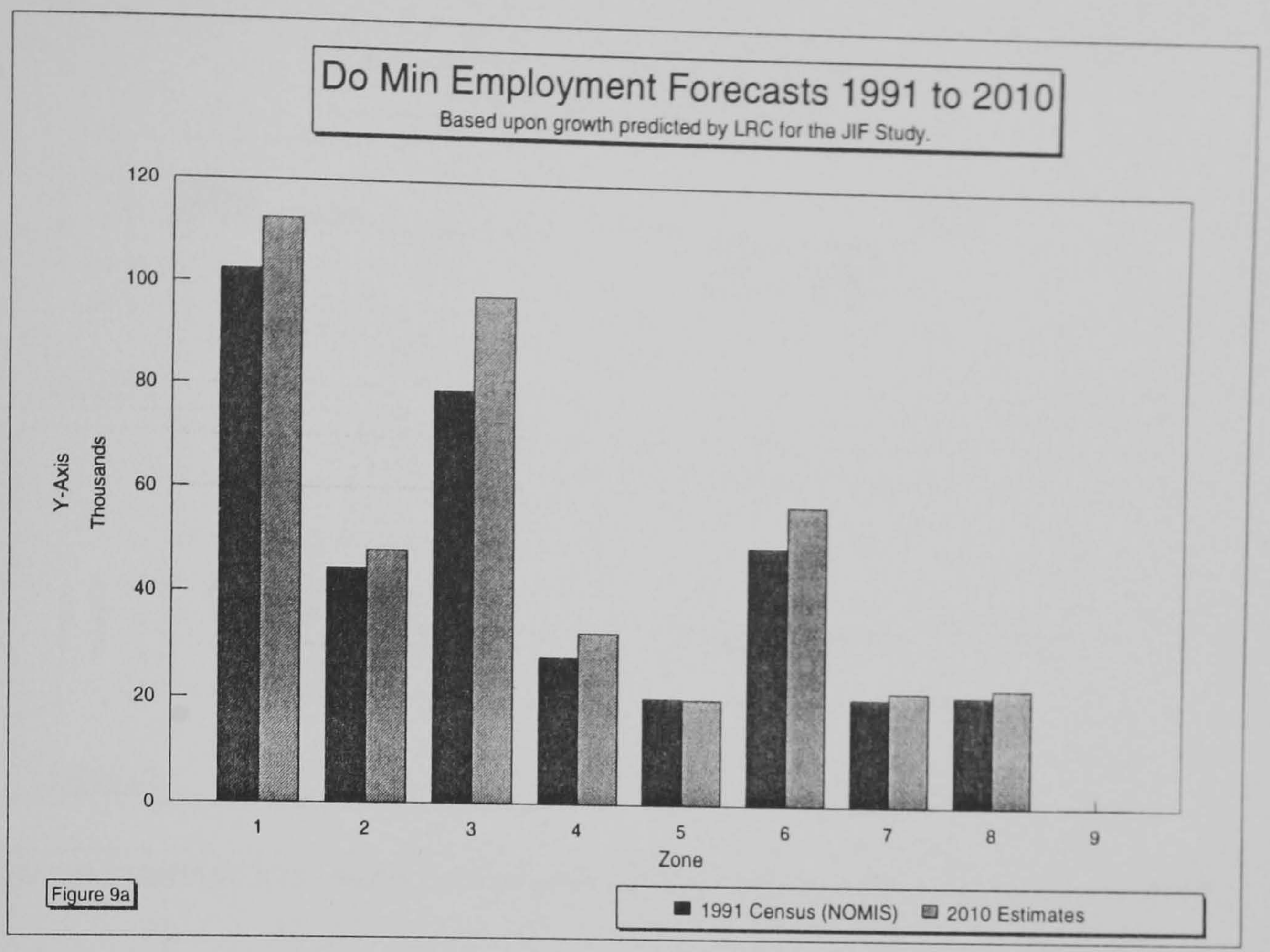


Figure 9a

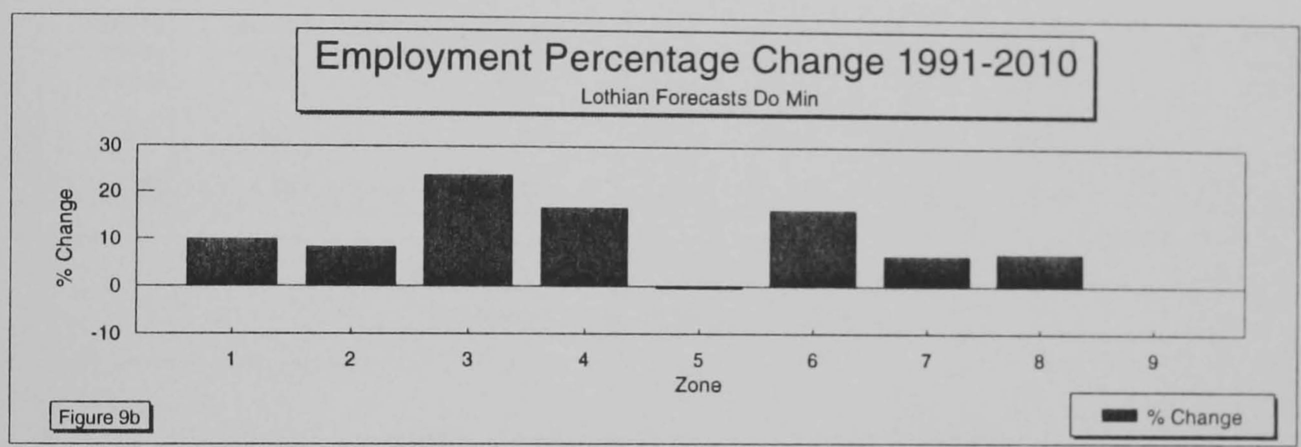


Figure 9b

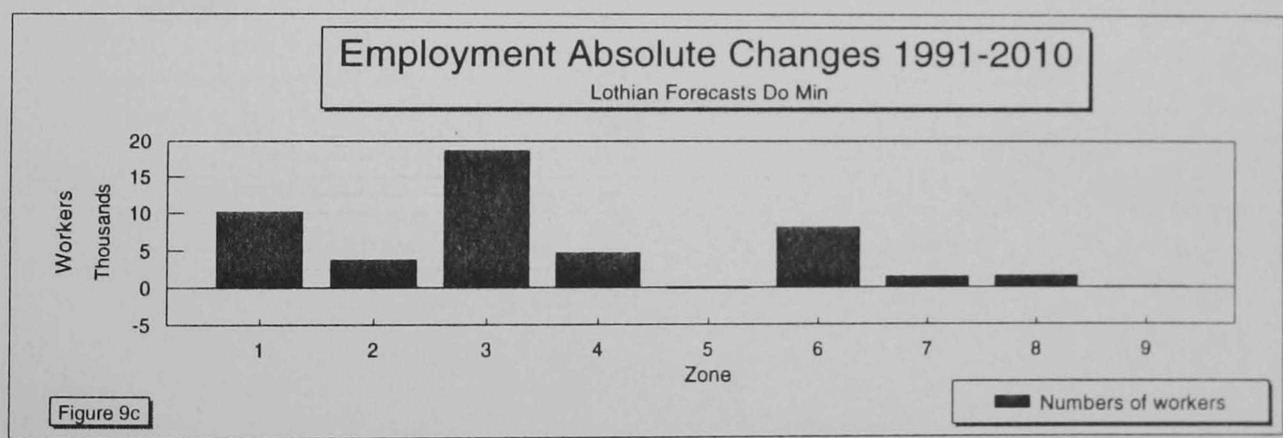
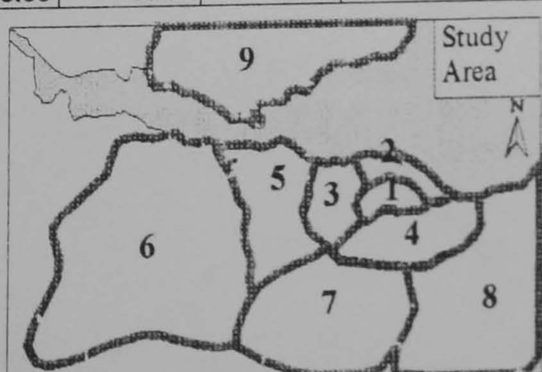


Figure 9c

LOTHIAN Employment Forecasts: Do-Min										Totals
Zone	1	2	3	4	5	6	7	8	9	
1991 CENSUS	102400	44300	79000	28000	20300	49400	20700	21400	0	365500
Retail Sector	*18878*	*9119*	*16536*	*6178*	*4416*	*9830*	*5104*	*5927*	*0*	*75987*
Service Sector	*80797*	*24535*	*54801*	*19506*	*13761*	*20405*	*13754*	*11490*	*0*	*239048*
2010 Estimate	112475	47971	97643	32654	20199	57435	22023	22881	0	413281
Retail Sector	*20904*	*9810*	*21590*	*7184*	*4412*	*11396*	*5412*	*6343*	*0*	*87050*
Service Sector	*88480*	*26538*	*66876*	*22695*	*13654*	*23691*	*14737*	*12296*	*0*	*268966*
Absolute Change	10075	3671	18643	4654	-101	8035	1323	1481		
(from 1991-2010)					0					
% Change(91-10)	9.84	8.29	23.60	16.62	-0.50	16.27	6.39	6.92		



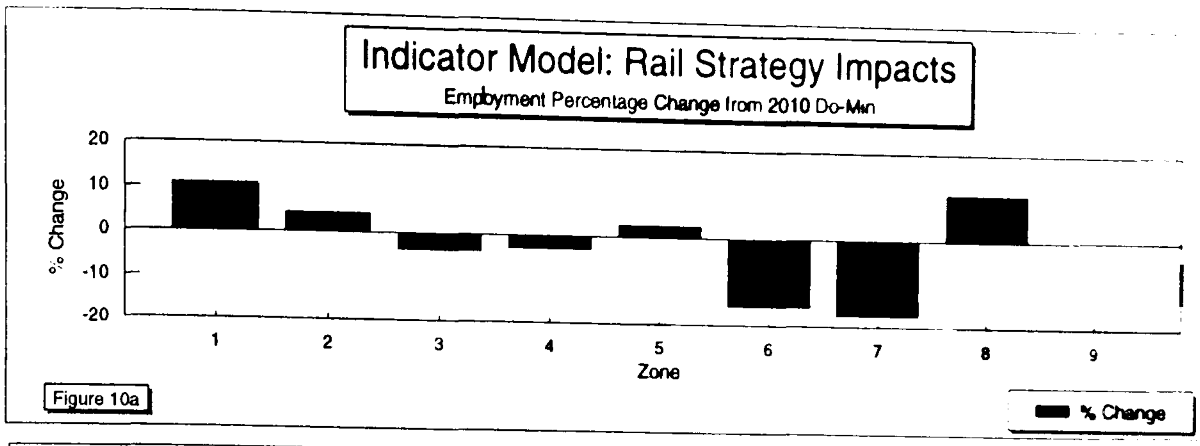


Figure 10a

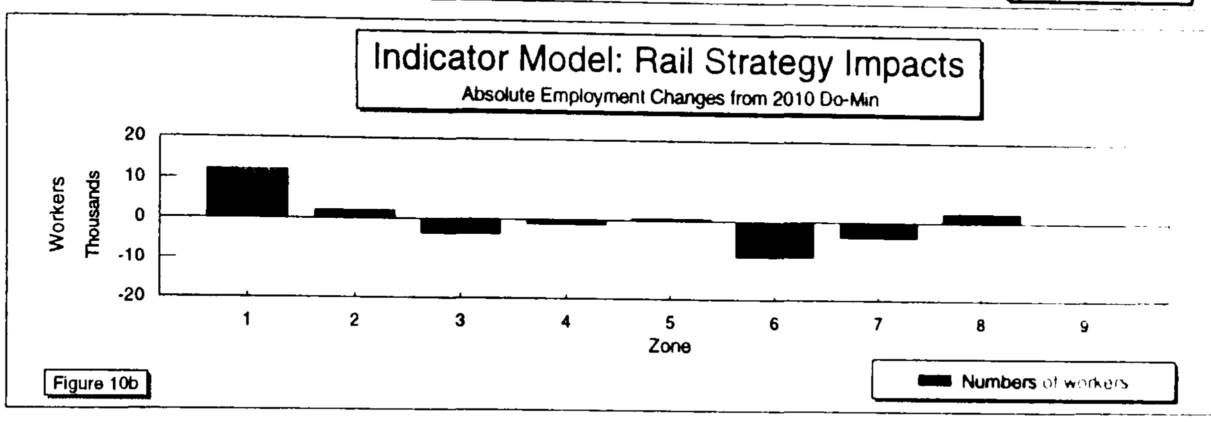


Figure 10b

INDICATOR Model Impacts on Employment Distribution due to Rail Based Strategy										Totals
Zone	1	2	3	4	5	6	7	8	9	
2010 Estimate	124513	50098	94092	31744	20729	48563	18211	25332	0	413281
Retail Sector	*25069*	*10663*	*20329*	*6945*	*4970*	*7335*	*3900*	*7839*	*0*	*87050*
Service Sector	*96353*	*27812*	*64585*	*22024*	*13626*	*18879*	*12437*	*13251*	*0*	*268966*
								0		
Absolute Chang (from Do-Min)	12037	2127	-3551	-910	530	-8872	-3811	2451	0	
% Change	10.70	4.43	-3.64	-2.79	2.62	-15.45	-17.31	10.71		

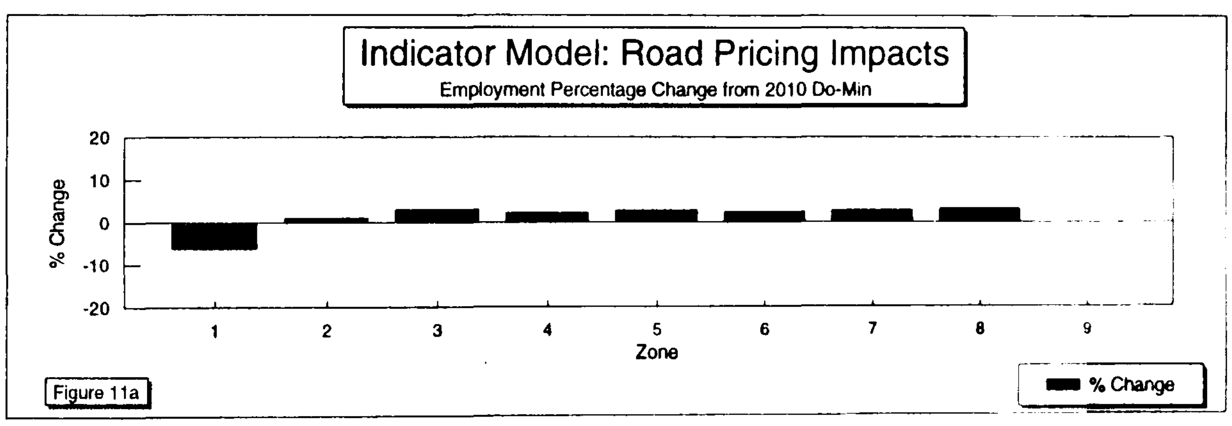


Figure 11a

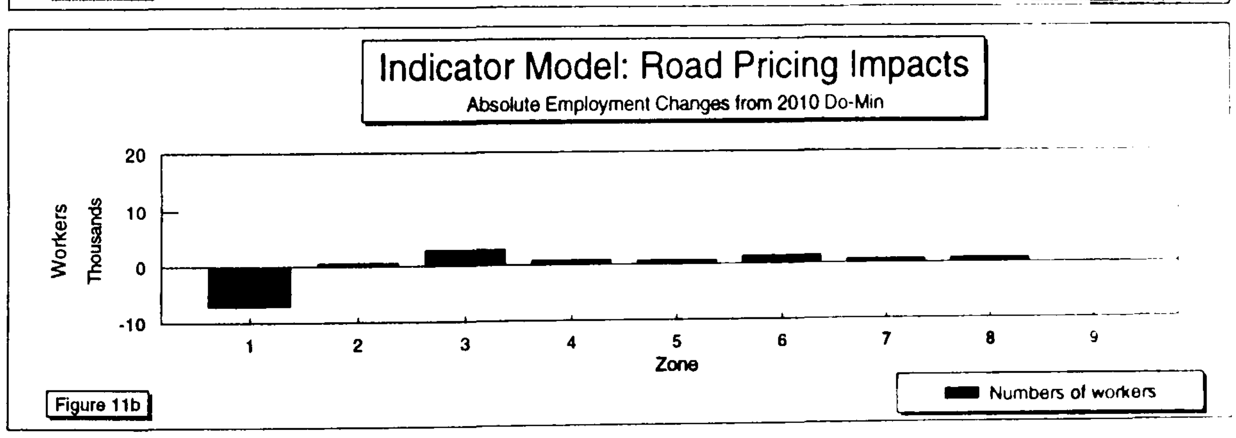
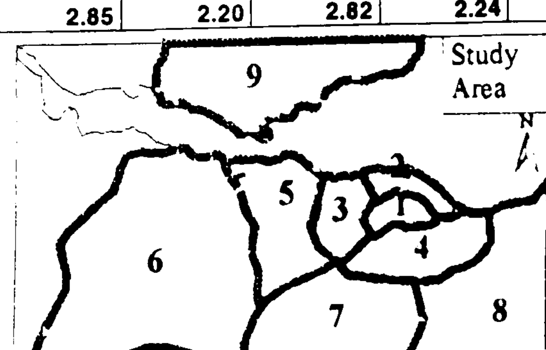


Figure 11b

INDICATOR Model Impacts on Employment Distribution due to Road Pricing Strategy										Totals
Zone	1	2	3	4	5	6	7	8	9	
2010 Estimate	105356	48406	100424	33372	20768	58724	22629	23602	0	413281
Retail Sector	*18362*	*9926*	*22535*	*7398*	*4598*	*11945*	*5619*	*6666*	*0*	*87050*
Service Sector	*83903*	*26856*	*68710*	*23200*	*14037*	*24430*	*15136*	*12695*	*0*	*268966*
Tot Absolute Ch (from Do-Min)	-7119	435	2780	719	569	1289	606	721	0	
% Change	-6.33	0.91	2.85	2.20	2.82	2.24	2.75	3.15		



Background Information on Method 3:
A Dynamic Land Use Transport Model (DELTA/START)

This model, which is still under development, is intended to represent a wide variety of processes in urban change, dynamically over time, with full land use transport interaction. This is illustrated by the various submodels:

1. **Development submodel**: which predicts the operation of private sector development for housing, offices, industry and retail, within planning constraints.
2. **Transition submodel**: which models population change over time, and employment change. 18 household types and 10 employment sectors are modelled. It determines the numbers of households and employees who need to be 'located'.
3. **Location submodel**: which locates employment and households. It takes account of changes in accessibility, transport related environmental factors (e.g. noise), area quality, and the rent of space (incorporated with other factors concerning location choice).
4. **Employment submodel**: which deals with the change in employment status of households as they are changed by the transition model.
5. **Area quality submodel**: which models the quality of different areas of the city according to the socio-economic characteristics of the people living there, and to other factors such as vacant space.
6. **A transport submodel**: which deals with the transport system. In this implementation, a modified JATES model (called START) is used.

It is worth considering the following points, especially in comparison with method 2:

- *The model operates* ***explicitly over time****, going forward in two year steps.*
- *There are many* ***time lags****: for example new development begun in one year will not be available until two or more years later.*
- *There are many* ***feedbacks****. For example the land market is modelled such that if demand for a particular zone rises, so does the value of property.*
- *Land use and transport are* ***interlinked.*** *The model takes accessibility and environmental data from the transport model, and supplies it with land use data for the next two year step. Each submodel thus runs sequentially for each time period.*

This model is designed to model urban processes in an intuitive and sensible way, and incorporates most of the important factors which influence location choice. It produces its own land use forecasts, can incorporate land use and transport policy, models floorspace, land, population and transport. Its predictions are grounded in a comprehensive modelling framework, based on previous research, and it can produce a wide range of outputs.

Outputs: **Full range transport / environmental outputs from the transport model.**
Floorspace and Land use changes by zone and space category type.
Rent changes by zone and space category type.
Population and household changes over time by zone, socio-economic group, and person type.
Employment change over time by zone and standard industrial classification division.

DELTA+START: Description of Figures

12a	This shows the **1991 census population** data by zone in the first bar. The second bar shows the DELTA estimate for 2001, and the third the 2011 estimate. This is to illustrate that DELTA is capable of producing data for years in between the base and horizon years. All the forecasts are internal to the model.
12b	This shows the percentage change in population 1991 to 2011 by zone.
12c	This shows the absolute change in population 1991 to 2011 by zone.
13a	This figures shows the changes in 2010 population that DELTA+START model predicts if the rail strategy is implemented, as a percentage change. The rail strategy includes only the JATES **light rapid transit**.
13b	This shows the absolute differences in 2010 population between the do minimum and the population as influenced by the rail strategy. It is thus the difference between the two forecast year predictions.
14a	As 13a, but for the **road pricing** strategy (£2.50 all day two way cordon around zone 1).
14b	As 13b, but for the road pricing strategy.
15a-15c	As 12a-12c but for **employment forecasts**. Note that the overall growth in the region by sector was taken from data in the Lothian Report of Survey. The location of that growth was determined by DELTA.
16a-16b	As 13a-13b but for employment impacts.
17a-17b	As 14a-14b but for employment impacts.
18a	This gives the DELTA estimate of **rent changes** in a **do minimum** case from 1995-2011 (note that 1995 has been given rather than 1991 to aid comparison with the Delphi results of rent estimates).
18b	This gives the percentage change in the DELTA estimates between the do minimum and the **rail (LRT) strategy** for 2011 retail rent levels. It is a comparison between 2 forecast years.
18c	This is the same as 18b, but for the **road pricing** strategy.
19a-19c	As 18a-18c but for **office/industry** rents (note that DELTA treated office and industry floorspace together).
20a-20c	As 18a-18c but for housing floorspace rents.

You will notice that for some zones, DELTA predicts some large changes in rents. This is a result of high demand but only limited floorspace available, and requires some fine tuning to obtain more realistic rent levels. However, it still gives a good indication of where the model believes pressure to develop to be highest.

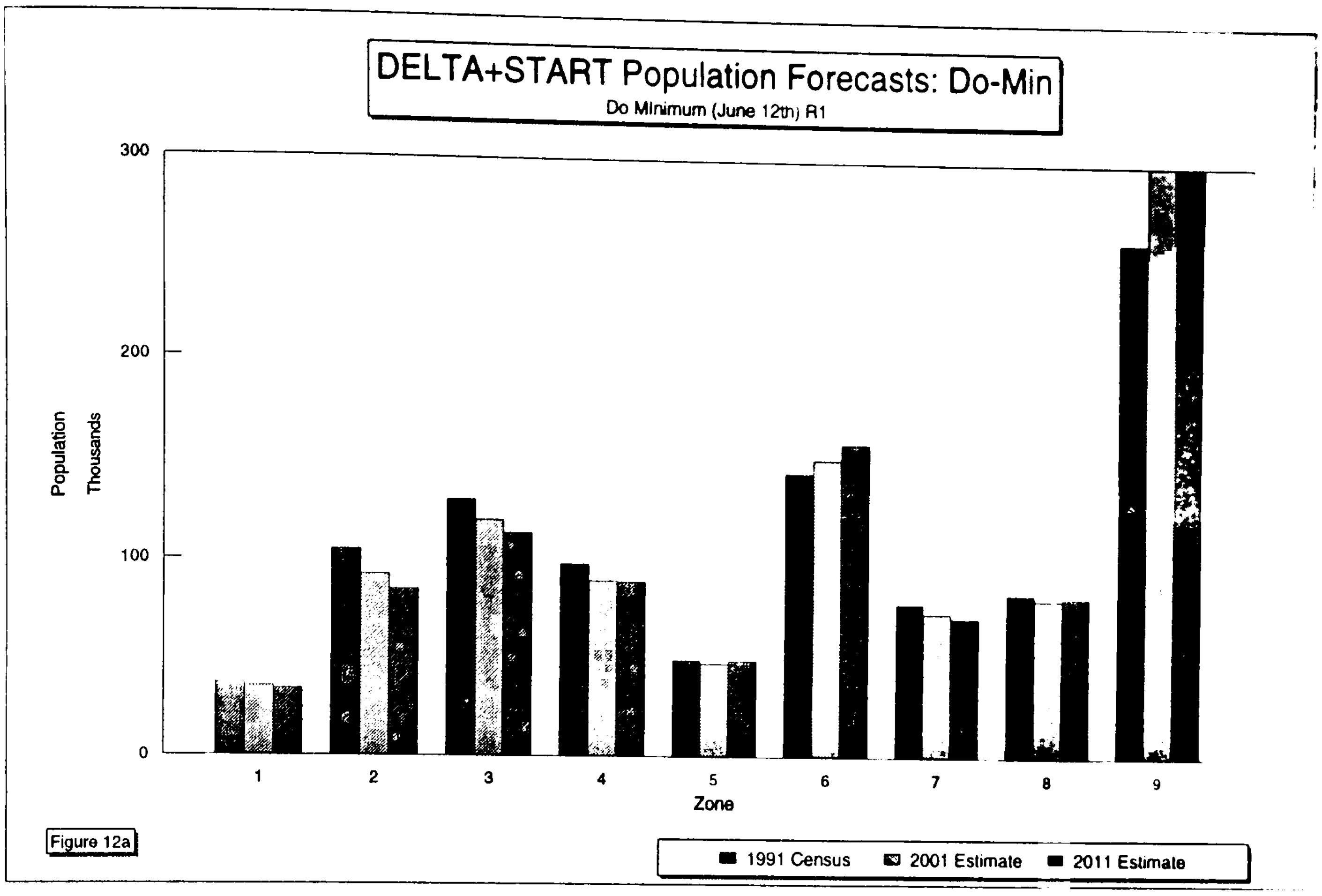


Figure 12a

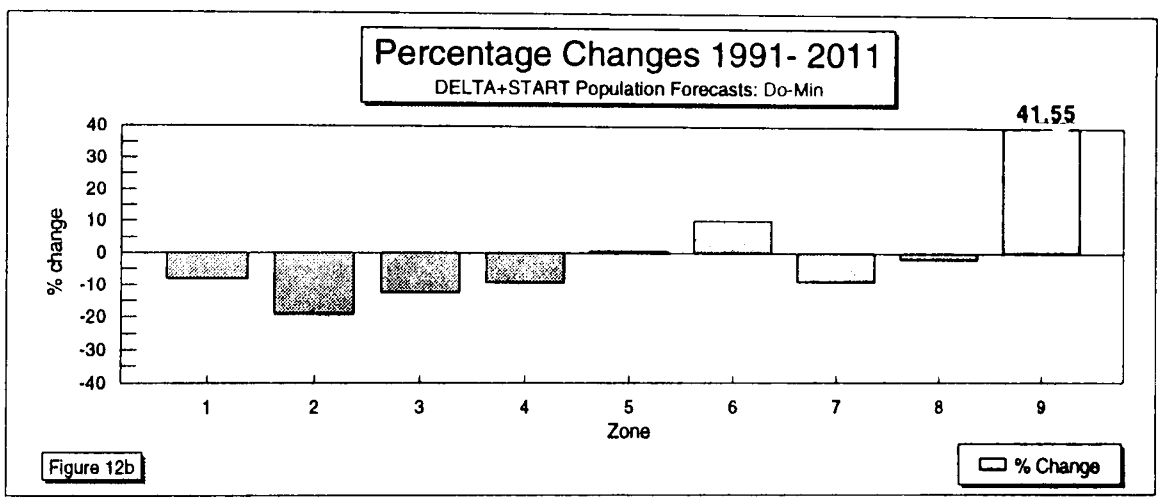


Figure 12b

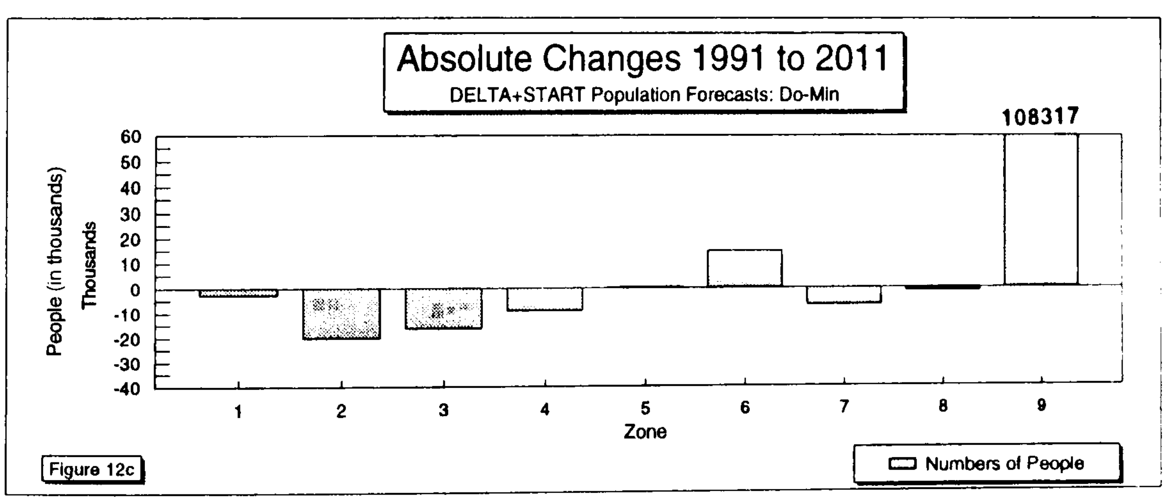
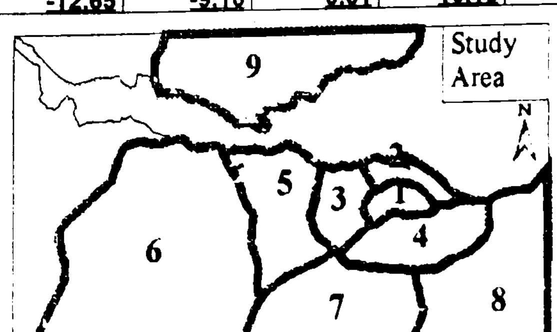


Figure 12c

DELTA+START Population Forecasts: Do-Min

Zone	1	2	3	4	5	6	7	8	9	Totals (Excluding Fife)
1991 Census	37269	104794	129477	98116	49256	144137	78845	84114	260663	726008
2001 Estimate	35478	92387	119850	89603	48013	150510	74350	81401	331084	691591
2010 Estimate	34257	84724	113093	89125	49557	158735	71741	82499	368980	683730
Absolute Change (from 1991-2011)	-3012	-20070	-16385	-8991	301	14598	-7104	-1615	108317	
% Change (91-11)	-8.08	-19.15	-12.65	-9.16	0.61	10.13	-9.01	-1.92	41.55	



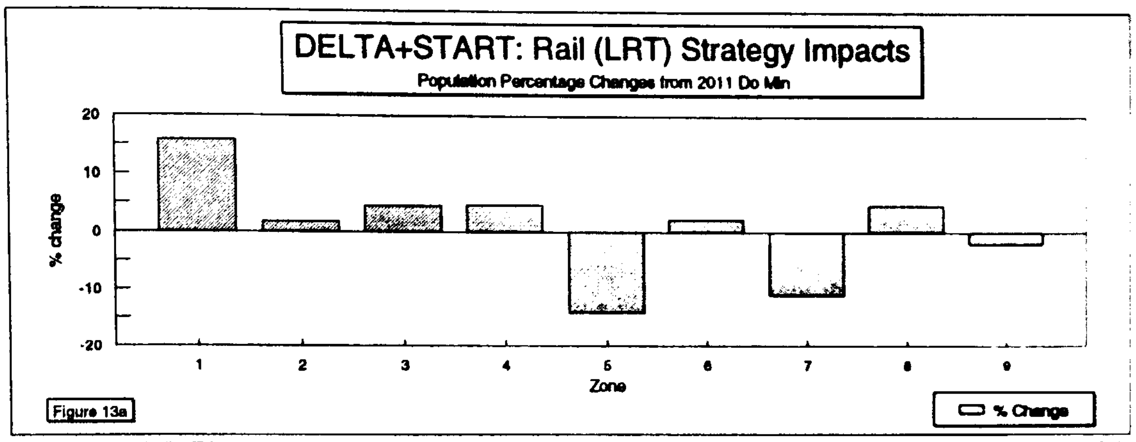


Figure 13a

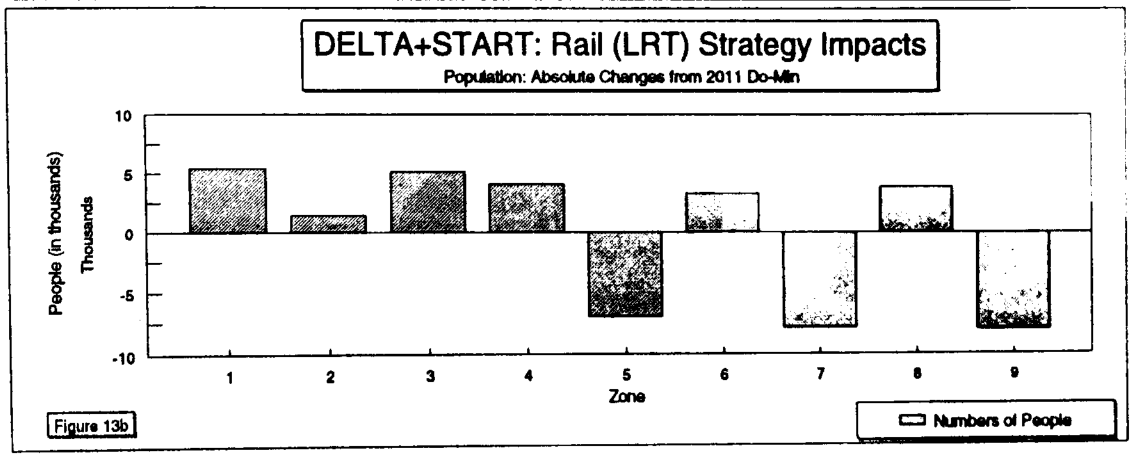


Figure 13b

DELTA+START Model Impacts on Population distribution due to Rail (LRT) Strategy										
Zone	1	2	3	4	5	6	7	8	9	Totals (Excluding Fife)
2001 Estimate	38676	92664	121752	89913	42408	146473	67242	81069	342480	680196
2011 Estimate	39648	86128	118197	93183	42545	162017	63826	86313	360862	691856
Absolute Chang (from Do-Min)	5391	1404	5104	4058	-7012	3282	-7915	3813	-8118	
% Change	15.74	1.66	4.51	4.55	-14.15	2.07	-11.03	4.62	-2.20	

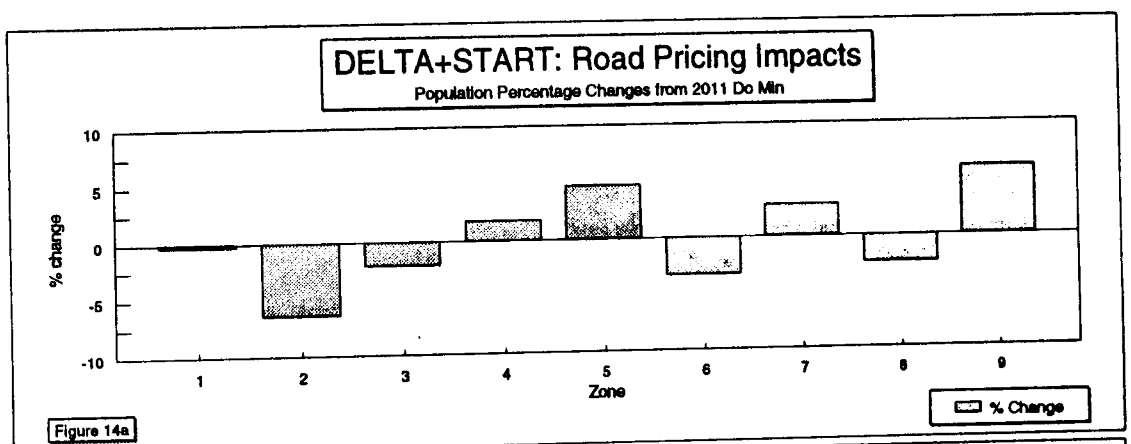


Figure 14a

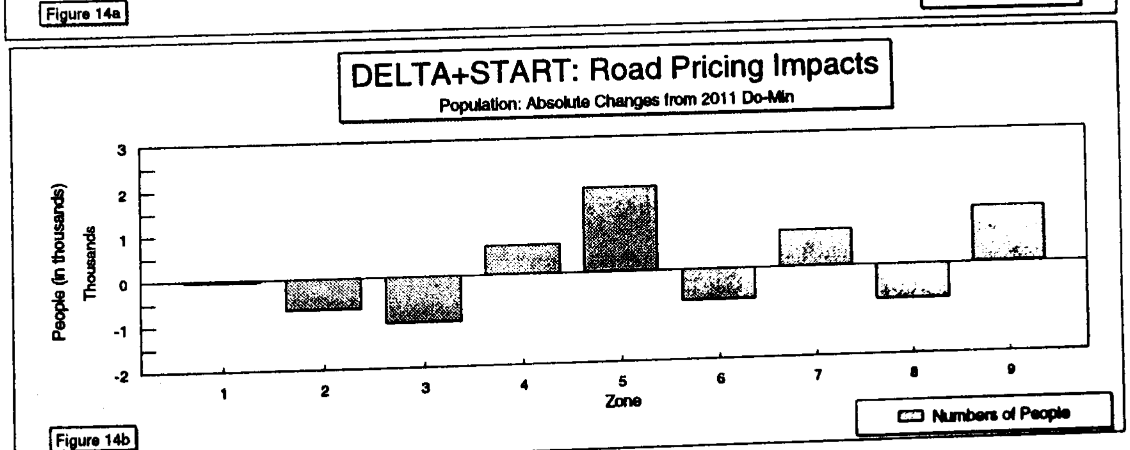
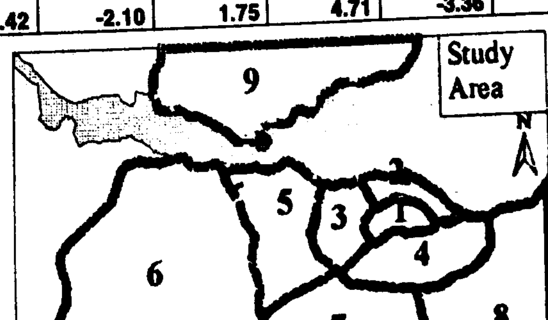


Figure 14b

DELTA+START Model Impacts on Population distribution due to Road Pricing Strategy										
Zone	1	2	3	4	5	6	7	8	9	Totals (Excluding Fife)
2001 Estimate	35043	92574	123723	91432	46716	150809 0	73609	82216	326556	696122
2011 Estimate	33612	84354	117278	91141	46342	158640	70251	82165	368940	683782
Absolute Chang (from Do-Min)	-32	-679	-1010	640	1884	-686	817	-788	1263	
% Change	-0.25	-6.42	-2.10	1.75	4.71	-3.36	2.84	-2.45	6.06	



DELTA+START : Employment Forecasts 1991-2011

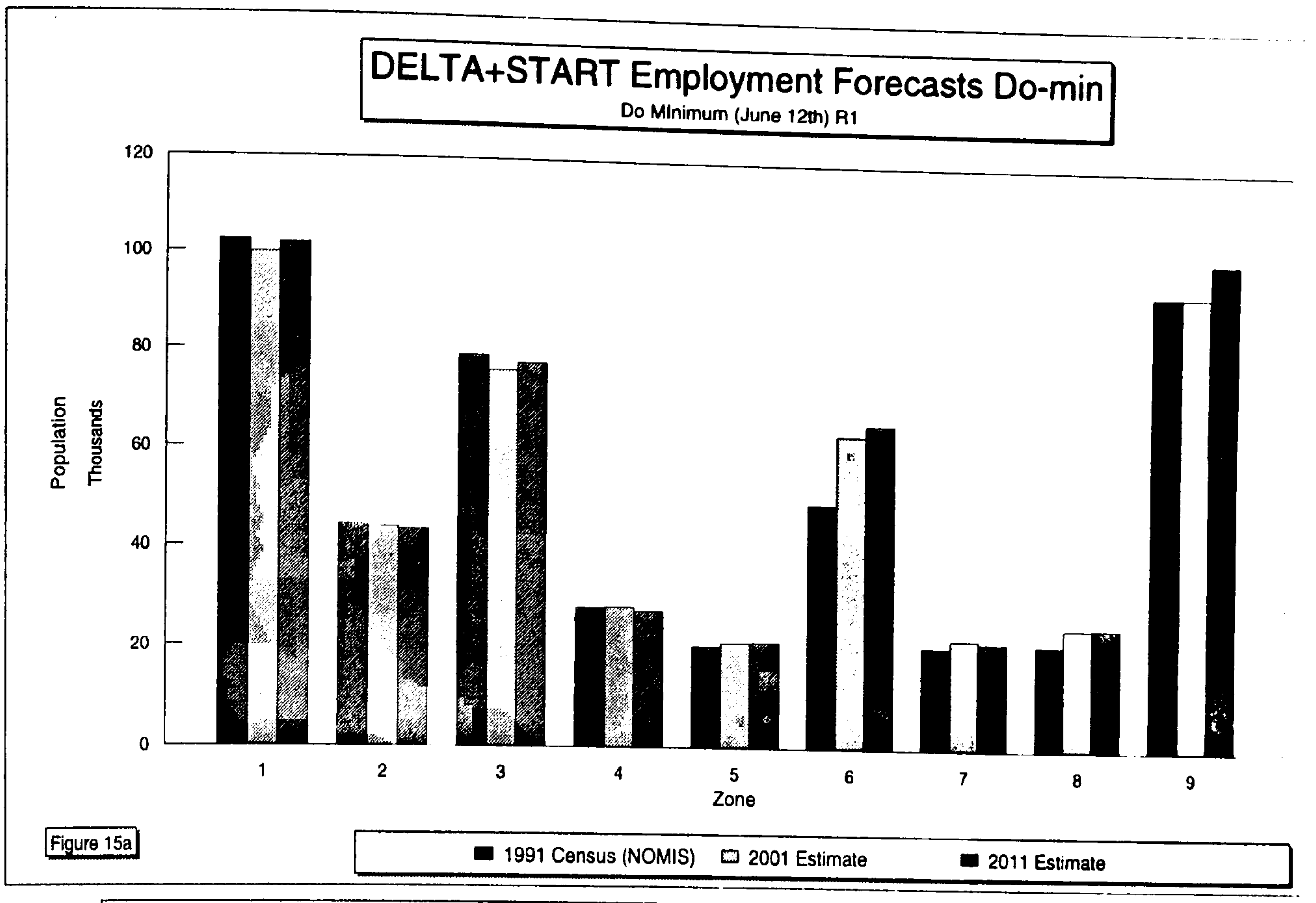


Figure 15a

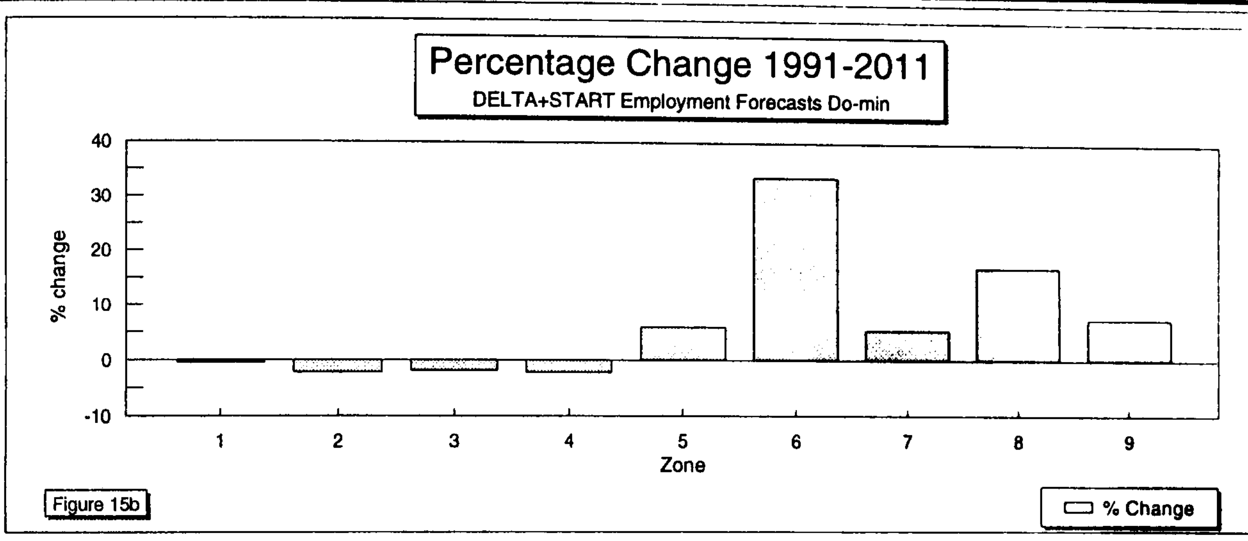


Figure 15b

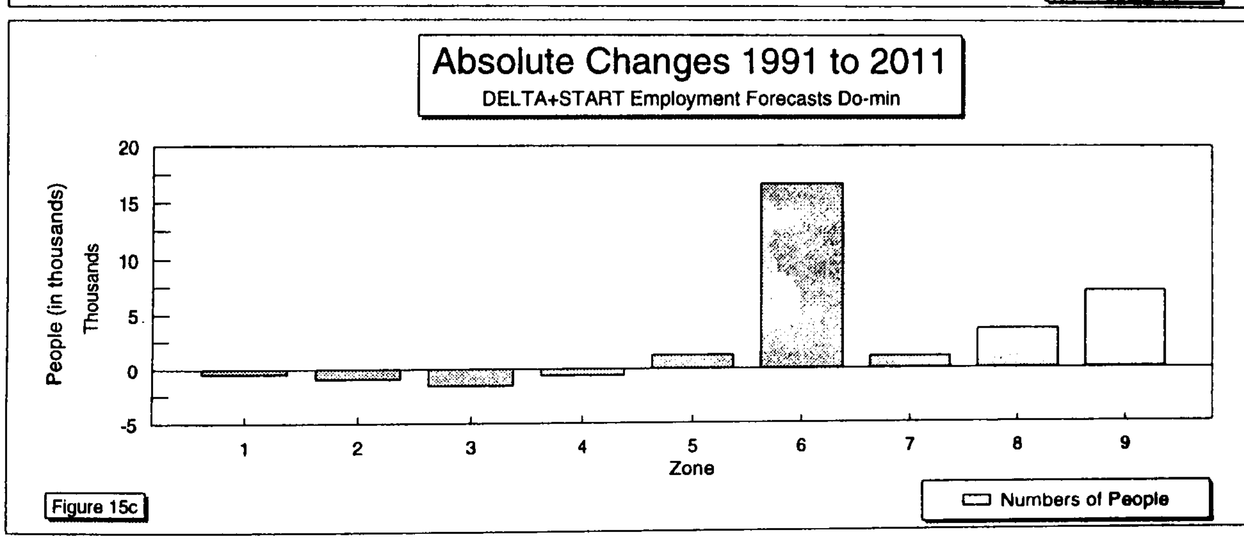
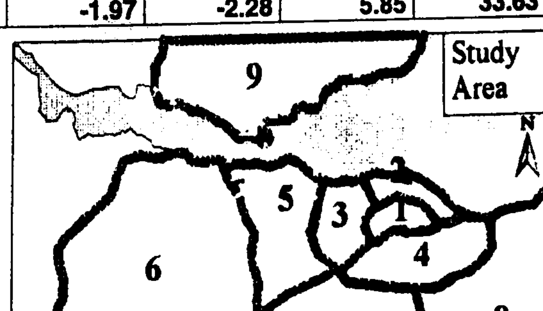
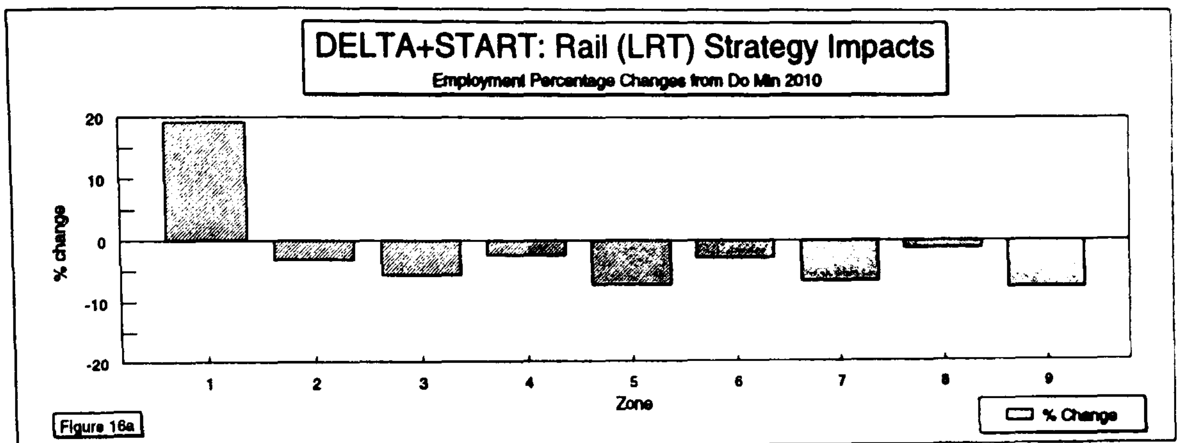


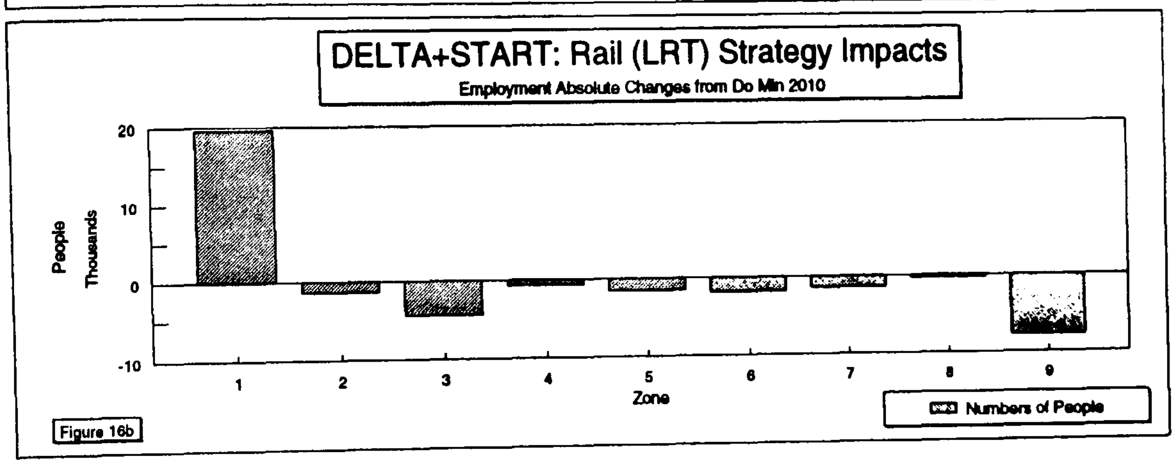
Figure 15c

DELTA+START Employment Forecasts Do-min

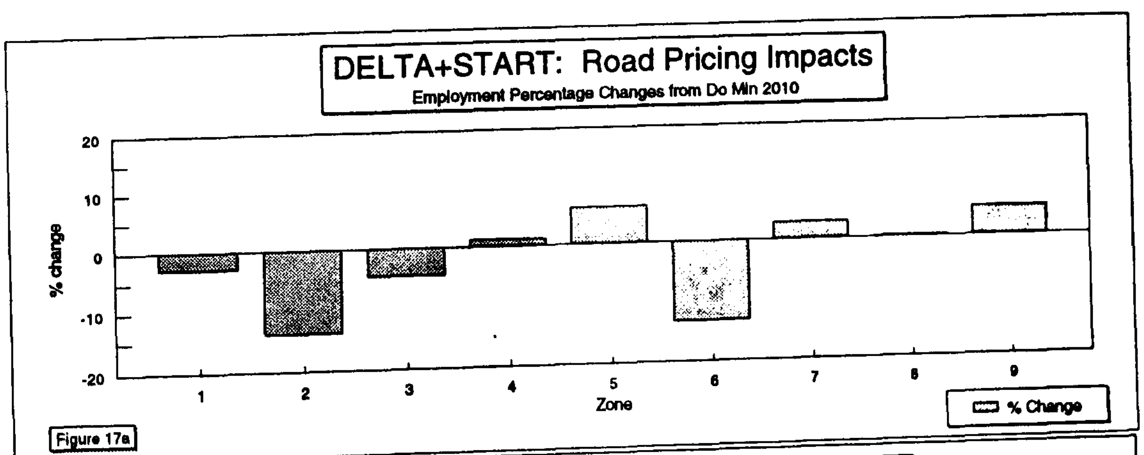
Zone	1	2	3	4	5	6	7	8	9	Totals (Excluding Fife)
1991 CENSUS	102400	44301	79000	28000	20300	49400	20700	21400	93800	365500
2001 Estimate	99922	43828	75895	28174	21212	63637	22411	24970	93866	380050
2011 Estimate	101935	43332	77445	27361	21488	66016	21780	25018	100847	384375
Absolute Change (from 1991-2011)	-465	-969	-1555	-639	1188	16616	1080	3618	7047	
% Change	-0.45	-2.19	-1.97	-2.28	5.85	33.63	5.22	16.91	7.51	

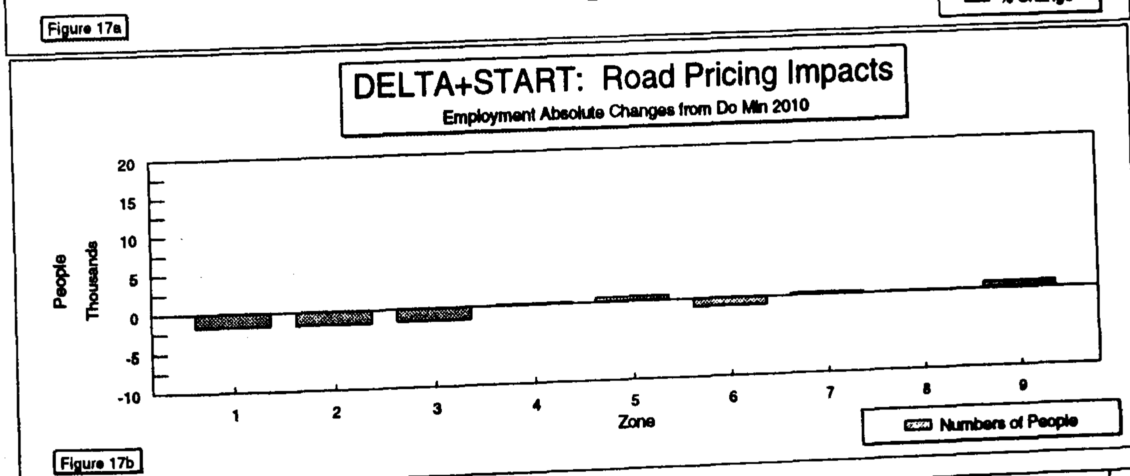




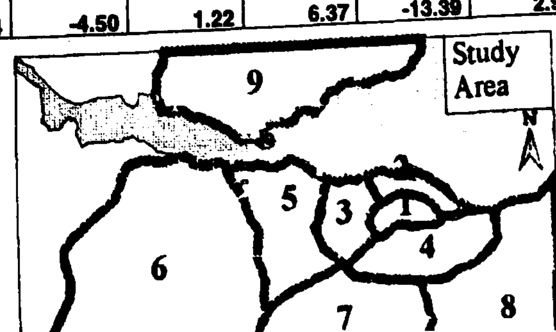


DELTA+START Model Impacts on Employment distribution due to Rail (LRT) Strategy										Totals (Excluding Fife)
Zone	1	2	3	4	5	6	7	8	9	
2001 Estimate	117065	42885	74514	27210	19418	58786	19972	23339	90722	383189
2011 Estimate	121432	41980	73003	26709	19943	64131	20338	24694	92994	392231
Absolute Change (from Do-Min)	19497	-1352	-4442	-652	-1545	-1884	-1443	-324	-7853	
% Change	19.13	-3.12	-5.74	-2.38	-7.19	-2.85	-6.62	-1.30	-7.79	





DELTA+START Model Impacts on Employment distribution due to Road Pricing Strategy										Totals (Excluding Fife)
Zone	1	2	3	4	5	6	7	8	9	376421
2001 Estimate	91701	43746	79909	28301	16851	66136	23356	26422	97490	383072
2011 Estimate	98437	41908	78782	27250	20283	68828	22068	25517	102149	
Absolute Change (from Do-Min)	-1680	-1625	-1536	112	568	-1003	324	9	834	
% Change	-2.80	-13.84	-4.50	1.22	6.37	-13.39	2.96	0.21	4.82	



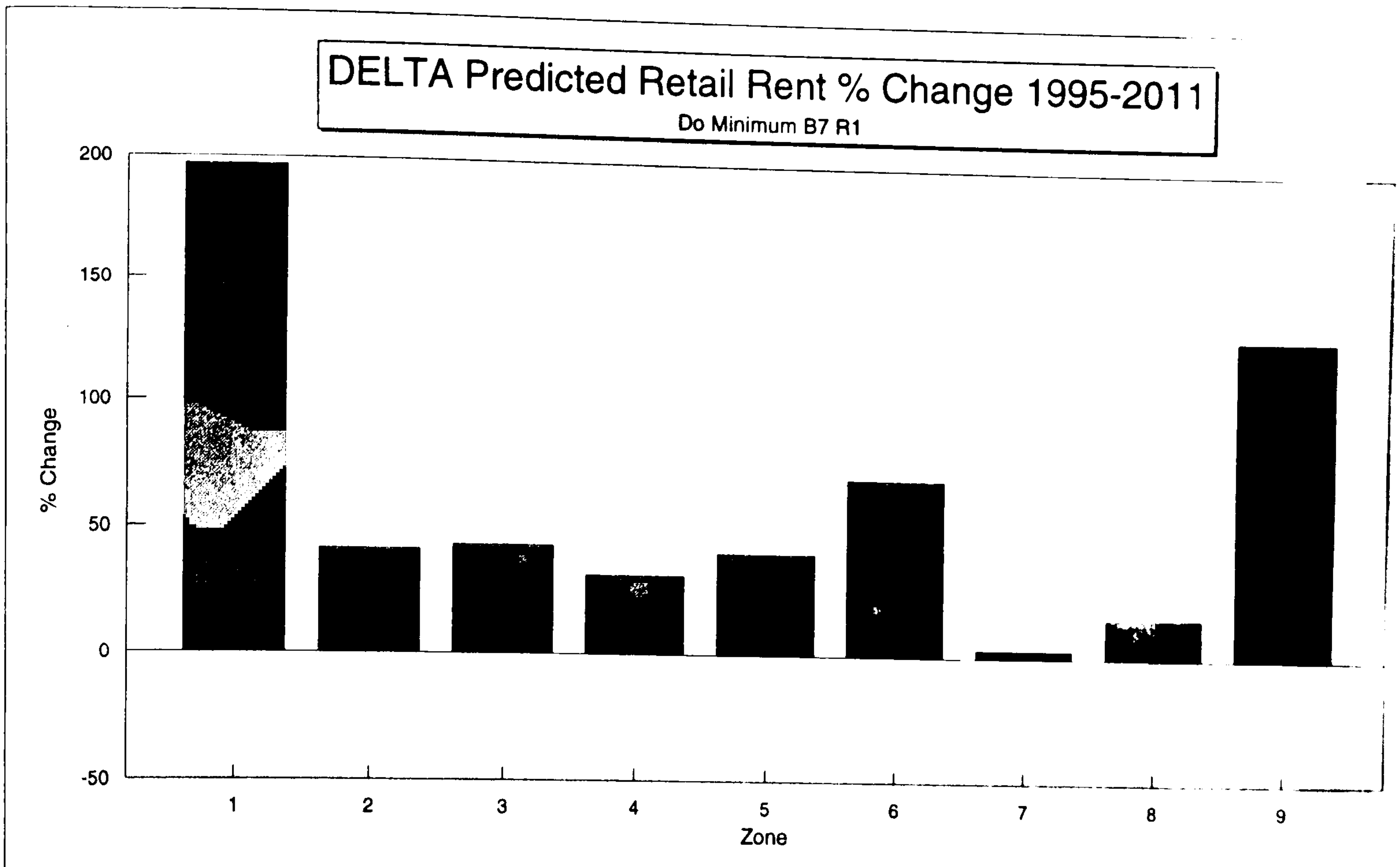


Figure 18a

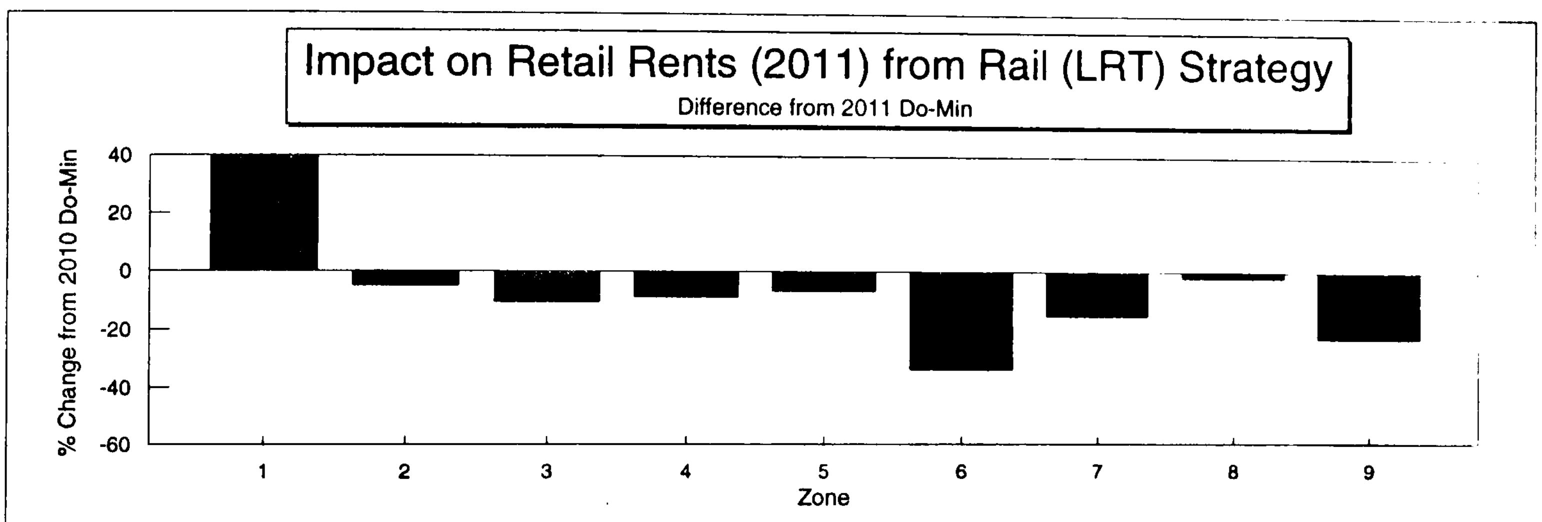


Figure 18b

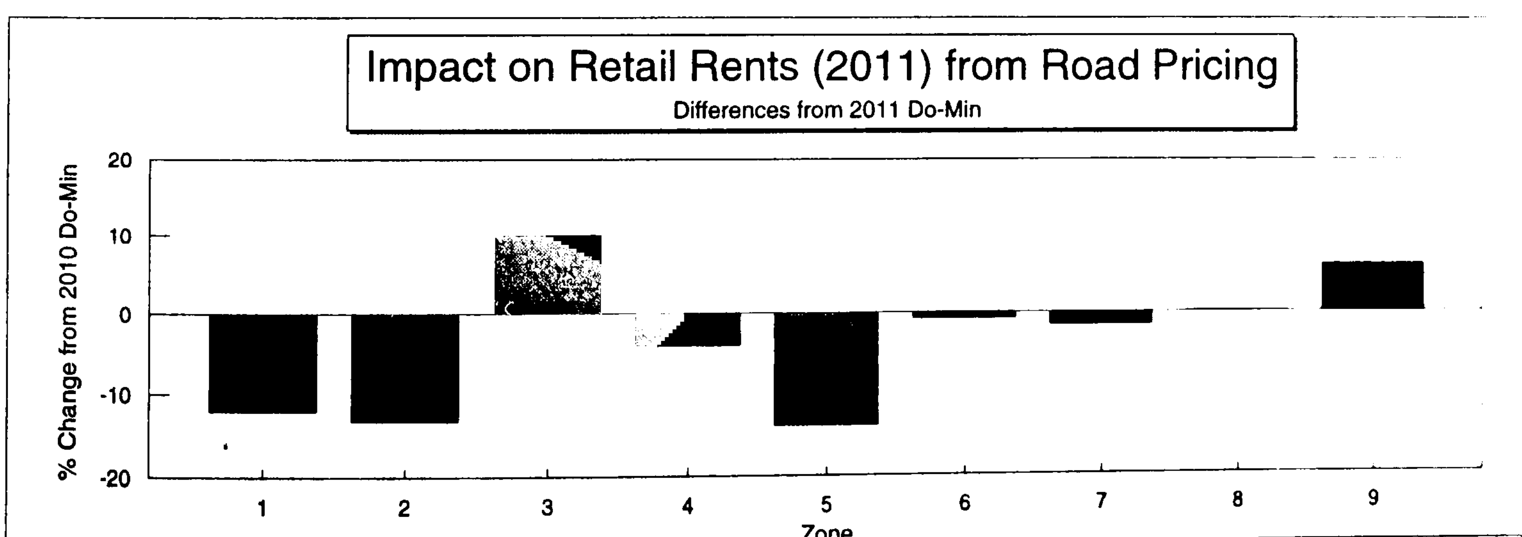
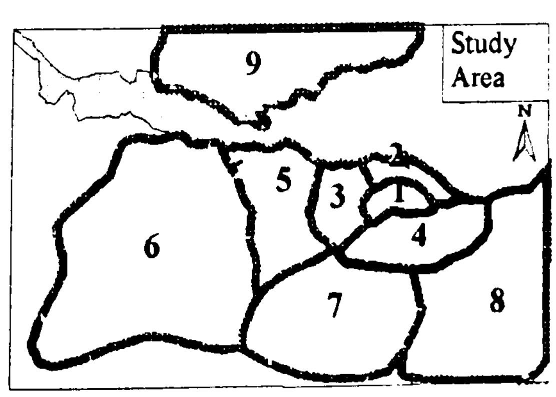


Figure 18c



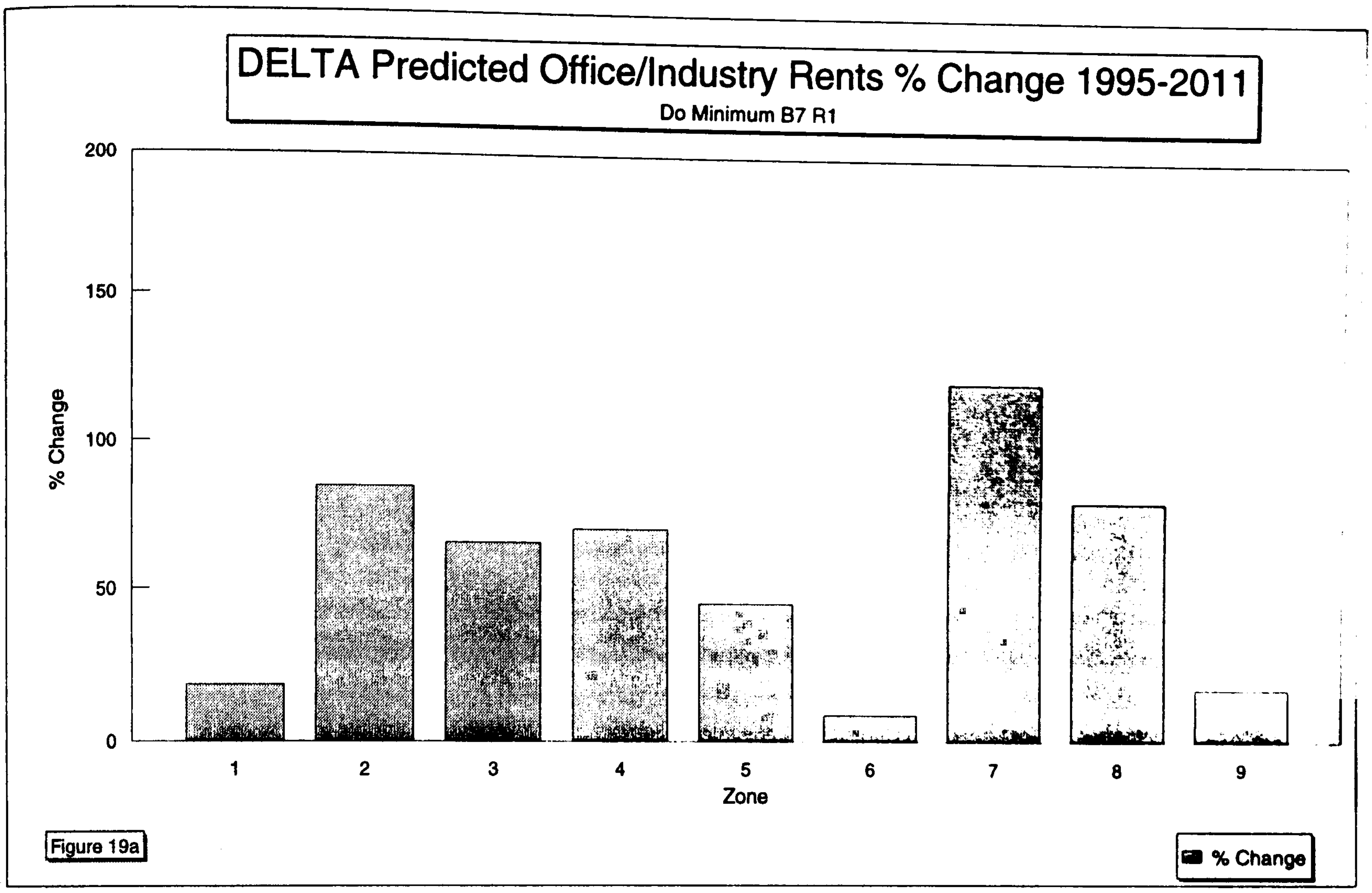


Figure 19a

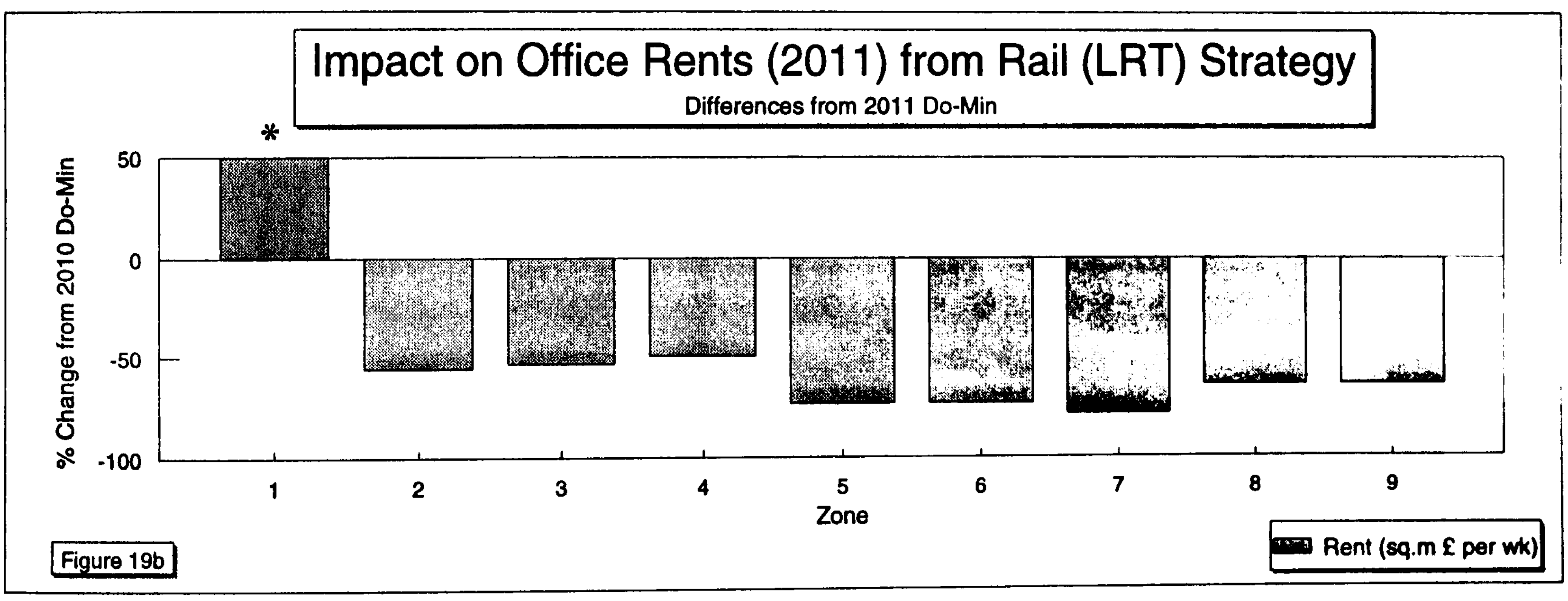


Figure 19b

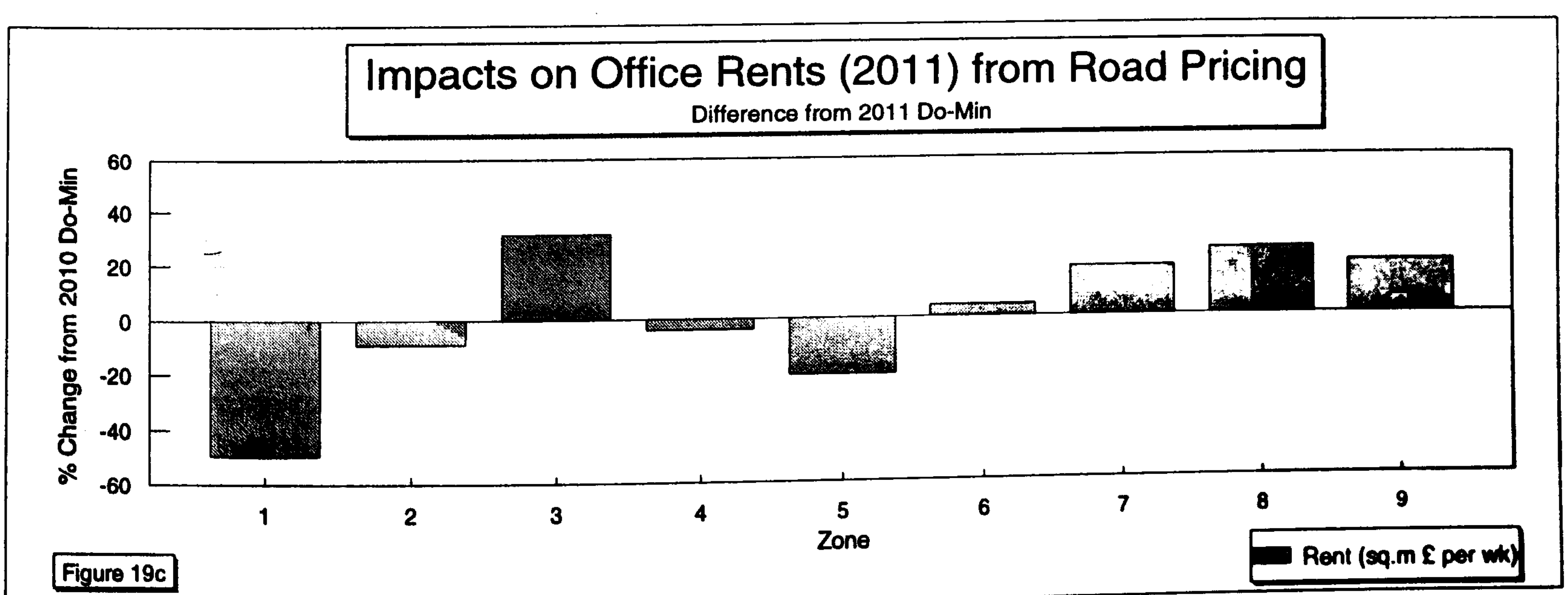
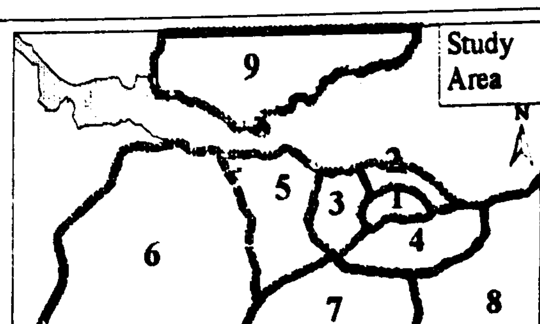


Figure 19c



* - High rents due to strong demand with only limited floorspace available.

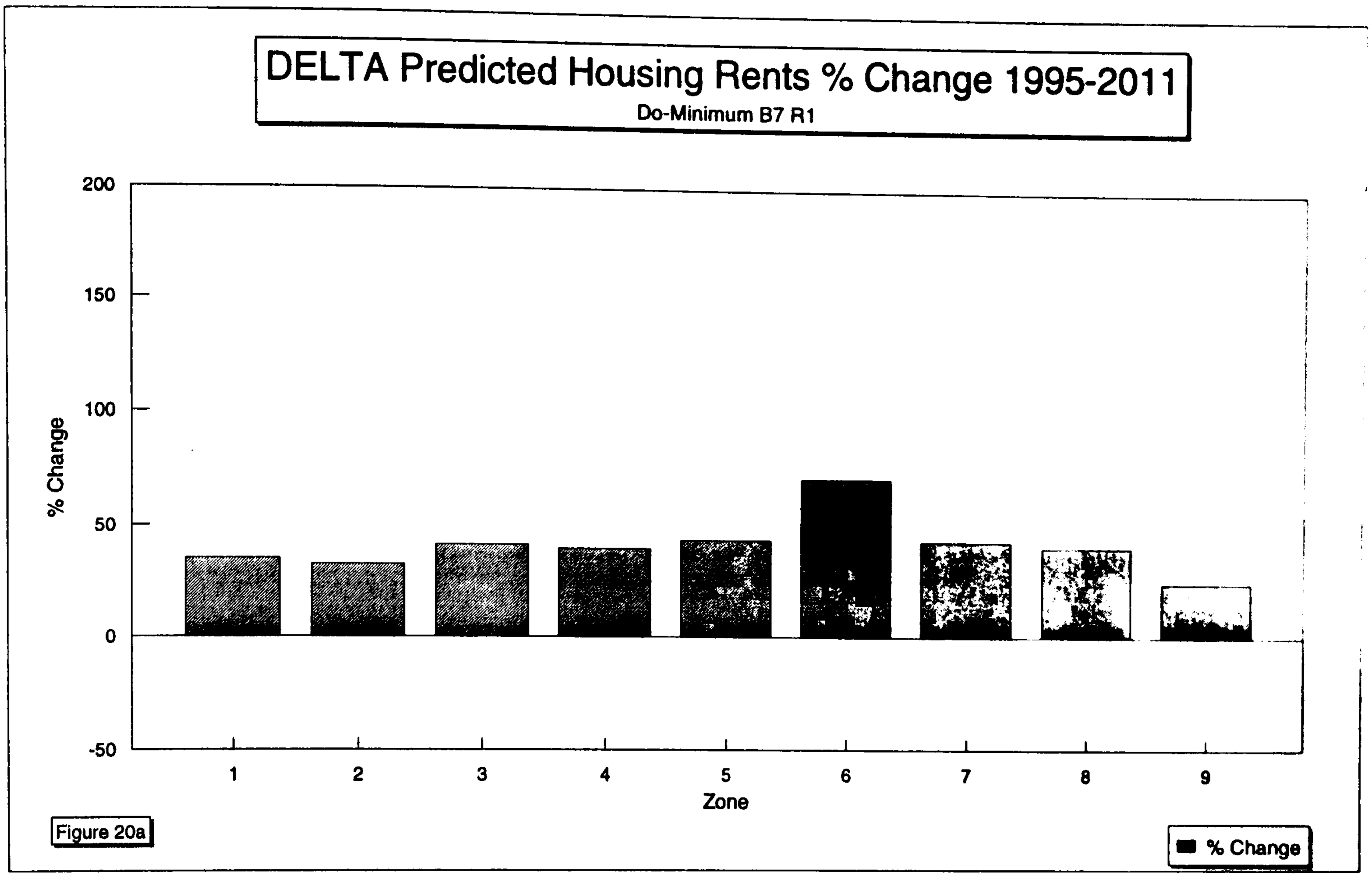


Figure 20a

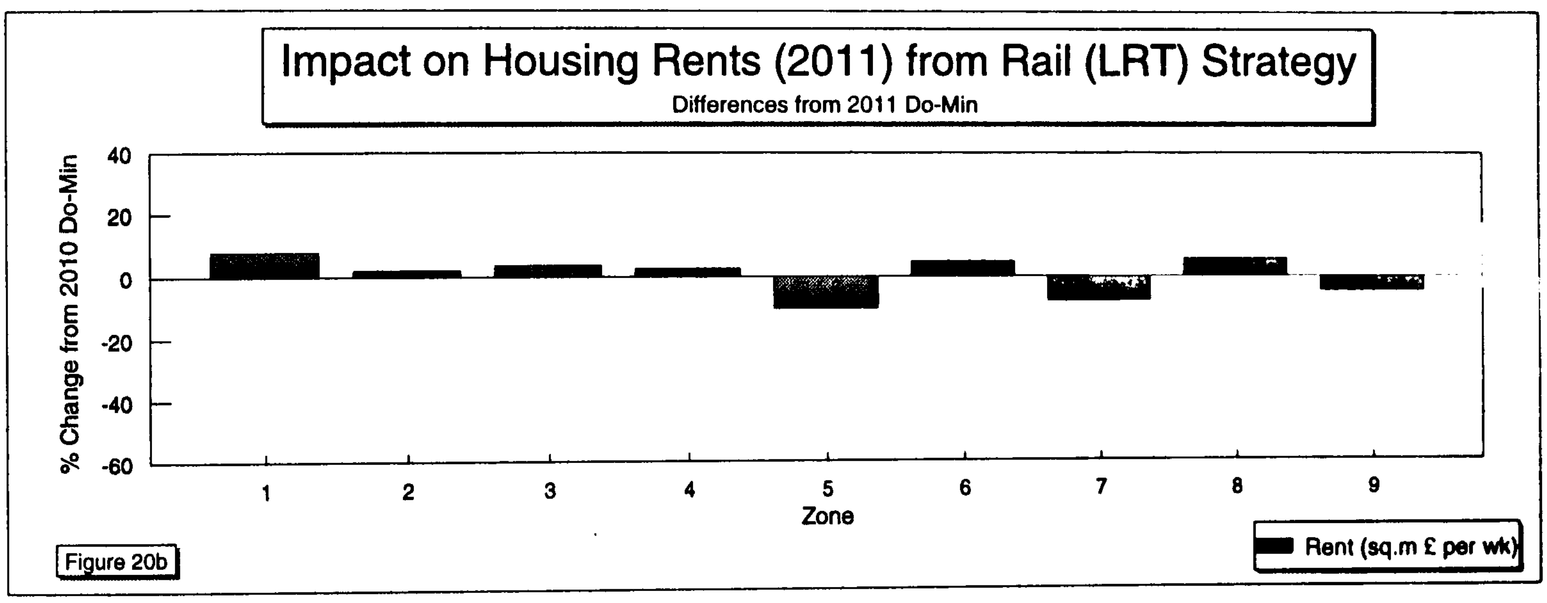


Figure 20b

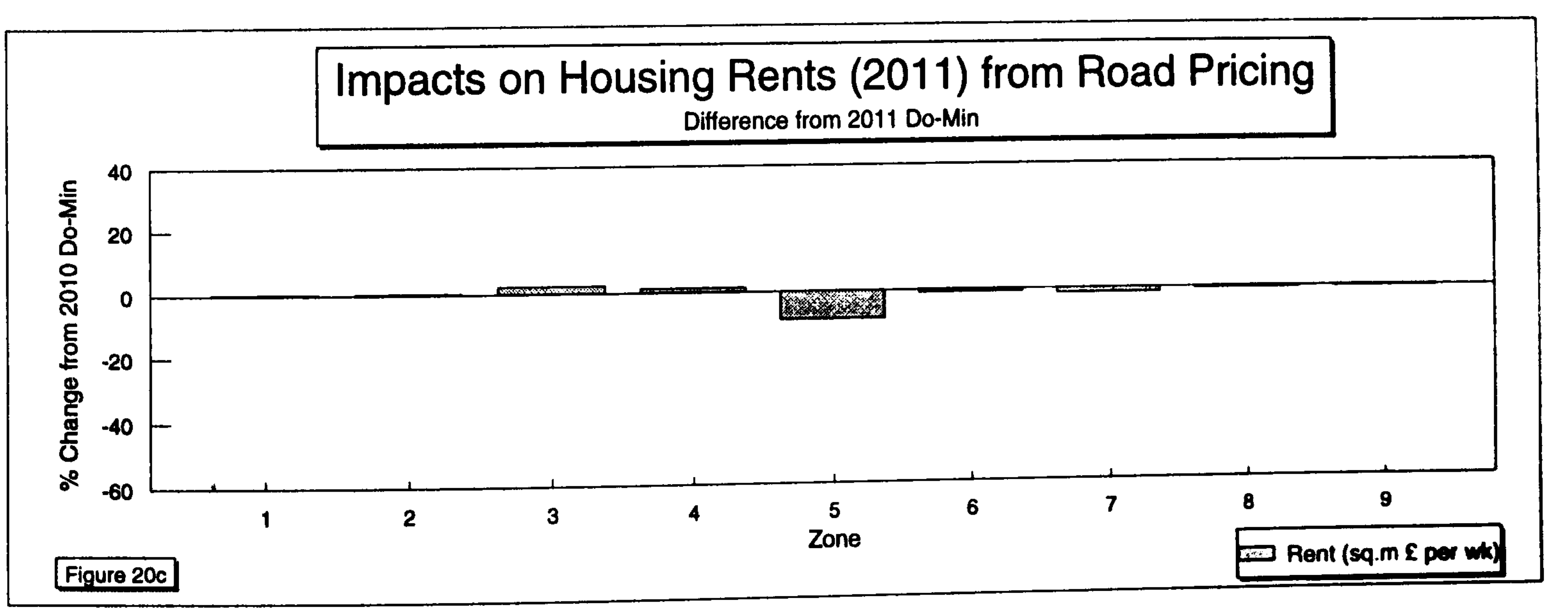
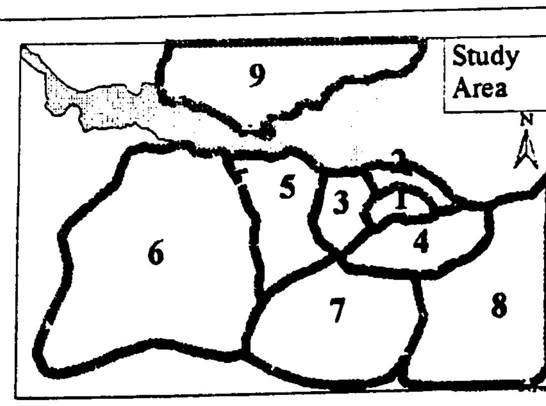


Figure 20c



Transport Impacts on Land Use
Interview Structure Questionnaire

ate of Interview:

Ben Still
Institute for Transport Studies
Tel: 0113 2335325

lease read through the 'Summary results' enclosed with this questionnaire for the following ethods:

1) The 'Expert Opinion' method (called the DELPHI method)).
2) The results of a static land use INDICATOR model.
3) The results of the START + DELTA interactive land use transport model.

Brief descriptions of the methods used are also enclosed. Having considered the results, please spend a few minutes summarising your views using the questions given below. When we meet, this questionnaire will form a structure for the interview.

Please note that all responses ***REMAIN CONFIDENTIAL AT ALL TIMES****. Thank you for your time and participation. Please contact me if you have any queries regarding this questionnaire.*

1.0 Relevance/ usefulness of this type of output to current planning

(in this section please ignore whether you feel the results themselves are plausible)

1.1

		Very relevant						Not relevant at all
Are outputs of this kind (regardless of the method), relevant to the work that you currently do? *(Please place a tick in the box that best describes your view and please ignore the results' plausibility)*		7	6	5	4	3	2	1

1.2

	Summary Notes
What application, if any, could forecasts of transport impacts on land use be used for in planning in general? *(please enter some phrases or notes in the box on the right that summarise your view. These can be drawn upon in discussion)*	

1.3

In your opinion, would information of this kind influence the decision making process for transport schemes / policy? *(Please place a tick in the box that best describes your view for each method)*		Yes, definitely 7	6	5	4	3	2	No, not at all 1

1.4

	Summary Points
What level of detail in the results is required to maximise the 'usefulness' of the results? *(please enter some phrases or notes in the box on the right that summarise your view. These can be drawn upon in discussion)*	a) Spatial Scales b) Population/Employment disaggregation c) Forecast horizon year d) Other *(please add)*

2.0 Validity of the methods

(please now consider the methods used to derive the results, again ignoring whether you feel the actual results presented are plausible or not)

2.1

How familiar are you, or your department with these three techniques?

(Please place a tick in the box that best describes your view for each method)

	Very Familiar						Not at all Familiar
Delphi	7	6	5	4	3	2	1
Indicator model	7	6	5	4	3	2	1
DELTA +START	7	6	5	4	3	2	1

2.2

How much understanding of the technique do you think is required for acceptable interpretation of the results? *(Please place a tick in the box that best describes your view for each method)*		Full understanding						None at all
	Delphi	7	6	5	4	3	2	1
	Indicator model	7	6	5	4	3	2	1
	DELTA +START	7	6	5	4	3	2	1

2.3

How confident would you be in accepting the forecasts of each method? *(Please place a tick in the box that best describes your view for each method)*		Very Confident						Not at all Confident
	Delphi	7	6	5	4	3	2	1
	Indicator model	7	6	5	4	3	2	1
	DELTA +START	7	6	5	4	3	2	1

2.4 Validity of the methods	***Summary Points***
What are the main drawbacks in the methods that you see? *(please enter some phrases or notes in the box on the right that summarise your view. These can be drawn upon in discussion)*	1) DELPHI method 2) INDICATOR model 3) DELTA/START

2.5 Method Improvements *Summary Points*

What (if anything) would increase your confidence in each method? *(please enter some phrases or notes in the box on the right that summarise your view. These can be drawn upon in discussion)*	1) DELPHI method 2) INDICATOR model 3) DELTA/START model

3.0 Plausibility of the forecasting results

(please now concentrate on the actual results presented, and your views on them)

3.1

How strongly do you agree or disagree with the DO-MIN forecasts that each method predicts?

(Please place a tick in the box that best describes your view for each method)

	Strongly Agree						Strongly Disagree
Delphi	+3	+2	+1	0	-1	-2	-3
Indicator (part LRC)	+3	+2	+1	0	-1	-2	-3
DELTA +START	+3	+2	+1	0	-1	-2	-3

3.2

How strongly do you agree or disagree with the ROAD PRICING land use impacts that each method predicts?

(Please place a tick in the box that best describes your view for each method)

	Strongly Agree						Strongly Disagree
Delphi	+3	+2	+1	0	-1	-2	-3
Indicator model	+3	+2	+1	0	-1	-2	-3
DELTA +START	+3	+2	+1	0	-1	-2	-3

3.3

How strongly do you agree or disagree with the LRT land use impacts that each method predicts? *(Please place a tick in the box that best describes your view for each method)*		Strongly Agree						Strongly Disagree
	Delphi	+3	+2	+1	0	-1	-2	-3
	Indicator Model	+3	+2	+1	0	-1	-2	-3
	DELTA+ START	+3	+2	+1	0	-1	-2	-3

4.0 The importance of examining transport impacts on land use

Given the forecasts and your answers above please rate each of the following uses of data on transport impacts on land use:	Very important						Not important at all
(1) To examine only additional benefits or costs of transport policy (i.e. by including land capitalisation)	7	6	5	4	3	2	1
(2) To examine the implications of transport policy for urban form and economic development in general terms.	7	6	5	4	3	2	1
(3) To examine the changes to transport demand as a result of the patterns of trip generation induced by the transport policy.	7	6	5	4	3	2	1
(4) To understand the potential benefits of an integrated land use / transport strategy.	7	6	5	4	3	2	1
(5) Other (*please list, and score for each*)	7	6	5	4	3	2	1

Thank you again for your assistance with this research.

APPENDIX IV
FURTHER DELTA/START (R4) TESTS

This appendix discusses the second set of DELTA/START runs that were undertaken as part of this PhD project. Although not essential to the policy and methodology conclusions, these runs were desirable for the following reasons:

1. to correct the error in the Fife data and examine how this altered the distribution of land uses in the do-minimum and transport policy tests;
2. to reduce the magnitude of the rent changes over time;
3. to examine the potential of using the changes in rents obtained from the Delphi panel to assist in fine tuning the responses of DELTA to transport policy.

The aim was that these changes would produce a more reasonable set of results that could be used for the EPSRC 'Sustainable Cities' project, which was examining the derivation of coefficients in the location model.

1.0 Changes to DELTA

1.1 Fife Error

An error was found in the land use database that was producing ten times more available space in Kirkcaldy than was intended. When this error was corrected the growth of population and employment in Fife was much reduced.

1.2 Rent changes over time

A more complex set of alterations were made to alter the sensitivities of rents in the location sub model. Three problems were identified:

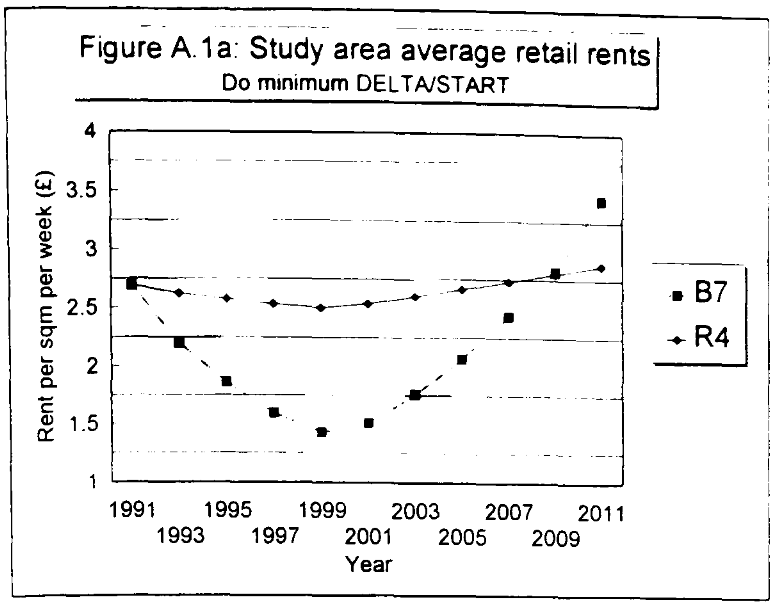
1. the 'U' shape of the retail rent curves over time, as shown in figure A.1b. This shape was thought unlikely to occur over the study area in reality;
2. the large changes in rent 1991-2011 for all three land uses;
3. the large changes in rent from the transport strategies.

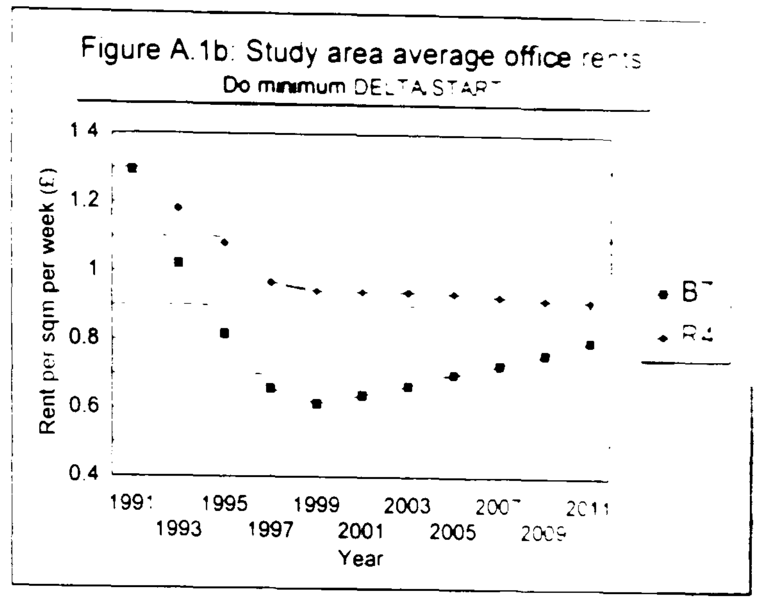
Correcting these problems involved three main stages. Firstly the supply of retail floorspace was increased slightly, with a continuous trickle of new available space appearing each period for each zone, totalling 1% every two years. This was intended to reduce rent increases from lack of available space, and was also felt to be a likely response from the planning system to the high demands found in the B7 tests.

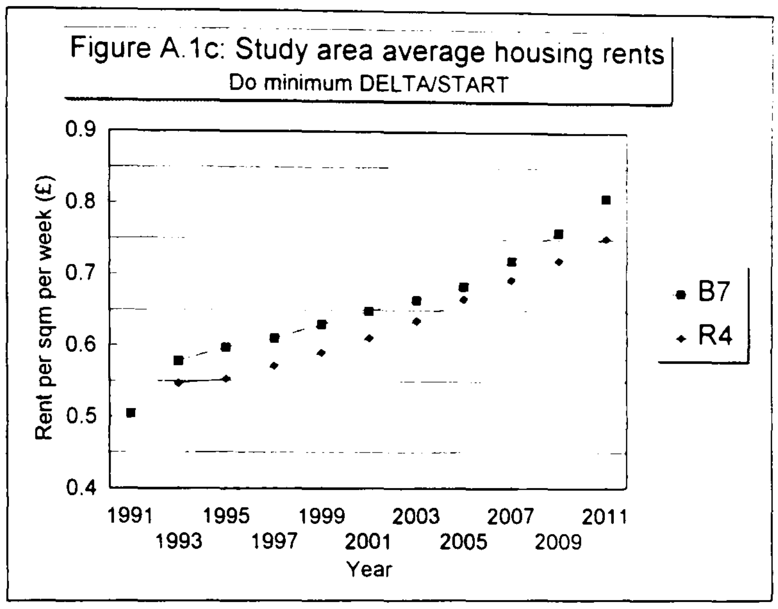
Secondly, the parameter that controlled the amount of space per employee that retail activities demand over time was set so that no increases would occur. In other words, prior to this the retail space per employee was increasing every period, intending to represent the trend towards warehouse type retail developments. So although retail employment was not growing rapidly, the space factor was consuming all the available retail space.

Thirdly, the elasticity of demand for floorspace with respect to rent was changed, after some sensitivity testing, from -0.3 to -0.7. This allowed larger changes in density to occur with smaller changes in rent. This was intended to lessen the magnitude of the rent changes over time. This change had a large effect, reducing average do-minimum retail rent increases from around 40-50% to around 20-27%. Retail rents in zones 1 and 5 remained high, reflecting the observed pattern of rents obtained for 1991.

The result of these changes when combined was a much reduced 'U' shape to the retail rent trends over time for R4 (see Figure A.1a). Similar steps regarding the elasticity of demand for floorspace with respect to rent were made for the 'office and other' space category, although the issue here was a surplus of space resulting in the fall in rents (figure A.1b).







For residential rents, the central problem was that while residential floorspace rose by around 13% over the study period, the amount that households have available to spend on housing rose by 87% (due to the assumptions about income growth from START and the fact that a fixed proportion of total income must be spent on housing; determined by the coefficients in the utility function). The solution required altering these coefficients, so that as income rose, the marginal propensity to spend additional income on housing fell. Thus coefficients were entered which changed every year, decreasing as incomes rose, rather than having fixed coefficients throughout the study period. The result of applying income related coefficients was that average rents rose by 50% rather than 60% overall (Figure A.1c). Note also that future utility parameters, calibrated specifically for the study area, may reduce these sensitivities further.

1.3 Use of the Delphi to fine tune sensitivities

The final change made to the DELTA model for the R4 test was to examine the sensitivity of the changes due to the transport strategies. It had been found that the response to LRT in the B7 test was very high. This was due in part to the large improvements in accessibility that LRT induced. Obviously the frequency of LRT could be have been reduced, but the large rent changes were still thought to be extreme, especially when compared to the Delphi data. The comparison is presented in table A.1 below:

Table A.1: Rent changes between Delphi and DELTA/START

Rent changes 1997-2011 Zone 1 (c29.1/BGS1 p29)	Delphi	DELTA/START (B7)
RP: retail impacts	-7%	+80%
RP: office impacts	-9%	-42%
LRT: retail impacts	+5%	+288%
LRT: office impacts	+3%	+211%

Delphi figures are for zone 1: approx. years 1997-2010.
DELTA/START figures are for zones 1,2,12, for period 1997-2011.

It was found that a more reasonable fit could be obtained by reducing the elasticity of sensitivity of employment to accessibility. After some initial testing, these were reduced to a fifth of their former values. This change was a compromise between the differences in these elasticities from the LRT and the road pricing results above, compared to those implicit in the Delphi results. Thus this should be seen as an experimental change rather than one that has been specifically researched. For example if the Delphi was to be specifically used in this way, then the questions would probably need to focus on the response to LRT at different levels of service.

2.0 R4 test results

2.1 Key features from the do-minimum

The distribution of trips may be expected to change between the B7 and R4 results, as fewer activities move to Fife over the forecast period. It was expected that trip km would decline from B7 to R4, and that perhaps trip numbers would increase. In fact the R4 test had both higher trips and trip km, as can be seen in table A.2. The reason for this growth appears to be activities moving into zones where there is an observed higher trip rate, as none of the growth factors have been altered. Note that from the comparison with JIF in Chapter 8 this puts the growth in trips closer to JIF, and the growth in trip km higher still than the JIF forecasts.

Table A.2: Study area transport indicators: B7 and R4

Do-minimum Test	B7 test (2011)	R4 Test (2011)	% difference
Study area total trips	1009	1040	3%
Study area trip km	14161	14182	1%
Total trips by car	636	662	4%
Total trips by bus	297	322	8%

The pattern of **accessibilities** over time shows a worse accessibility for Fife, due to fewer activities located there, and the accessibility in the Lothian districts better than in B7. The R4 pattern is however, similar to B7; showing better accessibilities in Edinburgh relative to the other districts. The changes are not great however, indicating the dominance of the pre-existing land use pattern.

The impacts on rents for the study area have already been discussed in Section 1.2, and are shown in table A.3 on a district basis. Although the trends over time are the same, the magnitude of the changes has been tempered by the new parameters. This shows for retail and housing that West Lothian has the highest growth in rents, while the rest of Edinburgh maintains the highest rents for office space. This gives an indication that demand is rising for floorspace in West Lothian, although, for all sectors, absolute rents are still highest in the city centre.

Table A.3: Do-minimum rent comparisons between B7 and R4

Rent level	Residential (% chg. 1991-2011)		Retail sector (% chg. 1991-2011)		Office sector (% chg. 1991-2011)	
	B7	R4	B7	R4	B7	R4
City centre	60.6	45.7	18.7	6.8	-67.3	-28.5
Rest of Edinburgh	59.0	41.3	6.1	4.2	-42.4	-21.6
East Lothian	55.2	34.3	-4.3	4.1	-51.6	-25.8
West Lothian	89.0	65.9	81.0	15.9	-7.7	-36.2
Midlothian	72.0	52.3	-35.7	-1.1	-73.4	-32.0
Dunfermline	78.4	62.9	100.5	13.3	8.6	-42.8
Kirkcaldy	47.6	52.0	114.2	9.6	18.9	-42.2
Total study area	59.9	49.2	26.8	6.7	-40.3	-29.2

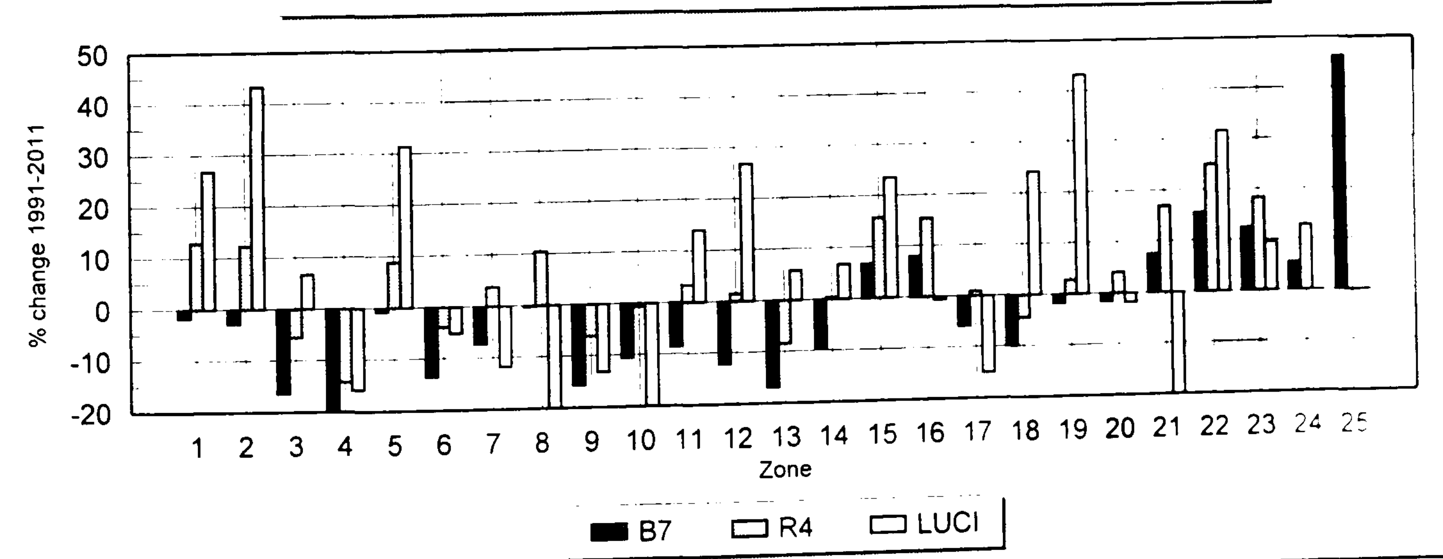
Differences in floorspace development between B7 and R4 show that correcting the Fife error reduces new development in Kirkcaldy and Dunfermline. Table A.4 shows this for all three sectors, with the most noticeable changes in housing development for Kirkcaldy. For retail, there are increases in all the zones due to the new increments added each period. However, the high demand for retail space (as shown by the rents in figure A.1b) means that retail space is still developed as soon as it becomes available.

Table A.4: Do-minimum floorspace comparisons between B7 and R4

Rent level	Residential (% chg. 1991-2011)		Retail sector (% chg. 1991-2011)		Office sector (% chg. 1991-2011)	
	B7	R4	B7	R4	B7	R4
City centre	23.0	23.0	0.9	10.0	9.2	12.1
Rest of Edinburgh	12.3	12.3	12.8	23.3	5.2	8.3
East Lothian	22.4	22.4	10.4	10.4	45.1	60.2
West Lothian	13.8	13.8	38.6	40.0	42.9	58.7
Midlothian	6.5	6.5	10.3	10.3	25.7	37.1
Dunfermline	14.9	9.9	9.3	10.7	8.3	10.1
Kirkcaldy	104.8	9.8	8.5	11.0	7.1	8.7
Total study area	29.4	12.6	12.0	18.2	13.3	18.3

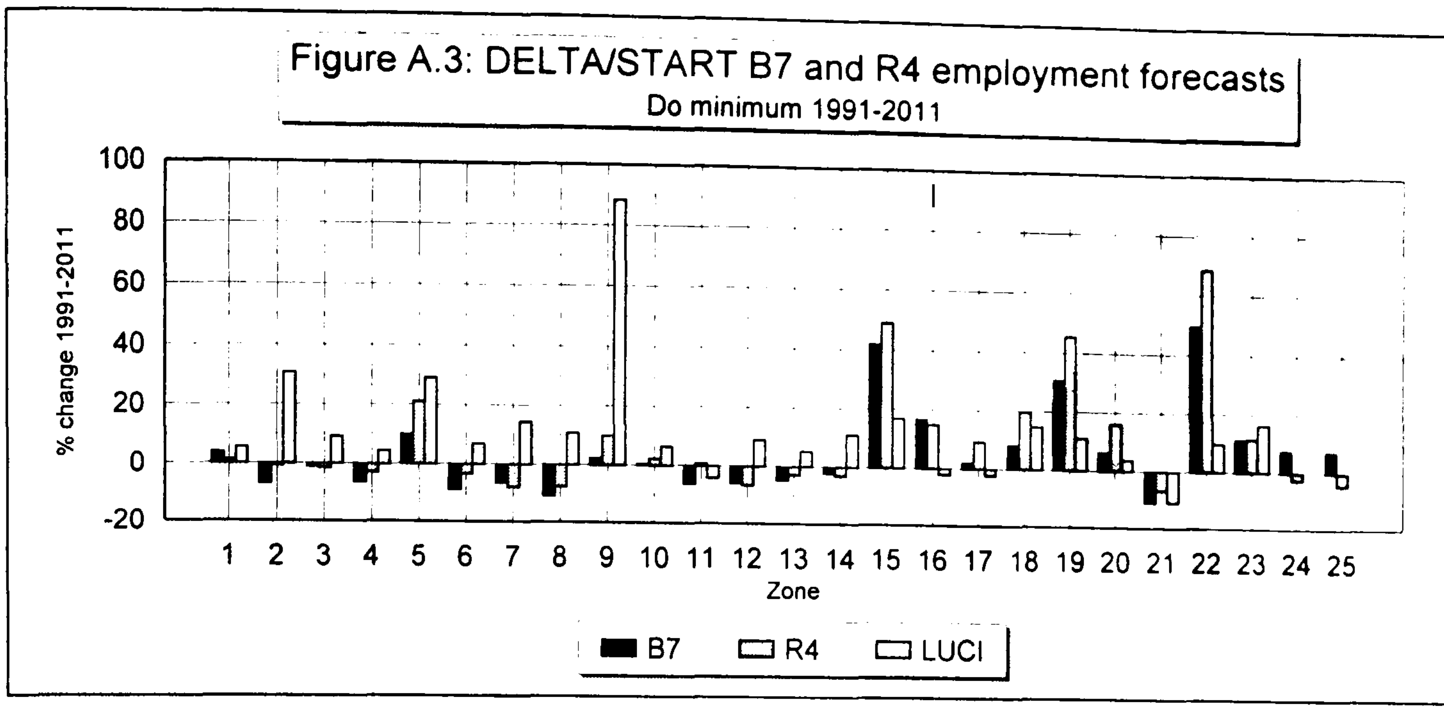
The impact on the distribution of population is shown in figure A.2, for B7, R4 and also for the Lothian Regional Council (LRC) forecasts used in the LUCI model. Three points can be seen from this figure. Firstly there is more agreement between R4 and the LRC results than B7 and LRC. This is clear from zones 1,2, and 5. Secondly, there is still considerable disagreement between the forecasts, especially in the magnitudes of the changes, with the LRC forecasts (which include an unknown migration component) higher than the DELTA model for most zones. Finally, more than B7, R4 is projecting a decentralisation to the Lothian districts, and much less growth in Fife.

Figure A.2: DELTA/START B7 and R4 population forecasts
Do minimum 1991-2011



The impact on employment is shown in Figure A.3, again for B7, R4 and LRC. Still most noticeable here (from Chapter 8) is the extreme growth projected in zone 9 by LRC, due to the Gyle developments. Again it should be noted that the Lothian projections for LRC are higher than DELTA's own predictions (which still came from the Lothian Report of Survey). Other than this, the B7 and R4 results are more similar than the population forecasts.

especially regarding the zones of greatest growth. At first glance it appears that more growth is occurring under the R4 test. In fact, the study area growth is the same (5.6%), but R4 has a decline in Fife's employment relative to B7, which accounts for larger absolute numbers of workers.



In summary, the do-minimum R4 test was considered a significant improvement over the B7 test, and generally produced impacts more in line with the structure plan predictions. The main feature was the damping of the land use response to transport changes, as expected from the changes made in the model parameters for R4. It is still slightly different from the LRC projections, mostly due to the lower levels of overall growth predicted. This is shown in table A.5 below. For the population forecasts, the differences are due to the rates in the transition model. For the employment forecasts, it is due to differences between the JIF scenario and the LRC structure plan forecasts.

Table A.5: Planning data forecasts comparisons

Lothian Region	Population 2011	Employment 2011
LRC	769200	413281
DELTA	743041	393019

2.2 Impacts of the LRT test on land use from the R4 tests

The impacts of LRT on the distribution of rents are given in table A.6.

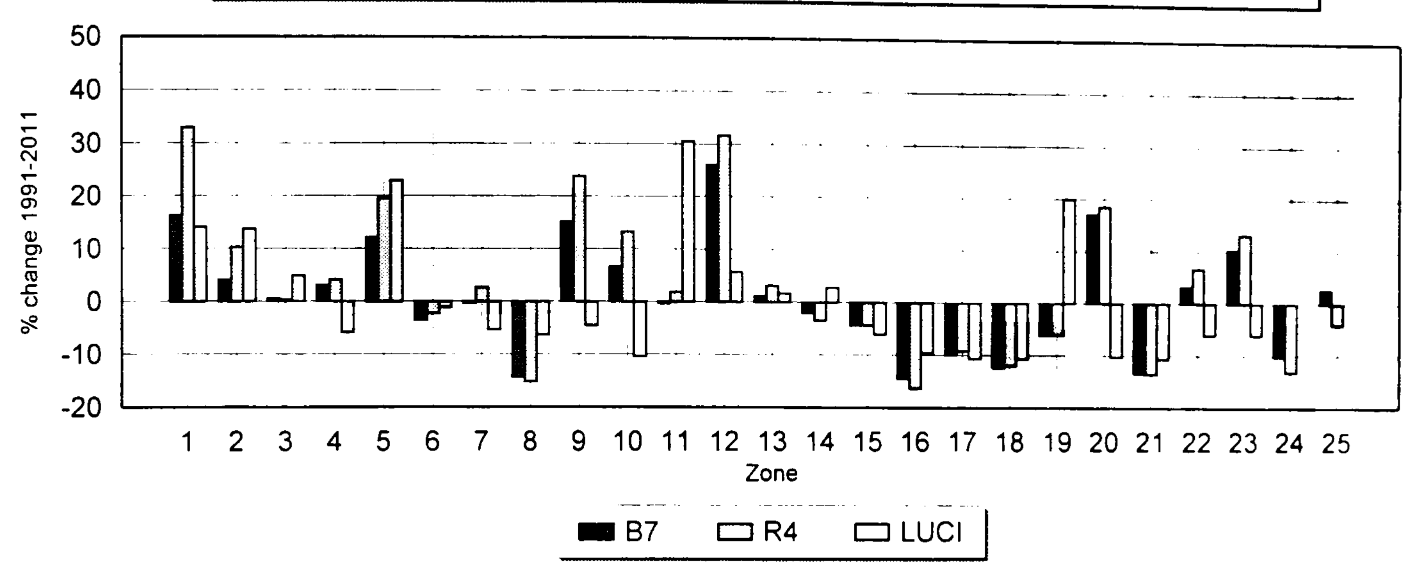
Table A.6: LRT impacts on rents: comparisons between B7 and R4

Rent level	Residential (% chg. 1991-2011)		Retail sector (% chg. 1991-2011)		Office sector (% chg. 1991-2011)	
	B7	R4	B7	R4	B7	R4
City centre	8.1	15.0	103.8	23.9	225.9	57.7
Rest of Edinburgh	0.4	1.7	-9.2	-0.3	-55.5	-6.7
East Lothian	6.7	7.5	-8.5	-5.8	-75.0	-22.7
West Lothian	4.5	5.2	-35.3	-7.4	-77.0	-23.8
Midlothian	-7.0	-6.6	-13.0	-12.8	-77.4	-34.2
Dunfermline	-7.8	-10.9	-38.8	-14.1	-85.8	-36.8
Kirkcaldy	-1.6	-6.6	-6.8	-11.2	-42.9	-29.8
Total study area	-0.4	-0.4	17.4	4.3	24.5	8.2

For the retail and office sectors the direction of change is identical to the B7, but the magnitudes of change are reduced, especially in the city centre. For the housing sector there is a greater rise in the rents in the city centre in R4 compared to B7, and the differences in rent levels are altogether closer. In terms of the pattern of rent changes to emerge from R4, overall LRT increases rents in the city centre, while depressing rents elsewhere. For housing, rents increased in all districts with LRT or access to LRT Park and Ride. Fife suffers falling rents in all sectors.

These housing impacts reflect on the population, as shown in figure A.4. The R4 bars show that population centralises in the city centre, at the expense of the outer districts. Note that the R4 and B7 results are similar, the two main differences being the magnitude of the Lothian impacts, (greater in R4, especially in the city centre) and the reduced impacts predicted by R4 for Kirkcaldy.

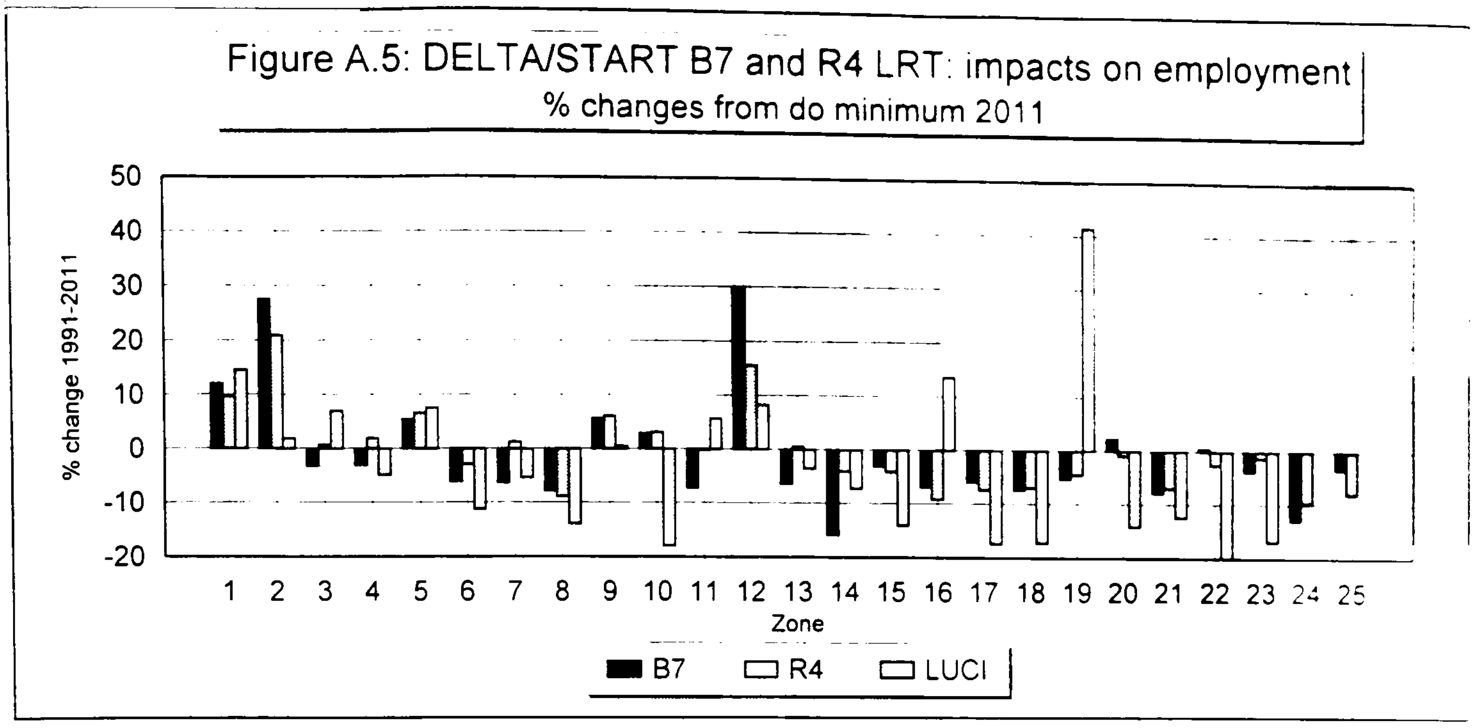
Figure A.4: DELTA/START B7 and R4: LRT impacts on population
% changes from do minimum 2011



Note that the R4 impacts still differ in direction from the LUCI model predictions in several zones. The two largest differences between R4 and LUCI are zones 9, 10 and 11, all zones with low growth or decline in population. Zone 9 (South Gyle) would be expected to increase population as it is on the LRT line, although it does not in the LUCI forecasts. This is because there are negligible changes in the accessibilities of zones 9-11 that drive the LUCI model. This means that they worsen relative to the improving zones, hence losing population to them.

The impact on employment again shows some marked differences between the LUCI, the R4 and the B7 results (figure A.5). The R4 impacts are generally of the same direction as B7, but smaller. This is a result of the reduced sensitivity to accessibility caused by reducing the values of the parameters on accessibility as discussed above. In general however, the main impacts outlined in Chapter 8 for the B7 results are still valid here; LRT benefits city centre employment, plus employment in the South East wedge and the Gyle.

The LUCI projections in zone 19 appear extreme in comparison, since this zone, although benefiting from LRT park and ride, would not benefit as much as the city centre. This appears to underline the suspicion that this is a mechanical error. In contrast, zone 16, which contains the airport, would be expected to benefit, and does so in the LUCI predictions, but not in B7 or R4. This is due to a lack of improvement in the accessibility in this zone, in contrast to most other zones in the study area.



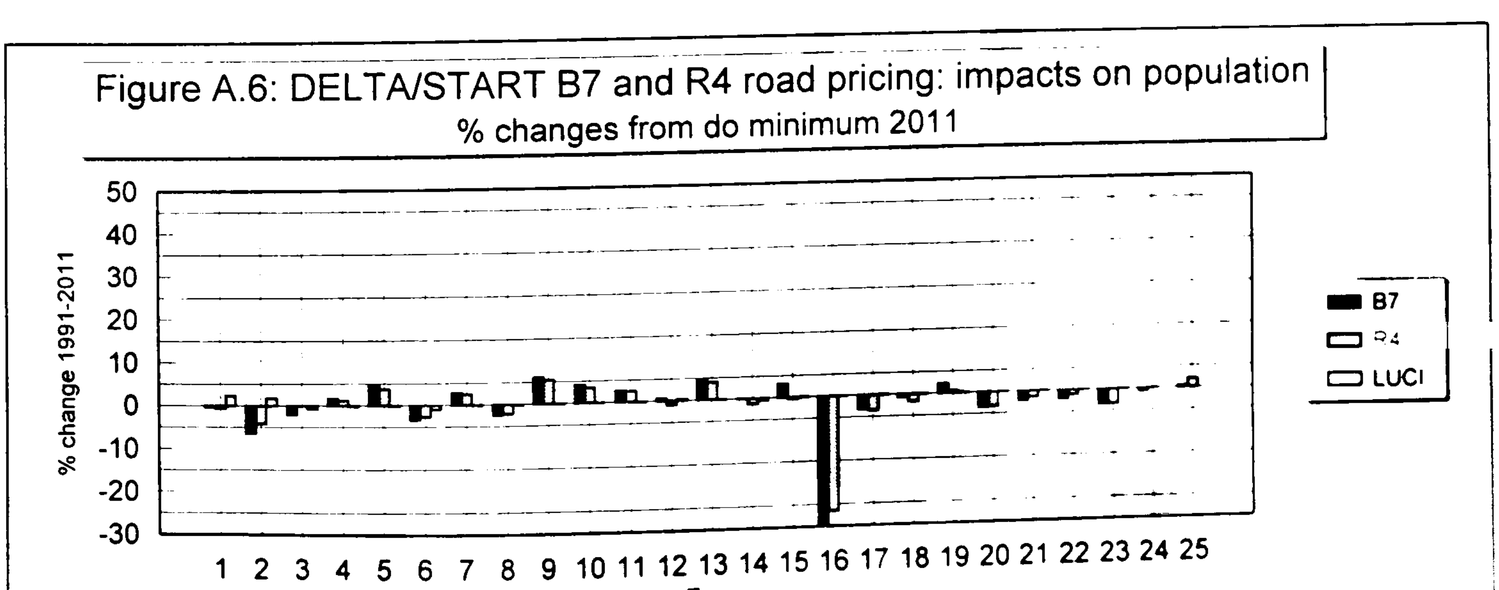
2.2 The impacts of road pricing on land use from the R4 tests

The impacts from road pricing are generally smaller (in percentage and absolute terms), than the impact of LRT, for the same reasons as discussed in Chapters 8 and 9. Again, the impacts on rents (table A.7) shows the same patterns for R4 as B7, with reduced magnitudes, although the direction of the Midlothian changes for the retail sector, probably due to the fact that employment increases in this zone under R4, whereas if fell in B7.

Table A.7: Road pricing impacts on rents: comparisons between B7 and R4

Rent level	Residential (% chg. 1991-2011)		Retail sector (% chg. 1991-2011)		Office sector (% chg. 1991-2011)	
	B7	R4	B7	R4	B7	R4
City centre	0.6	0.2	-5.1	-4.1	-39.8	-11.9
Rest of Edinburgh	0.4	0.2	-3.9	-0.3	1.1	3.2
East Lothian	-0.9	-1.4	2.2	3.9	25.6	8.9
West Lothian	-0.5	-1.1	7.2	3.4	18.0	5.7
Midlothian	-2.3	-3.0	-6.4	3.3	3.8	4.6
Dunfermline	-0.6	-0.1	6.7	3.1	21.9	8.3
Kirkcaldy	0.2	1.5	5.7	4.8	16.2	10.1
Total study area	-0.2	-0.1	-0.5	-0.2	-3.4	-0.4

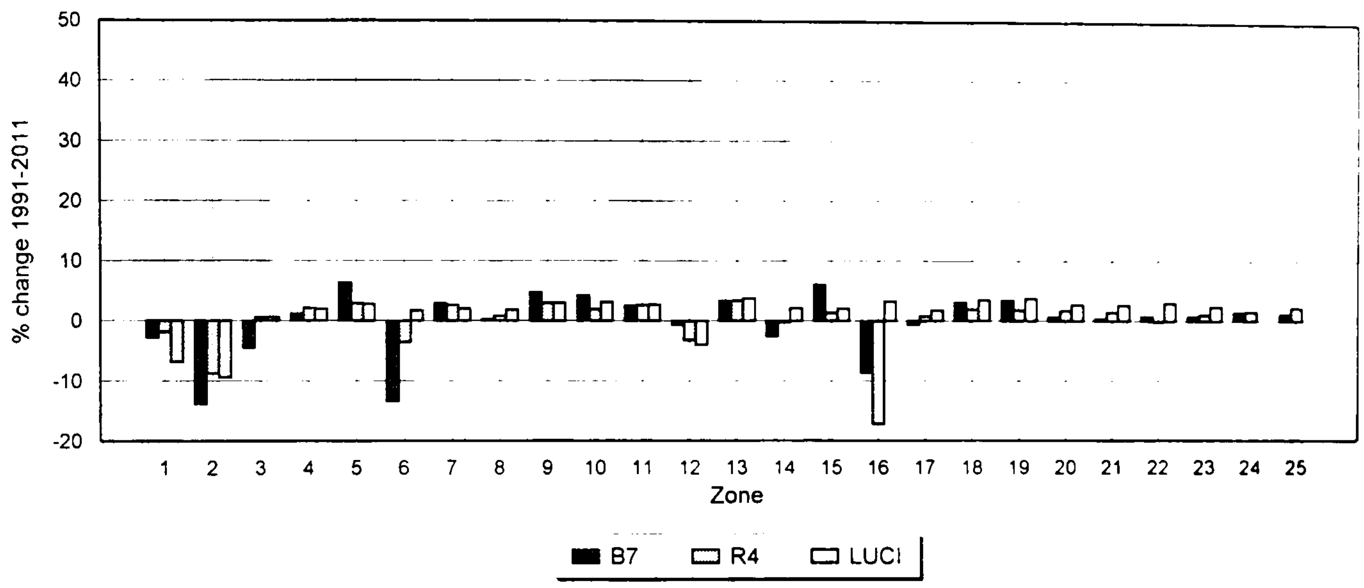
The impacts on employment in R4 were broadly expected to be a fall in jobs in the city centre, with compensating growth elsewhere in the study area. In fact, while employment does fall in zones 1, 2 and 12, it also falls in 6, 14, 16, (plus 3 and 17 in B7: shown in figure A.6). By contrast the LUCI model does not show negative impacts on non-cordoned zones. The DELTA estimates are the result of worsening accessibility for these zones, followed by improvements in accessibility over time in the city centre, which attracts employment back into the city at the expense of employment in these zones. The differences in accessibility may well reflect the more complex accessibility measures used in DELTA/START. However, it is the dynamic changes over time that explain these results, factors which LUCI cannot model.



Although the magnitude of these unexpected results for employment is less for R4 than for B7, the same basic pattern of impacts is still evident. The main exception is zone 16, where the spurious road pricing charge remains obvious. The impacts on population are much less, as shown in figure A.7. The large influence from zone 16, displacing population, is obvious here. Ignoring this, the other impacts show smaller magnitudes of change from R4 relative to B7, most noticeable in the smaller impact for zone 6, which in B7 was behaving as if it was inside the road pricing cordon, but now shows much less of an impact.

Figure A.7: DELTA/START B7 and R4 road pricing: impacts on employment

% changes from do minimum 2011



3.0 Summary and conclusions

Several points can be made by way of a summary of the R4 tests. The R4 results provide a better 'fit' than B7 to the prior expectations about how the study area would develop based on the broad comments in the Structure Plan. However, there are still significant differences in the do-minima between the LRC projections and DELTA, due mostly to the differences in the overall levels of growth, which are greater in the LRC projections.

The results show that the impacts of transport on land use are similar in direction, but differ in magnitude between R4 and B7. R4 shows less impact on land use. The sensitivity of DELTA to its parameters should be clear. The importance of obtaining 'justifiable' and 'rational' parameters has been underlined, as the impacts on land use depend upon these parameters.

The use of the Delphi as a guide to the expected sensitivities proved useful. However, the Delphi could be refined if specifically required for 'calibration' type use. For example, estimates of changes by sector for a subset of zones for both rents and activity impacts could be used to guide the model processes consistently, and estimates should obtain data for several different levels of service or charge/fare levels for the policies under examination.

Finally, it would still be very interesting, as a point of comparison, to 're-base' the LUCI model with the DELTA do-minimum future year predictions, and re-calibrate the model using the DELTA/START accessibilities. This would allow a useful assessment of how much the DELTA results are due to interactions over time and feedback effects, rather than just the initial accessibility change.