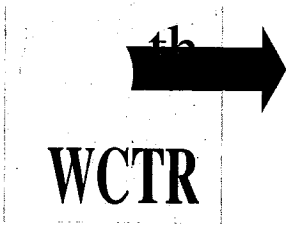

TRANSPORT IMPACTS ON LAND USE: POTENTIAL METHODS AND THEIR RELEVANCE TO STRATEGIC PLANNING

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Abstract

This paper examines the relevance to UK strategic planning of methods to estimate the impacts of transport policy on land use processes. Three differing techniques for forecasting these impacts were applied to a common study area. These were a Delphi survey, a simple static land use model, and a linked land-use/transport model. An assessment was made of the methods, using a sample of practising UK planners, against the criteria of relevance and plausibility of the approaches, and validity of the forecasts.

INTRODUCTION

This paper presents the main findings from a research project into the treatment of transport impacts on land use in the UK strategic planning system. The research was divided into two phases. The first (only briefly reported here), examined planners' attitudes to studying transport impacts on land use. The key issue to result from Phase 1 was that of selecting the most appropriate methods to examine such impacts. The second phase therefore examined this issue by the application of several methods to a common study area and then, of central importance, obtaining analysis on the results from a sample of professional planners with intimate knowledge of the study area.

'Transport impacts on land use' are broadly defined as any alteration to the distribution of urban, social or economic development caused by transport policy. The central indicators of distributional change can thus be either economic (such as property rents, employment levels or gross domestic product per head), or social/demographic (such as population or households).

OVERVIEW OF PHASE 1: CURRENT TREATMENT OF TRANSPORT IMPACTS ON LAND USE

In the UK there is growing interest in the role of transport policy in shaping urban development. However, it was suspected there was very little formal consideration of how transport influences land use, either in the UK or overseas. Therefore, in Phase 1, interviews were conducted with two samples of planners, one in the UK, and one from the USA. Only the UK interviews are summarised here, the US findings are discussed in more detail in Still (1996).

The UK interviews found no consistent or formal assessment of possible impacts of transport policy on land use as part of the transport or land use planning processes, including structure planning. There were four main reasons for this. Firstly there is no requirement to examine such impacts, and practically no mention of them in Planning Policy Guidance (PPG) 13, the government advice on land use and transport (Dept. of Transport and Dept. of Environment, 1994). Secondly, there is a perception among planners that the development control process can prevent unwanted impacts from occurring. Thirdly, the exact circumstances under which impacts occur are only vaguely perceived, with a belief that they are difficult to predict. Finally, practically all of the planners in the sample (both land use and transport) tended to be unfamiliar with the nature of the current methods that can be applied to estimate transport impacts on land use.

Phase 1 concluded that within the UK study of land use response should be undertaken as part of coherent land use / transport planning. Thus the research agenda must move on to the critical issues of identifying the methods that are most appropriate to examine transport impacts on land use.

POTENTIAL METHODS

The remainder of this paper therefore outlines the research undertaken to examine systematically which methods of assessing transport impacts on land use are most relevant to strategic land use and transport planning. To do this, several illustrative forecasting methods were applied to a common study area (Edinburgh and its surrounding region). The methods and their results were then assessed by a panel of strategic planners from the study area, who had agreed to assist in this project. Conclusions are then drawn regarding the validity of the methods, and the relevance and plausibility of the forecasts.

Table 1 outlines the possible methods for determining the impacts of transport on land use. The methods outlined in Table 1 are all 'operational' in that they have been used either in the UK or elsewhere to inform planning policy. Within this table, methods (1): planners' judgement and (2): informal use of experts' opinion, were identified from Still (1996) as the most commonly used in the UK.

The Delphi method (3) is common in the USA, where a rapid method has often been required to initially comply with air quality legislative requirements. Quantified assessment frameworks (4) have been applied for a few transport investments such as the proposals for the Strathclyde tram, and generally tend to examine employment and development impacts only. Where these frameworks have a fuller theoretical economic underpinning, they have been classified as economic frameworks (6). Simple land use allocation models (5) can examine population and employment impacts, and again are common in the USA (for example the use of DRAM/EMPAL; Putman, (1994) in the Atlanta case study), and have also been used in Sweden (Anderstig and Mattsson, 1992). Finally, dynamic land use transport models (7) are arguably the most comprehensive methods that can be applied, of which the 'Martin Centre models' have had the most applications (e.g. Williams, 1994).

To cover the spectrum of formal approaches, the illustrative methods applied in this research focused upon one example from each of (3), (5) and (7). Methods (1) and (2) were considered too informal, given that the planners' views would be sought in analysis of the other methods in any case. Method (4) tends to be open to more subjective judgement than the modelling methods, and was not considered sufficiently rigorous compared to method (5). Method 6 would ideally have been applied, but practical information on the assumptions within the framework, and how to apply it, were not available.

Table 1: The range of methods for examining transport impacts on land use.

	Method	Comments, example methodology
1	Individual planners' judgement	Often used in typical desktop based impact studies.
2	Informal use of group expert opinion	Professional panel from planning and property/development sector.
3	Formal use of expert opinion	Delphi method, deriving quantified responses from a similar panel to (2).
4	Quantified assessment frameworks	Assessment via an explicit and systematic framework of relationships.
5	Simple modelling	Static land use models linked to standard or existing transport models.
6	Economic frameworks	Calculations of economic benefits, using outputs from transport models.
7	Complex modelling	Dynamic land use transport model.

The Study Area and policies tested

Edinburgh was selected as the study area for this research. It is a city of high architectural and cultural value, yet one in which increasing traffic congestion is threatening to reduce its environmental quality. Edinburgh is also innovative in terms of its transport policy. It was one of the first UK cities to adopt an 'integrated urban transport strategy' (May *et al*, 1992), and is actively considering both light rapid transit (LRT) and road pricing, as potential elements in its plans to curb pollution and congestion within the city. The region has a number of transport models relevant to strategic planning and the methods considered below. Most important here is a version of The MVA Consultancy's 'Strategic and Regional Transport Model' (START; initially discussed in Bates *et al*

1991). This model was made available for the purposes of this research.

Figure 1 shows the study area, subdivided into the zones of the Lothian START model. The study area includes the districts that comprised Lothian Region, as well as southern Fife. Note that since the 1996 local government reorganisation, Lothian Regional Council has been abolished, and replaced by four Unitary Authorities following the original district boundaries.

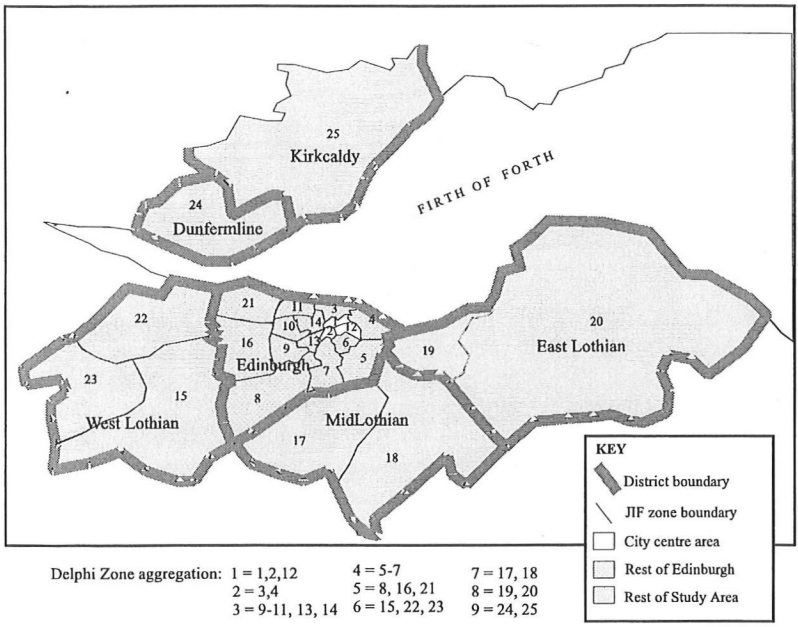

Figure 1: Study area map

Each of the three methods was implemented for two hypothetical policy tests, (which were based upon two elements of the best performing strategies in the Lothian integrated transport strategy, as outlined in May *et al*, 1992). The first was a road pricing cordon around the city centre (zones 1, 2 and 12 in Figure 1). A charge of £1.50 was applied for traffic passing each way through the cordon, operating all day. The second was an LRT system, with two lines operating with a five minute headway, each passing through the city centre (Waverley Station). The 'East-West' line ran from the airport (zone 16) to Leith (zone 4), the 'North-South' line ran from zone 3 down to the 'South-East wedge' (zone 5), an area earmarked for major housing and commercial development. LRT charges were assumed to be set as equal to bus fares. Each policy was compared with a 'do-minimum', which assumed no additional transport infrastructure, and fares, prices and frequencies following historic trends.

The Delphi method

The Delphi method aims to obtain quantified opinions of experts in a subject area, in a systematic and non-biased manner using repeated questionnaires. Each panellist remains anonymous to the others, hence reducing the risk of 'interpersonal static' and individual bias. Panellists can adjust their responses to the questions, once presented with the results from the previous round. This process aims to obtain a consensus on the direction and magnitude of the impacts within the panel.

The Delphi method has not been applied widely in transportation studies. Some examples of assessing transport impacts on land use do exist, (for example Cavalli-Sforza and Ortolano, 1984). The Delphi has also been used at the early stages of strategic plan formulation (e.g. Smyth, 1995), and hence is not unknown amongst practising planners.

In these cases the Delphi offered a cheap and practical means of obtaining opinions on likely impacts, using experts in the subject area, without the expense of developing a mathematical model. However, as a tool in planning, it is more limited than a mathematical model, for example it cannot be used to test the impacts of strategies other than those considered in the questionnaire. Furthermore, the sample must be carefully selected (and ideally multi-disciplinary) to encompass a variety of perspectives and minimise strategic bias. There is also a limit to the length of the questionnaire that can be successfully applied without respondent fatigue.

The panel approached consisted of property experts from the study area (property agents, surveyors and developers), planners from the local authorities, and planning consultants. The sample completing the entire Delphi consisted of 20 members, a typical number for a Delphi exercise (Amara and Lipinski, 1972).

The Delphi developed for Lothian was more ambitious than the previous 'transport impact' Delphi studies in terms of the spatial disaggregation, but considered fewer indicators as a result of this. The indicators selected were retail and office rents, and population distribution. These indicators represent those considered both sensitive and intermediary (e.g. commercial rents), and less sensitive and 'end-state' (e.g. population distribution). The 25 zones shown in Figure 1 were aggregated to 9 zones for the Delphi, to reduce the number of forecasts required (25 forecasts for each policy was considered too onerous for the respondents). The main aim of the questionnaire was to obtain responses regarding:

- the changes in office and retail rents over the next 15 years expected in each zone;
- the changes in population over the next 15 years expected in each zone;
- the impacts on these changes (expressed as percentage changes from the do-minimum forecast year) due to the LRT strategy, and the road pricing strategy;
- the timescale over which the impacts are likely to take place (in years).

The general results showed that there was a reduction in the standard deviation of the responses in the second round, suggesting that a better consensus was being obtained. However, resources did not permit more than two rounds of questionnaires to be undertaken.

The static land use model (land use change indicators)

Static land use models generally work by taking a set of forecast year accessibilities from a do-minimum and a given transport strategy, and calculating the changes in the activity distribution that is possible given the changes in accessibility (Figure 2). All other variables in the urban system are held constant. For this reason they are termed indicators rather than forecasts, as they are both simple and abstract measures, and have no explicit time element.

The structure in Figure 2 shows the static LUCI (Land Use Change Indicator) model, and its links, via accessibility indices, with the Lothian START strategic transport model (see Roberts and Simmonds, 1995). It is a simple model, and for example, does not include any feedback relationships. Thus no constraints were imposed on the amount of floorspace available in each zone, and market rent mechanisms were not represented. These simplifications mean that the model can be run very quickly once set up, requiring minimal additional resources or expertise.

The LUCI model had been calibrated using cross sectional data (Simmonds, 1991). It used the same zoning system as in Figure 1, and gave indicators of the likely impacts in each zone on population distribution, and employment, the latter split into retail and 'other' services sectors.

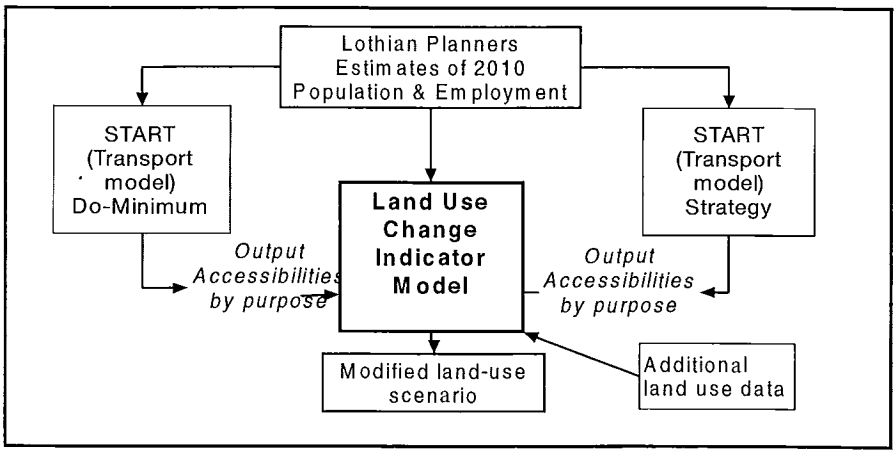

Figure 2: Structure of LUCI static land use model

The dynamic land use transport model

Significant study resources were devoted to the development of a dynamic land use transport model for the Edinburgh study area, in conjunction with David Simmonds Consultancy and The MVA Consultancy. The START model formed the transport model, largely unchanged in terms of its datasets, but modified to run dynamically, and for time periods of two years. To this was added a new land use model, DELTA, which represented the following urban processes:

- development of housing and commercial floorspace, via the operation of the private sector development process;
- demographic change via a 'transition' model of probabilities that households of one type will transform into other types (e.g. by the processes of childbirth, children leaving home, migration, death, divorce etc.);
- the location choices of employment and households, taking into account accessibilities and transport-related environmental quality (from START), plus the quality of the urban fabric and a measure of the amount of space demanded by each household (utility of consumption);
- the process by which urban areas increase or decease in quality, based upon the income of the residents living there.

A diagram of the relationships between these elements within a modelled time period is shown in Figure 3. A more detailed discussion of the DELTA/START model is given in a companion paper in these proceedings (Simmonds and Still, 1998).

DELTA is considerably more complex than the LUCI static model, but was designed so that the submodels represent familiar urban processes, that were felt to be important in urban development. In particular:

- time is explicitly incorporated, with the model moving forward in two year steps;

- time lags are therefore represented, for example housing development takes two years from the decision to build to when the floorspace becomes available;
- feedback effects are included, for example the land market is explicitly modelled, with increasing demand leading to rising rents;
- a variable is included which represents the differing, and changing, quality of urban districts.

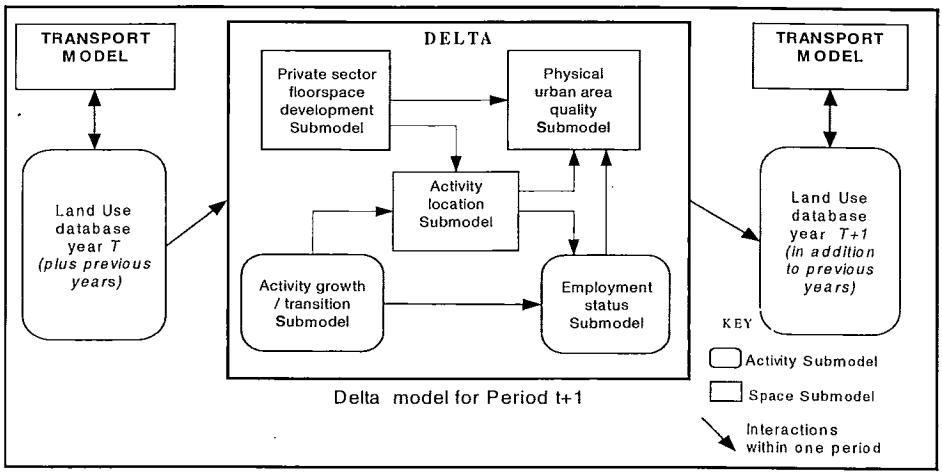

Figure 3: DELTA land use model structure

The result of the feedbacks and modelling of time periods is that land use and transport affect each other dynamically over time. The DELTA model is designed so that the individual submodels are calibrated individually. Due to the limited resources of this research, cross sectional calibrated co-efficients were used for the location model. The DELTA/START model required several hours' computing time for a typical (20 year) forecast (ten two-year periods). However, it generates a wide range of forecasts by zone and time period, including floorspace changes, rents, densities, employment and population estimates.

COMPARISON OF THE METHOD RESULTS

Introductory comments and the Do-Minimum forecasts

The do-minimum forecasts, which provided the basis for the comparison of the methods, each came from a different source. The Delphi panel were asked to estimate zonal changes in rents and population from current conditions, for a horizon year of 2010. The LUCI model itself is not capable of forecasting, and future year estimates were taken from the Lothian Regional Council planners' zonal 2010 estimates for their region. The DELTA/START model produced its own population (household) forecasts, but used control totals from the Lothian Structure plan to guide the overall population totals, and give the employment projections by sector.

Table 2 gives a sample of the comparable forecasts. For simplification, the study area is divided into the city centre, a ring encompassing the rest of Edinburgh district, and an outer ring enclosing the remaining districts (as shown in Figure 1). Table 2 illustrates that there is some disagreement between the methods on the distribution of change, in some cases in terms of direction, but mostly in terms of the magnitude of impact. In particular the Delphi results predict growth throughout the

study area, but are of a much lower magnitude compared to the planners' predictions or the DELTA model.

The growth outside of the city illustrates the decentralisation pressures that Edinburgh faces, but note that there is agreement that the city centre will be able to withstand these decentralisation pressures. Some additional disagreement in Table 2 concerns the distribution of employment growth. While the Lothian planners (LUCI estimates) predicted further growth in the centre, the DELTA model estimates greater decentralisation of employment. This can be traced to the availability of floorspace in the outer areas, coupled with lower commercial rents than the city centre or in the rest of Edinburgh. The LUCI estimate also places more emphasis on growth in the rest of Edinburgh, which a more detailed analysis would show is due to the Gyle edge of town commercial centre (zone 9).

Table 2: Do-minimum forecasts (% changes 1991-2011)

Population	*Delphi*	*Lothian planners**	*DELTA*
City centre	+2.4	+15.6	-5.6
Rest of Edinburgh	+3.3	-6.5	-10.0
Rest of study area	+2.6	+20.0	+14.5
Total study area	+2.8	+5.9	+4.4
Employment			
City centre	N/A	+9.8	-0.5
Rest of Edinburgh	N/A	+15.6	-1.2
Rest of study area	N/A	+11.8	+15.3
Total study area	N/A	+13.1	+6.0

* used to provide LUCI horizon year land use distributions.

Forecasts of transport impacts on land use

Although there was some disagreement between the do-minimum forecasts from methods, The first three columns of Table 3 show that all the methods' predictions agree that the impact of road pricing on the study area will be slight, relative to the changes over the forecast period in the respective do-minima. The main exception is the impact on employment, which are larger and (mostly) negative within the cordoned area (note that the Delphi panel and DELTA also predicted strong depressive effects on office and retail rents within the cordon).

Table 3: Impacts from the transport policy tests (% change from 2011 do-minima)

	ROAD PRICING			LIGHT RAPID TRANSIT		
Population	*Delphi*	*LUCI*	*DELTA*	*Delphi*	*LUCI*	*DELTA*
City centre	-1.3	+1.4	-1.9	+0.9	+11.1	+15.7
Rest of Edinburgh	+0.2	-0.3	+0.8	+1.3	+2.6	+1.1
Rest of study area	+1.0	+0.1	-0.3	+1.3	-3.8	+13.4
Total study area	+0.4	0.0	0.0	+1.3	0.0	+4.4
Employment						
City centre	N/A	-6.3	-3.0	N/A	+10.7	+19.0
Rest of Edinburgh	N/A	+2.3	-0.8	N/A	-0.9	-5.0
Rest of study area	N/A	+2.6	+2.3	N/A	-10.0	-5.4
Total study area	N/A	0.0	0.0	N/A	0.0	0.0

Although not apparent in Table 3, it is interesting to see which zones gain the employment that has moved out from the central area after road pricing is introduced. The LUCI model predicts a relatively even pattern of benefits, not focusing (as perhaps would be expected) on the Gyle developments, but responding only to the zones where accessibility remains highest. The DELTA model shows more growth where available floorspace is greatest, this being West Lothian (in particular Livingstone) and a major development area in zone 5 to the south of the city (Figure 1).

By contrast, LRT is forecast by the models (although not the Delphi panel), to have a much larger impact. This is due in part to the high frequency of the LRT service in the transport models. Also, in DELTA/START, it can be seen that over time land use shifts occur which reinforce the patronage of LRT, with higher growth in zones along LRT corridors (although the coarse nature of the zones means this impact is relatively aggregate). LRT is predicted to encourage strong population centralisation, which is partly a feature of the accessibility function (which is set up in such a way that households find the city attractive as a location from which to get to other parts of the region with ease). However, on the wider scale, it also appeared to encourage focus of activities within Edinburgh city generally.

Aside from the results presented here, the Delphi and DELTA/START model also predicted significant changes to the distribution of rents, with larger percentage changes in rents than in activities. Again, the magnitude of the change forecast by the DELTA model was greater than that given by the Delphi panel. Using the DELTA/START model it was also found that the transport indicators resulting from incorporating land use change gave different results from the START transport-only model. For example, the public transport mode shares were slightly higher for LRT when land use response was modelled.

THE PLANNER INTERVIEWS

The results from the methods outlined above were given to a sample of six study area strategic planners, working in land use and/or transport. The planners were interviewed in depth to discuss the methods and their results. Prior to these interviews, a sub-group of these planners (informally termed the 'steering group') were given additional presentations on the DELTA/START model, to explain its increased complexity, and illustrate its wider range of outputs. The planners affiliations are shown in Table 4.

Table 4: Planners in the sample

Organisation	*Number*
The Scottish Office: development (planning) department	1
The Scottish Office: roads directorate	1
City of Edinburgh Council: development dept (strategy)	2
City of Edinburgh Council: development dept (research)	1
West Lothian Council: planning department	1

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 other districts could have been found, or a sample of planners obtained from another area entirely. This latter option of obtaining another, entirely separate, sample of planners was not pursued at length as such planners would not have familiarity with the study area. However, the small number of key planners with strategic experience of Lothian 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 Lothian regarding

strategic issues.

The planners were asked to consider the appropriateness of the methods based on:
1. the relevance of the indicators produced by the methods;
2. the validity of the methods used;
3. the plausibility of the results produced;
4. and hence, finally the importance of these methods to different aspects of planning.

Relevance and choice of indicators

An issue that became clear in the interviews was that planners in different organisations tended to share the same technical views on relevant indicators, without necessarily having the same needs for a strategic assessment of land use impacts. Thus the central Government planners in the sample tended to have a much greater 'hands off' approach to modelling than district (and regional) planners. Within the districts, the practical interest in the methods depended upon whether the planners were considering transport policies that (they felt) would have land use impacts. Thus there was a pre-judging of whether transport policies would have land use implications, ahead of any formal analysis.

It was clear from the planners' comments that certain indicators were of more relevance than others, and there was significant consensus within the sample to this effect. Those indicators considered essential for planning tasks tended to be 'final' outcomes, such as the estimates of distribution of population and employment. These appeared important because of their role in conventional transport forecasting (i.e. trip generation), and because this is the 'hard data' with which planners work. The planners treated those indicators with which they were unfamiliar with caution. This applied especially to those in DELTA/START which were relatively novel, such as the urban area quality indicator, and disaggregations by socio-economic group or household type.

There was also a focus on 'horizon' years, rather than on outputs for intermediate years. Clearly this suits methods which only work to a given forecast year (Delphi or LUCI), and shows that the time period data, while essential for the theoretical underpinning of any land use transport model, had limited appeal as an indicator in itself.

The choice of spatial scale was very important. It was clear that land use planning requires information on a fine scale, in order for the distribution of the impacts to be clear. Zones of similar size are useful so that summary measures such as percentage changes are meaningful in a comparison. The planners noted that too large a number of zones can hinder analysis, and that some tiers of planners require more aggregated data than others. It is therefore important for land use data zoning to be flexible for aggregation, but still using spatial units that the planners are familiar with. This was particularly apposite in Lothian, where it was clear that local government re-organisation, by fragmenting the old Regional authority, has reduced the spatial scale of interest for any one of the Unitary Districts.

Validity of the methods

The planners' views on the methods ultimately reflected their views on modelling in planning generally, and in particular the additional complexity to transport modelling implied by the incorporation of land use. While this was not a large issue for the LUCI approach, it was more important for DELTA, which required substantial resources in addition to the transport model. However, complexity was perceived as beneficial if it made explicit the processes that underlay the model results. This is especially the case for DELTA, where the production of intermediate indicators such as rents and accessibilities was seen to aid transparency. In this sense the Delphi was

criticised as offering little formal explanation of the views of the sample.

Transparency was a key element which contributed to the planners' confidence in a given method. (Note that this study is concerned with *ex-ante* views on forecasts, which can only consider confidence in methods and results, and not the *ex-post* accuracy, which requires empirical validation. Certainly empirical validation contributes to confidence in a method, but was beyond the scope of this study). From the interviews, it was discerned that confidence comprised two broad areas. Firstly technical issues, such as the ease of calibration, validation and use of the model, coupled with the plausibility of the forecasts (see below). Secondly qualitative issues, such as the reputation of the model and the modelling team, perception of the success of past applications, and the training/education provided by the modelling team to the planner(s) in the use of the method.

Plausibility of the results

The plausibility of the forecasts was closely related to the confidence in the method used to produce them. Thus one planner was critical of the Delphi results because of the 'positive' bias in its do-minimum forecasts (where no zone in the study area was forecast to undergo absolute decline in either population or the rent indicators). There was also a suspicion of strategic bias in the Delphi results (i.e. members of the Delphi panel perhaps wishing to protest against road pricing in central Edinburgh).

For the modelling methods, given the comments in the previous section, it is perhaps not surprising that these forecasts were treated with the some caution by the planners. Firstly the planners (with one exception) had little familiarity with the methods, were perhaps not given sufficient description of the calibration procedures or sensitivity testing, and not given the chance to comment on early forecasts. This view was expressed even by those planners who had additional exposure to the DELTA/START via the 'steering group sessions' and implies that a great deal of interaction is necessary between the modelling team and planner clients during modelling (especially model development) projects. Moreover, the fact that DELTA/START was a new model, meant that it was an unknown quantity as regards its predictive capabilities and practical features.

The second important finding relating to the plausibility of results concerned the process by which forecasts were considered reasonable. In terms of the do-minimum forecasts given in Table 2, the planners tended to take the LRC(LUCI) forecasts as being most plausible, partly because they were developed by a team within the old Regional Authority. However, this meant that the DELTA do-minimum was seen as more plausible than the Delphi forecasts, because it was a closer approximation to the LRC forecasts. This was especially the case as differences between the LRC and DELTA do-minimum forecasts could readily be explained by some differing base assumptions.

However, in terms of determining the reasonableness of the forecast transport impacts on land use, there was much less to serve as a benchmark for comparison, as the planners had few preconceptions about what the distribution of impacts was likely to be. There was a general consensus that the directions of change were plausible, although several aspects went against the 'deductive' (or professional) expectations of the planners. For example the impacts of LRT from DELTA were felt to be too large, especially the centralisation of population.

The planners were also concerned about the largely negative impacts of road pricing. They commented that, before drawing policy inferences, they would require more knowledge of the sensitivities of the models, a wider range of tests, plus a clear explanation of why households and employment responded to road pricing as predicted by the methods.

Finally, it is interesting to note that there was interest in the relative impact between zones, even if

there were doubts about the absolute magnitudes of the impacts predicted. A good example would be that the pattern of increase in zonal households (relative to the do-minimum) from the LRT scheme was considered reasonable even if the magnitudes were considered high.

Overall importance and planning tasks

The planners were asked about the types of planning task to which methods of assessing transport impacts on land use were considered relevant. A task identified by those with land use planning backgrounds was in testing the links between land use and transport plans for the early stages of structure planning. In particular this was related to how transport could influence the city's urban regeneration initiatives. However, the main purposes identified by both land use and transport planners still focused on transport planning tasks, such as the appraisal of potential transport policies, and their sensitivity to land use assumptions. The focus of this research upon strategic planners seemed to be shown by the interest in the distribution of impacts, and the relative indirect impacts in different parts of the city, rather than in overall benefits from the transport schemes.

Although in general the planners' comments were very favourable towards incorporating assessment of transport impacts on land use in planning, the planners would not commit themselves upon whether future forecasting commissions would incorporate these relationships, although their desirability (despite the cost and resource implications) was claimed not to be in doubt. This uncertainty is perhaps a limitation of researching into planners' views, where there is very little revealed preference behaviour to draw upon.

DISCUSSION

The application of different methods with common policy tests to a common study area is rare. Some examples do exist, for example Anderstig and Mattsson (1992), who applied four appraisal methods for assessing economic impacts from transport schemes in Stockholm, but no other study has been found which aimed to examine which methods best met planners' requirements.

The 'evaluation panel' methodology adopted in this research, given the small number of strategic planners in a given study area, coupled with the need for the methods to be of local interest to the planners (to obtain participation), is inevitably qualitative and somewhat subjective. There are clearly limits to the generalisations that can be made from using an evaluation panel, as the needs of planners in different urban areas will vary.

However, the lack of totally consistent methods did not prevent the evaluation panel from examining the results, and responding to the four criteria discussed above. Furthermore, the consensus in the responses from the panel did imply that some general views were being obtained about the three very different methods tested. Finally, given that planners in different cities do not operate in isolation from one another, it is felt that some general conclusions can be reached.

The two key issues to emerge from the research are those of zoning and method complexity. Zoning proved a key constraint during the application of the methods, because once imposed it is very difficult to adjust. Furthermore, the level of zoning affects the results of the modelling. The evaluation panel were keen to have finer zoning, and there is no doubt that land-use response methods must move in this direction. A planner in the sample commented that Geographical Information Systems (GIS) could offer a way forward. The possibility of combining GIS with land-use/transport models is an exciting prospect that needs to be examined in detail.

The issue of method complexity is perhaps the most difficult to summarise. The evaluation panel

considered modelling methods to be more flexible and reliable than the Delphi expert opinion method. This is not surprising, and reinforces the conclusions from earlier interviews with planners in the USA (see Still, 1996) who considered that a modelling framework offered distinct advantages (of both forecasting flexibility and political credibility) over expert surveys or group discussion. The evaluation panel also favoured the more complex modelling approach in DELTA over the simple static LUCI model. This is based upon the view that the more complex model is (1) easier to conceptualise as it describes observable urban processes, and (2) provides a greater range of indicators to explain its operation. It is therefore more 'transparent' in that the results can be examined in intuitive ways. This is impossible with the LUCI model as implemented, and more difficult with static models in general. At the very least static models should include some representation of floorspace constraints and market mechanisms.

CONCLUSIONS

This paper began by arguing that the impacts of transport on land use are neglected within strategic urban planning, and that many planners acknowledge this. Three methods to examine such impacts were applied and the results assessed by strategic planners practising in the study area.

The panel evaluation interviews identified several criteria which any method for forecasting land use response to transport policy needed to satisfy. These can be grouped as follows:

1. there must be confidence in the method by the planners; this includes understanding:
   - the theoretical structure(s) underlying the method
   - the relationships incorporated, and any assumptions
   - key sensitivities (for example to accessibility in model-based methods)
2. the method must be capable of producing forecasts of households, population (including workers) and employment indicators;
3. the method must be able to use a zoning disaggregation that is both sufficiently fine, and can be aggregated up into appropriate planning units (such as local authority districts);
4. the method must produce, or make use of, a do-minimum that the planners endorse;
5. the method must be as 'transparent' as possible to enable explanation of the results.

In conclusion, land-use/transport modelling methods appear best able to meet criteria 2-5, although some issues of spatial disaggregation remain. The key area is criterion 1, where land-use/transport models must aim to maximise explanatory power with minimal complexity. With regard to the other methods, the Delphi approach can be seen as limited, but complementary to modelling work, whereas static land use models offer a relatively cost-effective method of examining land use issues, but fall short of offering a strong theoretical or transparent approach.

Clearly, greater use of these techniques will increase our awareness and understanding of the linkages between land use and transport. However, the sample of planners suggested that such methods are likely to enter mainstream use only if their costs can be reduced, or if there is a policy requirement to do so. Given the importance of understanding the impacts of transport on land use, future revisions to UK planning guidance should ideally incorporate such a requirement.

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