ADVANCES IN INTEGRATED URBAN/REGIONAL LAND-USE/TRANSPORT MODELLING USING THE DELTA PACKAGE

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Abstract: This paper will provide an update on the design and application of urban/regional land-use/transport interaction models using the DELTA package. DELTA was originally developed in the mid-1990s, and its prototype application, to the city of Edinburgh (Scotland) was reported to WCTR in 1998 (Simmonds and Still, 1998). Since then it has been extensively used in various parts of the UK, in conjunction with a number of different transport modelling packages. The paper will consider how the design and use of DELTA have responded to the changing policy and practical requirements of client organizations.

The paper will begin with a brief overview of the general DELTA approach and model design. It will then focus on a number of areas where the design has advanced since the early versions of the package. These will include (i) the need to understand study areas in context, taking account of their interactions with surrounding areas - especially in a relatively small and densely built-up country such as Great Britain, where urban areas are located in close proximity to one another; (ii) in the opposite direction, the need to represent study areas in finer spatial detail than was previously the case in land-use/transport interaction models, which tended to be applied at very "strategic" levels (iii) progressive improvements in the representation of household and business behaviour, particularly in terms of their response to changing transport and accessibility conditions; this will include improvements that have been made to the household relocation process itself, and current work on refining the representation of owner-occupation of housing ; and (iv) the need to improve the representation of land-use planning policies, in order to forecast the impacts of such policies on travel demand, congestion etc.

The presentation will be illustrated with results from recent work.

1 INTRODUCTION

This paper provides an updated report on the design and application of the DELTA package, which was the subject of a paper presented to the 1997 World Conference on Trnasport Research in Antwerp (see Simmonds and Still, 1998). It outlines the model, identifying and describing the main changes which have been made in the scope and workings of the model since the original paper. It then goes on to review the experience gained in application of the package and some of the lessons that should influence future work in model development and application.

2 BACKGROUND TO THE DELTA PACKAGE

Work on development of DELTA started in 1995 in response to a perceived demand for a new "land-use" modelling package with two key characteristics. The first, practical characteristic was that the model should be suitable for use as an add-on to otherwise free-standing transport models, in particular to "strategic" transport models (see Roberts and Simmonds, 1997). The second, theoretical requirement was that the model be constructed in terms of processes of change, drawing on the enormous range of research carried out in urban and regional economics, geography, demography, sociology, etc. These are essential sources of knowledge about urban change but have generally been ignored in the design and development of applied models. It was hoped that the resulting model would be more intuitive and more acceptable to users than the predominantly cross-sectional models which then dominated LUTI modelling practice.

The first application of DELTA, linked to a transport model of Edinburgh, was completed in 1996. Since then the model has been extensively used in a number of regions of Great Britain, in contexts ranging from academic research through to the presentation of results at public inquiries into specific transport schemes. This paper reports on the evolution of the model and on some of the lessons learnt from this experience.

3 STRUCTURE AND DESIGN

3.1 Structure of the DELTA models

The overall design of a DELTA-based model consists of four components, as illustrated in Figure 1, namely

- the transport model (to which DELTA is linked);
- the economic model;
- the urban land-use model;
- the migration model.

Of these, the transport and urban models work at the level of zones, whilst the migration and economic models work at the broader level of areas. Areas typically correspond to travel-to-work areas, at least within the region of main interest; zones represent finer units within these areas (or within the area we are concentrating on).

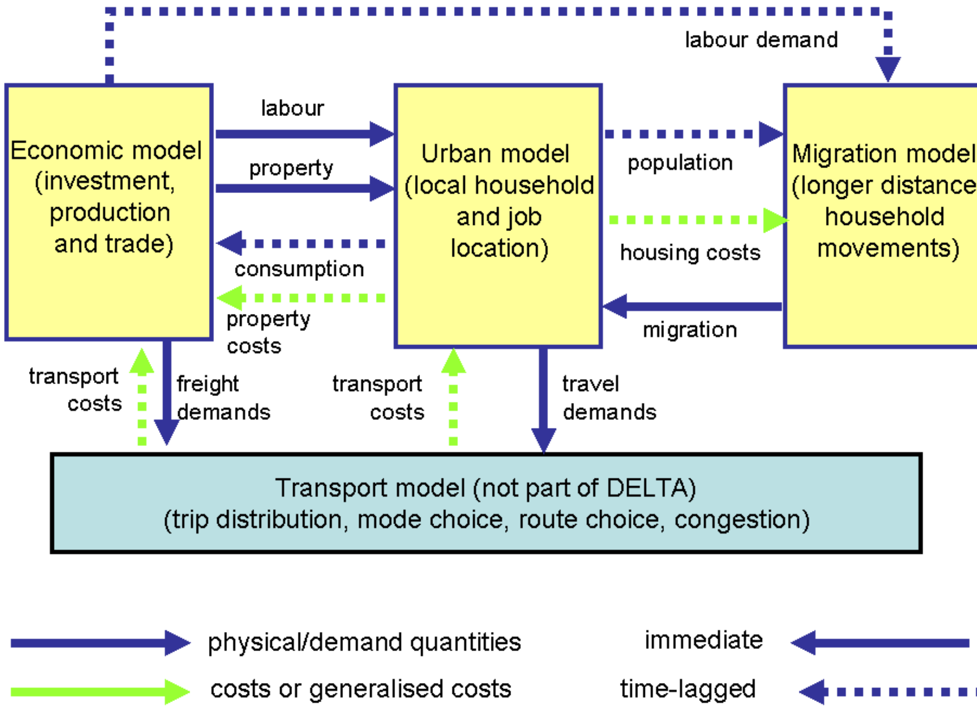

Figure 1 Overall structure of a DELTA-based model

The **transport model** takes inputs which describe activities (different categories of residents and jobs) by zone, for a given year. From this and from input transport system data it forecasts travel by car and by public transport. In doing so, it estimates costs and times of travel between each pair of zones, allowing for congestion caused by the forecast traffic.

The **economic model** forecasts the growth (or decline) of the sectors of the economy in each of the areas modelled. Its inputs include forecasts of overall growth in output and productivity. The forecasts by sector and area are influenced by

- costs of transport (from the transport model)
- consumer demand for goods and services (from the urban model)
- commercial rents (from the urban model).

Forecast changes in employment by sector and area are passed to the urban model. Freight transport outputs can be passed to the transport model.

The **urban model** forecasts the zonal location of households and jobs within the areas that are modelled in detail. Locations are strongly influenced by the supply of built floorspace. Locations are also influenced by accessibility, with different measures of accessibility influencing different activities, and by environmental variables. Households are influenced by accessibility to workplaces and services. Businesses are influenced by accessibility to potential workers and customers.

The locations of households and jobs are fed back to the transport model to generate travel demands. Household numbers are also used to calculate consumer demand for goods and services in each area, for use in the economic model. The rents arising from competition for property in each area affect both the economic and migration models. Information on job opportunities is passed to the migration model.

The **migration model** forecasts migration **between** areas within the modelled area. (Movements **within** areas are forecast in the urban model.) The inputs to this model include job opportunities and housing costs, from the urban model. Job opportunities are a strong incentive to migration; housing costs are a generally weak disincentive.

There are complex possibilities for feedback between the four components outlined above. For example, it is possible for an improvement in transport to generate economic growth, which generates additional travel, which may cause increased congestion and some worsening in transport conditions.

3.2 Sub-models within DELTA

The original DELTA package was intended to model a single compact area, with a given economic and demographic scenario for the total change in that area. It therefore consisted solely of the urban model (linked to a transport model), which at first consisted of five sub-models, three focussing on activities:

- the Transition and growth sub-model, dealing with household/population change and employment growth factors;
- the Location and property market sub-model;
- the Employment status and commuting sub-model;

and two focussing on the spaces occupied by activities:

- the Development sub-model;
- the Area quality sub-model.

The name DELTA was discovered as an acronym for these five sub-models (though unfortunately it is not a mnemonic for the order in which they are applied). The car-ownership sub-model was added as a fourth activity-related model in the application to Greater Manchester (see Copley et al, 2000).

The economic and migration models were added to allow the model system to represent either the wider interactions between a city area and its neighbours (without modelling other cities in any detail) or to model a region containing a number of urban areas. The first example of the latter was the Trans-Pennine Corridor Model (Simmonds and Skinner, 2001).

The following sections outline each of the sub-models, and the interfaces with the transport model, emphasising recent developments. The main linkages between the sub-models within a one-year period are shown in Figure 2.

3.3 Transition and growth sub-model

Demographic change is expressed in terms of rates of household formations, transitions (e.g. couple-without-children to couple-with-children) and dissolution. More complex changes are represented by combinations of these transition rates, which are (at present) independent of other factors within the model.

We do not claim that this is a sufficient population forecasting model in its own right; we adjust the rates of transition so that the population forecasts for the modelled area are consistent with those from other sources - particularly official projections. Our current work on household microsimulation (see Ballas et al, this conference) should provide synthetic panel datasets based on explicit models of survival/fertility and of household formation/dissolution which will allow us to improve the calibration of DELTA transition rates.

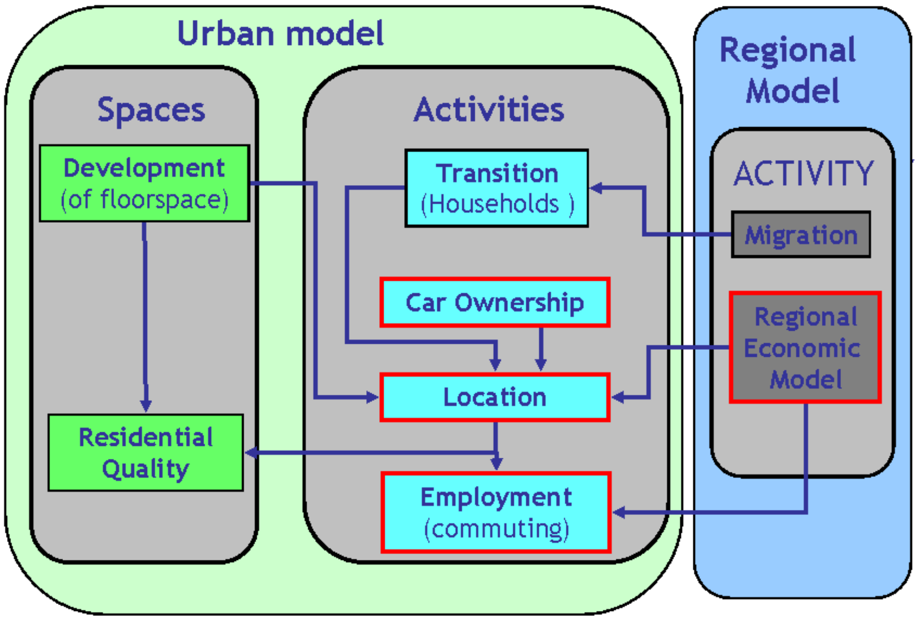

Figure 2 Sub-model sequence within a DELTA one-year cycle

Migration between modelled areas is forecast by the migration model which is discussed below. Migration to and from the total modelled area is defined by means of a proportion of each household type by socio-economic group that will leave in each period, plus a ratio of arrivals to departures.

In addition to the obvious importance of the demographic forecasting process for housing and transport demand, these changes themselves influence residential mobility and hence affect the response to transport changes. Newly-formed and newly-arrived households have to find a home; modified households are more likely to relocate than wholly unchanged households. A high proportion of unchanged households, especially those of older persons, are wholly immobile in any one year; they and the housing they occupy are excluded from the workings of the location model.

The employment growth component of the transition sub-model originally applied exogenous growth factors by sector, and is still used in this way for small-scale applications of DELTA to individual towns. In “full” applications it applies growth factors by sector and area from the economic model.

3.4 Location sub-model

This sub-model predicts the location of those households and jobs that are mobile in this period, given the property markets in which they are competing for space. For households the model takes account of:

- changes in housing supply;
- changes in accessibility;
- transport-related changes in the local environment;
- area quality;
- the rent of space.

in each zone. The model assumes that

- relocating households will tend to remain in the same location unless there are changes in one or more of the variables listed above;
- newly locating households will tend to locate in proportion to the previous distribution of similar households unless, likewise, there are changes in one or more of the variables.

The changes in accessibility, environment and quality are changes over a number of preceding years. These periods are short for young, more mobile households and long for older, more established households (especially the retired). The result of these time-lags (together with the mobility rates) is that (for example) the distribution of young single persons within an area responds quickly to changes in the transport system or in the pattern of destinations, whilst the distribution of the retired population is hardly affected at all by such changes.

The location process for employment is similar in structure but simpler, generally excluding the environment and quality variables.

Activities only interact within the location sub-model if they are competing for the same kind of space. The sub-model is therefore a set of independent models, one for each floorspace type (housing and several types of non-residential floorspace). The linkage between residential location and employment location works through the calculation of changed accessibilities, and therefore operates over time, never instantaneously.

In terms of the property market, demand consists of new and mobile households (or jobs). Supply consists of new development, already vacant space, and the space which may be vacated by households/jobs if they move in the present period (the last equivalent to representing property vacancy chains). Floorspace, including housing, is treated as a continuous variable, rather than as a set of discrete units. In this respect DELTA follows the Cambridge or “Martin Centre” tradition (Hunt and Simmonds, 1993). The location sub-model also follows that tradition in that it is run to convergence by adjusting rents for each floorspace type in each zone (with densities and activity location changing in response) until the demand equals the supply, though with the additional effect that if rents fall space will be left vacant. The process of convergence can be relatively time-consuming within the overall model run. Recent work making more use of the “error” information from one iteration to find the best estimate of rent for the next iteration has improved convergence speeds substantially.

The main refinements to the location model since the original version have been in integration with the higher level migration model, in explicit representation of household relocation and in the treatment of different kinds of housing. As explained further below, the migration/location modelling is based on the concepts of different streams of moves, with the zonal location model representing the most local level. The migration sub-model moves households between areas; the location sub-model locates arriving migrants and models local relocation within areas. Earlier versions of the relocation model ignored the effect of distance within each area. The latest version recognizes that there are significant distance-deterrence effects even at the most local levels, and for existing households applies the model in terms of a matrix of relocation movements with a distance-deterrence term. The latest versions also take account of different types of housing (eg public-sector "affordable" housing for lower-income households) as an influence on the initial occupation of new housing. Thereafter, rather than attempting to split the housing market into different segments, we rely on the incremental nature of the model to perpetuate the influence of such differences.

3.5 Employment status and commuting sub-model

The employment status sub-model is the one part of the package which works primarily in terms of persons rather than of households. It first calculates the demand for labour by socio-economic group, given the new number and location of jobs by sector. In a number of applications part of this process is done by splitting sectors into production and administration activities not only consisting of different groups of workers but also occupying different kinds of floorspace – this allows, for example, for the presence of manufacturing sector workers in Central Business Districts, where these are office workers in the administration of such companies.

The second stage of the sub-model adjusts the employment status of economically active individuals, and the commuting patterns of workers, until the required number of workers is supplied to each zone. These changes affect the income and hence the locational preferences of households; these take effect in the *next* modelled period. There is thus a short lag, for example, between an increase in the demand for labour and a resulting increase in the demand for housing.

The original version of this sub-model was a purely "mechanical" process based on scaling the previous database in proportion to labour supply, labour demand and transport-related changes. We are currently replacing this with a model of potential workers' choices of whether/where to work directly, using the generalised costs of travel to work and the wages offered for each type of work at each workplace as the variables to which they respond; the wages are adjusted so that all jobs are filled. (This could be extended to forecast that some jobs will remain unfilled at high wage levels; this would probably be a better approach to some of the very-high-employment situations we are working on (where there are significant numbers of unfilled vacancies at any one time), but would be contrary to the convention of a fixed total employment forecast within which we usually have to work.)

3.6 Car-ownership sub-model

The car ownership model is now based upon the national car ownership model developed by the University of Leeds Institute for Transport Studies for the Department for Transport (Whelan, 2001), converted into a zonal and incremental form. This forecasts changes in households' car-ownership as a function of income, employment, licence holding, car running cost, car ownership cost and company car distribution, and replaces an earlier version based on a comparable but simpler model by MVA (1996). Car-ownership is treated as conditional on location. Since income and licence holding by household type are exogenous inputs, the model response to policy comes either from changes in employment status or from relocation between zones.

A major advantage of adapting these national models to local use is that they ensure that DELTA car-ownership results are, in a sense, consistent with the national car-ownership projections published by the Department for Transport. Those car-ownership projections, along with economic and demographic variables, form the scenarios within which a great deal of local modelling within the UK is expected to work, in order to achieve a degree of consistency between regions. On the other hand, the "national" models are not ideal when applied to zonal data: in particular, they do not work where the base year car-ownership is above the saturation level – which is perfectly possible where modelling small zones. Further work in this area will be necessary.

3.7 Development model

The development sub-model seeks to predict the operation of the private sector development process. It takes into account the effect of the planning system, measured through the quantities of each type of development permitted in each zone. The model estimates the total amount of development of each kind (usually housing, retail, office and industrial) that will be proposed in each period, constrains it by planning effects, and allocates it to individual zones. Developers are motivated by the expected profitability of development, estimated by comparing current rents with construction costs. Time-lags in the development process mean that developments initiated when rents are high may not become available until rents have fallen again. The model can therefore simulate the 'boom-and-bust' cycle of the development industry, though this is unlikely to occur unless a strongly cyclical economic cycle is input. Public sector development and exceptional private sector schemes are exogenously input to the system.

One major omission here is car parking. Given the importance of car parking availability as an influence on mode choice in congested urban areas, this ought to be taken into account both in terms of parking developments per se (public parking garages) and private non-residential parking attached to offices, shops etc. It is regrettable that we have not had the opportunity to do this, especially given that some of our work (in Edinburgh: Simmonds et al, forthcoming) is linked to the TRAM package (Scholefield et al, 1997) which is the most sophisticated of the current strategic transport models in its treatment of parking.

3.8 Area quality model

The area quality sub-model hypothesises that the inhabitants of an area themselves influence its characteristics and, over time, affect its desirability as a place to live. The existence of upward and downward cycles of urban quality through such changes is much discussed in planning, but has been generally neglected in urban modelling. Positive influences include maintaining and improving buildings, cultivating gardens, planting trees, etc. Negative effects are neglect and misuse, such as use of residential property for "nuisance" purposes (such as breaking up cars in the front garden). In the present DELTA model, positive influences result from rising average incomes and decreasing vacancy rates, and vice versa. This sub-model is important to the overall design of the model, because it represents a process of "positive feedback" - the virtuous or vicious circles that tend to maintain or to enhance the differences between prosperous and deprived areas within cities.

Whilst the area quality model is mainly applied to housing, the area quality variables have been used to model the impact of urban quality changes as they may impact on businesses, in the context of a research project with Oxford University for the UK Department of Transport (see Whitehead and Simmonds, forthcoming).

3.9 Economic sub-model

The economic sub-model consists of the investment and production/trade sub-models.

The investment model is intended to represent several streams of investment and one or more processes of disinvestment. The underlying argument is that investment in productive capacity is influenced by a range of factors, differing depending whether the investment is (for example) inward investment, local reinvestment or a small business start-up. Relevant factors include labour supply, production costs and accessibility to markets and/or suppliers. Disinvestment may come about through the depreciation of equipment or through deliberate closure.

The production/trade sub-model is a spatial input-output model in which the main categories of final demand are exports and consumer demand. Exports are exogenously specified as part of the overall economic scenario. Consumer demand is determined as a function of the total expenditure on other goods and services in the location model (ie other than housing or transport). The pattern of trade is influenced by

- the demand in each area (final demand plus intermediate demand calculated by the input-output process);
- the capacity of each area (resulting from the workings of the investment model);
- the cost of production in each area (costs of inputs plus value added);
- the costs of transport.

Both investment and production/trade work at the same area levels as the migration model. The production/trade sub-model has similarities to the Martin Centre regional models. However, an important difference is that it is strongly influenced by capacity, ie the accumulated investment in each sector in each area, which only gradually changes over time as a result of the investment process.

3.10 Migration sub-model

The migration sub-model has been based upon recent research, particularly the multi-stream models developed by Gordon and Molho (1998). It is based upon "push" and "pull" factors which can be calculated from other variables within the model, and on a distance deterrence function. It can represent several different "streams" of migration influenced by different variables with different distance deterrence effects. It moves households between areas, typically groups of zones approximating to labour and housing markets. Migration is incorporated into the sequence of sub-models between the transition and location sub-models, which continue to deal with demographic change and with local (within labour/housing market areas) location respectively. Further work should shortly begin to refine the calibration of the migration model using results from the MIGMOD study (University of Newcastle upon Tyne et al, 2002).

3.11 DELTA-transport interfaces

The interfaces from DELTA to the transport model vary according to the requirements and capabilities of the latter. In the simplest case, DELTA provides zonal forecasts on numbers of person (by age group/working status) and numbers of jobs/other attractors, for each of the years in which the transport model is to run. In more complex applications, the interface involves DELTA forecasts of numbers of persons by household composition and car ownership, numbers of jobs by sector, travel-to-work matrices, goods movement matrices derived from the trade model (and disaggregated to zonal data using zonal employment to split area-area trade). In most cases the information is used as growth factors applied to an incremental transport model (see Bates et al, 1991 for the typical approach).

The current interfaces remain typical of land-use and transport modelling over the past 20 or 30 years in that they concentrate on the quantitative changes in the basic land-use variables of population, employment and retailing, more or less disaggregated, in particular by car ownership. This aspect of the overall system model should probably develop into a wider consideration of all the factors that affect mobility, including

- other pre-travel choices such as the ownership of two-wheel vehicles, season tickets/travel passes, and residential parking;
- mobility provision at destinations, especially parking provision..

3.12 Transport-DELTA interfaces and accessibility calculations

The main outputs from transport models to DELTA are matrices of generalized costs, normally in time units (ie minutes of travel (possibly with some travel elements such as walking and waiting time counted at more than the elapsed time) plus costs of travel divided by value of time). Information on changes in travel-to-work patterns is in some cases used to update the travel-to-work matrices in DELTA for the impacts of transport system changes.

Information on environmental impacts of transport is an important feedback to land-use which has been implemented in a number of DELTA models. The package design allows for linkage to an environmental model which could take account of non-transport sources and of the dispersal of pollutants. Such a linkage has never been achieved, and emissions are assumed to affect only the zone in which they are generated. Some effects such as noise are highly localised and hence difficult to represent except in models representing individual properties. One simplification of this which we have used in some cases is to take the volume of traffic in the zone as a proxy for the set of environmental variables: we would in any case argue that traffic itself should be considered as an environmental feedback in its own right, on account of the risk and severance effects that it causes.

Accessibility measures in the model fall into four groups. **Active accessibility** is calculated to measure how easily households of particular car-ownership levels can reach different sets of opportunities, such as jobs for workers of a particular socio-economic group, or shops. These measures are aggregated across purposes to calculate zonal accessibilities for households of different types, and changes in these are used in household location. **Passive accessibilities** calculate how easily destinations can be reached given the transport system characteristics and the distribution of potential "visitors" (eg customers, workers): changes in these values influence most aspects of the employment location model. In addition, numbers of trips arriving are used as a proxy for **footfall** as an influence on the location of retail employment. Finally, **market-size type measures** (the sum over areas of the demand for output of a particular sector, weighted by a function of the cost of delivering it to each area) are used in the investment model.

4 KEY DEVELOPMENTS

4.1 Introduction

This section reviews some of the key ways in which the DELTA package has developed from its early versions, to improve the representation of processes of change and in response to client requirements.

4.2 Modelling study areas in context

The applications of DELTA have always been designed so as to cover a larger area than the intended "policy area", ie the area within which land-use planning or transport interventions will be introduced into the model. Initially this was done simply by including large zones around the fringe of the modelled area, and making some provision for interactions with the rest of the world, particularly in terms of in- and out-commuting. More recently, it has involved the use of the regional level of the model to cover a larger area again, in most cases with the full detail of the urban model only being applied to the city or conurbation on which the work is focussed. Hence for example the original DELTA model of Edinburgh was concentrated on the City of Edinburgh itself, with a small number of larger zones representing the immediate hinterland of the city (the rest of the Lothian sub-region, and parts of the adjoining area of Fife), whilst the more recent model of Edinburgh incorporates a regional level of the DELTA model which covers the whole of Scotland, allowing the model to provide a reasoned analysis of how policies applied in and around Edinburgh would affect Edinburgh's share of the Scottish economy.

This move to modelling the wider spatial context has been driven by a number of factors, including on the analytical side an increasing awareness of the interactions between towns and cities within each region, and on the policy side both a growing interest (informed by that awareness) in wider, city-region level planning, and more specifically a need to consider the impacts of transport demand management measures which might be applied across or around the whole of a city – such as possible city-wide road user charging measures.

4.3 The need for finer detail

At the same time as land-use/transport modelling is taking a wider spatial view of cities or conurbations in their regional or national context, there are pressures to build models at finer spatial scales in order to represent policies which operate at detailed levels. This stems from the fact that many current planning strategy issues are less about whether cities should (say) expand northwards or southwards, and more about whether development should be concentrated in particular types of location such as (notably) corridors or nodes better served by public transport (transit).

As a result, the number of zones used to represent a given city has typically gone up by a factor of around 10 from the models developed in the mid-1990s to current work.

This has been supported in the UK by a generally improving availability of data at reasonably fine scales. It does however obviously raise the computing requirements for modelling, especially when combined with modelling increasingly wide areas, and markedly so in the associated transport models where all, rather than just some, of the key variables are zone*zone matrices. The speed and capacity of readily available desktop computers has fortunately kept pace with this growth in the size of models, such that in some cases the increase in scope and detail has been achieved whilst still allowing a complete run of the model, typically over 20 years, to be completed overnight.

The growth in the scale of model is not of course purely an issue of computing the forecasts themselves. It has also required increasing use of, and reliance on, computer graphics and mapping for the checking and analysis of results which are much too voluminous to be checked by reading through simple tables.

4.4 The representation of household location and commute behaviour

As mentioned earlier, the representation of household relocation choices from one limited to forecasting the net changes in household numbers, by household type (ie the increase of decrease of households of that type in each zone) to one which works with matrices of household movements at both the urban and the regional scales. The facility to identify different types of new housing, by defining the "expected initial occupiers", has also served to refine the model particularly in the representation of planning policies which seek to control the supply of different kinds of housing.

The treatment of decisions relating to commuting has likewise been developed, from a simple area-wide adjustment of the proportion of adults working to match labour demand in the first DELTA model, to explicit incremental choice models of whether-to-work and where-to-work in the latest versions. The latter operate by adjusting a wage variable (by work zone and socio-economic level) in order to ensure that the number of workers forthcoming (including commuters from outside the modelled area) matches the number of jobs (plus out-commuting). The wage variable has further potential value as an accessibility-to-labour measure for work zones reflecting both the distribution of labour supply (residents), the access from residential to work zones, and the overall degree of competition for that labour supply from the employment opportunities that each worker can reach.

Further work has been done on representing location and work choices using microsimulation of households within the overall DELTA structure. The microsimulation approach, which is the subject of a separate paper for WCTR (see Feldman et al, this conference), is at present seen as a research tool which will inform future DELTA developments and calibration rather than as a regular alternative for applied analysis in policy- and decision-making. Another line of development which might more readily be incorporated into standard applications is a current project, also for UK Department for Transport, which is looking specifically at the treatment of housing markets in land-use modelling. In this case, we are retaining an aggregate modelling approach, but explicitly representing the supply and occupation of housing by dwelling type (house, apartment etc) and by tenure; the modelling of household location behaviour is then strongly influenced by households' preferences of particular types and tenures, and their ability to afford those preferences in different locations. The modelling also seeks to take account of the way in which owner-occupiers regard housing as an investment as well as providing shelter and comfort;

this in turn requires that the model should consider their expectations of future capital returns as well as responding to the current situation. Some conclusions from this study should be available in time for the Conference.

4.5 Forecasting planning policy

We are often required to run land-use models for years or decades beyond the "horizon" year of published land-use plans, or even of plans in preparation. This is common in UK transport planning practice and probably arises elsewhere, certainly in countries where formal cost-benefit analysis is a major part of transport policy appraisal but not of land-use policy appraisal.

Our preferred approach is to ask local authorities to provide an informal (and if necessary off-the-record) assessment of what they think their spatial development policies will be beyond the time horizon of their formally adopted plans. This is fine providing all the authorities involved are willing to contribute in this way; if not, having information about longer-term expectations in some areas but not others could significantly distort the model results. Another possibility which we have had to resort to is simply to assume that no new permission for development will be granted once the development envisaged in existing formal plans is complete - this is obviously unrealistic but does ensure consistency between different government areas.

One suggestion that has emerged from this is the possibility that for the longer term it would be appropriate to build a model of the "planning system" to generate the quantified planning policy inputs by zone from more basic information about the physical characteristics of each zone and about likely future attitudes to development there. Another merit of such a "model of policy" would be that it could respond to market conditions. Pressure of development has long being a factor that UK planning bodies are required to consider in formulating land-use plans, though the emphasis on this has varied over time. Recently, in response to the Barker (2004) Review of housing supply, the UK Government has proposed that planning authorities should be formally required to adjust their plans for housing development so as to maintain housing prices within a specified level of affordability. Such a requirement would make it all the more necessary in forecasting that medium- and long-term local plans should reflect this kind of response.

There are of course complications if "responsive" rather than "fixed" land-use plans are used in forecasting the impacts of transport policies. The "responsive" plans may well produce more realistic forecasts, but the process raises questions for any assessment of benefits - how much of the benefits are then attributable to the transport intervention, how much to the changes in land-use plans which could (in principle) be made independently?

5 CONCLUSIONS

The DELTA package has now been in use for over 10 years. During that period it has been extensively used for a range of applications in Great Britain. Some of these were one-off studies, whilst others are ongoing modelling commitments being run by or for local planning and transport organizations. The use made of the applications has ranged from academic research through strategy studies to the final decision-making processes in respect of specific transport proposals.

The modular structure of the approach has shown itself to be robust. It has permitted a considerable number of extension and refinements, in particular to incorporate a wide range of enhancements stemming from other research and the inclusion of new and experimental approaches. Experience in application continues to suggest new ideas and new requirements for the design and the application of models, some requiring enhancements to DELTA and the way we use it, and some requiring substantial research in order to specify and calibrate such enhancements.

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