LAND-USE MODELLING WITH DELTA: UPDATE AND EXPERIENCE

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Abstract: This paper offers first an updated description of the DELTA package and then a review of issues in the use of land-use/transport interaction models. The package was developed as an urban modelling system in 1995-97, and was substantially extended by the addition of a regional level in 1999. It can model one city in detail, taking account of the surrounding areas, or all of the urban areas across a region. DELTA does not include a transport model, but is usually linked to a specialist transport modelling package. The paper summarises the design of DELTA, which is based upon sub-models representing different processes of change. This approach allows different components to be improved as opportunities arise. We outline some of these developments, and then review our experience of using DELTA-based models, in particular in terms of lessons for model design, model operation and the interpretation of results.

Keywords: land-use model, land-use/transport interaction, urban modelling, regional modelling, decision-making

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1 INTRODUCTION

This paper provides an updated report on the design and application of the DELTA package, which was first formally published in Simmonds (1999). 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).

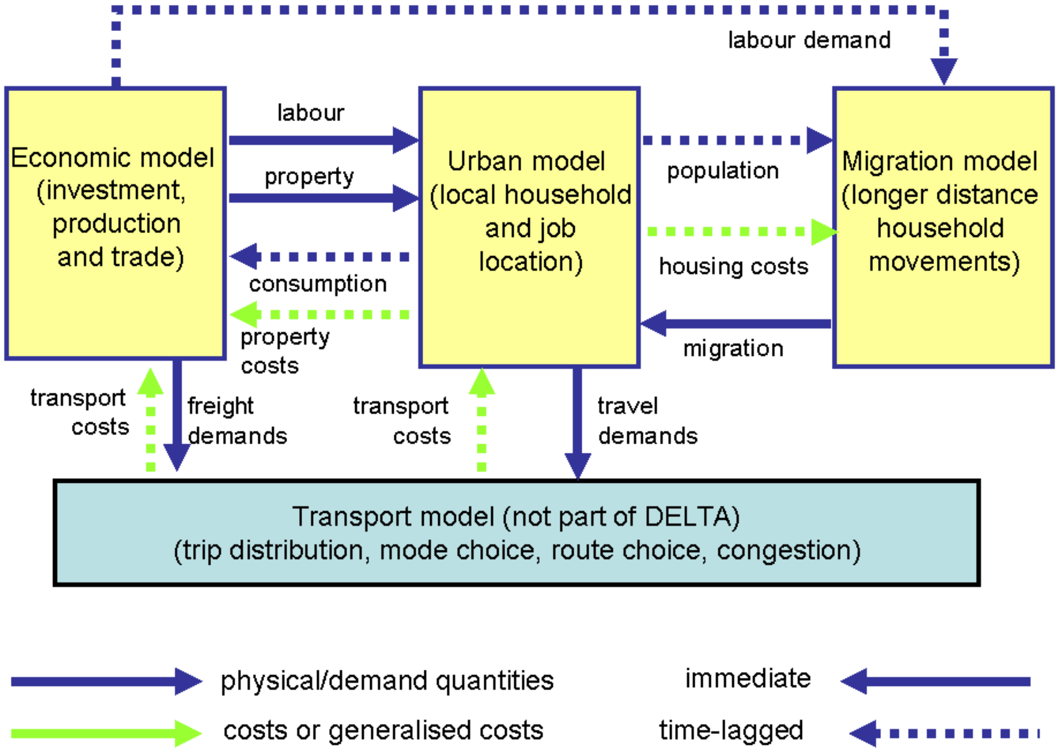

Figure 1 Overall structure of a DELTA-based model

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

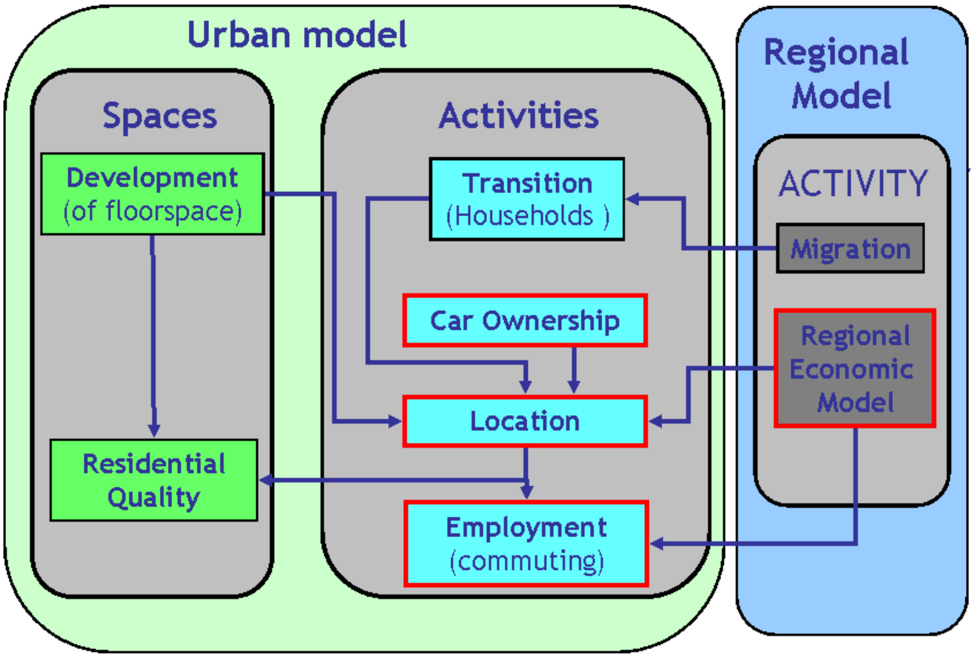

Figure 2 Sub-model sequence within a DELTA one-year cycle

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.

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 EXPERIENCE IN APPLICATION

4.1 Introduction

This section reviews some of the lessons we have learnt from application of DELTA-based models in recent years, not least in the hope of influencing the agenda for the development and use of future models. This is a purely empirical review and no attempt has been made to impose any theoretical overview or structure on these points.

4.2 Graphical interfaces for model users

Because the DELTA model consists of long sequence of component sub-model programs (including pre- and post-processors which manipulate data before/after many of the named sub-models), and because it is often run in conjunction with transport models which take hours to run and need to be operated overnight, the user interface while DELTA is running has never been that important. In particular, no graphic output and only a minimum of text output is produced while the model is running, since normally there is no one there to look at it! Also it is critical that the same sequence of programs is run each time and therefore – in contrast with some transport/traffic modelling packages – there is no requirement for a user interface to control which parts of the model are used on any particular occasion.

What happens before and after a model run is of more concern. Two graphic user interfaces (GUI) have been developed to set up tests. One of these is a wizard which leads the user through the process of setting up a new test: much of the use of DELTA involves the comparison of results for different scenarios or policy interventions, and the main function of the wizard is to help the user to choose which files to copy from previous tests, to edit those which need changing, and to start the test running. The other GUI helps to process planning policy information and is described below.

For post-run analysis the emphasis has been on allowing data to be passed to standard utilities such as spreadsheets and mapping programs. The argument here is that we wish to encourage users (internal or external) to think about the model outputs; that the best way to do this is to provide a wide range of possibilities for analysis, rather than a small set of fixed variables and formats; and that the best way to provide a wide range is to feed the DELTA output (or a steadily increasing proportion of it) into standard software tools so that – for example – a user can apply the full power of a commercial package such as Excel or MapInfo, without having to learn DELTA-specific tools. The main tool here is an interactive DELTA program which allows the user to select a table of DELTA output (eg one variable by zone and year) and to drop that table directly into a spreadsheet or GIS table. The user's thinking is assisted by documentation which suggests reasons why the model may forecast certain effects, ie helps the user to go backward in understanding why certain results appear, as well as documenting the system in the usual forwards direction.

Whilst we see limited value in an overall, purpose-written graphic user interfaces for DELTA in our own work, there is sometimes more enthusiasm for or even insistence on such an interface when the model is delivered to clients for their own use. Where there is a GUI for the transport model, it is easy to allow DELTA to be run from that interface in addition to the possibility of starting it from the DELTA wizard.

4.3 Tracing inputs

More work is needed to represent planning policies. At present these are represented fairly crudely in terms of the amounts of development (or occasionally demolition) which will be permitted or imposed. This overlooks many of the more subtle aspects of policy, especially those which aim to encourage particular types of development. There is a need to enhance the model's ability to deal with this – though as far as we are aware this criticism applies equally to other land-use models, and it is an area which relies on further research into planning processes to clarify when, where and how planning policies are effective. There are some counter-arguments to going into more detail of planning policies, and certainly it is important that future modelling should allow users to test separately the questions of "will this kind of policy be effective?" and "what will be the wider consequences if this particular policy is effective?".

One strong argument for developing models which will allow planning policies to be input in ways which correspond more closely to the published planning documents is the need for planning bodies to endorse the way their policies are modelled. The tendency in the past has been for modellers to produce the necessary quantification of what are often largely qualitative proposals. For acceptance of or even interest in the modelling results it is essential that this process of preparing model inputs should as far as possible be undertaken by or at least with the staff of the planning agencies. Recent projects where we have involved those agencies in preparing the model inputs themselves have been successful in generating more interest in the rest of the modelling process and in the information it can deliver for decision-making. As part of this, we have developed an interface which allows planning policy inputs to be stored in terms of “plans” and “proposals” as identified by the user or client, eg “2001 Structure Plan”, “2006 Proposed Structure Plan”; a GUI is then available to merge the set of plans required for a particular test into the DELTA files.

4.4 Forecasting planning policy

Related to the above is the fact that 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. If this is implemented, it 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?

4.5 Agreeing or reconciling scenarios

As mentioned earlier, DELTA is designed to work with a fixed economic and demographic scenario for the total modelled area, and to produce forecasts by zone within this context. The total modelled area typically covers a number of local government areas, each of which have their own economic and demographic forecasts upon which their plans and policies are based. The DELTA-based forecasts may well differ from these. One of the simplest points to emerge from our recent modelling practice is the need to compare the different sets of forecasts and to try to reconcile them in terms of the different assumptions on which they are based. There is nothing necessarily very difficult about this; the problem is rather that where the modelling is commissioned by one particular body (eg the planning authority for one area, or a transport agency) in order to test the impact of alternative strategies within their area, they may not be keen to devote resources to debating the underlying scenarios with neighbouring organizations. This can cause problems later.

4.6 Analysis of complex policies

There has on occasion been criticism that the model results are difficult to understand - that it is difficult to see why the impacts forecast follow from the policy that is being tested. This is most likely to occur when the model is being used to test a complex package of interventions whose impacts may well be pulling in different directions. We are strongly of the view that this problem can be overcome by disassembling such packages into their component parts, showing the simpler (intuitively more acceptable) impacts of each of the components, and then building back up to their combined effect (which is generally not the linear sum of the separate effects). On the occasions where we have been able to take this approach we have always been able to provide a better explanation of the overall results.

The problem in achieving this is partly that there may not be time to do this within the study timetable, and partly that it may be unacceptable to clients to disaggregate their proposals in this way. If a decision has already been taken that intervention X is only acceptable if combined with intervention Y (which is quite likely if X is a stick and Y a carrot), then it may be politically unacceptable to carry out analysis which might show that all the positive impacts flow from X and that Y is not worthwhile.

4.7 Use of modelling in planning

The above problem stems in part from the fact that modelling is often used to examine proposed interventions at a fairly late stage in the decision-making process, after extensive debate and when many of the key participants have publicly reached conclusions. The formal processes of appraisal tend to contribute to this by requiring more detailed, model-based analysis only in later stages of the formal decision-making process.

There is also a related conflict between the common pieces of advice in relation to modelling in planning. One is that models, especially complex land-use/transport models, should be used not to test specific proposals (or not just to test such proposals) but to explore the full range of possible scenarios and strategies in order to help the user/client to build up understanding, both of the model and of the planning questions to be considered. On the other hand, it is argued that models cannot cover all possible questions and need to be built for particular purposes - the "horses for courses" argument. We see problems the latter: we believe that models should be built that are capable of representing (and hence of systematically comparing) a wide range of scenario variables and of policy interventions. This of course takes longer and is more difficult, and generally requires that models should be commissioned much earlier than is typically the case - before the specific need for a model has been identified. Just as it has been argued that Government-sponsored research is always done too late, to answer the last round of questions rather than to address the next set of issues, so there are major challenges in ensuring that sufficiently versatile models are available when required.

5 CONCLUSIONS

The DELTA package has now been in use for nearly 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. 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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