The South and West Yorkshire strategic model

A MAJOR MULTI-MODAL TRANSPORT STUDY IS CURRENTLY BEING CARRIED OUT IN SOUTH AND WEST YORKSHIRE. THIS ARTICLE OUTLINES THE MODELLING SYSTEM BEING USED TO FORECAST FUTURE LAND USES AND TRAVEL DEMANDS AND TO EXAMINE THE IMPACT OF ALTERNATIVE TRANSPORT AND DEVELOPMENT PLANS.

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SWYMMS IS THE ACRONYM FOR THE SOUTH and West Yorkshire Multi-Modal Study, a study being carried out for the Government Office for Yorkshire and the Humber which has involved the development of a strategic land use/ transport interaction model.

The study has had to consider the interactions between 'land use' in the broadest sense, including population and economic activity, and the transport system. It has had to examine how demand for transport is affected by land use changes and how changes in transport may affect land use – with particular reference to impacts on economic performance. The consideration of transport must take account both of planned interventions and of other changes, such as worsening congestion.

In order to examine these changes and their linkages systematically, particularly to compare the consequences of different strategies, the study team has developed a formal computer model of transport and land use. This concentrates on the study team has developed a formal computer model of transport and land-use, known as SWYSM – the South and West Yorkshire Strategic Model. As illustrated in Figure 1, the model covers the whole of South and West Yorkshire plus a ring of adjoining areas such as Skipton and Harrogate (the Fully Modelled Area); in addition, a wider ring of adjoining areas (extending westwards to Manchester and eastwards to Hull) are covered in less detail (the Buffer Area), and external zones to represent movement to and from the rest of Britain.

THE START PACKAGE

In any area-wide transport modelling, compromises need to be made between the level of spatial detail at which the area is represented and the sophistication of the model in other respects, such as the treatment of modes of travel, the distinction of different types of traveller and different travel purposes, or the two-way linkage between demand and congestion. The ideal model would be detailed in all respects, but this is infeasible both because of the amount of computing which would be required and the amount of work needed to prepare its input data.

The START model has been developed by MVA since the early 1990s (Roberts and Simmonds, 1997) as a strategic planning tool.

The model is not intended to be used directly for the detailed design and appraisal of specific schemes, but linkages to detailed network models can be established for this purpose. This has been done in SWYMMS – in parallel with the strategic model described here, there are separate, detailed models of highway use and of public transport use; both of these have 570 zones compared with SWYSM's 92 zones.

Most conventional transport models have to be calibrated to reproduce the base-year situation. START adopts the alternative incremental approach: matrices of trips are estimated outside the model to describe the base-year pattern of travel, making use of all available data. The model then modifies the pattern of travel in response to factors 'external' to transport – mainly changes in land-using activities such as the number, mixture and car-ownership of residents, the number and type of jobs, etc. – and changes within the transport system itself. The following paragraphs summarise the preparation of the data for the base situation, the external forecasting model and the transport model proper.

Figure 1. The SWYSM Strategic Model: fully modified areas and buffer zones

BASE DATA

Data on base-year travel by motorised modes was obtained from the SWYMMS detailed highway and public transport models, which were in turn developed mainly from the extensive surveys carried out during 2000. Walking and cycling, which are not represented in the more detailed models, were estimated separately.

Most of the START supply representation was obtained by aggregating data already assembled in the detailed models. The primary sources of data for the detailed models were surveys of road traffic and public transport trip-making undertaken in Spring 2000. Approximately 140 road traffic interview sites were employed, covering all entry points to the motorways and the A1 within the study area. Public transport passenger surveys were undertaken in the centres of the 10 largest towns, with details of non-central movements provided via operator ticketing systems. Network data for the highway system was created using GIS techniques, and public transport networks were coded from timetables.

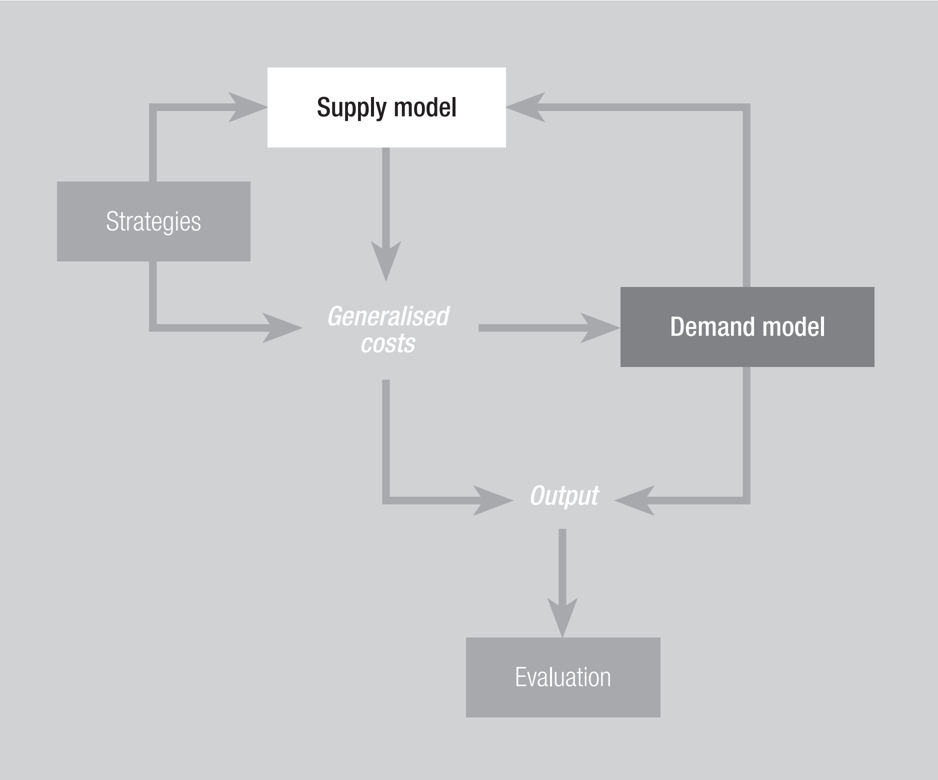

Figure 2. The START Transport Model

EXTERNAL FORECASTING MODEL

The External Forecasting Model (EFM) predicts changed travel patterns due to zonal changes in land use, including population, employment and car ownership. The model requires considerable detail about present and future land use by zone (age groups, household types), since such factors are known to influence the amount and the type of travel. In SWYSM, all of these are forecast by the land-use model outlined below.

The EFM assumes that future residents of a given age, employment status and car-ownership level will, if other factors remain equal, wish to make the same trips as comparable present residents. It works by factoring the different trip matrices in proportion to the numbers of residents by type and zone. Other factors will not of course remain constant. The land-use inputs contain non-transport changes, such as changes in jobs and shopping opportunities, and the EFM factors the matrices for these as well.

However, it does not consider changes within transport, such as better infrastructure or greater congestion. The output of the EFM is therefore an artificial travel pattern – what would happen if the land-use changes occurred but in the time and money costs of travel were unchanged. This is not a forecast, but simply an intermediate input to the model of the transport system itself.

TRANSPORT MODEL

The Transport Model (Figure 2) contains two components: the *demand model*, which adjusts travel in response to changes in transport conditions; and the *supply model*, which adjusts transport conditions in response to changes in the pattern of travel. These are automatically run in turn until the travel pattern and transport conditions are consistent with each other. The key variable linking them is generalised cost, which is used to describe every journey within the modelled area by a single value bringing together money, time, inconvenience or discomfort, etc.

The *demand* component of the Transport Model deals with all of the key choices available to travellers. These are frequency (how often to travel); destination (where to travel to); mode (car, bus, rail, tram, walk, cycle, taxi); time of day (when to travel); route (highway or public transport route alternatives); and parking (type, location and duration).

These choices are organized into a hierachy with the most sensitive choices at the bottom and the least sensitive at the top. The relative sensitivities, and hence the hierarchy, can differ between trip purpose. The choices respond to the changes in generalised costs appropriate to the choice – in this way, cost and time considerations affect all choices in a consistent way. If there were no changes in generalised cost, travellers would continue to make the same choices as in previous years.

Freight transport is also important in SWYMMS. Changes in the pattern of road freight movement are forecast on the basis of changes in the economy and in land uses. (Rail and water freight are being examined outside the model.)

The *supply* component of the Transport Model ensures that the level of service of the transport system, as defined by monetary costs and the various components of travel time, is compatible with the flows on the various transport networks. The highway supply definition is based upon the following key features:

- links that represent the speed/flow relationships for each zone (typically defined in terms of orientation with respect to the major urban centre – inbound and outbound radial, clockwise and anticlockwise orbital);
- motorway and other 'limited access' links defined as specific roads; and
- a set of fixed car and public transport routes for each pair of origin and destination areas, including intra-zonal movements, defined in terms of distance travelled upon each link.

A similar arrangement is applied to public transport, with the addition of specific rail network links. The public transport definition allows the representation of mixed mode trips, and crowding relationships are incorporated into the demand model to ensure that the generalised cost of travel is modified as demand approaches capacity. A further sophistication is that fares and frequencies for public transport can be made responsive to changes in the level of patronage.

Policies for testing are input to the process in one of two ways: either by directly modifying the generalised cost inputs, as might be the case, for example, with pricing policies; or by modifying the supply representation, to reflect changes in capacity – e.g. a programme of junction improvements. In either case, these result in changes to both demand and generalised cost matrices, which can then be evaluated against other strategies or against a suitable base case.

THE DELTA PACKAGE

The DELTA land-use/economic modelling package (Simmonds, 1999) was designed in the mid-1990s as a practical tool to represent urban and regional change and to interact with an appropriate transport model. The first application of DELTA was created in 1995-96 in collaboration with MVA and the University of Leeds Institute for Transport Studies (ITS).

Because land uses take a long time to respond to transport changes, the land-use model needs to represent change over time, in contrast with the transport modelling which describes transport supply and demand at particular points in time. Another requirement is to recognize that different processes operate at the urban and the regional levels: for example, different factors affect the level of economic activity in a particular area and the location of employment within that area.

The model accordingly contains urban processes which change in or between the 92 zones, and regional processes in which the units are (approximate) travel-to-work areas - typically districts, in SWYSM. The urban processes represent both physical changes in buildings and changes in activities.

The processes of physical change are development (residential, retail, office and industrial types) and quality change. The development sub-model predicts the amount of floorspace of each type built in each zone in each year. The total rate of development responds to the modelled property market which in turn reflects the economic scenario. Development in each zone is driven by model forecasts of property values, subject to inputs measuring what is allowed by the planning system. The model can be used to test the effect of alternative plans on development, on the location of activities and hence on transport.

The quality model recognizes that occupiers

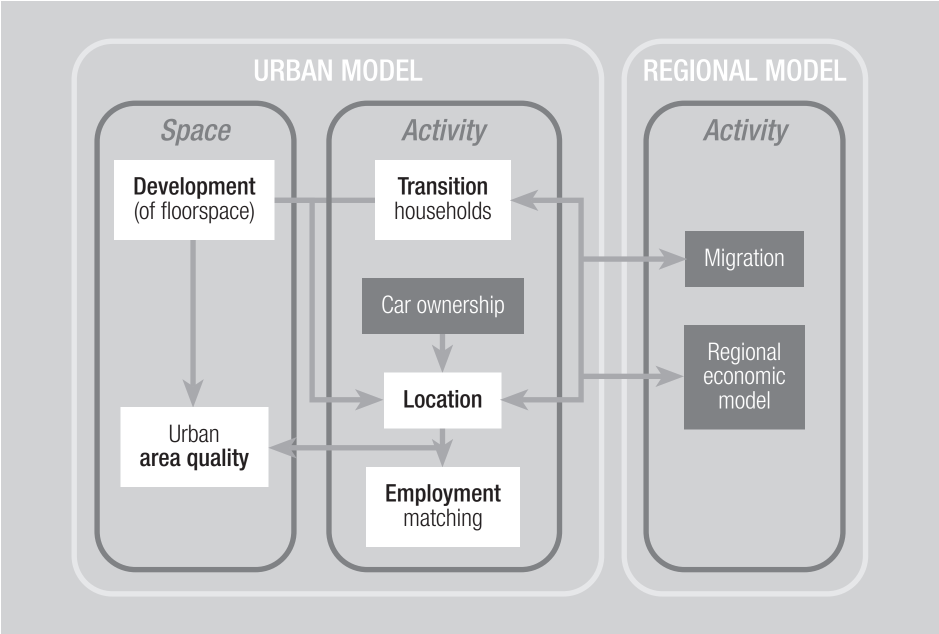

Figure 3. Land-use/economic model structure

of housing influence its attraction to other potential occupiers. A prestigious area may decline to slum status, or be revived from slum to high quality. The model incorporates a simple representation of this. Areas with high-income residents and low levels of vacancy are improved to or maintained at high quality. Areas with low-income residents (unable to afford repair and improvement) and high vacancy (likely to be neglected and vandalised) are likely to decline to or remain low quality.

The activity sub-models begin with the transition model, which represents population and household changes in terms of movements through a simplified lifecycle. Households of single people merge to form couples, have children who grow up and eventually leave to form households of their own, and so on.

The car-ownership model predicts the proportions of households of each type in each zone owning no car, one car or two or more cars. Car ownership increases mainly in response to increasing incomes, but the rate of change is affected by the relative merits of cars relative to public transport and walking, and hence by policies affecting different modes.

The location model is central to the whole system, since households in particular are influenced by everything else in the system. Only a proportion of households locate or relocate in each year. If other factors remain constant, newly-formed and newly-arrived households tend to locate where similar households are found (e.g. concentrations of high-income households will tend to persist over time) and existing households tend to remain where they are.

The 'other factors' which influence households' location are the supply of housing (modified by the development model), the quality of housing (modified by the quality model, accessibility (from the Transport Model and the location of land uses), the environment (from the Transport Model) and the cost of housing and how much space each household can afford.

The last of these are calculated within the location model. If the demand for housing rises faster than the supply in any zone, rent will increase. Increasing rents imply less space per household. The combination of increasing cost and less space makes the zone less attractive, and reduces the demand. Falling rents result in lower densities and increasing demand. There is also a vacancy effect – housing is more likely to be left vacant if rents are falling. The model adjusts for these effects until all households and all housing have been accounted for.

Similar but simpler processes locate employment into appropriate non-residential floorspace. Some employment categories, e.g. agriculture and education, are assumed either not to use floorspace or to use specialised buildings which are not represented in the model.

The final stage in the urban activity modelling is the employment status model. This updates the employment status of residents and their commuting pattern in response to the changes in the location of households and of employment.

Moving to the regional level, the migration model moves households between areas in response to differences in employment opportunities, housing costs and environment. The employment and housing variables are calculated within the model. The likelihood of migration between any two areas decreases with distance.

The regional economic model has two components: investment and production/trade. The investment model predicts greater investment in areas with improving accessibility and decreasing costs. The production/trade model is a spatial input-output model, which estimates production by sector and area and the patterns of trade between areas. The overall size of the economy depends on consumer demand and input forecasts of exports and other final demand. The patterns of trade depend on the capacity of each sector in each area (as adjusted by the investment model), the costs of delivering goods and services between areas, and the relationships between sectors (e.g. the quantity of agricultural output required to produce one unit of manufactured goods).

The processes are considered in a fixed sequence within each one-year step, as shown in Figure 3. However, there are also numerous time lags between the different processes which are equally or more important to the overall performance of the model.

LAND-USE/TRANSPORT INTERACTION

The model operation over time is a sequence of five one-year steps through DELTA, followed by a run of START to represent the resulting state of the transport system.

The effect of land-use changes on transport is immediate: the demand for transport is scaled in proportion to changes in residents and jobs, as described earlier.

Changes in transport conditions have gradual impacts on land uses and the economy. Changes in the costs of trade (goods passengers) affect the pattern of trade, the location of production and the more gradual investments in capacity. The generalised cost values are used to calculate accessibility measures which describe how difficult it is for residents to get to different kinds of destinations (e.g. work) or for businesses to be reached by workers and by consumers. These affect the location of households and businesses within each area. In addition, the environmental impacts of transport influence the locational preferences of households.

USE OF THE STRATEGIC MODEL

The strategic model was used extensively in the Strategy Development phase of SWYMMS. This had to establish a framework within which the team could develop plans for specific interventions, using the detailed models.

Two alternative background scenarios were developed against which to test options. The first involved a continuation of past trends based upon standard Government forecasts (known as TEMPRO forecasts). The second assumed significant economic expansion stemming from South Yorkshire's Objective 1 status and West Yorkshire's Objective 2 status.

The strategy testing phase was then divided into three main sections: travel reduction options; economic development options and combined transport/economic development options. For the first group the transport model was frequently used on a stand-alone basis, as direct transport effects were dominant. The full model was used for investigation of options for the second and third groups. The outcome of the strategy development process is fully documented in the SWYMMS Phase 6 Report which can be found on the SWYMMS website (*www.swymms.org*).

REFERENCES

Roberts, M. and Simmonds, D. (1997) A strategic modelling approach for urban transport policy development, *Traffic Engineering & Control*, 38, 377-384.

Simmonds, D. (1999) The design of the DELTA land-use modelling package, *Environment and Planning B*, 26, 665-684.