THE TRANS-PENNINE CORRIDOR MODEL

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1 INTRODUCTION

1.1 Introduction

This paper describes the development and application of the modelling methods used in the recent study of Strategic Environmental Assessment in the Trans-Pennine Corridor (SEATPC). This study - one of the most recent in a long series of Trans-Pennine studies - was simultaneously a pilot study into the feasibility of carrying out Strategic Environmental Assessment, and a "live" study of current issues for clients with ongoing policy responsibilities.

The client group which commissioned the study included the European Commission, DETR, Highways Agency and the associations representing local governments in both the North-West and Yorkshire and Humberside regions, and private organizations including Railtrack (the railway infrastructure owner), Northern Spirit (the major trans-Pennine passenger train operator) and Manchester Airport.

The study was carried out by MVA, David Simmonds Consultancy (DSC) and Environmental Resources Management (ERM). This paper concentrates on the modelling aspects of the study. An overall description of the study and its findings was published as Coombe et al (2000).

The model used was a land-use/transport interaction model implementing using MVA's START transport model package and DSC's DELTA land-use/economic package. The overall model application is known as the Trans-Pennine Corridor Model (TPCM). It should at this point be emphasised that the work described was a "Corridor" study and model only in so far as the focus of policy interest was on the linkages across the Pennines. The modelling sought to represent all of the travel to, from or within the Study Area (defined below) and a large majority of the travel modelled was in fact within the separate conurbations on each side of the Pennine chain.

2 OVERALL MODEL SCOPE AND DESIGN

2.1 Modelled Area

The Strategic Environmental Assessment was concerned with travel and transport in a corridor across Northern England, from the Irish Sea to the North Sea. The thin end of the wedge was to the east, where the area of interest narrowed to the urban areas and ports on the north and south bank of the Humber. The core area of interest was defined as the Fully Modelled Area (see Figure 1), with all model functions and processes operational. Around this - ie to the north and south - a Buffer Area was defined which was treated in less detail.

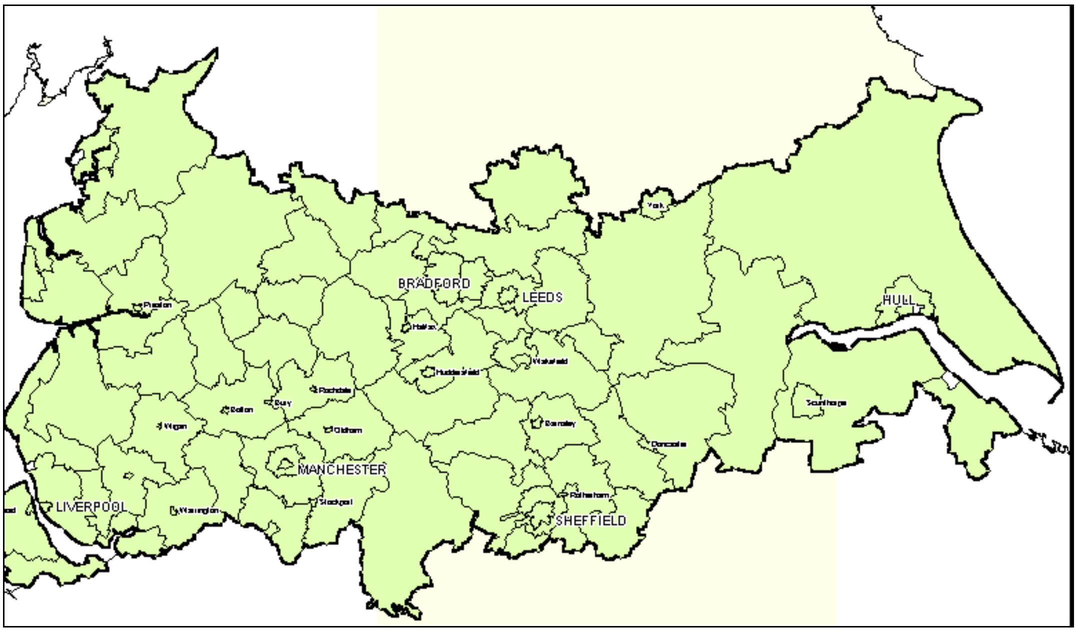

Figure 1: Fully Modelled Area

The model design was a development of the approach (and the software) already chosen for the Greater Manchester Strategy Planning Model (see Copley et al, 2000). This meant that the overall structure remained that of a "linked" land-use/transport interaction model, in which

- the transport model is run at five-year intervals to represent the average weekday operation of the transport system at that point in time
- the land-use model is run for five one-year steps between each transport model run.

This sequence is illustrated in Figure 2. The structure allows considerable scope for the land-use model and the transport model to be operated separately, where this is helpful to the project for which they are being used. At a more theoretical level, it assumes that travel patterns are strongly influenced by land-use and economic factors, without assuming that people's travel slavishly follows their economic actions.

A number of changes had to be made to reflect the larger spatial scale of TPCM compared with GMSPM. These are described in the following sections, followed by discussion of the interactions between the land-use and transport components.

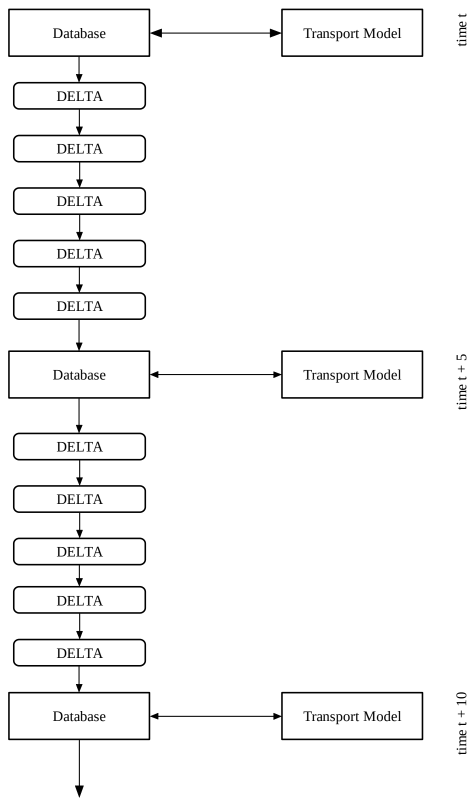

Figure 2

2.2 Transport model: design and new developments

Overview of the START Suite Models

The START suite was designed to be a strategic planning tool and in this sense differs from more conventional types of transport model. It is a full equilibrium model in which the demands for transport are balanced with the available supply. Highway speed flow adjustment and public transport crowding relationships ensure that the available level of supply is properly represented. It is multi-modal, handles a wide range of transport choices, including trip suppression and induction and time of day choice, and provides standard outputs in the form of operational data and economic and financial cost benefit analyses. These outputs are suitable for inclusion into an assessment framework designed for the assessment of transport policies and strategies. The model is not intended to be used directly for the detailed appraisal of specific schemes, but linkages to detailed network models can be established for this purpose.

The START Suite represents a philosophy rather than a fixed set of assumptions. While this philosophy is carried more or less intact from one study to the next, the level of detail will vary according to the situation. The

START model approach has been to provide maximum flexibility in the preparation of data inputs and for the detailed analysis of model outputs. However, there are also standard routines which carry out the required operational, environmental and cost benefit analyses, and a Strategy Data Organiser (SDO) to set up and document test scenarios.

START Suite models are designed to run on fast microcomputers with turnaround times typically between one and two hours. These short turnaround times enable very large numbers of model runs to be carried out in order to explore alternative transport and land-use scenarios, test model sensitivities, and generally to ensure that the development of preferred policies and strategies is carried out through an exhaustive analysis of available options. They also, as is the case with TPCM, allow START to be linked with a land-use model to provide a dynamic transport/land-use modelling framework.

In order to achieve this, whilst distinguishing between a number of different travel categories, there is a sacrifice in the level of spatial detail which can be accommodated in the model. In the applications to date, for example, the zone systems have between 15 and 125 zones covering substantial conurbations. TPCM is at the top end of this range.

Compromises need to be made in modelling between spatial detail and degree of disaggregation of traveller type. The ideal model would have both spatial detail and many different traveller types to permit a comprehensive approach to demand modelling. However, this is infeasible for reasons of computing capacity and the need to keep model run times short. This is the case even with increasing computing power, as this is usually absorbed by the continuing need for increased model functionality, and hence greater travel demand segmentation.

At the opposite extreme are the detailed local models, such as the junction based traffic models frequently set up for urban central areas and used for scheme assessment. These are very detailed in terms of networks and have very small zones. However, there is generally no demand modelling available, and no segmentation of traveller type.

Some network models have been set up with limited demand modelling capability but this often leads to a spatial and demand modelling compromise that fails to meet the needs of either policy modelling or detailed scheme design.

The spatial aggregation employed in START Suite models does not seriously restrict their ability to test strategy options. Through explicit linkages to detailed network models, it is possible to represent the impacts of individual schemes or policies that have only a local impact.

There are three essential components to the START model:

- the Base Situation;
- the External Forecasting Model;
- the Transport Model.

In contrast with most conventional transport models, the START model is not calibrated to reproduce the base situation: rather, it relies on externally derived matrices built to reflect the current pattern of travel, making use of all existing available data. The model is essentially an extrapolatory device applied to a reliable base of current travel patterns, backed up by as much understanding of travel behaviour as possible, an approach frequently referred to as incremental modelling. The quality of the representation of travel demand and supply in the base is of course critical to the reliability of the model.

External Forecasting Model

The External Forecasting Model (EFM) is the trip generation and attraction equivalent of the standard four-stage model. It also carries out a trip distribution function. Its aim is to take account of changed travel patterns due to zonal changes in population, employment, shopping floorspace and school places, and, in particular, car ownership. This results in predictions of origin and destination growth factors for each matrix that is distinguished in the model. In order to achieve credible estimates of growth for different kinds of travel, the model requires a reasonable level of detail about the base and the future population structure for each zone (different age groups, household types, propensity for car ownership etc.), since such factors are known to influence the amount and the type of travel. These can come either from a land-use model, such as DELTA, or from other methods of forecasting.

Within the START Suite structure it is assumed that the External Forecasting Model operates independently of any transport changes - in other words, it provides an estimate of the future demand in the absence of any changes in travel times and monetary costs. It is not implied that such a future demand is in fact realistic, and it is a function of the Transport Model to modify it in the light of changing transport conditions.

The Transport Model

The core of the START Suite modelling process is the Transport Model, which, contains two primary components:

- **Demand** - which, given a change in transport conditions, reflected in generalised cost, modifies the current travel demand estimate; and

- **Supply** - which, given the current estimate of demand, modifies the generalised cost by consideration of the level of demand relative to capacity.

These two components are run iteratively until the level of demand is compatible with the generalised cost matrices from the supply model, ie until equilibrium is reached.

Policies for testing are input to the process in one of two ways:

- 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 - eg 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 *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, walk, cycle, taxi;

- **time of day** - when to travel;

- **route** - highway or public transport route alternatives;

- **parking** - type, location and duration.

Note that in TPCM there is only one time period and hence no time of day choice. Similarly modes are restricted to car, bus, rail and a combined walk/cycle mode.

These choices are organised into a hierarchy according to which the most sensitive choices are dealt with first, at the bottom of the structure, and the least sensitive choices at the top of the structure. The order in which choices are dealt with can be different for each trip purpose. Each choice is governed by a comparison of the generalised costs appropriate to the choice - in this way, cost and time considerations affect all choices in a consistent way.

The model distinguishes between a number of different categories of travel for the following principal reasons:

- variation in generalised cost formulation - different purposes/person types may have different values of time, face different money costs and may also have different overall sensitivities;

- variation in choice sets - the alternatives available for certain choices may vary with purpose or person type: a well-known example is the availability of the car mode for households with different levels of car ownership;

- variation of hierarchy - variation in the order in which the various travel choices are structured is primarily due to journey purpose; for example, for commuting trips the choice of time of travel might be less sensitive to changes in network costs than the choice of mode, while being more sensitive in the case of social trips;

- sensitivity of output forecasts - for example, the various trip purposes will have different growth characteristics and will impact differently on the modes of travel being modelled.

The choice mechanisms within the model are generally in the well known hierarchical logit model formulation, which has had extensive application in the fields of mode and destination choice. The primary choices open to travellers (- frequency - destination - time of travel - mode - route -) are all represented. (The phenomena of suppressed and induced road traffic, which is a function of all these responses, can thus be fully modelled).

Within this structure the more sensitive choices are at the bottom of the hierarchy (ie travellers are least likely to change frequency and most likely to change route). However, as stated above, the hierarchy can be different for each trip purpose. Choice of car route and public transport sub-mode are part of the demand model, occurring at the bottom of the hierarchy, and it can be seen that this area can be particularly complex. Note that whilst START can deal with time of day choice, because of its 24 hour nature, this is not part of the TPCM choice hierarchy.

The *parameters* for the hierarchical logit formulation for the Transport Model are not fixed, but a set of initial estimates is available based on experience from other studies, which aim to reflect an informed view of the sensitivities of the various transport choices to changes in costs and times. In each application, a number of model runs are carried out to indicate the elasticities implied by these assumptions, and these may lead to modifications of the parameters to ensure credible results. The hierarchies used in TPCM are shown in the table below.

Model Hierarchies and Parameters in TPCM

Trip Purpose	**Choice Hierarchy (from top)**
HOME BASED PERSON TRIPS	
Home Based Work professional/managerial	F - D - M - S/R
Home Based Work other non manual	F - D - M - S/R
Home Based Work skilled manual	F - D - M - S/R
Home Based Work semi-skilled and unskilled	F - D - M - S/R

Trip Purpose	Choice Hierarchy (from top)
Home Based Education	T - F - D - M - S/R
Home Based Shopping	F - M /D - S/R
Home Based Other	F - D - M -- S/R
NON HOME BASED PERSON TRIPS	
Employers Business	* - S/R
Other Non Home Based	* - S/R
FREIGHT	
Freight	(D - F- M - T) - R

Key:

F - Frequency

D - Destination

M - Mode

T - Time

S/R - Sub-mode (public transport), Route (car).

*** = higher demand responses derived from changes in home- based trip choices.**

Note that in TPCM only *road* freight is currently represented, so the only response modelled is route choice. Changes in origins and destination of goods vehicle movements are handled through changes in land-uses input to the EFM from the DELTA land-use model. Overall growth in freight movement has been controlled to NRTF forecasts, and is not currently treated as responsive to changes in travel costs.

Typically it is considered appropriate that the model should be able to reproduce the generally acceptable elasticity of -0.3 for public transport fares and -0.1 for fuel price. (Note that the elasticities to be replicated may be different when the START model forms part of a dynamic land-use transport model, as land-use changes contribute to the elasticity value over the longer term.)

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;

- a set of fixed car and public transport routes for each OD pair, including intra-zonal movements, defined in terms of distance travelled upon each link (with allocation of trip proportions to routes carried out via the demand model).

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.

Evaluation

Preferred policies and strategies are developed from the evaluation of a large number of model runs, leading to the production of large quantities of output data. To assist with the interpretation of this data, and to enable consistent comparisons to be made between strategies, a comprehensive evaluation routine, known as 'EVAL' has been created. EVAL produces outputs covering the key operational, environmental, accessibility, economic and financial issues.

The operational, environmental and accessibility evaluations are specified to generate the type of information which is relevant to the policy objectives and targets relevant to the planning of transport systems. The economic and financial evaluations are standard routines which perform consumer surplus analyses for single forecast years, and stream costs and benefits over the evaluation period. At present the benefit calculations are, like most transport appraisals, only valid when land-uses are constant; work is in hand (under a different project) to develop benefit calculations appropriate to the full land-use/transport interaction model.

Given that transport strategies are likely to contain combinations of road, public transport and demand management measures, the routines apply a comprehensive and consistent economic and financial appraisal across all modes of travel including any new modes introduced in forecast years. The approach, known in the UK as the Common Appraisal Framework, has been adopted by the UK government for all strategy evaluations in recent years.

Environmental and accessibility outputs from EVAL are available as tables or as data files for input to a land-use model (see chapter 4). Accessibility calculations take account of the time and monetary costs of travel and the availability of facilities (eg retail floor space) at the destination end of the journey. Environmental calculations for emissions, noise, fear and intimidation and accidents are based upon the latest available research.

EVAL also provides, as standard, a number of useful indices such as total person trips, vehicle-km, measures of accessibility and public transport revenues by mode. In addition to outputs from EVAL, the entire set of travel matrices and cost matrices output by the transport model are available for examination, and it is straightforward to access these to estimate more aggregate quantities of interest. All outputs from START Suite transport models can be accessed using spreadsheet and database software.

START Data Requirements and the Strategy Data Organiser

The data requirements for a START type model are quite extensive, and require careful assembly. Demand is typically segmented by time period, purpose and mode. However, for TPCM the time period dimension has been omitted. Supply definitions are in terms of a set of alternative highway and public transport routes for each OD pair. A very wide range of other parameters are also required as inputs to the model. Whilst most of these are not particularly complex in themselves, taken together they present a considerable data handling and manipulation task. For this reason a Strategy Data Organiser has been added to the START Suite.

The Strategy Data Organiser (SDO) is a START Suite facility that enables the user to store and manipulate input data, in a manner that is both easy to understand and self documenting. Simple variations upon existing transport strategies can be created in seconds - eg a halving of public transport fares or a doubling of petrol prices. More complex variations can be set up in a way that allows other users to understand the processes that have been used. The SDO is effectively a self documenting method of creating and storing transport strategy inputs.

The SDO is an MVA licensed application of the Microsoft Access database system. It is able to read in data from spreadsheets, databases and ASCII files. Use of the SDO effectively means that the START Suite can be operated as a Windows application.

Data for the Trans-Pennine Corridor Transport Model

TPCM covers a very wide area for which only a limited volume of travel data was available. A decision was therefore taken to use the available data sets as a basis for synthesis of the demand data for all of the modelled area. Detailed network models on a 1200 zone basis were first created for highway and for public transport. These were used to provide costs for a gravity model process based upon 1991 Census trip end data, and national and local trip rates. The process involved creation of 24 hour trip matrices at the 1200 zone level, assignment of these matrices to the networks, and adjustment to road traffic and public transport volumetric counts. The matrices were then aggregated to the 123 zones of TPCM.

The person matrices were created by trip purpose and car ownership category, and goods vehicle matrices were segmented into light and heavy categories. Walk/cycle matrices were synthesised on the assumption that all such trips were intra-zonal, a very reasonable assumption once aggregation to the 123 zone system had taken place.

2.3 Land-use/economic model: design and new developments

The earlier forms of DELTA were developed specifically as urban models, to represent the processes of change within a relatively limited area (see Simmonds, 1999). For TPCM it was therefore necessary

- to add additional sub-models to represent the different processes by which changes in different urban areas interact
- to elaborate the existing urban sub-models to allow for more complex interactions between adjoining areas.

The previously developed urban sub-models consisted of four modules dealing with changes in activities:

- transitions (demographic change, application of employment growth rates)
- car-ownership (proportions of households of each type in each zone owning 0, 1 or 2+ cars)
- location (location or relocation of households and jobs, taking account of competition for floorspace of each type)
- employment status (forecasting the numbers of adults in work by household type and zone, and their travel to work patterns by car-ownership and socio-economic group, given the changes in number and location of households and of jobs).

Another two sub-models dealt with changes in spaces:

- development (changes in the quantity of floorspace available)
- residential area quality. It proved impractical to implement this within TPCM, and the model therefore assumes rather less change in area characteristics than our other DELTA applications.

The original location sub-model had been extended in GMSPM to deal with the case of relocation between the Study Area (Greater Manchester) and adjoining areas, but this was not felt to be sufficient for the more complex possibilities of the Trans-Pennine Corridor. It was therefore found necessary to add

- a migration sub-model to forecast movements of households between different labour market areas
- a regional economic model to forecast the growth or decline of each economic sector in each area.

These bring within the DELTA system higher-level changes driving change in each urban areas which were previously assumed to come from exogenous, non-DELTA forecasts.

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.

The regional economic model consists of two sub-models:

- an investment/disinvestment model
- a production and trade model.

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 may 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 initial Trans-Pennine application uses a very simple incremental treatment whereby investment tends to replace the reductions in capacity due to depreciation but may be relocated by changes in accessibility.

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 (derived from the most recent run of the transport model).

Both investment and production/trade work at the same area levels as the migration model. The addition of these sub-models modifies the working of other sub-models at the original urban level. The location sub-model now locates or relocates units of capacity, whilst the numbers of jobs to be filled in the employment sub-model are determined by the combination of capacity and production in each area. The production/trade sub-model has similarities to the Martin Centre regional models. However, an important difference is that changes in capacity are modelled explicitly as changes over time in the investment model, and may be influenced by other factors.

The migration and regional economic models interact in very different ways with the urban levels of the model. The migration model acts directly upon the urban model: it subtracts households from the origin area of each migration flow, and adds them to the "pool" of households to be located in the destination area. The influence of the regional economic model is less direct:

- changes in demands for floorspace are determined by investment and disinvestment in each sector in each area, ie by the changes in capacity of the sector
- changes in the demands for workers are determined partly by changes in capacity, partly by changes in production - the underlying assumption being that the numbers of managers tend to change in line with investment or disinvestment, whilst numbers of other workers change more directly in line with levels of production.

A variety of modifications had to be made to the urban sub-models to implement these linkages. In addition, the location model was modified so as to operate separately in each travel-to-work area, ie to locate and relocate households and jobs within subsets of the Modelled Area. In the case of households, the areas were fuzzily defined taking account of the extent to which people commute between areas.

The main sequence of the sub-models of the land-use/economic model within one one-year step are shown in Figure 3. Note that nearly all of the sub-models involve lagged responses to past change, and that there is therefore a much more complex set of connections between the sub-

models as the full system runs through time.

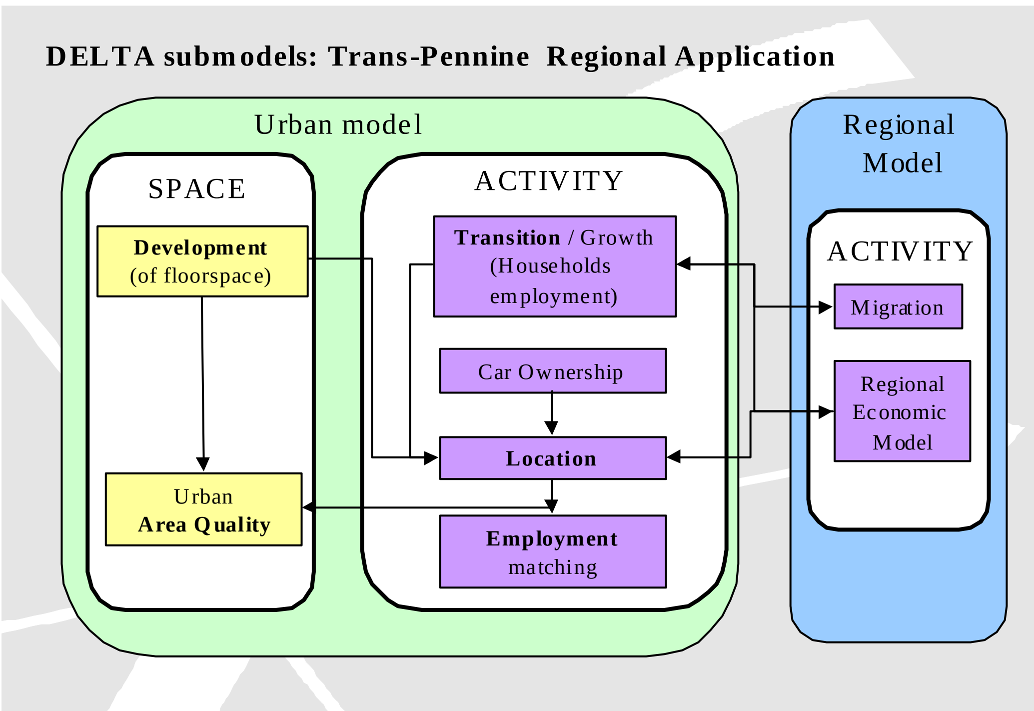

Figure 3.

2.4 Land-use/transport interaction

The influence of land-use change on transport remains as it was in GMSPM:

- changes in the distribution of travel-to-work, generated in the land-use model as the results of land-use change between successive transport model years, are extracted as matrices of growth factors which are applied to the corresponding trip matrices in the transport model;
- changes in resident persons, in jobs and in retail floorspace are used to calculate vectors of growth factors which are applied to the trip ends for other purposes.

Note that in TPCM, as in GMSPM, the latter process was applied to goods vehicle movements as well as to all purposes of personal travel other than travel-to-work. In more recent work, we are exploiting the possibility of using the trade matrices from the spatial input-output model as the basis for growth in freight movement.

The linkage from transport model to land-use/economic model depends on three outputs:

- matrices of generalised costs
- matrices of changes in travel-to-work due to redistribution within the transport model (ie the effect of changes in generalised cost)
- measures of the environmental impact of transport (noise, emissions).

Changes in the environmental measures form one of the changes in the attractiveness of zones for households. The transport-induced changes in travel-to-work are used to update the commuting matrices in the employment status sub-model.

The matrices of generalised costs are output as absolute generalised costs, by adding calibrated modal constants to the generalised costs calculated within the transport model. (Since the START model is incremental, the transport model only needs to account for elements of generalised cost which are liable to change, and invariant elements or modal preferences are normally implicit rather than explicit.)

The generalised costs are used in the urban level of the model to calculate accessibility measures. These are disaggregated by

- purpose (one set of measures for each transport model purpose);

- active or passive accessibility (active being how easy it is to reach a given set of destinations or opportunities from each origin, and passive being how easily each destination can be reached from a given set of origins); and
- for active accessibilities, by car-ownership level.

Changes in accessibility over time modify the relative attractiveness for each activity of the zones within each area. In addition, changes over time in the additional accessibility enjoyed by car-owners compared with non-car-owners influence levels of car-ownership: the greater the advantage conferred by car-ownership, the higher the car-ownership level.

The generalised costs are also aggregated to area-level matrices for use in the regional economic model. These matrices are used directly in the trade/production sub-model to influence the spatial pattern of purchasing decisions in the input-output model. They are also used to calculate measures of the accessibility of each area to the market for each sector's output. Changes in these accessibilities influence the level of investment of each sector in each area.

3 CONCLUSIONS

The development of TPCM illustrated both the use of a synthetic process to provide base data, particularly in the transport model, and the extension of the DELTA package to deal with the wider range of processes operating at the regional scale. A selection of TPCM results can be found in Coombe et al (2000) and in Simmonds (2001). The methods developed are being refined and reapplied in subsequent studies.

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