MODELLING THE REGIONAL ECONOMIC AND EMPLOYMENT IMPACTS OF TRANSPORT POLICIES

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Abstract

This paper reports some results from policy testing carried out with the South and West Yorkshire Strategic Model, a dynamic land-use and transport interaction model covering a substantial region of Northern England, developed by MVA Consultancy and David Simmonds Consultancy using the START and DELTA packages. The work was carried out for a major review of the economic implications of transport policy and planning commissioned by the UK Government. The purpose of the policy testing was to investigate the likely impacts of a range of transport interventions, with a view to drawing some broad conclusions as to which interventions – given the particular characteristics of the area – are likely to provide an effective contribution to the economy. Although the tests were purely illustrative, and the objective was not to make any recommendations about specific schemes, it was considered important that the tests were realistic in nature and capable of being implemented in the real world.

The tests undertaken included new infrastructure, public transport changes, highway demand management, and combinations of these. The paper will describe the model and will discuss the forecast land use and economic impacts of the transport schemes. Particular attention will be given to the processes which forecast the economic and employment effects and to the corresponding results.

Note: this paper will be complementary to the earlier description of the SWYSM model published in Simmonds and Skinner (2003) and to the paper about the Eddington work proposed for WCTR2007, providing more detail of the model design and reporting on the forecast of land-use and economic impacts.

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1  INTRODUCTION AND CLIENT NEEDS

This paper describes a model known as the South and West Yorkshire Strategic Model (SWYSM), and some of the tests which have been carried out with this model in recent work.

The model was originally developed during 2000-1 for use in the South and West Yorkshire Multi-Modal Study (SWYMMS). Further detail of the original context can be found in Simmonds and Skinner (2003). During 2005-6 extensive use was made of the model to inform the Eddington Study, which was commissioned by the UK Government as a major review of the economic impacts of transport policies (Eddington, 2006). This paper describes some of the results obtained in the course of that work in terms of the forecast impacts on the distribution of employment and population. A related paper in preparation for the 2007 World Conference on Transport Research will expand on this by reporting in some detail the new approach to assessment of wider economic benefits which was implemented using these model results.

The following section describes the components and structure of the model and the ways in which the land-use and transport components interact. Section 3 then demonstrates how the model is used for testing particular policies by discussion of some example results. Section 4 concludes by considering the growing need for such analysis in policy formulation and decision making.

2  MODEL DESIGN AND APPLICATION2

2.1 Scope of the model

The design of the model drew heavily on the study team’s previous experience with a number of similar models developed since 1995 (see for example Copley et al., 2000; Simmonds and Skinner, 2001). The approach adopted is that of a linked model system which brings together distinct transport and land-use/economic models. The basis of the approach is that the land-use/economic model forecasts the activities which generate the demand for transport, taking account of the interaction between demand and supply of urban space; and that the transport model forecasts the transport outcomes, taking account of the interaction between demand and supply in transport; and finally that information about the ease or difficulty of travel output from the transport model influences subsequent land-use and economic change.

A significant advantage of this approach is that because the land-use/economic and transport models remain distinct entities, it is very easy to run each one on its own. This helps in the development stage, where to a considerable extent the two models can be developed in parallel. It is also useful in the application stage: the transport model can be used on its own to test the transport impacts of different alternatives under common land-use forecasts, and the land-use/economic model can be run to test (for example) the land-use impacts of different economic scenarios assuming no change in transport conditions.

The transport model was implemented using MVA’s START package (Roberts and Simmonds, 1997). The land-use/economic model was implemented using DSC’s

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2 This description has been edited from that in Simmonds and Skinner (2003).
DELTA package (see Simmonds and Still, 1998; Simmonds, 2001; Simmonds and Feldman, 2005). In the following sections we describe the design of the South and West Yorkshire Strategic Model (SWYSM) model as used in recent work (with some detailed modifications from the original\(^3\)) and illustrate its application.

### 2.2 Scope of the model - space and time

The focus of the study was on the ‘motorway box’ formed by the M62, A1(M), the M18 and the M1. It was recognized in the SWYMMS study that the forecasting process needed to consider not only what happens within this box, but also to consider in equal detail what happens in a significant area around it, and in less detail what happens further away. Accordingly the model covers the whole of South and West Yorkshire plus a ring of adjoining areas such as Skipton and Harrogate; this is the Fully Modelled Area (see Figure 1). Around this, a wider ring of adjoining areas (the Buffer Area, extending westwards to Manchester and eastwards to Hull) is covered in less detail, with larger zones and fewer model processes working. Beyond these a set of External Zones is used to represent movement to and from the rest of Britain.

Within the Fully Modelled Area, the zones were defined initially as 1991 wards or groups of wards, within district boundaries; these conditions facilitate the use of data both from the 1991 Census of Population and from other sources. The grouping of wards into zones within districts was intended to distinguish the main urban centre of each district (in the event, some subdivision of wards was required), and then as far as possible to create zones of reasonable size and shape in relation to the transport networks. The process was constrained by the number of zones which was compatible with practical computing times and memory requirements, especially in the transport model where both time and memory increase as the square of the number of zones. In total there are 92 zones in SWYSM – in contrast with the 570 zones in the more detailed highway and public transport models also used in the SWYMMS study. The model was set up so that the base year is 2000 and the forecasting process works forward to 2020; this involved an element of forecasting, informed by a limited amount of observed data, to create the 2000 base.

\(^3\) The SWYSM application of DELTA has also been used to provide the context for a new microsimulation model of household/individual changes and location/work choices – see Feldman et al (forthcoming).
3 Transport Modelling: The START Package

Unlike many conventional transport models which have to be calibrated to reproduce the base year situation, START is incremental in 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 to 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.

3.1 Transport model base data

Data on base year travel by motorised modes was obtained from the SWYMMS detailed highway and public transport model. 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 surveyed, 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 study area towns, with data on other movements obtained from operators’ ticketing systems. Network data for the highway system was created using GIS techniques, and public transport networks were coded from timetables.
3.2  External (Transport) 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, et cetera), 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.

The EFM assumes that future residents of a given age, employment status, car-ownership level, etc 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, i.e. in proportion to changes in the land-uses that produce and attract trips. The output of the EFM is therefore an artificial travel pattern - what would happen if the land-use changes occurred but the time and money costs of travel were unchanged? The impacts of time and money changes are considered in the transport model proper (see below).

3.3  The transport model

The transport model (Figure 2) consists of 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 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 relative sensitivities, and hence the hierarchy, differ between trip purposes.

Changes in the pattern of freight movement are forecast by the land-use/economic model. Only road freight is currently represented in SWYSM; this is equivalent to assuming that the road share of freight movement for each commodity and each origin-destination pair will remain constant. Growth in road goods vehicle movements is forecast by DELTA as a result of changing land-use and economic conditions.

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 flow groups in each zone (typically defined in terms of inbound and outbound radial, clockwise and anticlockwise orbital);
- motorway and other ‘limited access’ links representing specific roads; and
- 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 for mixed mode trips. Crowding
relationships are included so that generalised costs increase as demand approaches capacity. Fares and frequencies can be made responsive to changes in patronage. A number of indicators of the environmental impact of transport are calculated within the transport model, and some of these influence subsequent land-use change. In addition, for SWYMMS, more extensive analysis of the environmental impacts of the transport interventions considered was carried out as an input to the strategy appraisal process.

4 Land-Use/Economic Modelling: The DELTA Package

The DELTA land-use/economic modelling package has been developed by David Simmonds Consultancy since the mid-1990s. It was designed as a practical tool to represent urban and regional change and to be able to interact with any appropriate transport model to create a land-use/transport interaction model. The approach draws upon previous modelling experience and upon the wide range of relevant research carried out in geography, urban economics, etc (for a fuller description of the model, see Simmonds, 2001).

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 conventionally describes transport supply and demand as in equilibrium at particular points in time. Another requirement for land-use/economic modelling at this scale is to recognize that different processes operate at the urban and at the regional levels: for example, different factors affect the total economic activity in an area and the distribution of employment within it. The model accordingly contains urban processes which changes in or between the 92 zones, and regional processes in which the units are (approximate) travel-to-work areas - typically districts in the SWYSM application.

The urban processes represent both changes in the built environment and changes in activities. The processes of physical change are:

- development: the amount of floorspace by zone and type (residential, retail, office, industrial); this is driven by the economic scenario and the modelled property market, and controlled by inputs measuring what is allowed by the planning system; and
- the housing quality model, which models the way in which a residential area may decline into a slum, or be revived from slum to high-quality.

The urban activity sub-models are:

- the transition model, which represents household (and hence population) changes in terms of movements through lifecycle stages and household compositions;
- the car-ownership model, which predicts the proportions of households by type and zone owning 0, 1 or 2+ cars, mainly in response to increasing incomes;
- the location model, which locates or relocates a proportion of households and of employment in each year, and also models the property market within which location occurs; and
the employment status model, which updates the work status of residents and the commuting pattern in response to the spatial changes in households and employment.

At the regional level, there are three models, all of human and economic activities:

- the migration model moves households between areas;
- the investment model allocates investment to areas (taking account of changes in accessibility and property costs); and
- the production/trade model (a spatial input-output model) estimates production by sector and area and the patterns of trade between areas.

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.

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5 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 (Figure 4). Land-use changes have immediate impacts on transport, through the EFM described earlier. At the area level, changes in the costs of trade (goods and passengers) affect the location of production and of new investments. At the urban level, generalised costs are used to calculate various accessibility measures which affect the location of households and businesses within each area. In addition, the environmental impacts of transport influence the locational preferences of households.
3 USE OF THE STRATEGIC MODEL

3.1 The strategy testing process

As with most models, the strategy testing process using SWYSM is comparative. A strategy option is examined by appropriate changes to the model inputs; running the model over time; and comparing the resulting outputs with those from a previously run reference case. This process applies whether transport options, land-use options or combinations of the two are to be tested.

Transport policy changes are introduced into START either as direct adjustments to generalised costs or as changes in the characteristics of the transport supply. They influence land-use and economic change through the accessibility and environmental values that are passed from START to DELTA. Land-use policy changes are introduced into DELTA via a sequence of policy files, which is used mainly to specify annual changes in how much of each type of development is permitted in each zone in
each year (a variety of other inputs is possible). Policies may not have immediate effects: for example, an additional allocation of land may not be used immediately – or at all, if there is a serious lack of demand.

### 3.2 Example results

We illustrate the workings and outputs of the model using just one set of comparative results from recent work. These results are from a test looking at the possible improvement of the highway links between Leeds and Sheffield, ie between the two main centres of the region under consideration, compared with a reference case without that improvement. The scheme tested involved widening the existing M1 motorway by one lane (ie from dual three to dual four lane), and widening the connecting roads linking the M1 to central Leeds and to central Sheffield. The focus is on the impacts of this improvement (referred to for simplicity as the M1 improvement test) relative to the Reference Case, rather than upon the absolute forecasts.

The following paragraphs describe the results in the order transport-economy-population, because this is the dominant logic of the model in relation to this particular test (at least in looking at the regional rather than the local pattern of impacts). It should however be kept in mind that there are numerous interactions between these three areas of the model in the course of the forecast, eg there is feedback from the land-use economic modelling to the transport model as the forecasts run forward over time.

**Transport Impacts**

The overall travel demand effects of this test across the Fully Modelled Area (FMA) are relatively small in proportional terms, relative to the Reference Case. This is quite typical at this level of modelling; although the improvement of the highway links would be a major investment, it is still a relatively modest change in the overall transport supply of the region.

Over time, car trip making rises slightly faster than in the Reference Case, as one would expect given the increase in highway capacity. The impact on car trip kilometres is slightly higher, with the increase beginning at 2005 (the year in which this hypothetical scheme was assumed to open). The overall results for goods vehicles traffic are similar. Bus passenger trips and trip kilometres show an increase as a result of this intervention (2.5% for trips and 1.7% for trip kilometres in 2020). This is because of the benefits to bus operations from the highway capacity increase. By contrast, as would be expected, rail shows a slight decrease in 2005 (where only transport impacts are present). In the later years, the impact of economic activity stimulated by the intervention leads to a small increase (less than 1%) in rail travel, an effect that is also occurring for bus.

Changes in vehicle kilometres, as well as being small in overall terms, do not exhibit any great variation between districts or by time of day. In 2020, Wakefield, Barnsley, Sheffield and Rotherham exhibit increases in traffic flows consistently around the 1% level across the day.

The location-specific transport results for this test can be summarised as follows:

- by 2020 there are significant numbers of extra commute and business trips, particularly by car. These are mainly in Leeds and Sheffield, but
growth occurs in many other districts with connections to this improved motorway alignment;

- Sheffield experiences significant growth in goods vehicle trips;
- as would be expected given the provision of extra road capacity, Sheffield to Leeds and Rotherham to Leeds experience the largest reduction in congestion; and
- some increases in congestion occur where trip making has increased (note that for Sheffield the test includes some urban highway capacity increases to connect the city centre to the M1 motorway northwards).

Land-use/Economic Impacts

Employment: The employment effect of the test is concentrated on the Leeds to Sheffield corridor. The effect on the total employment by local authority for the highway test (HP) compared with the Reference Case (HO) is shown in Figure 3-1. As can be seen, 2021 employment with the highway improvements is slightly higher than the in the Reference Case for all Districts within South and West Yorkshire except Calderdale. The more significant positive impacts are for the districts along the Leeds-Sheffield highway route, ie Leeds, Wakefield, Barnsley, Rotherham and Sheffield.

![Employment: Test hp-ho](image)

**Figure 3-1 Employment differences between M1 test and Reference Case**

These results are a good illustration of a common feature in forecasting regional economic impacts: small percentage changes representing rather large absolute numbers. The impacts of the test on Sheffield and Rotherham are increases of less than 0.5%, but this represents a gain of nearly 2000 jobs compared with the Reference Case.

The impacts come about in the first instance through the workings of the regional economic model. The main effect is in the investment model. The improvement in transport along the M1 corridor slightly improves the accessibility of locations in that corridor to some of their markets and suppliers. As a result, a slightly higher proportion of the investment or reinvestment that takes place in each sector, each year,
is attracted to the areas in the corridor. This higher rate of investment, and the higher levels of production that result from it, require slightly more labour than was employed in the Reference Case, resulting in the increases shown in Figure 3-1.\(^4\)

The transport improvement, introduced as a single step change in 2005, has a direct effect on investment for the following 10 years. This period is related to the rates of reinvestment: the model assumes that one-tenth of all investment has to be replaced (and is influenced by changed circumstances) each year and hence that all investment is influenced within 10 years of a transport change. Changes in area employment after 2015 (beyond 10 years from the transport change) are therefore due to a combination of:

- continuing multiplier effects between industrial sectors;
- multiplier effects as a result of population and consumer expenditure effects (see below), including in particular those from continuing migration in response to earlier employment changes;
- the transport improvement itself having increasing effects over time: the time savings due to the improvement (compared with the Reference Case situation) tend to increase in significance in later years as a result of increasing values of time and increasing levels of congestion in the Reference Case; and
- changes in the supply of commercial floorspace, themselves induced by the changes in demand resulting from the transport improvement.

The graph indicates that whilst the three districts most remote from the M1 Corridor – Bradford, Calderdale and Doncaster – all suffer slightly negative effects in the early years after 2005 as a proportion of investment is diverted into the areas that become more accessible, there are slight upturns in their results in the late years of the forecast, indicating that these longer-term multiplier and similar effects are more widely distributed, through spillovers (or “leakage”) between areas, rather than being concentrated close to the initial transport improvement.

The impacts of the road improvements on employment by zone in the final year of the forecast (2020) are shown in Figure 3-2 and Figure 3-3. Figure 3-2 shows the absolute changes in numbers of jobs; the area of the symbol for each zone is proportional to the difference in the number of jobs between the two tests. Increases (more jobs as a result of the M1 investment) are shown as green circles, and decreases (fewer jobs) as grey circles. Figure 3-3 shows the same changes as percentages of the numbers of jobs in the Reference Case forecast for 2020: the successive green tones show different levels of increase, the peach/light brown colour changes close to zero, and grey shows decreases (in this particular map there is only one level of grey). They maps confirm that the impacts are fairly broadly distributed around the highways affected and not limited to immediately adjacent zones.

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\(^4\) Note that unless otherwise stated, “employment” results are always employment by workplace. The numbers of persons in work could also be tabulated by their place of residence if required, for example in order to examine impacts on areas of social deprivation.
Figure 3-2 2020 changes in employment, M1 investment vs Reference Case

Figure 3-3 2020 % changes in employment, M1 investment vs Reference Case

**Population:** Figure 3-4 shows that the main population effects of the test relative to the Reference Case are gains in Sheffield-Rotherham and in Barnsley; by 2020 there
are smaller gains or no net change in all the other districts of South and West Yorkshire. It can be seen that Calderdale has marginally the most negative population result of these districts, as it did for employment. It is also apparent that the area-level population impacts are smaller than the employment impacts for the four districts where the employment impacts are most significant.

![Population: Test hp-ho](image)

**Figure 3-4 Population differences between M1 test and the reference case**

These impacts are the results of changes in the pattern of migration, plus some slight redistribution of natural demographic changes as a result of those migration changes (eg that children are born in different places because their parents have migrated to a different place). The impacts of the transport test on the pattern of migration come about because the modelled migration is influenced by employment opportunities (a strong positive influence) and by housing costs (a weak negative influence). Younger households are more likely to move than the older or the retired. Areas where employment opportunities improve relative to the Reference Case therefore attract or retain more people than in the Reference Case, and to experience some further population growth in later years as a result of this.

All the migration effects come about as changes in the balance between in-flows and out-flows for each area. Migration tends to increase towards areas which have a higher proportion of residents in work. More jobs in Leeds as a result of the highway scheme will therefore result in more in-migrants to, and fewer out-migrants from, the areas which supply labour to Leeds, not just to Leeds itself.

There is generally migration in both directions between any two areas. Longer-distance migration flows, though important in this analysis, are generally small in number compared with the volume of local moves, which are mainly driven by lifecycle and housing factors. These local moves can also result in households relocating across area (generally district) boundaries, so the population impacts shown in the graphs include some element of these short-distance moves.

Figure 3-5 and Figure 3-6 show the absolute and percentage impacts of the highway investments in 2020, in the same formats as the employment maps but with blue rather than green tones for positive impacts.
The maps show that the impacts of the highway investment on population are more widely dispersed relative to the improved road links than the employment impacts. The population impacts are essentially the effects of improved accessibility to work.
and service opportunities, but also take account of the (relatively small, but absolutely rather significant) employment effects shown above. (There is also of course an element of employment relocation in response to the population effects; we are here presenting the results of an recursive process in a linear form.)

As a final example of the results produced from these tests, we focus on the zone in the north of Sheffield which stands out clearly in the maps as experiencing a positive population impact in response to the M1 investments. The first point to note is that this zone, zone 54 in the model, is experiencing a decline in the population in the Reference Case, and that the positive impact is essentially a slowing down in this decline. This is shown in Figure 3-7.

![Figure 3-7 Population impacts in zone 54](image)

The second point to note is that whilst the population “increases”, relative to the Reference Case, by nearly 5%, there is no corresponding increase in households; these have not been plotted, since there is little to see for this zone – the number of households varies by less than 0.5% from the Reference Case. The implication is that the change is largely driven by changing household sizes resulting from a changing mix of households in the zone. This is illustrated in Figure 3-8 which shows the average household size in zone 54 in the Reference Case and the M1 investment test; it also shows the model-wide average household size which is (by design of the model) the same in both tests.
As further explanation of the household sizes, the impact of the M1 test on the numbers of persons by type resident in zone 54 is shown in Figure 3-9. This brings out clearly that the increase in population is due to increased numbers of children and of working-age adults, offset by a loss of retired persons. Considered together the graphs indicate that the effect of the M1 test is to bring forward a change in the population composition of the zone, which would have started around 2012 but is brought forward, and made more marked, by the effects of the transport intervention. Analysis of the accessibility impacts of the M1 investments (not plotted) has shown that whilst this zone is the one which experiences the greatest improvement in accessibility; but the particular form and scale of the population impact is affected by the demographic characteristics of the zone and the ways in which these are changing over time even in the Reference Case.
4 CONCLUSIONS

The use of land-use/transport interaction models such as that described here is becoming increasingly common in the analysis of major policy alternatives. The increasing focus on the evidence base for decision making, and on the quantification of economic, social and environmental impacts, is tending to enhance this trend. The paper has sought to show both how appropriate models can be built up by building land-use/economic modelling, itself based on results from regional science and other disciplines, around relatively conventional transport models. It has also demonstrated the results of such a model in terms of emerging changes over time. Experience has shown that both specialists and non-experts can understand and appreciate such dynamic results in relation to land-use and economic impacts more readily than they can the results of equilibrium models representing only a single future year.

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necessarily those of any other organization or individual. The land-use and transport policies represented in the model have been examined for research purposes and are not necessarily representative of the policies of any authority or agency.

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