MODELLING THE ECONOMIC IMPACTS OF TRANSPORT CHANGES: EXPERIENCE AND EMERGING ISSUES IN THE UK

DAVID SIMMONDS – *DAVID SIMMONDS CONSULTANCY LTD*
SUITE 14, MILLERS YARD, MILL LANE, CAMBRIGE CB2 1RQ ENGLAND
PHONE +44 1223 316098 /FAX +44 1223 313893
david.simmonds@davidsimmonds.com

OLGA FELDMAN – *DAVID SIMMONDS CONSULTANCY LTD*
SUITE 14, MILLERS YARD, MILL LANE, CAMBRIGE CB2 1RQ ENGLAND
PHONE +44 1223 316098 /FAX +44 1223 313893
olga.feldman@davidsimmonds.com

ABSTRACT

This paper describes and illustrates the approach to land-use/transport/economic interaction modeling that the authors and colleagues have implemented as the DELTA software package and have used to forecast and appraise the economic impacts of a range of proposed or possible transport strategies and schemes under consideration in different parts of the United Kingdom. It first describes the background to the development of the approach. Secondly it outlines the models developed within this approach, focusing in particular on the two-level representation of space and on the links between transport and the economy. The workings of the model in practice are then illustrated with some example forecasts from one major study. We then outline the current approach to appraisal of wider economic impacts, and discuss the appraisal results corresponding with the example results. The final section discusses some current developments.

INTRODUCTION AND STRUCTURE

This paper describes the family of models which have been implemented using full applications of the DELTA software package, with an illustration of the model's use and discussion of some current areas of development. The first section of the paper describes the background to the development of this particular modeling approach, The second section presents some of the detail of the approach, in particular focusing on the ways in which the transport system affects employment and the economy. The working of the model is illustrated with results from one particular application. The fourth section then outlines the approach to appraisal of economic impacts which is currently mandated by the UK Department for Transport (DfT), and discusses the appraisal results corresponding with the example forecasts previously presented. The final section considers issues arising from the assessment of wider economic impacts and some of the ways in which the modeling approach is being further developed in response to these issues.

In UK transport planning practice, the *ex ante* estimation of the costs and benefits which are expected to accrue from a proposed intervention is referred to as **appraisal**, whilst *ex* *post* estimation of the costs and benefits flowing from a completed intervention is referred to as **evaluation**. That convention is observed in this paper.

BACKGROUND

The DELTA package was originally developed as a single-level urban model intended to model a medium-sized city as a single economic unit (the design and prototype applications of this version were described in Still and Simmonds, 1998, and Simmonds, 1999). The design concentrated on representing incremental change through inter-related processes operating over time, the main processes of change being the development of building stocks, changes in housing quality; household change (reflecting demographic and social change); household and employment location; and the employment status (working/not working) of household members.

Initial applications of this purely "urban" model in Edinburgh and Manchester led to an invitation to apply the same approach to the much larger area of the Trans-Pennine Corridor, extending some 250Km across the full width of Northern England, covering four metropolitan conurbations, a number of other major urban areas and some more rural areas. In the early phases of this project we had to consider the widespread agreement in the literature of spatial economics and location analysis that the variables affecting households' or businesses' choices of where to locate within a city are to some extent different from those affecting their choices of location between cities. In the demographic field, for example, Gordon and Molho (1998) have shown that different variables drive household moves over short, medium and long distances (even within the limited distances within the UK). The equivalent point about economic phenomena is emphasized by McCann (2001, p3).

The differences between "intra-urban" and "inter-urban" processes of change and location meant that we could not develop the Trans-Pennine model simply by scaling up the earlier Manchester model. We therefore extended the DELTA design to add higher-level economic and migration models, representing choices or processes working between rather than within urban areas. The urban (zonal) level models remained largely unchanged in the expansion to the two-level system, but now take their controlling inputs for each modelled year from the higher level models rather than from exogenous inputs to the system, and return values to the higher level models which influence subsequent migration and economic change. The resulting design, summarized in Figure 1, has provided the basis for the DELTA package over the past decade.

The fact that the DELTA package allows for two distinct levels of spatial choice, representing local choices (usually within urban areas) and sub-regional or higher choices (usually between urban areas) is an important feature and one which we believe is unusual if not unique in land-use/transport/economic interaction modeling.

THE REGIONAL ECONOMIC MODEL IN DELTA

Within the limits of this paper we cannot attempt to describe the whole DELTA design in detail. Instead, we concentrate on the higher-level representation of economic change, ie the regional economic model, and its interactions both with the lower, zonal level and with the transport model.

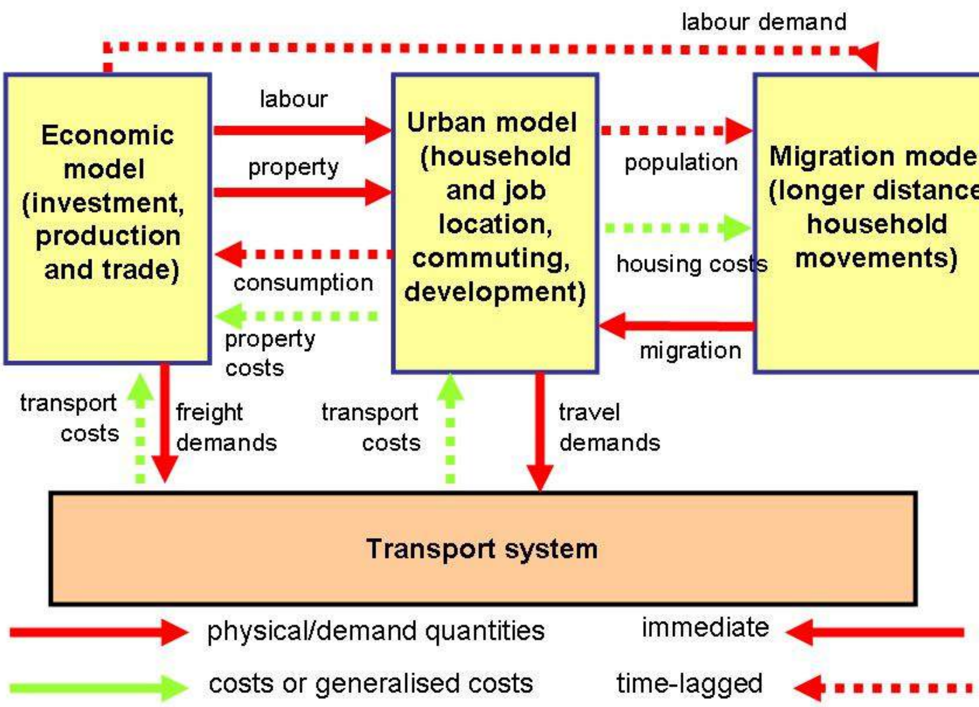

Figure 1 Structure of the DELTA model: main components

The regional economic model itself consists of two components: a cross-sectional spatial input-output model, and an incremental model of investment or disinvestment over time in each sector in each sub-region. The spatial input-output framework is widely used in land-use/transport interaction modelling. Unlike some model systems where the spatial input-output framework provides most or all of the model mechanism, its use within DELTA is limited to representing the short-term economic outcome for economic sectors at the higher spatial level (unlike some other applications, it is not for example used to forecast household numbers or locations). The final demand consists (quite conventionally) of exports, government expenditure and fixed capital formation, which are exogenous inputs defining the modelled scenario, and of consumer expenditure which is endogenous to the model and calculated from the number, mix and employment status of households. The pattern of trade is forecast within the model and is sensitive to the costs of transport between sub-regions; these include both freight haulage and business travel costs, and are calculated from the associated transport model outputs so that they vary with changes in transport policy, transport infrastructure or forecast levels of congestion.

The spatial input-output model can be summarized in three main equations. First, the demand for commodity *s* in area *j* at time *(t+1)* is, as usual, defined as being the sum of final and intermediate demands:

$$Y^s_{(t+1)j} = Y(F)^s_{(t+1)j} + \sum_r a^{sr}_p . P^r_{(t+1)j} \tag{1}$$

where

$Y^s_{(t+1)j}$	is the total demand for commodity *s* in area *j* at time *(t+1)*
$Y(F)^s_{(t+1)j}$	is the final demand for commodity *s* in area *j* at time *(t+1)* (inclusive of consumer final demand, which is endogenous to the model)
a^{sr}_p	is the technical coefficients of the input-output matrix, ie the quantity of *s* input per unit of *r* output during period *p*
$P_{(t+1)j}{}^r$	is the total production of *r* in *j* at time *(t+1)*.

Secondly, the demand for commodity *s* in area *j* is allocated to production areas by a logit trade model which takes account of the production capacity of each area and the costs of delivery from production area to consumption area:

$$T^s_{(t+1)ij} = Y^s_{(t+1)j}\left[1 - m^s_p\right] \frac{K^s_{(t+1)i}.\exp\left[-\lambda^s_t (p^s_{(t)i} + c^s_{Tij} + b^s_{(t+1)ij} + r^s_{ij})\right]}{\sum_i K^s_{(t+1)i}.\exp\left[-\lambda^s_t (p^s_{(t)i} + c^s_{Tij} + b^s_{(t+1)ij} + r^s_{ij})\right]} \tag{2}$$

where

$T^s_{(t+1)ij}$	is the trade in *s* from *i* to j at time *t+1*
m^s_p	is the proportion of demand for *s* which is met by separately modelled imports in period *p*
$K^s_{(t+1)i}$	is the capacity of zone *i* to produce *s* at time *t+1*
λ^s_t	is the distribution coefficient for *s* in period *p*
$p^s_{(t)i}$	is the production price of *s* at area i and time *t*
c^s_{Tij}	is the cost of transporting one unit of *s* from *i* to *j* in the previous transport model year *T*
$b^s_{(t+1)ij}$	is the non-transport cost (border effects, etc) per unit of trade in *s* between *i* and *j* at time *t+1* (if used)
r^s_{ij}	is the residual disutility per unit of trade in *s* between *i* and *j* at time *t* (if used).

Thirdly, the production of each commodity in each area is defined as the sum of the trades it supplies:

$$P^s_{(t+1)i} = \sum_j T^s_{(t+1)ij} \tag{3}$$

The model is solved iteratively, with the levels of production calculated in the third equation being substituted back into the equation (1) until the system converges having accounted for the total economy of the modeled region.

The sub-regional capacities by sector which constitute the "size" terms in the logit models for the trade distribution model are forecast by the model of investment distribution, which represents longer-term business decisions, and a simple model of disinvestment, based on a fixed depreciation rate. The investment model is an incremental model which is sensitive both to the costs of producing each sector's output in each one sub-region and to the sub-region's accessibility to the market for that sector. The key equation is

$$K(N)^s_{pa} = K(N)^s_{p*} \frac{K^s_{ta} \cdot \left[\frac{A^s_{t_A a}}{A^s_{t_B a}} \right]^{\alpha^s_p} \cdot \left[\frac{c^s_{t_A a}}{c^s_{t_B a}} \right]^{\gamma^s_p}}{\sum_a K^s_{ta} \cdot \left[\frac{A^s_{t_A a}}{A^s_{t_B a}} \right]^{\alpha^s_p} \cdot \left[\frac{c^s_{t_A a}}{c^s_{t_B a}} \right]^{\gamma^s_p}} \quad \textbf{(4)}$$

where

$K(N)^s_{pa}$	is the quantity of new investment in sector *s* allocated to area *a* during period *p*
$K(N)^s_{p*}$	is the total new investment in sector *s* to be allocated during *p*
K^s_{ta}	is the pre-existing capacity of sector *s* in area *a* (before disinvestment or new investment)
$c^s_{t_A a}, c^s_{t_B a}$	are recent and time-lagged measures of cost of producing *s* in area *a*
$\alpha^s_p,\ \gamma^s_p$	are coefficients defining the sensitivity of investment location to accessibility and to cost; and
$A^s_{t_A a}, A^s_{t_B a}$	are more and less recent time-lagged Hansen measures of accessibility to consumption, using the same variables and distribution coefficient as the trade distribution model (equation (2))

$$A^s_{ta} = \sum_z \left\{ Y^s_{tj} . \exp\left(\lambda^s_t \left[c^s_{taz} + b^s_{(t+1)ij} + r^s_{ij} \right] \right) \right\} \quad (5)$$

(Note that only the main equations for the modelled areas are shown here, excluding various complications relating mainly to imports and exports.)

INTERACTION BETWEEN ECONOMY, URBAN ACTIVITIES AND TRANSPORT

DELTA's regional economic model provides the "drivers" for its modeling of changes in employment at the zonal level. Employment is assumed to be determined partly by capacity (typically "management" jobs) and partly by the level of production. These employment outputs determine both the the total demands for floorspace by each sector in each area, and the demand for labour by sector and socio-economic group in each area. These linkages are represented by the downwards arrows from the area level (the regional model) to the zonal level Figure 2. The modelled employment sectors are often rather more disaggregate at the zonal level, mainly to take account of different types of employment within one sector using different types of floorspace (eg office rather than industrial).

The zonal-level location models allocate employment changes to zones, taking account of the availability of space (a very strong effect) and accessibility to labour, customers, etc (generally a weaker effect at the zonal level, but varying markedly between sectors). The employment status model distributes the resulting located jobs to residents, given the supply of workers at each point in time, determining both the mixture of working/non-working residents in each zone and the matrices of commuting. Both the supply of floorspace for employment activities, and the number and mix of residents (the supply of labour) are the results of other sub-models responding to change over time (and not necessarily in equilibrium with the economic model).

From the results of these zonal sub-models, the levels of consumer demand by area (calculated from households and their incomes), and with floorspace costs are passed back up (with time-lags) from the zonal level to the area level.

Transport costs feed into the modeling of economic and employment change in a variety of ways, illustrated in Figure 3, where the key components of Figure 2 are in the upper-right part of the diagram. In a typical application,

- goods vehicle costs (GV) and costs of travel on employer's business (EB) are converted into typical costs per unit of trade which enter directly into both the production/trade submodel and into the accessibility-to-market calculations for the investment model (they also enter indirectly from the production/trade submodel to the accessibility-to-market calculations as part of the costs of inputs)
- the generalized costs of home-based travel (to work and to other destinations, including shopping and services), and of employer's business travel, enter into the zonal-level calculations of accessibility which affect the changes in employment location within each area (and of course within the available floorspace supply); they also enter into the accessibility calculations which affects households' choices of location (again of course within the available housing supply).

In relation to Figure 3, note that not all the linkages are shown: in particular, the location of employment (by socio-economic level) is an essential variable in the accessibility to jobs calculation, particular types of jobs or particular types of floorspace are used in the accessibility to services, and numbers of workers by place of residence in accessibility to labour.

Different components of change in the transport system therefore affect different processes of change – and different actors within those processes – in the land-use/economic system. This can in some cases result in complex influences of transport upon land-use, especially if the nature of a transport intervention under consideration is such as to have differential impacts on different segments of transport demand.

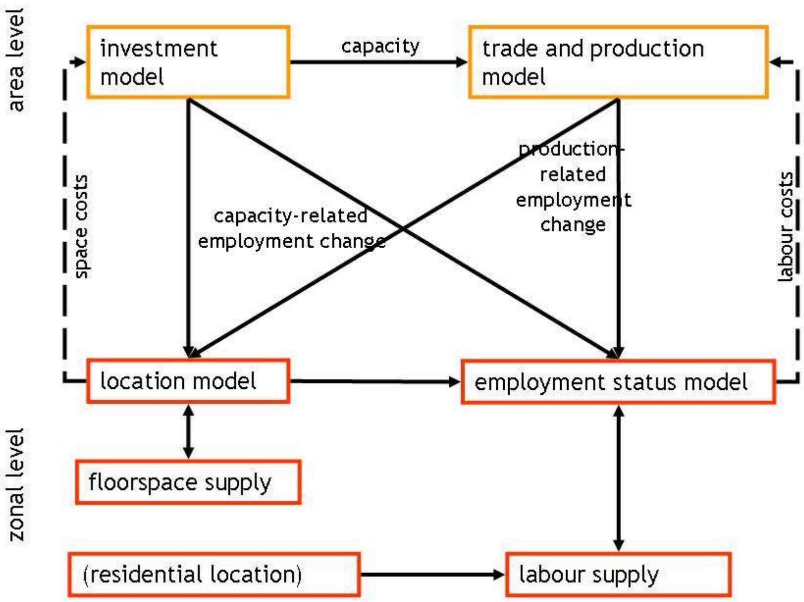

Figure 2 Linkages between area and zonal level: economic/employment

NB other inputs affecting floorspace supply and residential location not shown.

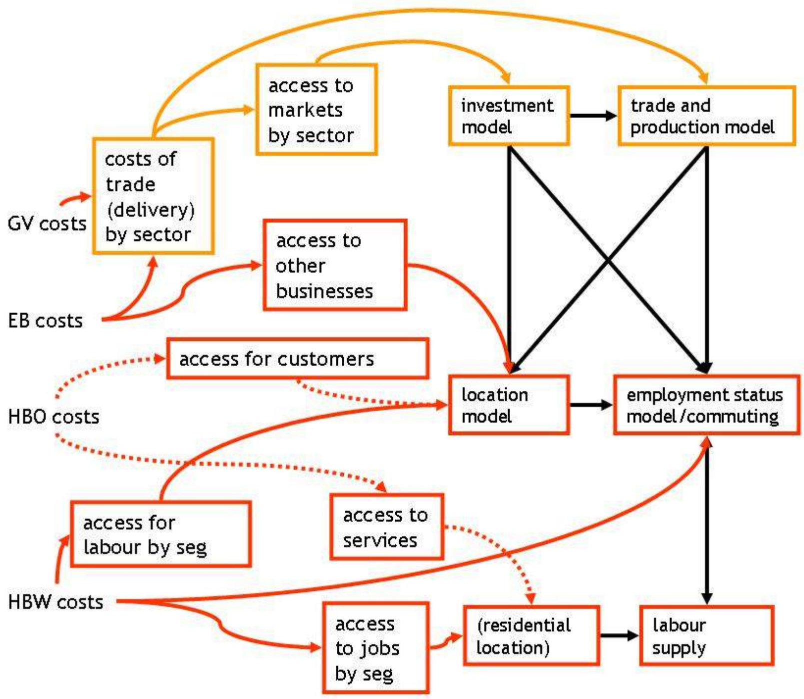

Figure 3 Linkages from transport generalised costs to model processes

Note: GV = goods vehicle, EB = employer's bsusiness, HBW = home-based work, HBO = home-based other (ie non-working travel, including commute). "Costs" = generalized costs.

For example, a congestion charging scheme which increases the generalized costs of commuting but reduces the generalized costs of business travel and goods distribution will tend to make some locations more attractive to certain activities whilst at the same time making them less attractive to others. Moreover the different activities and processes affected have different rates of response within the dynamic structure of the model, sometimes leading to complex effects over time (especially if the interventions are substantial enough that the indirect effects are also significant).

Some general patterns of impacts can be discerned, generalizing across different applications of the model. Major transport changes affecting connectivity between urban areas tend

- to have their main direct impacts on the distribution of economic activity, and hence of employment, across the areas modeled;
- if the transport changes are important enough, significant multiplier effects will arise both through supplier and income effects, potentially affecting sectors which may have been largely unaffected by the initial change;
- impacts on the location of population come about first through the impact of changing employment levels on incomes (which affects locational preferences both by modifying the affordability of housing, and by affecting car ownership and hence the perception of accessibility), and then more gradually as the change in the pattern of employment opportunities modifies the pattern of migration between areas.

In contrast, transport changes mainly affecting local travel tend to show that

- their main direct impacts are on residential location (and hence on commuting patterns) within urban areas;
- their employment impacts arise mainly in terms of changes in the quantity and distribution of service employment resulting from the changes in residential location and incomes, with further small-scale multiplier effects following from these;
- most of the impacts (measured as percentage changes in zonal variables from the equivalent year of the reference case) occurs within 5 to 7 years of the initial intervention.

APPLICATIONS

The two-level form of DELTA has been used, in conjunction with various four-stage or more elaborate transport models, in a number of major studies and ongoing projects in different parts of the UK, as listed in the following table.

Core area/study	**Transport modelling package used**	**Comments**	**Reference(s)**
Trans-Pennine Corridor/ Strategic Environmental Assessment in the Trans-Pennine Corridor	START	Urban/regional model	Simmonds and Skinner (2001)

Core area/study	Transport modelling package used	Comments	Reference(s)
South & West Yorkshire Strategic Model (SWYSM)/South and West Yorkshire Multi-Modal Study, Eddington Study and other projects and scheme appraisals	START	Urban/regional model	Simmonds and Skinner (2002, 2004); Feldman et al (2007)
Glasgow & Clyde Valley/ Central Scotland Transport Corridors Study, Clyde Corridor Study, appraisals of major motorway schemes	TRIPS (CSTM3A application)	Urban model focused on West Central Scotland; regional model covers whole of Scotland	
Edinburgh & Lothian (3)/ New Transport Initiative	TRAM	Urban model focused on Edinburgh and Lothian; regional model covers whole of Scotland	Simmonds et al (2005)
Strathclyde(SITLUM)/ for use by transport and land-use planning agencies	STM	Urban model focused on Strathclyde; regional model covers whole of Scotland	Aramu et al (2006)
TELMoS (Transport/Economic/Land-use Model of Scotland)/ Scotland (various successive versions)	TRIPS (Transport Model for Scotland application)	Urban/regional model	Nicoll et al (2006)
GMSPM2 (Greater Manchester Strategy Planning Model 2)	TRAM	Urban/regional model, focused on Manchester City Region	for transport model see Benbow et al (2008)
LonLUTI (London, East and South-East England)	LTS	Urban/regional model, focused on London	

Table 1 DELTA applications using full regional/zonal approach

In all of the cases listed the usual practice is that the LUTI modelling (DELTA+transport model) represents a substantial region, whilst the transport and land-use planning proposals is carried out on the basis of fixed economic and demographic scenarios for a large region; the additional models of wider economic impacts which have been developed by the UK Department for Transport are used to assess the net economic change for that region as a whole. Those models of wider economic impacts and their use in conjunction with a DELTA-based LUTI model were described in detail in Feldman et al (2008) and are summarized below. It should also be noted that whilst there is an increasing emphasis on forecasting the impact of transport improvements (or transport management) on total economic activity, there is also an increasing requirement for spatial detail in order to represent land-use planning policies in more detail and to take account of network detail in the transport model's representation of highway and transit networks.

EXAMPLE RESULTS

We illustrate the workings and outputs of a typical DELTA model using a set of comparative results from the SWYSM model for South and West Yorkshire. The model was extensively used in 2005-6 to forecast and appraise the impacts of a wide range of largely hypothetical schemes, as input to the Eddington Review; the results quoted are taken from one of these tests. The model itself is a full DELTA model application covering the South and West Yorkshire subregions and a substantial adjoining area. This fully modelled area, shown in the maps below, had a base year population of just under 3.5 million persons; this is surrounded by a very substantial Buffer Area, modelled in less detail, occupied by a further 7 persons. Further detail of the model is given in the references for SWYSM in Table 1.

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 4. 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.

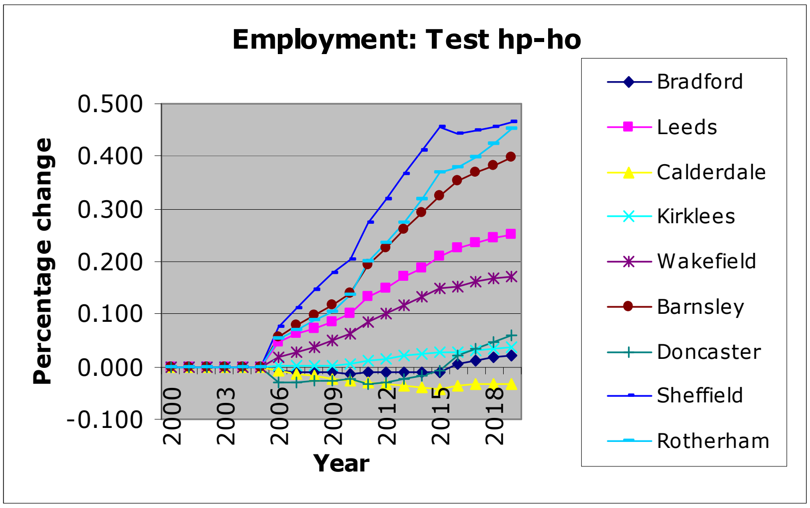

Figure 4 Employment differences between M1 test and Reference Case

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 4[1].

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 5 and Figure 6. Figure 5 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 6 shows the same changes as percentages of the numbers of jobs in the Reference Case

[1] 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.

forecast for 2020: the successive green tones show different levels of increase, the peach/light brown colour shows changes close to zero, and grey shows decreases (in this particular map there is only one level of grey) . The maps confirm that the impacts are fairly broadly distributed around the highways affected and not limited to immediately adjacent zones.

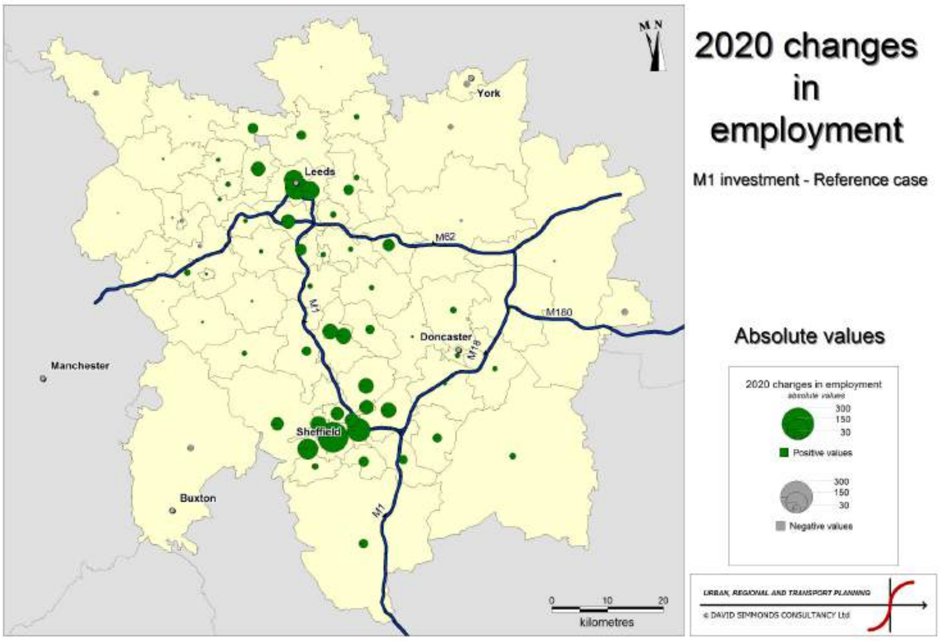

Figure 5 2020 changes in employment, M1 investment vs Reference Case

Population: Figure 7 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. (Note that Sheffield and Rotherham are within one area for regional economic and migration modeling, and the gain in Sheffield at the expense of Rotherham is due to local rather than regional factors).

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.

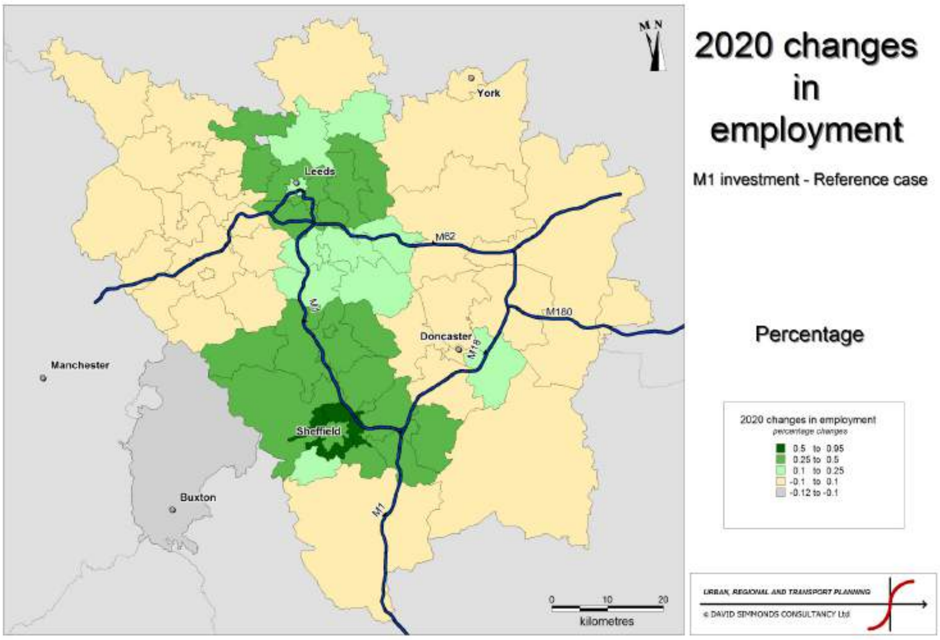

Figure 6 2020 % changes in employment, M1 investment vs Reference Case

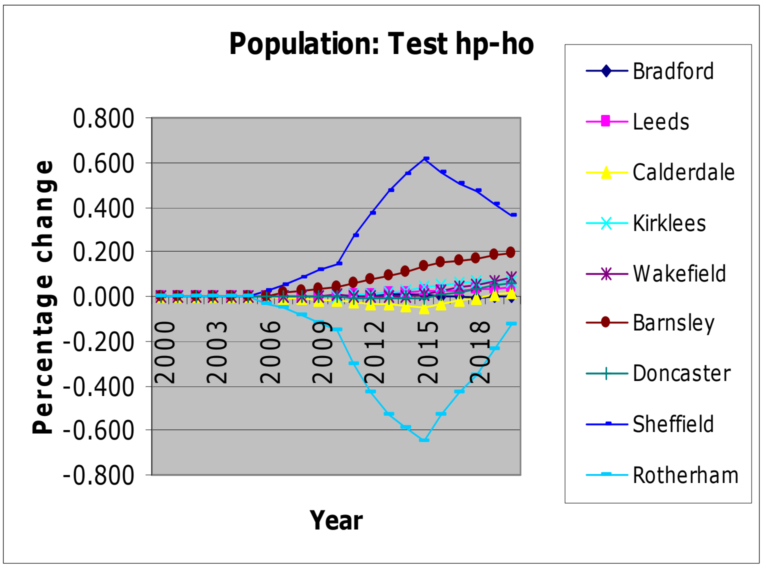

Figure 7 Population differences between M1 test and the reference case

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 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 8 and Figure 9 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.

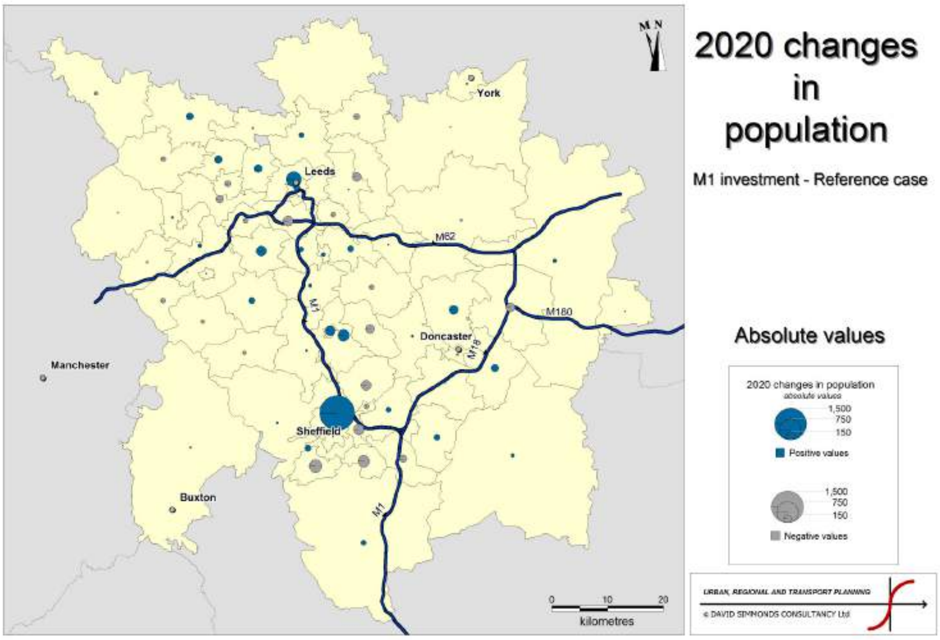

Figure 8 2020 changes in population, M1 investment vs Reference Case

The maps show that the impacts of the inter-urban 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 a recursive process in a linear form.)

WIDER ECONOMIC IMPACTS OF THE EXAMPLE TEST

The DfT methodology identifies a number of types of potential welfare benefits which are either missing or only partly counted in the standard appraisal of transport economic efficiency. These include the following (for full list and discussion see Feldman et al, 2008):

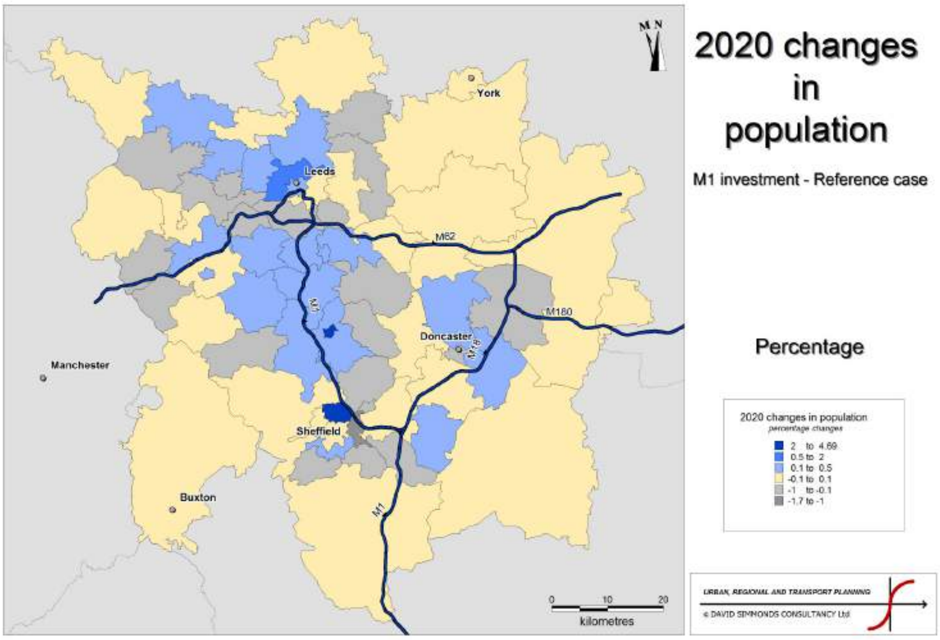

Figure 9 2020 % changes in population, M1 investment vs Reference Case

- agglomeration economies: these describe the productivity benefits that some firms derive from being located in higher density areas, due to better functioning labour and supply markets and to spillovers between firms;
- benefits from improved labour supply, due to improved travel for commuters leading some people to work who would otherwise choose not to work
- moves to more productive jobs: the DfT approach argues that certain areas display higher productivity than other areas, and hence that, if the effect of a transport intervention is to move jobs from a lower-productivity area to a higher-productivity one, there is an additional economic gain.

These benefits (or disbenefits) are shown in Table 2 for each of the 10 local authority areas in South and West Yorkshire, plus the fringe area which makes up the rest of the Fully Modelled Area shown in the maps above, and the surrounding Buffer Area (not shown on the maps). (These are extracted from Tables 13, 14 and 15 of the Appendix to the original report, see ETSR, 2006) Note that these are all converted to present value (£M, 2002) terms, ie they represent the total value of these benefits over the entire appraisal period. Note also that the move to more productive jobs is the present value of the change in value added due to more (or fewer) jobs being located in the area; the figures shown for the Fully Modelled Area are offset by negative values in the surrounding Buffer Zones giving an overall negative result of the test in this particular effect.

	Agglomeration	More people working	Move to more productive jobs
Bradford	10	-0.2	63
Leeds	83	-1.3	1338
Calderdale	2	0.1	-35
Kirklees	9	0.3	82
Wakefield	17	0.0	286
Barnsley	15	0.0	407
Doncaster	8	0.1	98
Sheffield	61	5.2	1643
Rotherham	23	1.9	535
Fringe areas	*27*	*1.5*	*-62*
Buffer zones	*32*	*6.6*	*-4465*
Total (NPV)	**287**	**14.4**	**-111**

Table 2 Wider economic benefits of the M1 investment test, £M, 2002.

The Wider Economic Benefits of the M1 investment test are chiefly due to the positive effect on agglomeration. As illustrated in Feldman et al (2008), this is typical of the relative scale of the different benefits from a variety of transport interventions. The pattern of agglomeration benefits is one of positive results throughout South and West Yorkshire, the largest contributions being from the gains in Leeds and Sheffield. Even areas which are relatively disadvantaged by the improvement of transport between Leeds and Sheffield, and where the employment effects are neutral or very marginally negative, gain in agglomeration due to a combination of more jobs relatively close by (in Leeds) and better access to a range of employment centres further afield. (Note that more recent research (Graham, 2009) suggests both more concentrated effects and, for some sectors, lower elasticities. The effect of this would probably be to reduce agglomeration benefits, particularly in the case of benefits which appear to be arising at a significant distance from the transport changes or their major economic impacts). The benefits from improvement in labour supply – improved commuting conditions drawing more people into work - are very small compared with the agglomeration benefits.

The positive benefits in terms of increased productivity from improved agglomeration are significantly offset by the negative impact of jobs relocating to less productive areas. This is primarily because the transport change induces a net relocation of jobs to South Yorkshire, where (in the base data) productivity per job is distinctly lower than in any other part of the modeled region. (Changes in productivity due to increased agglomeration are all attributed to the agglomeration effect, and it is assumed that no other changes in differential productivity will occur.)

FURTHER DEVELOPMENTS AND CONCLUSION

DELTA models have contributed to a number of major studies and to decisions about major schemes over the past decade, by providing a reasoned and quantified basis for assessing the impacts of proposals particularly in terms of the impacts of transport interventions on land-use and economic change. As ever, there is ample scope for further work to extend the formal calibration of the model. In addition, we are continuing to develop the modeling approach further both to refine the existing design and to extent its scope in order to meet emerging requirements. (This is of course in addition to the equivalent refinements and extensions that are being pursued in the associated transport models).

As an example of potentially important current work in refinement and attention we return to the methods currently used in the UK for analysis of wider economic impacts, summarized and illusrated in the preceding section. These are not just a means of appraisal but a set of models of additional processes of change within the economy. One area of current work is to consider the possibilities and implications of bringing these wider economic impacts within the dynamic LUTI framework itself.

The component of wider economic impacts which is closest to being implemented in DELTA is the “more people in work” effect - the extra benefits (outside the conventional consumer surplus calculations) from increased labour supply[2] due to better transport effectively increasing real wages (net of commuting time and cost). The issue that has to be addressed in bringing the labour supply response into the LUTI modeling is that the existing DELTA design, like most models in the LUTI tradition, constrains the labour supplied –residents in work plus net in-commuting – to equal the labour demand determined by the workings of the regional economic model. From a modeling point of view, it is obviously unreasonable to represent an increase in the number of residents in work without considering where they work (or indeed whether there are further workers available); moreover, to record a benefit from “more people in work” without accounting for the additional congestion and environmental impact that will result from their travel to work is difficult if not impossible to defend.

To implement a working model therefore requires that the response should be treated as one of labour **demand** rather than labour **supply**. The **demand** for labour has to be made elastic with respect to the changes in real wages resulting from the transport scheme under appraisal; the model’s normal mechanisms for matching supply to demand will then ensure that the additional jobs are filled (or the reduction in jobs is matched), and impacts on commuting patterns, congestion and environment will follow automatically. In addition, the model will also take account of multiplier effects arising from the additional employment, including not only the increase in consumer demand resulting from the net increase in incomes but also the impact of increased income (and of increased employment itself) on car-ownership. Increases in car ownership will of course further modify the travel, congestion and environmental impacts – and may quite possibly arise from public transport (transit) improvements as well as from highway investment.

Another area for improvement is the possibility of bringing the productivity changes due to changes in agglomeration within the model itself - again for consistency, to ensure that the impacts of higher productivity are taken into account. There is a need for better

[2] More precisely, the DfT methodology identifies the extra benefit as the additional direct taxes paid by people who would be brought into work as a result of the transport improvement; it assumes that the net benefit to those people is captured as part of the conventional consumer surplus measure in the transport economic efficiency calculations. This will not always be the case: in many models the constraints within the transport model will not allow the labour supply response that would produce that element of consumer surplus. In that case the whole increase in GDP resulting from the additional employment should be counted, rather than just the tax component.

understanding of the different components of agglomeration economies, because the three conventional components of agglomeration –deeper labour markets, better matching of suppliers to customers, and knowledge spillovers between firms - must be influenced by different aspects of transport supply. The labour market must be very strongly influenced by the conditions of transport for commuter travel; in contrast relations between suppliers of goods and services and business consumers must be influenced by the conditions affecting business travel and the delivery of goods. There seems to be the beginnings of a consensus that the labour market element of agglomeration economies is generally the most important; in contrast there is some evidence that distance and transport now play very little part in some forms of knowledge spillover. For example, Gallié (2009) concludes that within collaborative technological networks, "the distance that separates partners does not constitute a barrier to knowledge flows" when the partners are located within France or within the European Union, even though it is true that face-to-face meetings are required within such partnerships. She finds that the situation is different between European and non-European partners, though to what extent distance is the barrier, to what extent institutional and cultural factors slow knowledge flows, requires further study. This suggests that in some sectors, some forms of knowledge spillover may take place at a level such that the agglomeration of activities is at a continental rather than a regional or urban level – though of course in other sectors or for other aspects of knowledge it may still be that daily face-to-face contact is essential for such spillovers to occur.

A congestion charging scheme which successfully prices commuters of the congested roads in order to improve conditions for business travel and goods movement would therefore contribute to greater agglomeration economies in supplier-consumer relations but would create diseconomies in the labour market. The present DfT methodology is a compromise, measuring agglomeration as accessibility to jobs based on a weighted average of commuting, business travel and goods generalized costs. Further refinement of this calculation is highly desirable, and clearly possible making use of the different types of transport costs and different measures of accessibility already modeled (as shown in Figure 3).

The modeling framework we have described has proved effective and valuable in practical planning applications. It is very much open to further refinement in the light of further research and calibration, but we believe the process-oriented, dynamic framework will continue to provide an effective context for such work and for the use of models to inform both strategic policy-making and the decisions on major transport and planning projects.

REFERENCES

Aramu, A., Ash, A., Dunlop, J. and Simmonds, D C (2006) SITLUM – the Strathclyde Integrated Transport/Land-Use Model, *Proceedings of the EWGT 2006 International Joint Conferences,* Politecnico di Bari.

Benbow, N., Kidd, P., Woolley A., Skinner, A., Palmer, I. (2008). The Continued Innovation of Aggregate Transport Demand Models. *Proceedings of the European Transport Conference 2008,* PTRC, London (on CD).

ETSR, (2006). Wider Economic Impacts of Transport Interventions, *Eddington Transport Study Report*, Research Annex, Vol. 3. Available at

http://www.dft.gov.uk/about/strategy/eddingtonstudy/researchannexes/researchannexesvolume3/widereconomicimpacts

http://www.dft.gov.uk/about/strategy/eddingtonstudy/researchannexes/researchannexesvolume3/widereconomicimpactsappendices

Feldman, O, J Nicoll, D C Simmonds, C Sinclair, and A Skinner (2008): Integrated transport land use models in the wider economic benefits calculations of transport schemes. *Transportation Research Record, Vol. 2076, pp 161-170*

Feldman, O, D C Simmonds, J Nicoll (2007): *Modelling the regional economic and employment impacts of transport policies*. Paper presented at the 20th Pacific Regional Science Conference, Vancouver, May 2007 (available at www.davidsimmonds.com).

Gallié, E-P (2009): Is geographical proximity necessary for knowledge spillovers within a cooperative technological network? - the case of the French biotechnology sector. *Regional Studies*, vol 43(1), pp 33-42.

Gordon, I R and I Molho (1998): A Multi-stream Analysis of the Changing Pattern of Interregional Migration in Great Britain 1960-1991, *Regional Studies*, vol 32 No 4, pp309-324.

Graham, D (2009): *Productivity effects of transport investment.* Presentation to Transport Economists' Group, London, 6 March 2009 (proceedings in preparation).

McCann, P (2001): *Urban and regional economics.* Oxford University Press, Oxford.

Nicoll, E J, Aramu A. and Simmonds D C (2006) Land-use/transport interaction modelling of the Bathgate-Airdrie railway reopening. *Proceedings of the European Transport Conference 2006*, PTRC, London (on CD).

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

Simmonds, D C, Leitham, S., White, V. and Williamson, S. (2005) Using A Land-Use / Transport / Economic Model in Edinburgh. *Proceedings of the European Transport Conference 2005*, PTRC, London (on CD).

Simmonds, D C and Skinner, A (2001) Modelling Land-Use/Transport Interaction on a Regional Scale: the Trans-Pennine Corridor Model, *Proceedings of the European Transport Conference 2001*, PTRC, London (on CD).

Simmonds, D C and Skinner, A (2002) The South and West Yorkshire Strategic Model, *Yorkshire and Humber Regional Review*, 12.

Simmonds, D C and Skinner, A (2004) The South and West Yorkshire Strategic Land-Use/Transport Model, in *Applied GIS and spatial analysis*, Clarke, G. and Stillwell, J. (eds), Wiley, Chichester.

Simmonds, D C and Still, B G (1999) DELTA/START: Adding Land-Use Analysis to Integrated Transport Models, in *Transport Policy*, Meersman, H., van de Voorde, E. and Winkelmans, W. (eds), Elsevier, Amsterdam.