

Assessment of UK Land-Use and Transport Strategies Using Land-Use/Transport Interaction Modelling

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This paper considers the contributions to economic assessment that have been achieved in a series of UK studies which have used applications of the DELTA package as the land-use/economic component of a dynamic land-use/transport interaction model. There are three main sections to the paper. The first examines the use of these models as ways of integrating knowledge about spatial and social change for the purpose of examining alternative land-use and transport strategies. The second reviews some of the results obtained from recent projects in relation to current debates about the impacts of transport change. The third considers progress and outstanding issues in relation to the formal appraisal of the costs and benefits arising from transport interventions. The concluding section comments on some of the remaining issues to be dealt with in using these modelling and appraisal methods in relation to questions of sustainability.

Keywords: land-use/transport interaction; land-use/transport modelling; economic impact; land-use planning; transport planning; policy appraisal.

1. Introduction

1.1 Background and structure

This paper discusses land-use/transport interaction modelling in relation to strategic land-use/transport planning. It has been prepared drawing upon the experience of the author and his colleagues in a number of recent studies in the UK, namely

- Strategic Environmental Assessment in the Trans-Pennine Corridor (SEATPC – see Coombe et al, 2001);

- the South and West Yorkshire Multi-Modal Study (SWYMMS – see Simmonds and Skinner, 2004); and
- the Central Scotland Transport Corridor Studies (CSTCS – see www.cstcs.co.uk).

The paper also draws on technical developments in relation to appraisal which have been pursued in the course of work on a fourth project, the Greater Manchester Strategy Planning Model (see Copley et al, 2000). All of these have used the DELTA land-use/economic modelling package, linked to an appropriate transport model.

The paper is structured into four main sections. The first three review, in turn,

- land-use/transport interaction modelling as a means of integrating a range of knowledge about different kinds of change, for use in relation to the examination of alternative strategies;
- some of the results obtained from such modelling in the projects mentioned above;
- the key issues faced in formal appraisal of policy impacts when land-use/transport interactions are taken into account.

The final section considers some of the issues that remain to be dealt with in future work. The paper as a whole is necessarily an overview of a number of related topics rather than an in-depth account of any one of them.

In all four of the projects mentioned above, the modelling has been undertaken by the author's firm, David Simmonds Consultancy (DSC), in collaboration with MVA Consultancy. In each project, MVA have developed the transport model, and the work of running the model has been carried out jointly by MVA and DSC (and client organizations, in the GMSPM case). Full details of the studies, including the clients, the other consultants involved, and the wide range of other work undertaken, will be found in the various references. All of the opinions expressed in this paper are those of the author, and are not necessarily those of the client organizations for the studies mentioned, nor of the other consultants involved.

2. Models as methods for integrating knowledge

2.1 Land-use/transport interaction: the meaning of “land-use”

The term ‘land-use’ is used throughout this paper to cover a range of human activities, the state of the built environment, and some aspects of the natural environment.

‘Land-use’ so defined is of relevance to ‘transport’ for at least three reasons:

- activities and the interactions between them generate the demands for transport;
- those activities and interactions are to a greater or lesser extent influenced by the availability of transport; and
- the linkages between transport and activities may be important to the appraisal of transport strategies - especially when trying to consider whether the transport system is providing the kinds of accessibilities that activities (i.e. people and businesses) require, rather than simply providing mobility.

2.2 Actors and markets

A theme which we have been developing for a number of years is the need to understand land-use/transport interaction in terms of the decisions made by different categories of economic “actors”, within the different markets in which they interact. Figure 1 illustrates the role of transport in relation to the different groups of people and organisations who are influenced by transport. It identifies three main categories of actors:

- the population, as individuals and as households;
- firms and other productive organisations; and
- government.

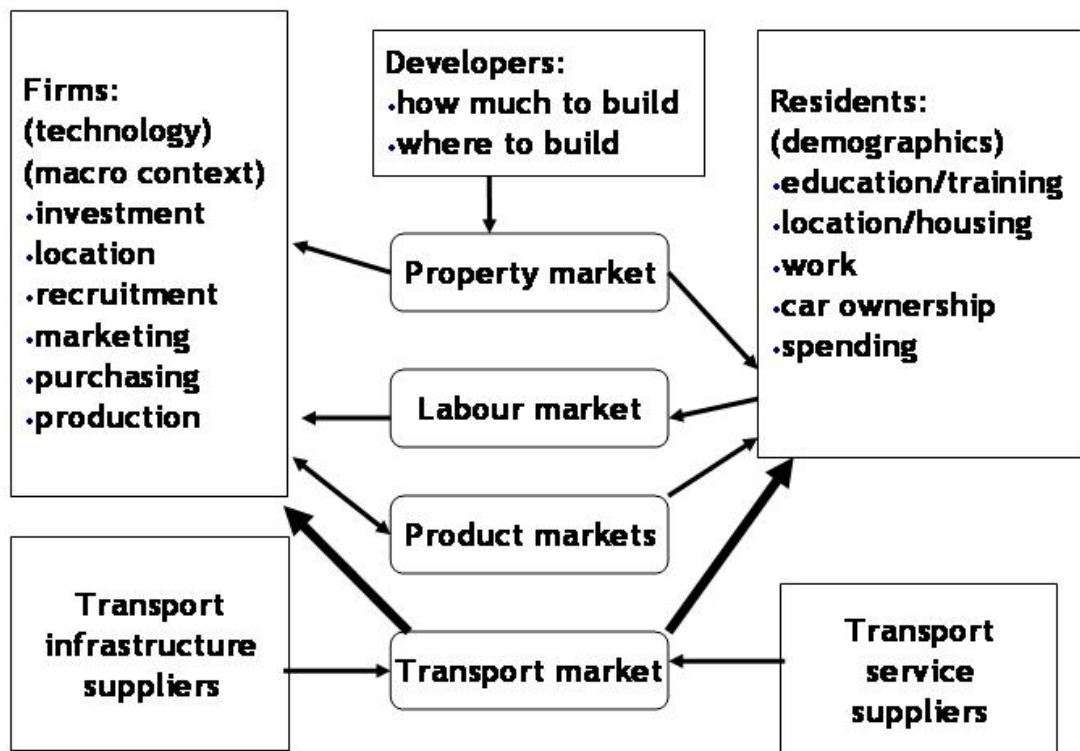


Figure 1. Key decisions by land-use actors

The diagram identifies three particular categories of firms of special interest:

- property developers,
- transport infrastructure providers, and
- transport service providers (e.g. public transport operators),

all of which may be special cases either of firms, or of government activity, or both. Note that the diagram is drawn so that property developers and transport are not directly connected: we hypothesize that developers are influenced by transport only in so far as it affects the potential occupiers of property (though they may try to anticipate the impact of transport on

potential occupiers), and transport is influenced by development only through the decisions of actual occupiers.

Residents and firms interact with each other through a number of markets, mainly:

- in property
- labour, and
- goods and services.

Through these interactions, changes in transport may have indirect impacts on people or businesses that have no direct interest in the transport change at all. It therefore is necessary to consider not only predicting the land-use consequences of transport change, but also the implications for appraisal of the way in which the influence of transport is passed on through the interactions of different actors.

It is important to recognise that the 'land-use' system is never static, and that 'transport' is only one of the factors that influence how it changes. The treatments of all the other factors - such as demographics, the workings of the development process, etc. - are among the things which distinguish the different approaches to land-use modelling.

2.3 The influence of transport on land-use

Transport influences the decisions of residents and firms in a number of ways, which are considered in more detail below. These influences can be clarified by considering the key decisions made by different categories of land-use actors, also shown in Figure 1.

All of the different kinds of decisions listed for firms and residents are likely to be influenced, in most cases and to some degree, by the transport system. One of the features of these decisions is the range of frequencies with which different kinds of decisions are made – and for how long these decisions commit the actors. For example, households make decisions about shopping weekly or daily, and can go shopping in different locations every week or every day if they wish. The cumulative effects of households' shopping decisions will influence the decisions of developers and retailers about where to provide shops. These decisions are less frequent and will typically commit retailers for years and the use of the land possibly for decades. (For further discussion of the dynamics of decisions and their consequences, see Wegener et al, 1986.)

Other points to note are that:

- the land-use impacts of a transport change may extend far beyond the spatial scope of the transport proposal itself - they can extend at least as far as the area in which the transport change affects accessibility, and secondary effects may extend further (see Vickerman, 1991);
- a great deal of locational change takes place through changing occupation of existing buildings, with changes in either the density or the nature of the occupation (for example, one type of business replacing another, or retired persons occupying housing previously occupied by families with children), and new building accounts for only a minority of the supply available to potential occupiers¹;

¹ For example, the figures in Bramley et al (1995, p128, Table 6.4) show that new building accounted for only about 12% of the gross supply of housing taken up in Great Britain in 1987.

- the value of property is an important influence on its occupation; if improvements in transport increase the demand for space in a particular location, the resulting increases in rents may affect households or businesses who have no direct interest in the transport change itself.

It follows from the above points that

- in many cases changes in composition are likely to be more significant than changes in totals - for example, changes in provision for commuter travel may have a significant impact on where the working population and its dependants live, but a much smaller impact on the distribution of the total population (as households without workers move into the areas that the workers are leaving); and
- significant land-use effects may occur within the market for existing property, with no new development and no formal change of use, and therefore beyond the control of the planning system.

It should also be noted that 'regeneration', 'economic impacts' and so on are all particular aspects of what are here referred to as land-use effects.

2.4 The DELTA package in this context

The DELTA package (see Simmonds, 1999, 2001) which the author and his colleagues have used in the various UK studies mentioned in the introduction represents all the actors and many, though not all, of the decisions represented in Figure 1. A major limitation is that, in common with most land-use and many other models, it represents sectors rather than businesses; developers are effectively treated in the same way. Households and their members are represented, and the package models (in varying levels of details) all of the household/individual decisions shown in Figure 1 except for education/training choices (which are assumed fixed as part of the input socio-economic scenario). Developers' choices of where and how much to develop are represented. For firms, all of the choices shown are modelled (again, in varying levels of detail) except for marketing – in common with most of the models which incorporate a spatial input-output model, DELTA tends to assume that consumers (final or intermediate) choose where they will buy from, rather than firms choosing where they will sell to. It also assumes a simple approach to recruitment and investment – again, choices between labour-intensive and capital-intensive production for each sector are largely built into the input scenario rather than being outputs from the model. In terms of markets, the property market is modelled in terms of a number of wholly separate markets for main floorspace types (usually housing, retail, office and industrial) with the demand consisting of new and a proportion of mobile households (or of a proportion of jobs) and supply consisting of a usually small proportion of new development, a highly variable proportion of previously vacant space, and a substantial proportion of recently-vacated or vacatable space (the last equivalent to representing housing chains). The labour market is represented in terms of the number of potential workers (usually by socio-economic group) available at each residential location, the number of jobs (again by socio-economic group) at each work location, and the resulting matrices of commuting (current work is enhancing this to a more explicit choice process influenced by the trade-off between wages and commuting costs). Both property and labour are treated at the zonal level. Markets in products and

services are represented at the area (higher) level through the operation of a spatial input-output model.

The treatment of transport varies considerably between the different applications and the various transport modelling packages used, but all of the applications listed take account of destination choice, some element of mode choice and route choice, and congestion of the network resulting from levels of road traffic.

Overall, therefore, the various model applications mentioned represent highly sophisticated systems covering a large part of the ideal system illustrated in Figure 1. There is a great deal that can be done to further refine such models – including overcoming the omissions and simplifications mentioned in the preceding paragraphs – but it seems reasonable to regard them as defining at least one version of best practice in current land-use/transport modelling. Comparison with other operational packages can be found in Geurs and Van Wee (this issue).

3. Results form recent work

3.1 Introduction

The object of this section is to show a very small sample of recent results, partly to demonstrate LUTI modelling in action, and partly to bring out some of the characteristics of such analysis which are significant for economic assessment.

3.2 The South and West Yorkshire Multi-Modal Study

The example results are taken from recent work on the South and West Yorkshire Multi-Modal Study (SWYMMS). The study was commissioned by the Government Office for Yorkshire and the Humber (GOYH) as part of a major programme of studies announced by the Government in July 1998, generally focussed on particular problems in the trunk (ie national) road network. SWYMMS was required to make recommendations for:

- an integrated and sustainable **strategy** for the strategic road, rail and water networks in the Study Area (outlined in Figure 2); and
- a **plan** of specific interventions to address the most urgent key strategic problems in the Study Area through to 2021.

All of the Multi-Modal Studies had to address both general government objectives relating to

- to reduce the direct and indirect impacts of transport facilities and their use on the environment;
- to improve safety, i.e. reduce loss of life, injuries, fear, and damage to property from transport accidents and crime;
- to improve the economic efficiency of transport, and the efficiency of economic activities;
- to improve accessibility, i.e. access to the transport system for all members of society;
- to improve integration within the transport system, and with other sectors;

and a number of study-specific objectives. The study-specific objectives for SWYMMS were:

The land-use/transport interaction model developed for SWYMMS played a key part in testing proposals against the last two objectives, and was also important – in conjunction with more detailed traffic and public transport models – in testing them against the first two objectives.

3.3 The South and West Yorkshire Strategic Model

The model used is a land-use/transport interaction model developed by integrating applications of MVA's START transport modelling package (Roberts and Simmonds, 1997) and of the DELTA land-use/economic package. The models were built by the two consultancies and integrated into a single system allowing the full model to be run automatically to test land-use, economic or transport policies, or any combination of these.

It should be stressed that this strategic LUTI model was only one of the forecasting methods used in the project; and that whilst the results themselves are taken from the published reports, the discussion of them is the author's own, drawing very much on previous discussion in Simmonds and Skinner (2004). Further detail of the model design can be found in that paper.

3.4 Road infrastructure projects

One of the tests carried out (identified as test ED3 within SWYMMS) was to look at the combined impact of two packages of road building and widening schemes. The packages were a group of schemes aimed at economic regeneration, and a group of schemes aimed at the relief of traffic congestion in areas where economic regeneration is a priority concern.

These schemes were concentrated in the South Yorkshire area between Rotherham and Doncaster, plus improvements to the road network north of Doncaster. **Fout! Verwijzingsbron niet gevonden..** They were introduced into the transport supply in 2005, and the model system was run to 2020. The following discussion of their impacts is based on comparison with the reference case; except for the road schemes, there were no differences in transport or land-use policy inputs between the ED3 test and the reference case.

The effect of the schemes was to increase slightly the accessibility of the zones in the Doncaster area, and of the area as a whole; the pattern of the schemes was such that the Doncaster area gained rather more in accessibility than the other areas, even though the road improvements naturally improve access in both directions. As a result, Doncaster tended

- to attract a slightly larger share of investment, and hence of production – the scale of this effect varying across the different sectors modelled – than in the Reference Case
- as a result of the increased production, employment increased slightly, relative to the Reference Case, and hence
- because of the improvement in employment opportunities, the patterns of net migration were modified, and the population rose slightly relative to the Reference Case.

Because of the gradual operation of the investment and migration processes, the effect was mostly very gradual. This is illustrated in Figure 3, which shows the impacts on value-added for the three South Yorkshire travel-to-work areas modelled. One of the characteristics of this particular growth was that the positive impact on the Doncaster area levelled off after 2015 (about 10 years after the investment in roads). This suggests that the schemes did not generate self-reinforcing levels of growth in the Doncaster area – they contrast with other

results obtained from transport schemes with the same model in other areas, where the positive impacts on the economy tended to increase (albeit more slowly) for considerably longer.

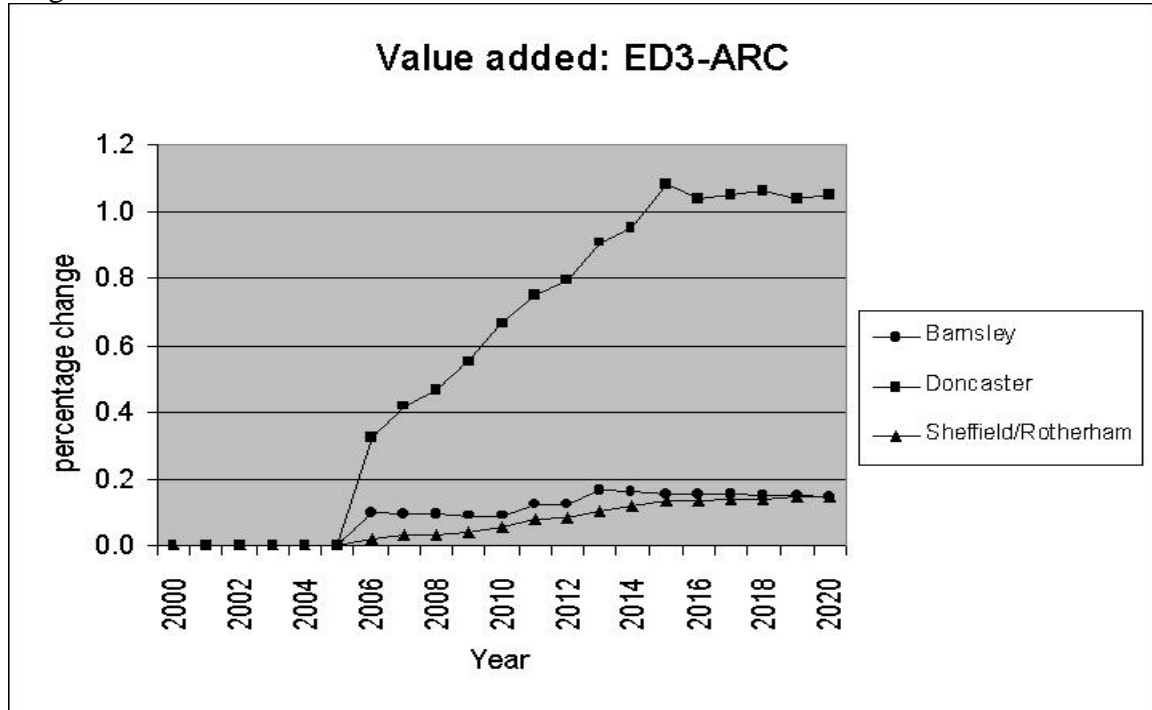


Figure 3. Impact of ED3 schemes on area economies

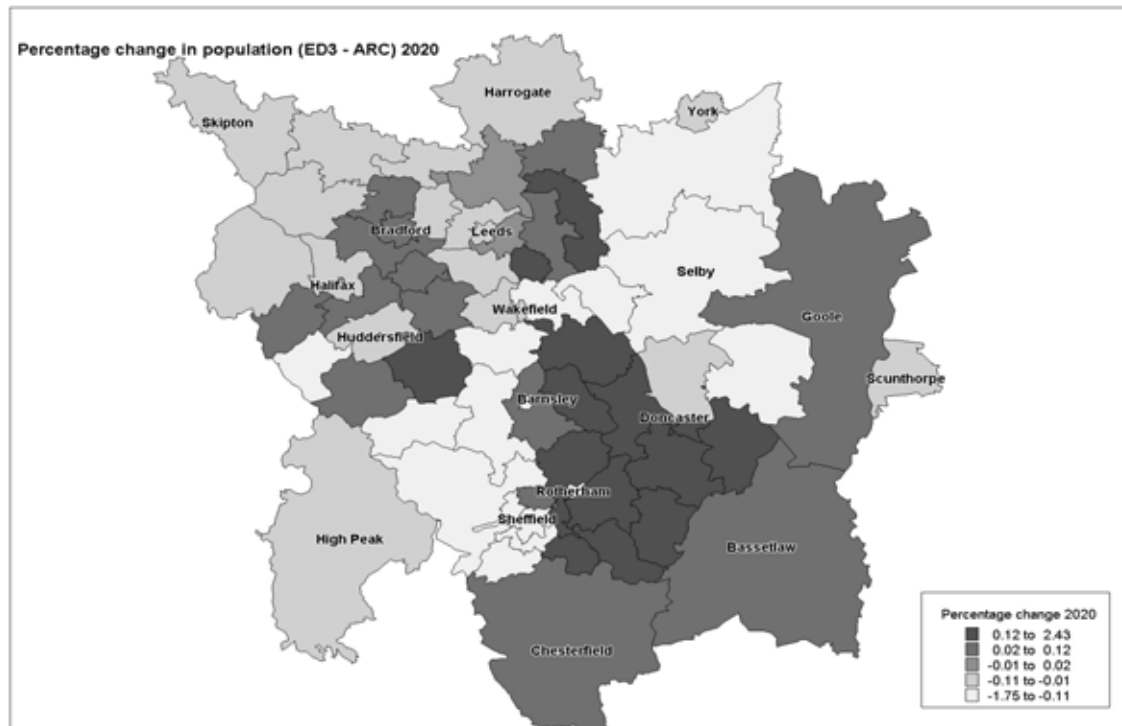


Figure 4. ED3 test: impacts on population, 2020

3.5 Economic development incentives

The impacts predicted by the land-use/transport interaction model do not always go in the expected direction. An example of this arose in testing another strategy within SYWMMS, which involved substantial (and entirely hypothetical) incentives to the development of retail, office and industrial floor space in town/city centres and selected Strategic Economic Zones of South Yorkshire. (Details can be found in the SWYMMS Scenarios and Strategies Report, as test ED6.) No other changes were introduced. The development incentives resulted in significant extra construction in the zones affected. However, to the initial surprise of the modelling team, the impact on total employment in South Yorkshire was **negative**. This was traced to

- much of the additional development in South Yorkshire being in congested locations;
- businesses relocating into the additional floor space thus moving into congested locations and contributing to making congestion even worse (with no provision in the strategy for transport improvements);
- the resulting increases in congestion and the increases in the proportion of activity in the most congested locations, making South Yorkshire slightly less competitive as a location for production and slightly less attractive as a location for investment.

Other planners who have discussed these results have described them as an entirely *unsurprising* and intuitively obvious example of what is likely to happen if land-use and transport plans are not properly integrated!

3.6 Comprehensive transport packages

One of the comprehensive packages which emerged from SWYMMS shows that much more significant impacts are predicted in some cases. The package considered, referred to within SWYMMS as the HINT package, involved the wide range of measures listed in Table 1. Figure 5 shows the impacts on employment, in terms of percentage changes from the Reference Case forecasts for 2020. These range from -6% to +8%. Figure 6 shows that the impacts on population range from -19% to +19%.

Table 1. Measures in HINT package

Theme	HINT interventions
Travel reduction	Distance-based road user charging in urban areas: 20p/Km Distance-based road user charging on motorways: 2p/Km, peak only
Economic development	Economic development-oriented road schemes: package ED3 (see text above) Incentives to commercial development: package ED6 (see text above)
PT investment	High level of investment in all aspects of public transport Information technology-based traffic management
Road investment	Green travel plans All motorways and A1 trunk road widened

This example is included mainly to avoid giving the impression that the impacts of transport upon land-use are always vanishingly small. It also illustrates the importance of testing the component interventions within complex packages. We can see that this package has

significant effects, but given the number and complexity of the component parts we cannot readily say much about why it has that effect. Whilst there were major constraints on the SWYMMS project that made it impractical to examine all the component parts in detail, it is worth emphasising that some of the advantages and explanatory power of modelling is lost if complex packages are only tested in their entirety. There is also a question of what happens in appraisal, where there is both a general requirement to justify the components of a package and typically a later need to appraise each of the interventions separately at the stage of securing the powers and/or the funding for them to go ahead.

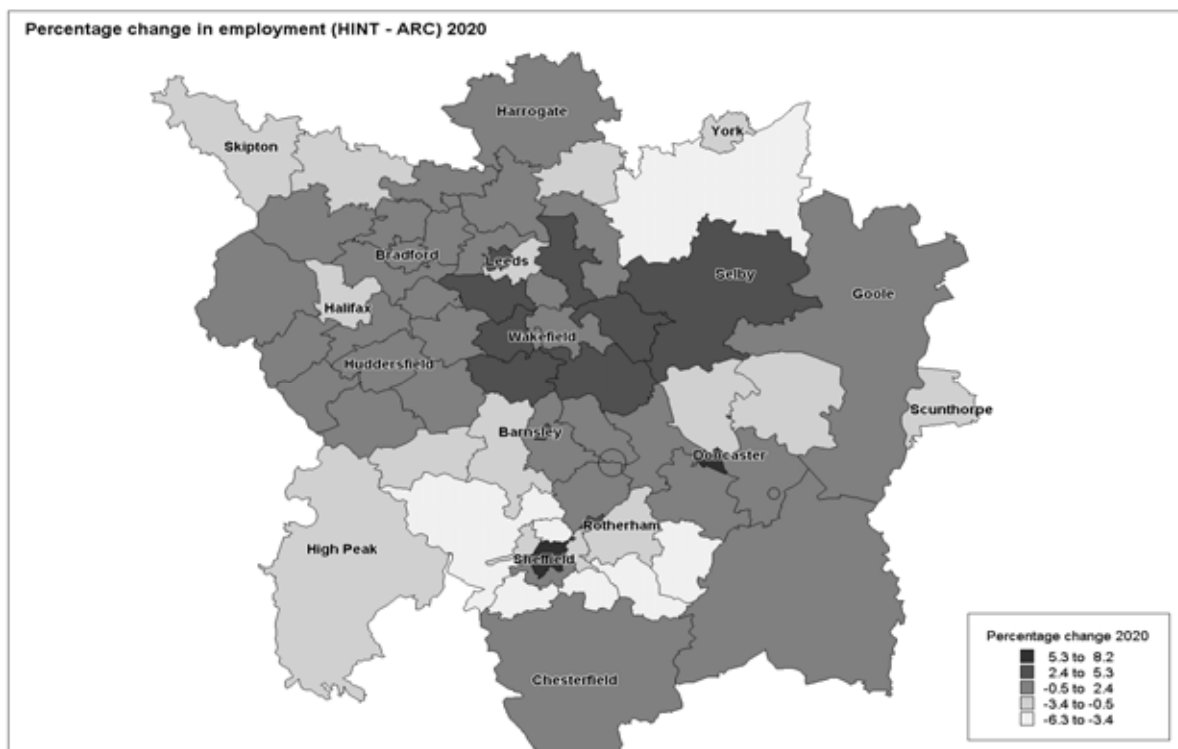


Figure 5. HINT package: impact on employment, 2020

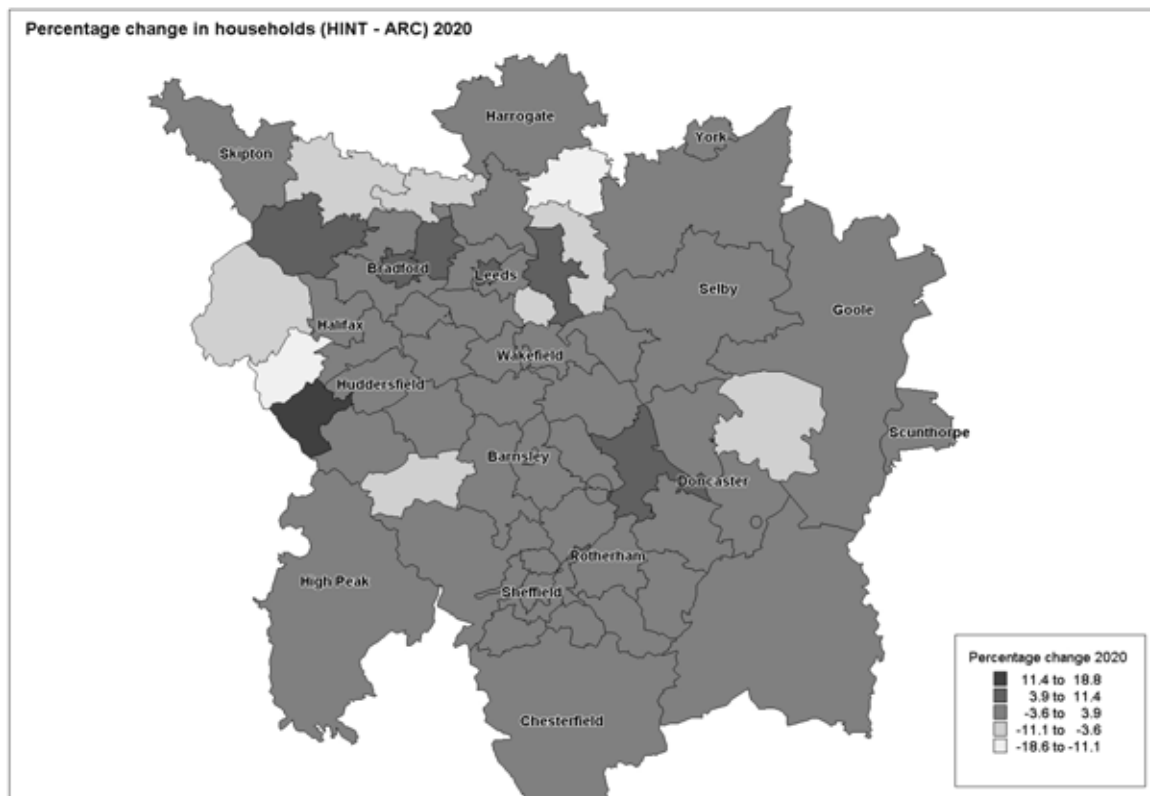


Figure 6. HINT package: impact on households, 2020

3.7 Points emerging from practical experience

Transport schemes on their own tend to have impacts which are very slight in percentage terms but may be more significant in absolute terms. The road schemes considered in section 0 are not (as perceived within the strategic model) relieving a constraint, but only providing moderate improvements in accessibility where it is probably quite good already.

This does suggest that there is scope for further work on the relationship between transport problems as users (especially commercial users) see them and as they are modelled. Is the pressure for road network improvements just “rent-seeking” in the sense of users hoping to get improvements at someone else’s expense, or is it the case that congestion in some locations and some circumstances is genuinely more important than our analysis can detect?

Analysis of delays to freight (McKinnon, 2003) suggests that road congestion as it affects freight is serious but no more serious than some of the other sources of delay which arise within shippers’ own operations off the road network. This perhaps give weight to the hypothesis that road congestion is considered especially significant because someone else ought to deal with it, not because it uniquely onerous to business. This is consistent with the informal observation that, at least in the UK, there is little evidence that congestion itself is leading firms to relocate to less congested areas, but that when they have other reasons for relocating they may well prefer to move to less congested locations.

On the other hand there may well be cases where present modelling practice is not picking up some of the constraint mechanisms. A particular case in UK planning is where planning

permission is refused on grounds that development would generate additional traffic on already congested roads. This issue was much discussed in SWYMMS, but did not in the event enter into the strategic modelling, ie we did not assume that more development would be permitted if the road schemes considered in the ED3 test (or any other) went ahead. The logic of this was to concentrate purely on the induced economic effect, and not to confuse this with the effects of changing planning policies. With hindsight, this may be understating the significance of the increases in road capacity: if the planning policy proper is in favour of development, but permissions are being refused (or not sought) on highway congestion grounds, it would be reasonable to include the additional scope for development as an outcome of the transport change rather than as a separate policy decision.

If we did so, however, we ought to recognize that forecast congestion levels could well lead to further restrictions on development, and to reflect those in the land-use development model. Technically, this would be a challenge, but it would tend to make the impacts of congestion-relieving investment much greater. This needs further consideration in relation both to modelling and to appraisal.

4. Problems and progress in appraisal

4.1 Background²

In recent years, there has been a sharp increase in concern about the impacts of transport on urban and regional change. Within the UK, this has been reflected in the 1999 report of the Standing Advisory Committee on Trunk Road Assessment (SACTRA) on *Transport and the economy*, and in parts of the official *Guidance on the methodology for multi-modal studies* (Department of the Environment, Transport and the Regions, 2000), and in a number of modelling projects.

In the documents just mentioned, and elsewhere, it has repeatedly been pointed out that the conventional approach to the measurement of the user benefits of transport strategies is incorrect if the patterns of land-use are forecast to change as a result of the strategy. This is true whether simple or complex models are used in the transport side of the analysis. In some projects, such as the Strategic Environmental Assessment of the Trans-Pennine Corridor (SEATPC), two model-based analyses have been carried out: one with land-use held constant, modelling transport change only and applying conventional methods to measure transport user benefits, and the other with land-uses responding to the transport strategies, used for less formal appraisal of other effects. SACTRA's 1999 report recommended something along the same lines: a full analysis of transport effects, assuming no change in land-uses or economic activity, supplemented by analysis of other impacts. Both recommendations and recent practice have started from the understanding that the available methods of appraisal are inconsistent with changing land-uses. It is appropriate to begin by clarifying the reasons why conventional measurements alone are incorrect in such circumstances.

² This section is based on work carried out in collaboration with John Bates Services for the UK Government Office for the North-West (David Simmonds Consultancy, 2001, 2002).

4.2 The problem

The conventional approach to measurement of transport user benefits is based upon estimating the changes in consumer surplus accruing to transport users by applying the rule-of-a-half calculation to each component of demand.

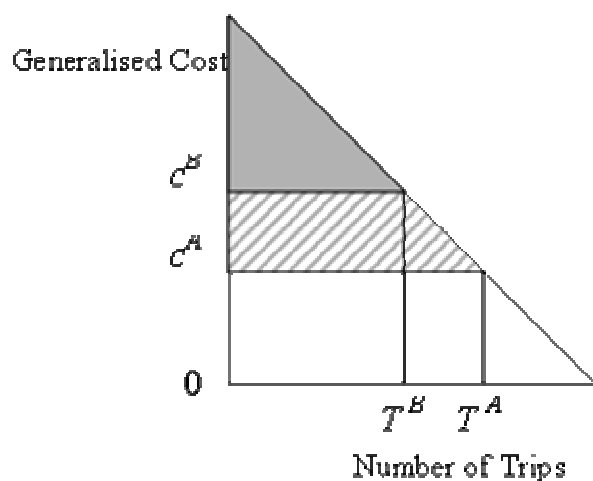


Figure 7. Rule of a half calculation

The basis of the rule-of-a-half calculation is the familiar diagram shown in Figure 7. In the Base situation, the generalised cost of using this particular part of the transport system (eg one mode from one origin to one destination during one period of the day, for one purpose and type of traveller) is c^B , and the number of trips made is T^B . In the Alternative situation, as a result of an Alternative transport strategy, the generalised cost is reduced to c^A , and the number of trips increases to T^A . We can draw a line through the points (T^B, c^B) and (T^A, c^A) to show the *demand curve*, and for the purposes of analysis we can extrapolate it to the vertical axis.

The key economic concept that now comes into play is that of *consumer surplus*, which is the difference between what consumers are willing to pay in generalised cost (money, time and inconvenience) for a good or service (in this case, for a particular kind of trip) and what they actually pay. The total consumer surplus in the Base situation is given by the shaded triangle. The change in consumer surplus due to going from the Base situation to the Alternative is given by the hatched strip. If we make a number of assumptions³, including the assumption that the demand curve is a straight line between the Base and Alternative points, then the area of that strip can be calculated by some very simple geometry as

$$\Delta S = -\frac{1}{2} \left\{ \sum_i (T^A + T^B) (c^A - c^B) \right\}$$

³ Typically, the assumptions upon which it is based do not hold, but it is accepted as a practical approximation. A particularly significant group of assumptions relate to perfect competition both in the transport-supplying sectors and in the transport-using sectors. These assumptions, and the implications of market imperfections, are discussed in Chapter 4 of SACTRA (1999).

Equation 0 -1

This is known as the rule-of-a-half. To calculate the benefits resulting from an Alternative strategy, this has to be applied to all of the travel options in the system whose generalised costs may possibly change as a result of adopting the Alternative strategy rather than the Base. In real applications to congested urban systems, even a simple strategy will have many complex impacts on generalised costs and on the use of the different parts of the transport system. It can be shown that the total benefits estimated by applying rule-of-a-half to **all** the components of the transport system will be sensibly calculated (subject to the other assumptions) provided that **all** of the changes are attributable to generalised cost changes within the system.

However, as soon as we introduce changes that are not represented in generalised cost, this conventional approach becomes less reliable, and may be wholly misleading. This risk arises whatever the reason for introducing such changes. The case of interest is of course that of land-use changes, whether these are estimated by a model or by professional judgement. Consider for example a land-use change associated with the Alternative strategy make a particular destination more attractive but draws more trips into a congested part of the network. The rule-of-a-half based on generalised cost will detect the worsening congestion but not the increased attractiveness of the destination; as a result, the strategy will appear to produce disbenefits to travellers, even in cases where it can be shown that all travellers are either unaffected or enjoying benefits compared with the Base situation. In general, it can only be said that if the Alternative involves changes which affect travellers choices in any way except through generalised costs, the rule-of-a-half calculations based on Equation 0 -1 will estimate an arbitrary set of partial changes, with the potential to reach a wholly misleading total. This is clearly an unsatisfactory situation with regard to the appraisal of strategies which may involve and/or result in land-use changes.

4.3 A proposed solution

If transport supply changes can lead to land-use changes as well as to transport demand changes, and those land-use changes can lead to further transport demand changes, then it is necessary to include in the appraisal the changes in consumer surplus arising in the land-use system as well as the conventionally included changes in consumer surplus arising in the transport system. The intuitive argument for this is it should deal with consumers choosing to transform transport benefits into land-use benefits – for example, if some commuters respond to the speeding-up of a suburban railway by relocating to more attractive suburbs further from the central city, giving up some or all of the time saving they would have enjoyed had they stayed put. The appraisal should also be able to take account of the ways in which residents responding to a transport change can have impacts on other residents, through the property markets.

Earlier studies in this area (notably Neuberger, 1971; Flowerdew, 1978; Morisugi et al, 1990) are interesting but do not provide a full response to the issues. In particular

- the studies which have added further calculations to conventional transport benefit measures do not sufficiently explain their reasoning, or demonstrate why their methods are sufficient to measure all benefits without double counting

- those which propose alternative methods require, at the very least, greater changes in appraisal practice, and they may be compatible only with particular land-use/transport models.

More recently, Marcial Echenique & Partners (1994) and Martínez and Araya (1998, 2000) have separately proposed less conventional methods, which have been implemented around their respective land-use/transport models. Some of Martínez's work in particular has a certain similarity to the argument we develop below, in that he suggests that comprehensive benefits can be estimated either from transport model variables or from land-use model variables.

In a "comprehensive" land-use/transport interaction model where all land-uses are affected by transport or accessibility changes, and all travel is affected by land-use changes, there are different ways of considering any one set of changes. For example, a change in shopping provision may be considered either by looking directly at the change itself⁴ – for example, in terms of the increase in retail floor space area in a zone – or at the transport changes resulting from the change – the increase in shopping trips attracted to that zone.

This means that it might be possible to estimate all of the benefits using data already present within the **transport** model. This is most straightforward where the transport model is conceived on a production-attraction basis, with one set of factors (such as household location and car-ownership) affecting how many trips of each kind are produced in each zone, and other factors affecting which zones they are attracted to. In this case, the benefits fall into three groups:

- those associated directly with changes in **generalised costs**;
- those associated with changes in the **attraction** of trips; and
- those associated with changes in the **production** of trips.

The first category is calculated by the conventional rule-of-a-half approach. The benefits associated with changes in the attraction of trips can fairly readily be calculated by applying rule-of-a-half to variables taken from the trip distribution model. The benefits associated with changes in the production of trips are more difficult, but it is possible to deduce the appropriate variables by assuming an appropriate location model, and to apply rule-of-a-half to these.

Alternatively, it may be equally possible to estimate all of the benefits using data already used within the **land-use** model. In this approach, the benefits can be broken down into

- those associated with changes in **accessibility**; and
- those associated with changes in other variables affecting **location** (eg the supply of housing, its rent, the environment quality of each zone).

We have examined the relationship between changes in accessibility and the benefits to transport users arising from changes in generalised cost and in trip attraction. It can be shown that, under certain conditions,

⁴ Note that in the case of appraising a land-use plan, we should consider the consequences of the plan (including those working through the property markets, such as the decreasing rents in existing shopping centres when new competition is introduced), not just the plan itself.

- the benefits resulting from changes in generalised cost and from changes in attraction are the same as the benefits which can be calculated from changes in accessibility, and
- the benefits associated with changes in trip production are the same as the benefits associated with land-use variables other than accessibility.

This equivalence is summarised in Table . A major practical consideration is that in many projects the conventional rule-of-a-half calculations for benefits derived from generalised cost changes can readily be applied using existing software. The possibility of reusing the existing software for this part of the task is highly appealing, particularly if it can be used without any changes at all. However, substantial work is needed to deal in practice with the other variables, especially the non-accessibility variables in complex land-use models, where a variety of lagged effects are involved.

Table 2. Equivalence of benefits calculated from transport or land-use variables

Classification of benefits based on transport model variables	Classification of benefits based on land-use model variables
Benefits based on generalised cost changes (conventional transport change only calculation)	Benefits based on changes in accessibility
Benefits based on changes in trip attraction	
Benefits based on changes in trip production	Benefits based on changes in other variables affecting location (ie other than accessibility)

It also needs to be emphasised that this discussion is wholly to do with **user** benefits. These should not be ignored in appraisal (though sometimes there seems to be a risk of this in relation to land-use changes), but equally they are not the whole of the analysis.

5. Conclusions: outstanding issues for economic impact analysis and appraisal

5.1 Outstanding issues

One of the outstanding issues is the need to develop means of examining the environmental implications of broad-brush forecasts of transport and land-use impacts, if possible without requiring strategic modelling to go into levels of spatial and network detail which would further restrict the numbers of scenarios and strategies considered.

One particular aspect of this is the relationship between such analysis and planning policies. The output from land-use/transport modelling includes the quantities of building of different types taking place in each zone, and these vary according to the transport strategy tested. At present these tend to be appraised not so much in terms of their environmental impacts as such, but in terms of their conformity or otherwise with existing planning policies and policy guidance. This raises at least two issues:

- the impacts which are being forecast often extend significantly beyond the horizon year of current land-year policies;

- the planning policies themselves may not have been subject to as rigorous an assessment of their environmental consequences as the ones which we are attempting to carry out, using land-use/transport modelling, for transport strategies.

In addition, the process of bringing sustainability issues into formal appraisal puts more emphasis on later years (see recent review in the PROSPECTS study – May and Minken, 2003). This increases the demands on modelling, especially in the need to take account of all the gradual feedback effects which are only significant in the longer term; but it also needs to be addressed by improving the use of models, particularly the use of alternative scenarios (of technological and social change, as well as the more conventional scenarios of economic growth) and of sensitivity tests. These latter needs are not so much a challenge for modellers as a challenge for the wider study and decision-making processes which (despite many recommendations to the contrary) tend to work within a single scenario and not to engage in sensitivity testing.

5.3 Conclusion

This paper has attempted briefly to outline something of the scope of land-use/transport interaction modelling, to give a sample of the kinds of results it can produce in practice, and to raise some of the key issues relating to the appraisal of policies.

Land-use/transport interaction modelling is the only available method of formally and systematically considering an important range of the impacts which may arise from planning decisions in land-use, transport and the economy. Sometimes these impacts are highly significant; on other occasions, the modelling is useful in showing that the impacts may not be as significant as the proponents of particular schemes would like to claim.

There are many issues to be addressed – within the models themselves, and in the use of the models both in practical terms and in terms of formal appraisal and assessment methodology, but recent experience in the UK demonstrates the contribution which such modelling can make.

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⁵ Note that this paper is still of relevance for its description of the initial thinking behind the design of DELTA, but is very much out of date as regards the detailed content and scope of the package; these are better outlined in Simmonds (2001).