DO IMPROVEMENTS IN MODELLING TRAVELLER RESPONSES DISTORT ECONOMIC ASSESSMENT?

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"The views expressed in this paper reflect those of the authors, solely, and do not constitute either actual, or, at this stage, potential policy of Transport Scotland or the wider Scottish Government."

ABSTRACT

It has long been demonstrated that there has been a strong correlation between transport and the economy. More recently, there has been much debate on decoupling the relationship between transport and the economy such that economic growth can continue without commensurate increases in the travel of goods and people. Notwithstanding this though, there is still a need to understand how transport interventions will affect both national and local economies.

The assessment of the economic impact of transport interventions would ideally involve the quantification of the impact that travel has on the broad economic sectors, or factors, of production: land, labour and capital, how impacts in these sectors affect productivity and hence the impact on economic growth (we shall call this the "full" method). However, quantifying these impacts is not a straightforward exercise and to date, the authors are unaware of an agreed methodology for undertaking a "full" economic assessment.

Traditionally, transport economics has used the impact on factors such as travel time, vehicle operating costs and fares i.e. the generalised cost of travel as a "proxy" for economic benefit. Changes in the generalised cost of travel feed through the three factor markets to impact on productivity and hence economic growth. Whilst some of the gaps between these initial impacts and the final economic effect are being filled (i.e. agglomeration benefits), the approach still essentially relies on assumptions about how the factor markets behave when faced with changes in (travel) costs.

Transport models though are evolving and techniques continue to improve the capture of traveller responses to an intervention.

The purpose of this paper is to consider whether the improvements in replicating traveller responses in transport models is capturing some of the impacts on the factor markets and hence leading to distortions in the economic impacts captured using the "proxy" method.

1. INTRODUCTION

In the field of transport modelling, it has long been recognised that the *fixed trip matrix* assessment is inappropriate for deriving robust future predictions of the number of vehicles on a road, passengers on a train, etc. For many of the purposes of undertaking a transport appraisal such as design flows, environmental impact, transport models attempt to capture as many of the responses to a change in the transport network as possible. These responses include:

- What route to travel
- What mode to use
- When to travel
- Whether / how often to travel
- Where to travel to
- Where to travel from

A model which robustly captures all of these responses will provide far better forecasts of the future demands on the transport network than a simple fixed trip matrix assessment.

However, is it appropriate to include all of these responses in an economic assessment though?

When we undertake an economic assessment of a transport scheme, the main benefits are realised through journey time savings and to a greater or lesser extent, savings in vehicle operating costs.

However, empirical evidence shows that no matter what improvements we make to the transport network, average personal travel time has remained largely constant at approximately one hour per day over at least the last 30 years. Personal travel includes all travel where the person reaching a destination is important including business and commuting travel. Paid travel associated with delivering goods, other people, cleaning streets, etc. is excluded.

If (or more hopefully when) transport models become sophisticated enough to robustly capture all the responses to a transport intervention, the logical conclusion, based on past trends, is that there would be no travel time savings remaining for personal travel.

If we look at the underlying principles of the economic assessment of a transport scheme, we find that the use of travel time savings is just a proxy for the true economic benefits that accrue. It is worth noting that this is different to the development of a *business case* which involves the identification of a revenue stream, particularly for a public transport intervention.

Terminology:
For this paper, the term **cost** can be positive or negative. Hence a change in travel cost may be either a benefit or a disbenefit. If a specific direction of

cost change is important, this will be indicated using the terms benefit and disbenefit. Additionally, travel costs include both time and money – the notion of generalised cost – expressed as either a time value (generalised journey time) or a cost value (generalised cost).

This paper firstly examines the empirical evidence on personal travel time and distance in Section 2. Section 3 attempts to explain how economic assessment is undertaken and how this assessment is related to the realised economic impact of transport interventions. Section 4 presents a stylised model that demonstrates the core thesis of this paper and Section 5 concludes.

2. PAST RESPONSES TO IMPROVEMENTS IN THE TRANSPORT NETWORK

Since the early 1970's, data is available on how far and how long people travel for (Table 1).

Table 1 – Distance and hours travelled per person per year: 1972/1973 to 2006[1]

	Distance travelled (miles)	Time taken (hours)	Average trip length (miles)	Average trip time (minutes)
1972/1973	4,476	353	4.7	22.2
1975/1976	4,740	330	5.1	21.2
1978/1979	4,791	377	4.4	20.6
1985/1986	5,317	337	5.2	19.8
1989/1991	6,475	370	5.9	20.4
1992/1994	6,439	359	6.1	20.5
1995/1997[1]	6,981	369	6.4	20.4
1998/2000	7,164	376	6.7	21.1
2002	7,135	380	6.8	21.8
2003	7,192	381	7.0	22.1
2004	7,103	382	6.9	22.3
2005	7,208	385	6.9	22.1
2006	7,133	383	6.9	22.2

1 Data from 1995 onwards has been weighted, causing a one-off uplift in trip numbers, distance travelle
1992/1994 and 1995/1997.

Source: National Travel Survey 2006

Note: The NTS does include travel related to commuting and business travel where the traveller reaching the destination is important but excludes travel related to activities such as delivering goods, paid delivery of people (e.g. bus or taxi driver) or travel in specially adapted vehicles (e.g. AA/RAC vehicles).

Table 1 demonstrates that over the 3 decades for which information is available, changes to the UK transport network have resulted in a slight increase in travel time and a large increase in travel distance of over 50% (2,500 miles per annum).

From this empirical evidence, we can surmise that past improvements in the UK's transport infrastructure are valuable to travellers but this translates predominantly into a change in how far we travel rather than how much time we spend travelling.

In other words, savings in travel time accrued through an improvement to a part of the transport network leads to travellers on average using these benefits to make longer journeys rather than shorter journeys.

Unfortunately the historical data in Table 1 provides little information on how people would respond to an intervention where travel time is increased. Do people keep their travel distance constant and accept an increase in travel time or keep their travel time constant and reduce their travel distance?

Notwithstanding this limitation, it is the aim of transport models to replicate how travellers respond to changes in transport infrastructure. As such, it is not unreasonable to expect that a transport which is fully capturing traveller responses would demonstrate virtually no net change in the total time spent on travelling at least for improvements to the transport network. Note that this response is not necessarily applicable to the freight industry.

If this is case then what are the implications for economic assessment? In order to answer this question it is necessary to go into some detail in terms of the theoretical background to the economic assessment of transport interventions.

3. ECONOMIC ASSESSMENT OF TRANSPORT INTERVENTIONS

When a transport intervention involves the expenditure of public monies, it is the responsibility of those spending that money to ensure that it is good value-for-money. Another way of expressing this is; will this change benefit society by more than it costs to implement?

This leads to the question of what do we mean by "benefit society"?

In the UK, better off is not restricted to purely fiscal benefits but also to more ethereal benefits such as air quality, improved landscape, lower noise, etc. Put together, these are called *welfare costs*. Not all of these impacts are monetarised but there is a continuing programme of work, both nationally and internationally, to move in this direction.

This paper will focus on a specific sub-set of welfare costs which relate to travel time, vehicle operation (fuel, wear and tear, etc.) and accidents.

3.1 Some (Transport) Economic Theory

The current way of assessing the impact of a transport infrastructure project on the economy comprises two components: a Transport Economic Efficiency Analysis (TEE) and the Economic Activity and Locational Impact (EALI) study. Whilst the TEE aims to capture the net economic benefits of a project at the national level, the EALI is more concerned with the spatial distribution of these national impacts to allow an assessment of the impact on the local economy. The EALI complements the TEE but does not generally identify additional economic impacts that could be added to the TEE results. The EALI, in a sense, deals with the Wider Economic Impacts of transport – who gains who loses and is not directly considered here. Note that the Wider Economic Impacts in terms of distribution considered in the EALI should not be confused with recent work on the Wider Economic Benefits of Transport that seek to improve traditional CBA.

The TEE covers the direct costs of a project (construction, ongoing maintenance etc) and measures the main user benefits in terms of time savings and savings in vehicle operating costs. These impacts all arise within the transport sector and can be thought of as the direct economic impacts of the project. These impacts are expressed in terms of monetary values, by Cost-Benefit Analysis (CBA), which are added together and discounted to produce a Net Present Value (NPV).

A positive NPV implies that the benefits to users are of greater value than the costs whereas a negative NPV implies the benefits have a lower value than the costs. Any project with a positive NPV is, in some sense, worth undertaking, but in order to more easily compare projects of differing size (and costs), a benefit cost ratio (BCR) (the discounted value of benefits divided by the discounted value of costs) is calculated. The BCR represents the net benefit of spending each £1 on the project. If the BCR is greater than one, then, simplistically, the project is worth undertaking.

It is worth noting, that Scottish Transport Appraisal Guidance (STAG) also considers the impacts of a project on the Environment, Accessibility and Social Inclusion, Safety and Integration. No formal weight is given to these four factors and the economy criteria. At present the impacts on the Environment and accessibility and integration are assessed in a non-monetarised manner and do not form part of the NPV or BCR. It is fair to say that this situation is changing and STAG will take cognisance of developments in this area. Where applicable, a significant component of safety benefits is currently monetarised and included within the TEE.

The TEE does not consider employment impacts or GDP directly but the transport costs and benefits captured by the TEE, and collated into an NPV, are intended to represent an acceptable approximation of the full economic impacts of a project, expressed in terms of economic welfare. The SACTRA (1999) report on Transport and the Economy considered in some detail the extent to which these impacts are indeed an acceptable approximation. The report argued that in a notional perfectly competitive economy the net transport benefits of a project as assessed in cost benefit analysis would be identical to the total economic benefits. This was despite the TEE analysis being framed in terms of economic welfare, rather than in terms of key economic variables such as Gross Value Added.

SACTRA considered the implications of relaxing the assumption of a perfectly competitive economy and concluded that standard cost benefit analysis may either under-estimate or over-estimate the full economic benefits of a transport project. However, SACTRA concluded: 'At this stage, the evidence available to us suggests that a fully-specified and properly executed cost-benefit analysis, of the kind traditionally undertaken for transport projects, will often provide a sufficiently good approximation for the size of the total economic impacts…'.

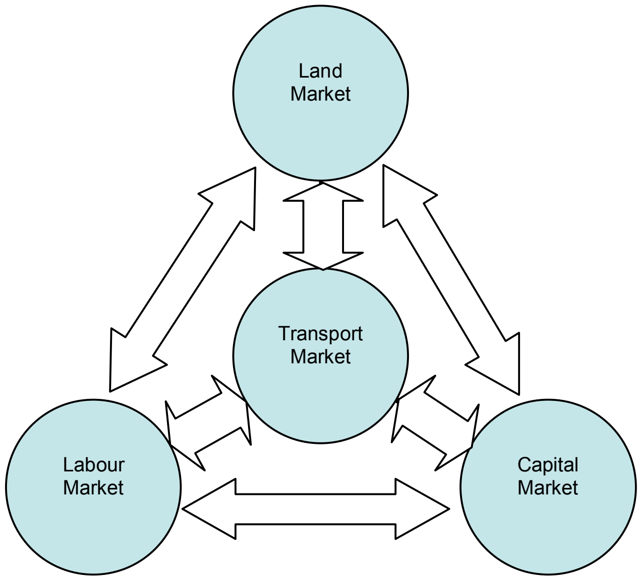
This view has been refined somewhat since the SACTRA report and this refinement process is ongoing. This has lead to work on capturing the Wider Economic Benefits of transport through Agglomeration etc. This is best thought of, and will be seen below, to be an improvement to traditional transport economic analysis rather than a replacement for it.

In order to assess the suitability of a transport model to capture the economic impact of an intervention it is useful to examine, in some detail, the linkages between transport provision and economic growth. A more detailed description can be found in Park, A (2007) and the remainder of this section draws heavily from this paper.

It is helpful to start with the view there is a market for transport provision. Within this market, all transport has a price, but that this price is not simply monetary in nature. Rather, as detailed above, it reflects both money and time. Transport demand should be viewed as the willingness of agents (households, business users etc.) to travel a particular route given the cost of travel and the time it takes. In this context, transport supply is not the physical transport infrastructure per se but the transport services it provides. These services include standard public transport services such as trains and buses but, importantly, also the ability to use private cars on the road network. The interaction of this transport demand and supply results in an equilibrium level of transport provision. It is important to remember, throughout the following discussion, that this equilibrium is the result of significant feedback effects and iteration.

Basic economic analysis talks of the factors of production in an economy being land, labour and capital, being bound together by the entrepreneur. It can be strongly argued that transport has an impact on the markets for all of these three inputs to production. This is illustrated in Figure 1.

Figure 1 - Linkages between transport and economic markets



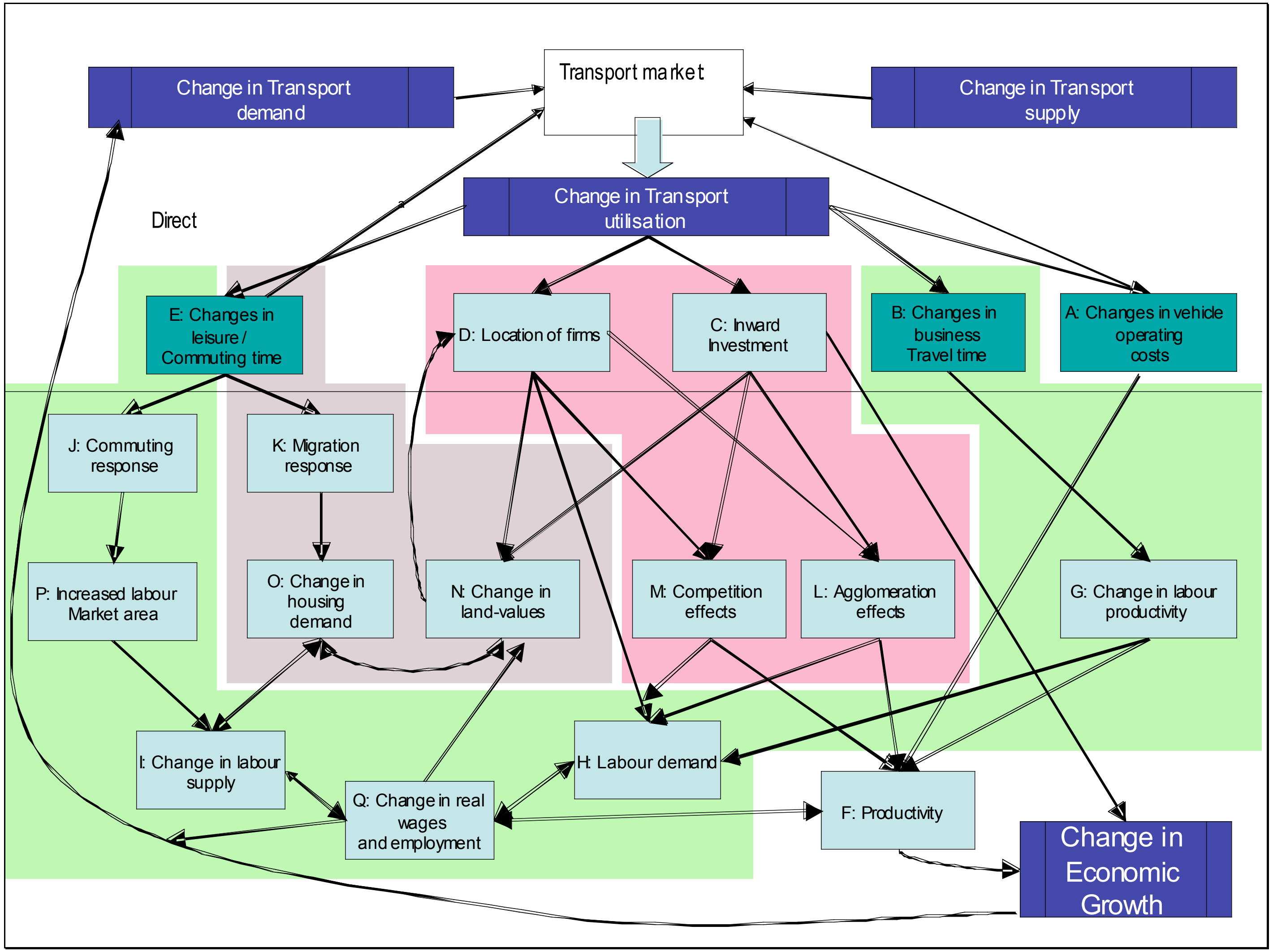
Simplistically, the transport market will have an impact on the labour market through commuting and migration effects on the supply of labour, on the capital market, in terms of the location and productivity of firms and on the land market, in terms of the impact on land prices of increased transport provision. These impacts are complex and interlinked and affect both the supply and demand within each market. As an example, increased transport provision may cause a relocation of firms which will affect the demand for labour, whilst the increased provision may well affect the supply of labour in that area. Both of these impacts are likely to influence the land market through a change in commercial rents and/or house prices.

The next step is to follow through transport's impacts on factor markets to its impact on economic growth. This is illustrated in Figure 2. The top section of the diagram shows the interaction of transport demand and supply, as defined above, through the transport market resulting in a level of transport utilisation. A change in the level of transport utilisation will have five main physical impacts. These physical impacts, detailed below, feed through to potential impacts on economic growth through the processes shown in the lower half of Figure 2.

The 5 main ways in a change in transport utilisation has a physical impact are:

- savings in vehicle operating costs;
- savings in business travel time;
- savings in leisure/commuting time;
- the location of existing firms;
- inward investment.

Figure 2- Linkages between transport and economic growth



Of these 5 factors, the direct impact of three – savings in vehicle operating costs and changes in business/leisure/commuting time - currently form the foundation of Transport Economic Efficiency analysis as detailed above. The impact on the location of firms and potential inward investment is not currently considered in formal appraisal guidance nor is an attempt made to capture the subsequent effects shown in the lower half of Figure 2 nor turn the TEE economic welfare measure into an impact on GVA or employment.

The appropriate framework for considering the impact on economic growth is through changes in (total factor) productivity (Box F in Figure 2) - any change that impacts on productivity will impact on economic growth. If a change in transport utilisation causes increased inward investment then there may be a direct boost to economic growth as the productive capacity of the economy will be increased.

The analysis of changes in vehicle operating costs (Box A) is relatively straightforward. It represents a change in the price of transport, the effect of which on consumers or households is captured by the change in transport demand, whilst the impact on business is that there will be a direct increase in the productivity of the haulage sector which will lead to an improvement in the productivity of the economy as a whole (Box F). Simplistically, existing journeys will cost less and whilst there may be increased demand for journeys, all journeys will have a lower unit cost.

Savings in business travel time (Box B) will have an impact on labour productivity (Box G) and hence labour demand by firms (Box H) and overall productivity (Box F). Savings in leisure and commuting time will have an impact on the supply of labour (Box I) through both a commuting (Box J) and migration (Box K) response. The commuting response will increase the relative size of labour markets (Box P) whilst the migration response will change housing demand (Box O) and impact on land prices more generally (Box N).

The (re)location of firms (Box D) and potential inward investment (Box C) may increase economic performance directly or through agglomeration effects (Box L) - increases in productivity due to the spatial (time rather than distance) concentration of firms – or competition effects (Box M) but will have an impact both directly and indirectly on labour demand (Box H) and an indirect impact on labour supply (Box I) through changes in land-values (Box N) and hence house prices (Box O).

Changes in labour supply (I) and labour demand (H) will result in changes in real wages and hence employment (Q) which will affect productivity and economic growth.

The impact on the capital market is clearly important within this process but the effect on the labour market is central to the impact of transport on the economy as transport affects both labour supply through commuting and migration responses via the land-housing market and labour demand through impacts on product markets. The land-housing market is in turn affected by both the labour market and product markets from the location of individuals and firms.

It will have been noted that the transmission process outlined above is extremely complicated and this goes some way to explain why the current systems are in place. SACTRA's argument was that the use of the measurement of the direct impacts served, all things being equal, as an appropriate proxy for the final impact.

The key question is, however, that by improving transport modelling and moving past the measurement of purely direct impacts to model responses but still using the direct impact as the measure of economic impact is there a danger of underestimating the economic effect of an intervention?

The following section presents a stylised model that acts as initial suggestion that this is an area that requires further work.

4. A SIMPLE ECONOMIC ILLUSTRATION – COMMUTING AND HOUSING LOCATION.

Assume that a country's economy is comprised of a single industrial hub.

Each individual, i, chooses to locate a distance x_i from the hub. This distance is based on the individual's preference between distance and travel time, t_i. Each individual would prefer to be as far from the hub as possible but has a preference against travel time. For simplicity it is assumed that the maximum travel time possible is 1 unit.

In economics, the notion of "Utility" is used to express notions of well-being or happiness in a mathematical form. In this model, each individual has a utility function

$$U_i = x_i^{a_i} (1 - t_i)^{1-a_i}$$

Eq. 1

where a_i is a parameter that reflects the individuals preferences between distance from the hub and travel time. If a = 1, then the individual is only concerned with distance and will locate the maximum distance away from the hub. If a=0, the individual will locate at the hub.

For simplicity it is assumed that the traffic network is stylised by a constant centripetal speed, s. Denote this speed before a transport intervention as s_m and after the intervention as s_s.

As such, the utility function before the intervention can be written as:

$$U_i = x_i^{a_i}\left(1 - \frac{x_i}{s_m}\right)^{1-a_i}$$

Eq. 2

Using standard calculus techniques, maximising this utility function with respect to x_i gives:

$$x_i = a_i s_m$$

Eq. 3

That is to say individuals would prefer to locate a distance away from the hub that is proportional to the travel speed. Thus individual utility is given by:

$$U_i^m = (a_i s_m)^{a_i}\left(1 - \frac{a_i s_m}{s_m}\right)^{1-a_i} = (a_i s_m)^{a_i}(1 - a_i)^{1-a_i}$$

Eq. 4

The point individuals wish to locate is a linear function of s. As s changes, x will change. Within the model this change is "costless" but for expositional purposes it is assumed to take some finite time. Hence, in response to network speed changes, there will be a short run impact purely from the speed change and a long-run impact once location changes.

Now suppose the speed changes to s_s. In the short run, before individuals relocate, Utility is given by:

$$U_i^{SR} = (a_i s_m)^{a_i}\left(1 - \frac{a_i s_m}{s_s}\right)^{1-a_i}$$

Eq. 5

Whereas in the long run, once individuals have relocated, utility is given by:

$$U_i^{LR} = (a_i s_s)^{a_i}\left(1 - \frac{a_i s_s}{s_s}\right)^{1-a_i} = (a_i s_s)^{a_i}(1 - a_i)^{1-a_i}$$

Eq. 6

In terms of Utility as defined by the equations above, $U^m<U^{SR}<U^{LR}$. In other words, utility increases when speed increases and increases still further when this speed induces a change in location.

However, if one turns to measuring travel time savings, then the analysis is as follows:

Initially, travel time for an individual is given by:

$$TT^m{}_i = \frac{x_i}{s_m} = \frac{a_i s_m}{s_m} = a_i$$

Eq. 7

When speed increases to s_s, but before individuals locate, travel time is given by:

$$TT^{SR}{}_i = \frac{x_i}{s_s} = \frac{a_i s_m}{s_s}$$

Eq. 8

And after relocation, travel time is given by:

$$TT^{LR}{}_{i} = \frac{x_i}{s_s} = \frac{a_i s_s}{s_s} = a_i$$

Eq. 9

Comparing the first and third travel time equation, demonstrates the extremely stylised view of the world within this model. After relocation there are no travel time savings. Travel time savings, as measured before relocation are positive (assuming $s_s>s_m$) but individuals use all of this saving up in relocating. In other words, individuals act in such a way as to convert travel time savings into a location impact. Whilst this may be seen as extreme, it is consistent with the empirical evidence presented earlier in this paper.

So in this stylised view of the world, the measurement of travel time savings after individuals have changed location results in a measurement of zero benefit when, in terms of utility, the model predicts an increased benefit (and an increase over the situation before relocation).

Of course this is a very simplistic view of the world and does not take into account either the fact that relocation is costly or perhaps more importantly, interactions within labour or product markets. It does serve to demonstrate however that the issue of when to measure economic benefits is one worthy of further investigation.

5. CONCLUSIONS AND RECOMMENDATIONS

The assessment of the economic impact of transport interventions would ideally involve the quantification of the impact that travel has on the broad economic factors, of production: land, labour and capital, how impacts in these sectors affect productivity and hence the impact on economic growth. However, as has been demonstrated this is a hugely complex issue and although improvements are being made, the calculation of the change in travel time costs from a transport intervention is used as a proxy for these true economic responses.

However, the empirical evidence in the paper has demonstrated that for personal travel, travel time is largely constant.

How do we reconcile this apparent inconsistency? The answer lies in understanding which traveller responses to improvements in the transport network are part of the *true* economic welfare impacts and to ensure these are not included in the *proxy* economic welfare impacts.

Whilst it is suggested that this is an area that requires some considerable further investigation, it is possible to draw some preliminary conclusions, or at least to ask some key questions.

Firstly, in modelling terms:

- Which responses should be enabled for the assessment of travel time costs?
- Which responses should be enabled for the assessment of vehicle operating costs?
- Which responses should be enabled for the assessment of accident costs?

These questions, regardless of the answers, have implications for *Model Structure*.

Many transport models adopt a ‘4-stage’ process that considers trip generation, mode choice, trip destination and assignment. The initial stage of the process is always trip generation. The final stage is always assignment. The intermediate stages of mode choice and trip destination though can be either way round, i.e. mode choice precedes trip destination or vice versa. The choice of which stage precedes which, may affect the ability to “turn off” the intermediate stages.

In terms of the answers to these questions, this paper is considered to be a preliminary examination of the issue but it is possible to offer some initial thoughts. The conclusions of the simplistic theoretical model outlined in Section 4 suggest that it may be inappropriate to enable destination choice for the assessment of travel time savings for personal travel at least. It would seem sensible that a similar approach is taken for the assessment of vehicle operating costs.

Accident savings may well be different however. Although accident savings are included, separate to the Transport Economic Efficiency analysis, as part of the Benefit Cost Ratio (although the forthcoming STAG refresh will recommend that they are additionally reported separately), they are a direct impact – the reduction in accidents given a monetary value, - and it would seem sensible that they are assessed on the most accurate prediction of final traffic levels that is possible. In other words, all modelling responses should be enabled.

This has a fairly major implication. If the conclusions of this paper are confirmed and are to be followed in practice, any model which has a range of traveller responses must be developed in such a way as to allow those responses which are not to be considered in the economic assessment to be disabled without affecting those responses which still need to be enabled. This may be problematic.

5.1 The continuing need for full response assessment

The economic welfare assessment of a scheme is only one part of the transport appraisal process. The impact of a scheme on the environment, accessibility, etc. requires predictions of the vehicle and person demands with all responses to the scheme considered. Additionally, the conclusions of the previous section suggest that full modelling response is appropriate for the assessment of accident impacts.

Developing the business case for a Public Transport scheme will require predictions of likely passenger demand with the scheme in place and the changes that will occur in where people and businesses may locate as a result of the scheme progressing. As such, it is not the suggestion of this paper that improvements in transport modelling are not required but simply that, at this stage, further thought needs to be given to when and how, in the context of such models it is most appropriate to undertake the economic assessment. It is likely that different elements of the economic assessment are performed at different times.

5.2 Further Work

This paper has focussed on the economic assessment of permanent transport interventions which are introduced in response to problems identified by either national or local government. Within this context the paper has identified a potential issue and it is suggested that there is a need to explore this further.

There is another type of permanent intervention which has not been considered within this paper. This is where a change is made to the transport network to enable access to a new land-use. The transport use generated by this change in land-use is obviously important and complicates significantly the issues raised in this paper.

As well as permanent interventions there is also the case of temporary interventions. These may be either planned, such as road works and event management, or unplanned, such as accidents or adverse weather conditions. As discussed in this paper, the value of time (either lost or saved) through changes to the transport network is a proxy for the response of economic welfare to an intervention. With temporary changes the short and long-run issues discussed in section 4 become of critical importance. Just how short is the short run?

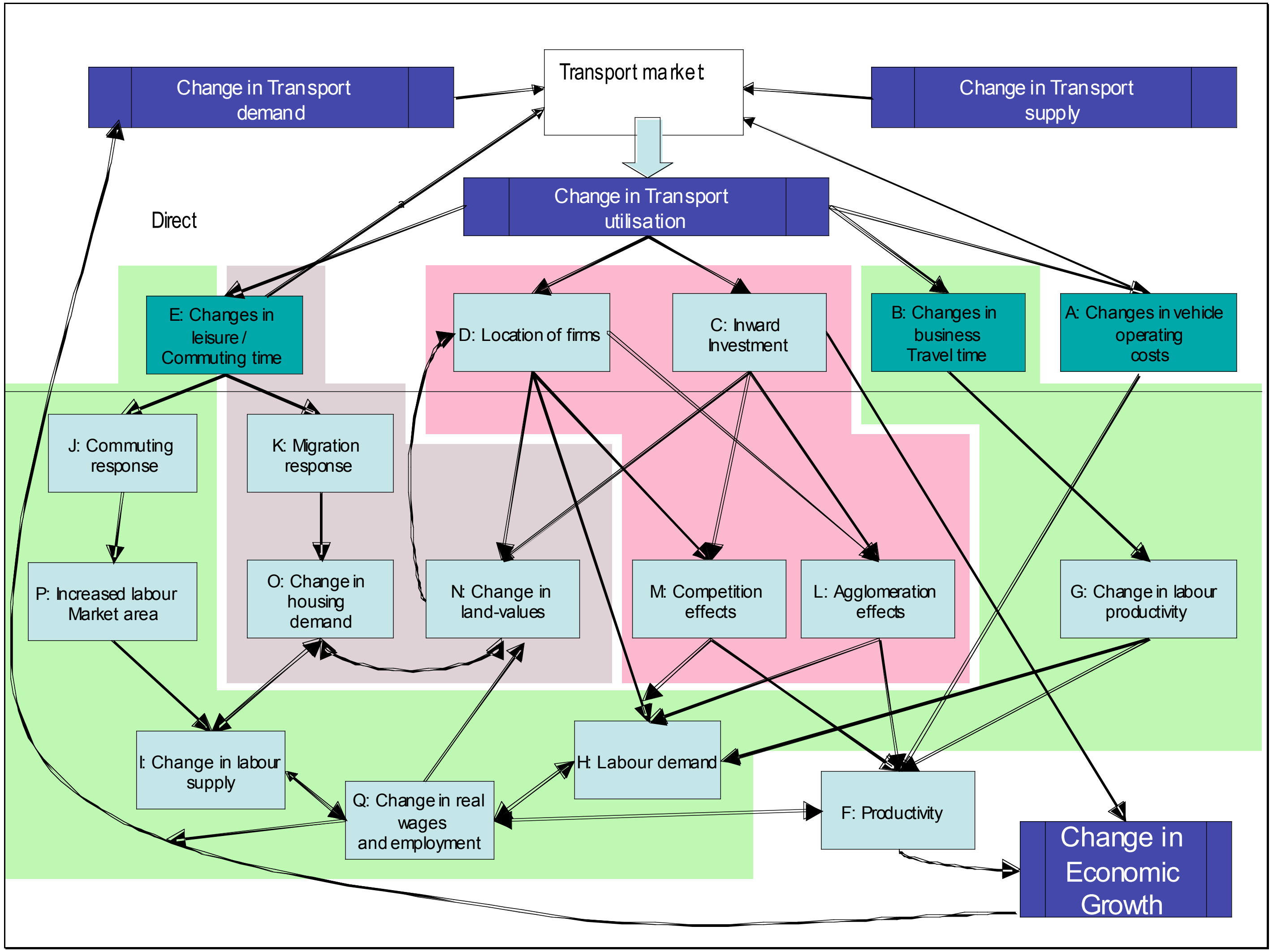
Bibliography

National Travel Survey: 2006, Department for Transport, London.

Standing Advisory Committee on Trunk Road Assessment (1997), *Transport and the Economy*, HMSO, London.

Park, A (2007), An Examination of the Linkages between Improvements in Transport Provision and the Economy, Scottish Government Economic Service Discussion Paper (http://www.scotland.gov.uk/Topics/Economy/17858/10374)

Figure 2- Linkages between transport and economic growth



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Eq. 3

That is to say individuals would prefer to locate a distance away from the hub that is proportional to the travel speed. Thus individual utility is given by:

$$U_i^m = (a_i s_m)^{a_i}\left(1 - \frac{a_i s_m}{s_m}\right)^{1-a_i} = (a_i s_m)^{a_i}(1 - a_i)^{1-a_i}$$

Eq. 4

The point individuals wish to locate is a linear function of s. As s changes, x will change. Within the model this change is "costless" but for expositional purposes it is assumed to take some finite time. Hence, in response to network speed changes, there will be a short run impact purely from the speed change and a long-run impact once location changes.

Now suppose the speed changes to s_s. In the short run, before individuals relocate, Utility is given by:

$$U_i^{SR} = (a_i s_m)^{a_i}\left(1 - \frac{a_i s_m}{s_s}\right)^{1-a_i}$$

Eq. 5

Whereas in the long run, once individuals have relocated, utility is given by:

$$U_i^{LR} = (a_i s_s)^{a_i}\left(1 - \frac{a_i s_s}{s_s}\right)^{1-a_i} = (a_i s_s)^{a_i}(1 - a_i)^{1-a_i}$$

Eq. 6

In terms of Utility as defined by the equations above, $U^m < U^{SR} < U^{LR}$. In other words, utility increases when speed increases and increases still further when this speed induces a change in location.

However, if one turns to measuring travel time savings, then the analysis is as follows:

Initially, travel time for an individual is given by:

$$TT^m{}_i = \frac{x_i}{s_m} = \frac{a_i s_m}{s_m} = a_i$$

Eq. 7

When speed increases to s_s, but before individuals locate, travel time is given by:

$$TT^{SR}{}_i = \frac{x_i}{s_s} = \frac{a_i s_m}{s_s}$$

Eq. 8

And after relocation, travel time is given by:

$$TT^{LR}{}_i = \frac{x_i}{s_s} = \frac{a_i s_s}{s_s} = a_i$$

Eq. 9

Comparing the first and third travel time equation, demonstrates the extremely stylised view of the world within this model. After relocation there are no travel time savings. Travel time savings, as measured before relocation are positive (assuming $s_s > s_m$) but individuals use all of this saving up in relocating. In other words, individuals act in such a way as to convert travel time savings into a location impact. Whilst this may be seen as extreme, it is consistent with the empirical evidence presented earlier in this paper.

So in this stylised view of the world, the measurement of travel time savings after individuals have changed location results in a measurement of zero benefit when, in terms of utility, the model predicts an increased benefit (and an increase over the situation before relocation).

Of course this is a very simplistic view of the world and does not take into account either the fact that relocation is costly or perhaps more importantly, interactions within labour or product markets. It does serve to demonstrate however that the issue of when to measure economic benefits is one worthy of further investigation.

5. CONCLUSIONS AND RECOMMENDATIONS

The assessment of the economic impact of transport interventions would ideally involve the quantification of the impact that travel has on the broad economic factors, of production: land, labour and capital, how impacts in these sectors affect productivity and hence the impact on economic growth. However, as has been demonstrated this is a hugely complex issue and although improvements are being made, the calculation of the change in travel time costs from a transport intervention is used as a proxy for these true economic responses.

However, the empirical evidence in the paper has demonstrated that for personal travel, travel time is largely constant.

How do we reconcile this apparent inconsistency? The answer lies in understanding which traveller responses to improvements in the transport network are part of the *true* economic welfare impacts and to ensure these are not included in the *proxy* economic welfare impacts.

Whilst it is suggested that this is an area that requires some considerable further investigation, it is possible to draw some preliminary conclusions, or at least to ask some key questions.

Firstly, in modelling terms:

- Which responses should be enabled for the assessment of travel time costs?
- Which responses should be enabled for the assessment of vehicle operating costs?
- Which responses should be enabled for the assessment of accident costs?

These questions, regardless of the answers, have implications for *Model Structure*.

Many transport models adopt a '4-stage' process that considers trip generation, mode choice, trip destination and assignment. The initial stage of the process is always trip generation. The final stage is always assignment. The intermediate stages of mode choice and trip destination though can be either way round, i.e. mode choice precedes trip destination or vice versa. The choice of which stage precedes which, may affect the ability to "turn off" the intermediate stages.

In terms of the answers to these questions, this paper is considered to be a preliminary examination of the issue but it is possible to offer some initial thoughts. The conclusions of the simplistic theoretical model outlined in Section 4 suggest that it may be inappropriate to enable destination choice for the assessment of travel time savings for personal travel at least. It would seem sensible that a similar approach is taken for the assessment of vehicle operating costs.

Accident savings may well be different however. Although accident savings are included, separate to the Transport Economic Efficiency analysis, as part of the Benefit Cost Ratio (although the forthcoming STAG refresh will recommend that they are additionally reported separately), they are a direct impact – the reduction in accidents given a monetary value, - and it would seem sensible that they are assessed on the most accurate prediction of final traffic levels that is possible. In other words, all modelling responses should be enabled.

This has a fairly major implication. If the conclusions of this paper are confirmed and are to be followed in practice, any model which has a range of traveller responses must be developed in such a way as to allow those responses which are not to be considered in the economic assessment to be disabled without affecting those responses which still need to be enabled. This may be problematic.

5.1 The continuing need for full response assessment

The economic welfare assessment of a scheme is only one part of the transport appraisal process. The impact of a scheme on the environment, accessibility, etc. requires predictions of the vehicle and person demands with all responses to the scheme considered. Additionally, the conclusions of the previous section suggest that full modelling response is appropriate for the assessment of accident impacts.

Developing the business case for a Public Transport scheme will require predictions of likely passenger demand with the scheme in place and the changes that will occur in where people and businesses may locate as a result of the scheme progressing. As such, it is not the suggestion of this paper that improvements in transport modelling are not required but simply that, at this stage, further thought needs to be given to when and how, in the context of such models it is most appropriate to undertake the economic assessment. It is likely that different elements of the economic assessment are performed at different times.

5.2 Further Work

This paper has focussed on the economic assessment of permanent transport interventions which are introduced in response to problems identified by either national or local government. Within this context the paper has identified a potential issue and it is suggested that there is a need to explore this further.

There is another type of permanent intervention which has not been considered within this paper. This is where a change is made to the transport network to enable access to a new land-use. The transport use generated by this change in land-use is obviously important and complicates significantly the issues raised in this paper.

As well as permanent interventions there is also the case of temporary interventions. These may be either planned, such as road works and event management, or unplanned, such as accidents or adverse weather conditions. As discussed in this paper, the value of time (either lost or saved) through changes to the transport network is a proxy for the response of economic welfare to an intervention. With temporary changes the short and long-run issues discussed in section 4 become of critical importance. Just how short is the short run?

Bibliography

National Travel Survey: 2006, Department for Transport, London.

Standing Advisory Committee on Trunk Road Assessment (1997), *Transport and the Economy*, HMSO, London.

Park, A (2007), An Examination of the Linkages between Improvements in Transport Provision and the Economy, Scottish Government Economic Service Discussion Paper (http://www.scotland.gov.uk/Topics/Economy/17858/10374)