Article:

Laird, JJ, Nash, C and Mackie, PJ (2014) Transformational transport infrastructure: cost benefit analysis challenges. Town Planning Review, 85 (6). 709 - 730 (21). ISSN 0041-0020

https://doi.org/10.3828/tpr.2014.43

TRANSFORMATIONAL TRANSPORT INFRASTRUCTURE: COST BENEFIT ANALYSIS CHALLENGES

7th February 2014

(accepted for publication in *Town Planning Review*)

James Laird Chris Nash and Peter Mackie

Institute for Transport Studies

38-40 University Rd

University of Leeds

Leeds LS2 9JT

Research interests:

James Laird (J.J.Laird@its.leeds.ac.uk): cost benefit analysis; value of travel time savings; rural transport appraisal; wider economic benefits; and demand forecasting.

Chris Nash (C.A.Nash@its.leeds.ac.uk): rail transport; transport appraisal; transport pricing and externalities.

Peter Mackie (P.J.Mackie@its.leeds.ac.uk): cost benefit analysis; transport appraisal, value of travel time savings; wider economic benefits; and bus regulation

TRANSFORMATIONAL TRANSPORT INFRASTRUCTURE: COST BENEFIT ANALYSIS CHALLENGES

ABSTRACT

Current economic conditions are dominated by the imperative for growth, so the planning context to transport infrastructure is increasingly one of supporting economic growth. This change creates challenges for the appraisal of transport projects particularly transformational ones. In this paper, the technique of transport cost-benefit analysis (CBA) is reviewed with particular emphasis on incorporating the wider economy impacts. CBA is a robust framework, but when dealing with truly transformational projects where land uses change, CBA methods need to develop. Further empirical evidence on the scale of economic change induced by the change in accessibility is also needed.

KEY WORDS

Transformational projects; cost benefit analysis; land use change; economic impact; transport appraisal

TABLE OF CONTENTS

1. INTRODUCTION 1
2. TRANSPORT COST BENEFIT ANALYSIS 5
3. TRANSPORT BENEFITS—AN ECONOMY WIDE INTERPRETATION 9
4. THE REST OF THE ECONOMY 13
5. PREDICTING TRANSFORMATIONAL IMPACTS 18
6. COST BENEFIT ANALYSIS VERSUS GROSS VALUE ADDED METRICS 23
7. CONCLUSIONS 25
REFERENCES 27
ACKNOWLEDGEMENTS 39

1. INTRODUCTION

Transform (verb): make (especially considerable) change in form, appearance, character, disposition, etc., of.

Oxford Dictionary (Sykes, 1978)

Transport infrastructure has the ability to transform. It can transform many aspects of our lives including where we choose to work, where we choose to live, the range of available goods and their prices, where our children go to school, where we go on holiday. It also has a profound impact on the urban landscape. The motor car transformed the shape and feel of our streets, and now pedestrianisation by removing the car transforms the environment of city centres. It is widely believed that trams can also transform cities. Whether or not a tram changes the way we travel or creates economic growth it has an iconic visual impact frequently used in mass media as an image of the city. Interregional and international transport projects are also seen as agents of economic change through their impact on connectivity:

> *"Like the original coming of the railways, HSR* [High Speed Rail] *has the potential to transform the shape of the national economy and make a substantial contribution to economic growth."*

(KPMG, 2010 p3)

This paper addresses a specific issue that has come to the fore in recent years; how to conduct project appraisal so as to inform public decisions on major transport projects that potentially could transform an economy. It has been forcefully argued that cost-benefit analysis, with its emphasis on valuing travel time savings, is not able to capture all the benefits of such projects and that new approaches to examining the impact of transport projects on land use and on the economy are needed (e.g. Network Rail, 2010). Differences in the economic benefits from a cost benefit analysis and an economic impact analysis (also known as a Gross Value Added (GVA) approach) are cited as support for this position. For instance, for the proposed high speed rail line from London to Birmingham, Manchester and Leeds (HS2) KPMG (2013) estimated an increase of GVA to the national economy of £15 billion per annum. In contrast the present value of benefits from the CBA is expected to be £63.6 billion (over a 60 year period) (HS2, 2012 p3). That is the 60 year benefits (albeit discounted) are expected to only be 4 times a single year's GVA gain. For another major infrastructure project, Heathrow Airport, it has been argued that if it is not expanded economic activity in the UK (as measured by GDP[1]) would be reduced by £8.5 billion each year and employment would be lower by 141,400 (compared to an unconstrained case) (Oxford Economics, 2012). Much of this economic activity is no doubt transferred from hubs elsewhere in the world, but still it is an economic gain to the UK. In contrast the 60 year present value of benefit in the cost benefit analysis is £20.7 billion[2] (MTRU, 2008 p6). That is the 60 year (discounted) benefit from the cost benefit analysis is only 2.5 times a single year's GDP impact.

Undoubtedly the fact that transport tends to re-distribute economic activity, means that local impacts can be very high. For example the Northern Hub (a significant expansion of rail capacity in Manchester) is estimated to generate an additional £2.1billion in GDP for the North of England of which £0.9 billion is additional to the UK economy (GMPTE, 2010).

[1] Gross Domestic Product (GDP) is GVA plus indirect taxes.

[2] Net Present Value of £9.05 billion and a Benefit Cost ratio of 2.29.

However, even here the projected GVA gain at a national level seems to be much higher than the expected present value of benefits from the cost benefit analysis – where 60 year present value of benefits is estimated to be £12.7 billion (SDG, 2009 p76), i.e. the 60 year benefits (albeit discounted) are only 13 times greater than a single year's national GVA gain and only 6 times larger than a single year's regional GVA gain.

There also exists a view that the results of welfare economics are arcane and unconvincing to decision makers. Mouter et al. (2013) for example finds that spatial planners and transport professionals are sceptical about the role that cost benefit analysis should play in appraisal decision-making, whilst other commentators have found that investment decisions are only partially, if at all, influenced by cost benefit analysis results (Nilsson, 1991; Odeck, 1996, 2010; Nyborg, 1998; Eliasson and Lundberg, 2012; Laird et al., 2012). These arguments are being played out against a background of institutional changes such as the City Deal in England (HM Government, 2012) – where decision-making is de-centralised to local government who have been given the priority of maximising economic growth at the regional level. This has led to a further upsurge in interest in methods for calculating the GDP or Gross Value Added effects of major projects. For example Greater Manchester is now prioritising its transport investments to maximise the GVA of Greater Manchester (Association of Greater Manchester Authorities and Greater Manchester Integrated Transport Authority, 2011); South Yorkshire is prioritising transport investments to maximise the Sheffield City Region's GVA subject to a minimum constraint that certain social and geographic constraints are met (Sheffield City Region Local Enterprise Partnership, 2013); and the Leeds City Region is doing the same (LCR, 2012 p13).

However, arguably cost benefit analysis is a more holistic and equitable[3] approach to investment decision-making than an approach based off a single indicator - such as GVA. Such a narrow approach does not account for the social benefits of personal travel, nor the costs or benefits of changes in journey time, safety or in the burden placed on the environment. CBA uses values that society place on these benefits and costs rather than weights from a 'representative' set of stakeholders, and therefore is not as vulnerable to 'pork barrel politics' critiques than other methods. In this paper we therefore explore the challenges faced when using cost benefit analysis to appraise transformational transport projects, why cost benefit analysis results will differ from economic impact analyses (i.e. GVA metrics) and finally consider whether or not it is an appropriate tool for use in the planning of transformational projects. In addressing these questions we focus on transformational in an economic sense, that is projects that transform the economy of a nation or a region by facilitating a step change in one or more of the number of jobs, the quality of jobs, business performance, economic output (GVA), and wealth. To help set the context we illustrate the paper by drawing on the British high speed rail proposals introduced earlier.

A characteristic of long lived infrastructure projects is uncertainty. Benefits and revenues depend on growth rates of population and income per head and on changes in preferences across several technical revolutions over the life of the project. Inevitably there will be error in forecasts and in benefit valuation. Added to this is the possibility of bias: decision makers may become committed to projects in advance of the supporting evidence base and analysis

---

[3] See Wong and Webb (2014) in this special issue for a discussion on spatial equality issues associated with transformational infrastructure.

and optimism bias may result (Mackie and Preston,1998, Flyvbjerg 2006). These are features common to all forms of decision analysis and are not considered further here.

After introducing the key principles of transport cost benefit analysis in the second section of this paper, we examine the appropriateness of cost-benefit analysis as a tool for assessing transformational projects. In particular, we explore issues relating to benefit measurement (section 3), the treatment of impacts on the rest of the economy (section 4) and the forecasting of the economic impacts (section 5). We then briefly compare cost benefit analysis (CBA) and Gross Value Added (GVA) approaches in section 6, before concluding.

2. TRANSPORT COST BENEFIT ANALYSIS

Transport cost benefit analysis as conventionally deployed is a partial equilibrium method in which prices are taken to equal marginal social costs outside of the transport market. The benefits of a project can therefore be computed by summing the user benefits, the changes in producer surplus (of transport operators) and environmental and safety externalities. At the core of transport cost-benefit analysis lies the computation of the user benefits using the so-called 'rule of a half' measure (Neuberger, 1971). A transport improvement is associated with a change in generalised user costs ($TC_0 - TC_1$ in Figure 1(a)) so that the rule of a half measure of user benefit is:

$$\tfrac{1}{2}(TC_0 - TC_1)(X_0 + X_1) \qquad \text{(Equation 1)}$$

Where: TC_0 and TC_1 are the transport costs before and after the transport intervention

X_0 and X_1 are the transport demands before and after the transport intervention.

Much of the effort in practical appraisal involves measuring this in time and space (zones, links, peak, off-peak, this year, in ten years time) and then in aggregating the benefit over the life of the project. Although conceptually clear, this is quantitatively challenging because the single demand curve in Figure 1 is representative of a family of interdependent travel demand curves which interact when costs in one part of the demand system change (Mackie and Nellthorp, 2001).

<Insert Figure 1 around here>

Our interest in this paper is in whether the indirect benefits that a transformational transport project has on the labour market, the product market and the land market and their dynamic interaction are fully captured in such an approach. In the 1950s and 1960s the economic impact of transport infrastructure such as the Severn Bridge (Cleary and Thomas, 1973) and the Transpennine M62 motorway (Dodgson, 1974) were studied, and the necessary theory was developed (Dodgson, 1973; Mohring, 1976). In essence transport user benefits, the direct benefits of a transport project, link into other markets by lowering input costs of production leading, under competitive conditions, to a fall in outturn prices (P_0 to P_1 in Figure 1(b)). With elastic demand this leads to an expansion in output and employment, possibly generating second order effects in all markets, until a new equilibrium is reached. This is depicted in Figure 1 for the case of a reduction in business and freight costs. Theory indicates that the surpluses generated in the wider economy, that is the indirect benefits represented by surpluses C and E in Figure 1(b) and Figure 1(c), double count the direct benefits of the project (Area A plus Area B) and are not additional (Dodgson, 1973, Jara-Diaz, 1986; Mohring, 1993; Boardman *et al*., 2011 p121. Rouwendal, 2012). Furthermore with an elastic supply of products/services, labour or any other input to the production process (e.g. land) the transport market is the only market in which a full measure of the benefits of the transport quality improvement can be measured. This is the intellectual justification for the adage 'Measure the direct transport benefits accurately and you will have a fair proxy for the total economic benefits of a scheme.' (ACTRA 1977 Appendix G for example).

The virtue of this approach is the strong link between the modelling of the physical changes in travel time, cost and other journey attributes and the estimation of social value for money in the cost-benefit analysis. There are fundamentally good arguments for coherence between predicting the outcome of changing the transport system in a model, and valuing the benefits to users, operators and the rest of society.

There are however some problems with this approach. The first is that it only holds good for a perfectly competitive economy. The presence of imperfect competition, economies of scale or production externalities destroys the equivalence between transport benefits and the full economic impact of a project. There also exists an obvious disconnect between a method that focuses on the direct transport impacts and what some transport scheme promoters, especially politicians, are really interested in – the impact of building a piece of new infrastructure on the local or regional economy. A combination of economic and institutional forces have increased the strength of this disconnect in recent years. This does not mean that the output from a cost benefit analysis is wrong but it does put the methods and assumptions of cost benefit analysis under a spotlight, particularly where transformational impacts on a local or national economy are expected.

Three features of the apparatus of Figure 1 are worthy of attention. Firstly, it is tacitly assumed in the presentation of such diagrams that the rectangle of benefits to baseload users[4] (area A) is large relative to the triangle of benefits to induced traffic (B). For many transport projects which are incremental in nature, this assumption is quite reasonable. But for step-change projects such as the railroads to the American West or the UK canal system, the ratio of the triangle to the rectangle will be large, raising questions of how to forecast induced changes in demand and final equilibrium with any confidence. At some level, partial equilibrium methods break down and a study of the impact on the economy as a whole is required.

Secondly, in an all-round competitive market, area D and area F are of little consequence. The increased value of output to the economy is exactly counterbalanced by the increased resource cost of production (including the foregone leisure time required to work). But if markets are imperfect, divergences –possibly large—arise between the two quantities. Our observation is that while the economic/engineering approach underpinning transport CBA places high weight on A plus B as the key appraisal indicator, the recent shift by planners' in the UK towards the use of the change in GVA as the main decision criteria tends to emphasise Areas D and Area F [5]– the latter of which does not form part of a CBA.

---

[4] Users who are predicted to travel with or without the improvement.

[5] Area D represents the expansion in output (at ex post prices), whilst areas E plus F are the increase in earnings. An estimation of a change in GDP would only use one of these areas

Thirdly, practical transport CBA tends to be restrictive in its assumptions, and specifically tends to assume fixed land-use patterns. This jars with the objectives of transformational projects which are expected or intended to change land-use. This is especially true of the type of project which has land-unlocking characteristics. Linked land-use and transport interaction models are challenging for appraisal. It has been known for years that the rule of half measure cannot be used to evaluate the benefits of combined transport and land-use change where the attractiveness of locations alters (Neuberger 1971). Instead direct integration of the accessibility function is needed – a function that needs to capture how the attractiveness of locations alters with changes in land uses (Neuberger, 1971; Martinez and Araya, 2000; Simmonds, 2004; Bates, 2006). Applications of such approaches include Geurs *et al.*, (2006; 2010), Hensher *et al.* (2012) and Simmonds *et al.* (2012).

3. MEASUREMENT OF TRANSPORT BENEFITS

The prime way in which transport projects work is by changing the pattern of accessibility at local, regional, or in rare cases, national level. So, modelling the impact of transport projects involves prediction of the changes in time, reliability, cost and other travel attributes. These changes in generalised cost are then channelled in dozens of ways through to changes in the value of economic output to the final consumer. Whether the benefits measured in the transport market are taken to stand proxy for an outcome spread widely across the economy, or more sophisticated methods are being used to attempt to measure the ultimate changes these transport benefits drive, correct valuation of the transport benefits

– which area is dependent on the method used. An income based method (GVA approach) would use Area E plus F, whilst an expenditure method would use Area D.

remains crucial. However, there is an issue about whether the values used for travel time and reliability are in fact good proxies. Are the values right?

This is important because time and reliability benefits for all journey purposes typically account for the majority of monetised benefits in the benefit:cost ratios of transport infrastructure projects, with most of this accruing to employers' business and freight traffic. For example time savings form more than half of all user benefits for the proposed London to West Midlands high speed rail line, and business time savings are almost three times those for non-work time savings (DfT, 2012 Table 10 p42). Whilst arguments can be constructed that non-work user benefits can via commuting cost and wage effects grow an economy, the lion's share of the economic impacts of a transport project are created by the efficiency gains employers experience.. Measuring the direct use benefits employers experience is therefore critical to ensuring economic impacts are fully captured. This is never more important than for transformational transport projects as such projects are expected to transform business operations.

The most popular approach adopted in valuing savings in travel time on employers business is the cost saving approach (Odgaard, Kelly and Laird, 2005). This says that in a competitive labour and product market, firms hire labour to the point at which the value of the marginal product is equal to the wage rate; thus the value of the time saving is equal to the marginal gross cost of labour including labour related overheads. To arrive at this conclusion a number of well documented assumptions are implied regarding the labour market and the allocation of time between work and leisure (Harrison, 1974). The assumptions that time released by the travel time saving goes into work not leisure, that travel time is unproductive and that the business traveller is indifferent between travelling and working were first challenged by Hensher (1977). Since then developments such as flexitime, the mobile office (phones, wi-fi, etc.) and changes in the economic structure and the importance of the service sector have made these assumptions appear less plausible. The remaining criticisms of the cost saving approach – which are equally applicable to the Hensher approach - concern whether the wage rate really approximates the value of the marginal productivity of labour (this requires a competitive labour and product market and no involuntary unemployment) and whether indivisibilities in the use of time for production exist. The cost saving approach is a rickety edifice on which to base the valuation of a large fraction of the transport benefits unless it can be buttressed or supported in other ways.

Accounting for productivity whilst travelling significantly lowers the value of business travel time savings compared to values derived from the cost saving method (Fickling *et al.*, 2008). These arguments have sprung to life in the context of high speed rail in the UK. On the one side are those who say that it is obvious that rail travel time is partially productive so that an adjustment is required to the cost saving approach. On the other are those who say that the willingness of businesses to pay a very high price for a peak ticket from say Manchester or Leeds to London demonstrates the value companies place on additional time for their workers at that destination, enabling more meetings to be fitted into one day and therefore avoiding the need to make further journeys or to stay overnight. Given these competing arguments which cannot be resolved by theory the value of business travel time savings becomes even more an empirical matter. In one of the earlier empirical studies on the value of business travel time savings Fowkes, Marks and Nash (1986) whilst finding "no empirical support for the assumptions upon which the present valuation conventions are based [the cost saving approach], [their] empirical work suggests these conventions yield values which are approximately correct". They therefore found that the two arguments empirically roughly cancel each other out. Such a finding is of course dependent on the sample and the technology available – which in Fowkes, Marks and Nash's case was primarily long-distance rail travellers using 1986 technology. Many further studies of the willingness to pay for medium and long distance business travellers to save time have confirmed a value several times that for leisure travel or commuting (Wardman, 2004; Abrantes and Wardman, 2011).

Similarly, there are uncertainties relating to the value of freight time savings and also to valuing reliability. Once again there two approaches exist to valuation: bottom up cost saving approaches and more top-down willingness to pay studies. We do not review the methods associated with valuing reliability and the benefits to freight traffic here (see de Jong *et al.*, 2004a for a review) but make two observations pertinent to the objectives of this paper. Firstly, transformational transport projects (e.g. London Gateway) have the potential to transform supply chains. Mackie and Simon (1986) for example found that the Humber Bridge led to internal re-organisation of firms facilitating "a more transport-intensive solution to the production/ distribution problem than would otherwise have been feasible". A much more intense modelling effort is therefore required to take into account network effects in the supply chain including the spatial re-organisation of distribution operations (Laird, Nellthorp and Mackie, 2005). Secondly, with respect to reliability the potential benefits of improved reliability to business are expected to be large (SACTRA, 1999; McQuaid *et al.*, 2004). Some progress has been made on valuing changes in reliability to businesses (Noland and Polak, 2000; Eliasson, 2004; De Jong et al., 2004b) and the use of simulation models in the modelling of supply side effects.

Clearly where transformational transport projects are concerned a much greater effort needs to be made to model the changes in accessibility and the values associated with it than is the case for more incremental projects. If that effort is not made then the cost benefit analysis and the whole decision making process is weaker as a consequence.

4. IMPACTS ON THE REST OF THE ECONOMY

Transport cost benefit analysis is a partial equilibrium method. Prices are taken to equal or at least broadly approximate marginal social costs in secondary markets (labour, land, etc.). The implication is that changes in demand in secondary markets do not generate additional benefits over and above thos in transport markets. Such secondary markets are therefore excluded from the cost benefit analysis. If however prices do not equal marginal social costs in the secondary markets, the primary transport market surpluses do not capture all the benefits of the project. As SACTRA (1999) showed, excluding the secondary markets from the appraisal may either over or underestimate the total economic impact of the transport project. For transformational transport projects this point is important as by their nature we expect the transformational projects to deliver large and significant additional benefits outside the transport market. Evidence suggests three market failures affecting secondary markets of labour and goods/products are relevant in terms of the scale of additional surplus they may generate:

- **Agglomeration externalities.** Productivity is observed to be higher in locations which have large economic mass. As transport improvements affect economic mass they can potentially increase productivity more than would be expected from the time and cost saving alone (SACTRA, 1999; Venables, 2007).
- **Imperfect competition in the product market.** Firms product differentiate as a means of maintaining market power. Additionally in geographically dispersed markets firms hold some degree of market power. As firms in monopolistic markets restrict output below that at which price equals marginal cost, an expansion of output has an additional benefit equal to the difference between price and marginal cost over and above what is reflected in the transport market.
- **Market failures in the labour market.** Two sources of labour market failure are relevant. Firstly, income taxes distort the labour market. As a consequence if total earnings alter (either through moves to more productive jobs or increases in employment) surpluses will occur in the labour market (in the form of changes in tax revenue) additional to transport user benefits. Secondly, if unemployment is more than just frictional then some form of market failure is preventing the wage dropping to a level that clears the labour market. In such circumstances not all the surplus associated with increasing employment is double counted by transport user benefits.

If these market failures are present then a cost benefit analysis that only considered the transport market – neglecting both the product market for goods and services and the labour market – would give an incorrect estimate of the economic impact of the transport project. . A fully specified cost benefit analysis would need to take a multi-market approach

– looking at surpluses that occur in each of the relevant markets and then adjusting these surpluses for double counting where relevant.

Venables (2007) uses a multiple market spatial computable general equilibrium (SCGE) model of a conceptual city economy to demonstrate that including agglomeration effects on productivity in an economic appraisal could give rise to between 85 and 147% additional benefits. This is for commuting journeys only and the comparator is transport cost benefit analysis based on commuter user benefits (for a 20% reduction in commute times). The range in results depends upon the assumption made regarding the impact of taxation. Bröcker et al. (2004) estimate that product market effects (including imperfect competition and economies of scale) are estimated to add to 20 to 30% more economic benefit than would be measured in a normal transport cost benefit analysis for all the priority Transnational Transport projects (TEN-T).

Using partial equilibrium approaches[6] the UK Department for Transport estimate that the additional agglomeration benefits of Crossrail, a transformational urban rail project serving central London, to be approximately 24% of user benefits (DfT, 2005; Graham, 2007 Table 6). Including other missing markets (imperfectly competitive goods market and the distorting effects of a labour tax), but within a partial equilibrium type analysis, increases the additionality to 65%. In the UK experience this is at the upper end of the spectrum of additionality (DfT, 2006). The experience in the UK is also that the additional benefits identified by including missing markets is very scheme and context dependent: missing

[6] Second order interactions between the markets are taken to be zero and each market is treated in isolation. Such assumptions become questionable if many market failures are considered.

markets are typically more important in urban networks than inter-urban corridors (Eddington, 2006, Figure 1.5 Volume 3 p129), but that quite a large variation can exist within urban areas (Eddington, 2006, Figure 4.8 Volume 3 p195).

Focusing on agglomeration benefits exclusively Graham and Melo (2011) estimate for a high speed rail line between London and Scotland changes in productivity due to agglomeration will increase GDP by between 0.02% and 0.19% depending on journey speed and diversion from other modes. This is a lot less than KPMG (2010)'s estimate of the GDP impacts of the same high speed rail proposal – by at least a factor of 10. In part this is because Graham and Melo keep land uses fixed, whilst KPMG do not. But the main difference is that Graham and Melo use a measure of connectivity based on all journeys in the course of work, for which rail is a small contributor, whereas KPMG use a specific measure of rail connectivity. Whilst there is a possibility that Graham and Melo underestimate the impact by failing to allow for the possibility of a much greater rail market share amongst managerial and professional workers on intercity trips and that these trips may be more important for agglomeration effects than other journeys in the course of work, there is a danger that the KPMG results exaggerate the effect of rail connectivity if it is highly correlated with connectivity by other modes.

Hensher et al. (2012) in an evaluation of a rail journey speed improvement to central Sydney also allow land uses to change. Whilst the additional benefits they attribute to missing markets are modest at 17.6% of user benefits, an interesting feature of their work is that they separate out the wider economic impacts of changes in land use (what they call general equilibrium effects) from agglomeration impacts. They find that what they term the general equilibrium component of the wider economic benefit is seven times the agglomeration benefits. That is they find that improvements in "*spatial efficiency*" are more important than agglomeration.

Elhorst and Oosterhaven (2008) show in their appraisal of four variants of a MAGLEV[7] line that missing markets can have a substantial impact on scheme benefits. Depending on the route of the MAGLEV line under consideration, they found that a multiple market analysis may change benefits as measured in a conventional transport cost benefit analysis by between -1% and +38%[8]. Their results are very interesting in a number of ways. Firstly, they demonstrate that including missing markets into an appraisal can lower as well as increase economic welfare, and secondly they indicate that for what appear to be very similar projects (each project variant is a MAGLEV line) very different levels of additionality can be obtained. The differences between the project variants arise as a result of the different impacts they each have on the labour market. The two variants that provide a high speed link between the four cities of the Randstad, that is the variants that re-inforce the Randstad agglomeration, have positive impacts for the overall productivity of the Randstad region, whilst having a negative welfare impact on the regions from which labour is extracted. The opposite is the case for the variants that link the periphery (Groningen) to the core (the Randstad). As the welfare gain from improving the efficiency of the labour market exceeds the productivity decrease from shifting employment from the core to the periphery, the MAGLEV variants which link the Randstad (the core) to Groningen (the

[7] Magnetic levitation train
[8] Oosterhaven and Elhorst (2003) report a wider range (-15% to +83%) derived from earlier versions of the model.

periphery) have more net positive additionality than the projects that link the four cities of the Randstad.

The number of applications of multiple market cost benefit analysis to transport schemes is limited. As we will discuss below modelling the impacts of transformational transport projects is challenging and that is one of the reasons. Data to parameterise models is one of the key reasons: by how far do prices for goods and services exceed marginal social costs? What is the elasticity of productivity to agglomeration? What is the shadow price of labour? These are not trivial questions and need substantial economic research with implications for appraisal far beyond the transport sector. The commissioning of such research requires long term planning and strategic thinking, and cannot usually be justified on the 'back' of an individual transport project. Saying that, the evidence to date is that including missing markets into a cost benefit analysis would at best double the benefit to cost ratio with the caveat that land uses remain broadly comparable before and after the intervention – and as in the case of some of the Dutch MAGLEV variants may worsen the case (Laird et al., 2005; Eddington, 2006).

5. PREDICTING TRANSFORMATIONAL IMPACTS

A cost benefit analysis is only as good as its inputs. If the inputs are weak then the analysis will be weak too. A key input into any transport cost benefit analysis project is demand. For transformational transport projects estimating demand changes relative to the base and over time is non-trivial. Typically network effects – both transport network effects and transport-economy network effects (Laird *et al.*, 2005) – will be large. Estimating the level of generated traffic is therefore challenging – even more so when it is considered that few examples of such projects will exist against which forecasts can be benchmarked. As Mohring and Williamson (1969) showed, in a perfectly competitive economy the user surpluses associated with generated traffic capture spatial re-organisation benefits. Good estimates of generated traffic are therefore essential to ensuring that the economic impact of transformational transport projects is captured. The proposed high speed line in the UK is anticipated to attract 24% of its demand from new trips (see Table 1). This is a large number and reflects the new economic opportunities that a high speed line offers – predicting such a value with a high degree of confidence is of course challenging, but essential.

<*Insert Table 1 around here*>

For HS2 (the London to Manchester/Leeds via Birmingham high speed rail line) these generated traffic predictions have been based on conventional transport modelling approaches using demand elasticities to changes in journey attributes (e.g. journey time and cost). However, there is a range of challenges to the effect that this approach misses the dynamic responses of the economic system. No travel demand model, it is argued, can capture all the indirect responses through land use change and consequential feedbacks to the spatial distribution of population and employment. Consider what the economic geography of Britain would look like without the motorway network – difficult to say, but rather different from today's reality we conjecture. On the other hand, the elasticities themselves are based on experience of major transport changes in the past.

Alternative approaches would be based on forecasting the increase in economic activities that HS2 would lead to[9]. Such techniques are at the cutting edge of regional science. In addition to predicting economic growth due to the basic lowering in input and output prices (from reduced transport costs), when dealing with transformational transport projects such approaches need to account for spatial re-organisation, economies of scale in production, substitution within the production process to more transport intensive methods, population migration, and increased competition and its effect on the location of economic activities. A number of different model types have been employed in this regard of which three have received some prominence: multiple region input-output models, regional production function models and spatial computable general equilibrium models (SCGE). Wegener (2011) provides a review of these model genres.

In the UK cross-sectional analyses on the relationship between wages and accessibility have also been used to predict the economic impact of transport projects (e.g. SERC, 2009; KPMG, 2010; KPMG, 2013). Rather than modelling the underlying economic behaviour that give rise to varying levels of economic activity with accessibility, such models focus on aggregate relationships. Care therefore needs to be applied in using these models to ensure that the underlying economic conditions exist for this economic potential to be realised (e.g. in for example the upskilling of workforces). The application of these methods to the HS2 high speed rail project has been strongly criticised on both statistical grounds and for the

---

[9] Given the presence of market failures outside of the transport market modelling the economic impacts of transformational transport projects is also necessary to predict economic impacts in terms of changes in output (GDP), employment and productivity due to agglomeration.

realism of the underlying ability of the economy to transform itself (Overman, 2013; Peston, 2013). This is not to say that these cross-sectional methods do not have their place in modelling regional economic impacts, but it is important to recognise that the quality of the predictions rest on the quality of the model estimated (and its underlying data) and also the reasonableness of the underlying economic assumptions.

A key outstanding research issue is that these economic models can give very different predictions of the economic impact of transport projects – by up to a factor of 10. The reasons for this are not fully understood but hypotheses include how the models are specified[10] (labour and capital mobility), but also that some models, like the SASI production function model are quasi-dynamic, and demonstrate self-reinforcing cumulative impacts over time, whilst static equilibrium models (e.g. CGEurope an SCGE model) may primarily predict short term impacts (Bröcker et al., 2004, pp168-175). These differences in model results are, ultimately, at the heart of the debate regarding transformational impacts of transport projects.

Benchmarking anticipated economic changes on those that have occurred elsewhere is an alternative method for predicting change. This is a form of reference class forecasting (Flyvbjerg, 2006). In practice, there are now a number of ex post appraisals of high speed rail lines (see for instance Cheng, Loo and Vickerman (2013), and most studies include a review of previous experience at least as a form of benchmarking – though in the main such reviews focus on the primary transport market rather than impacts on the economy. There

[10] It is important to also note that each model within its genre will be specified differently – making different assumptions about capital, labour and how the markets for those function/close.

remains a dearth of ex post studies on the economic impacts of transport projects, thus more ex post studies are needed particularly given that it is necessary to consider the variety of circumstances in which such investments can take place. However in the case of transformational projects this implies commitment over a long time period ; some of the options being considered by the UK Airports Commission might open at the end of the 2020s while the HS2 project is due for completion in 2032. The economic adjustment might be taking place over twenty years. A challenge with all ex post work is the definition of the counterfactual – differences in differences methods can go some way to resolving this issue (Gibbons and Machin, 2005; Gibbons et al., 2012).

Finally there is, to our minds, a major issue regarding the interface between the planning system and the spatial market system. In the above, we have assumed that planning is broadly reactive; changes in accessibility will drive changes in land values in different uses which stimulates development and relocation and creates new opportunities. What if the view taken of the planning system were to be much more prescriptive – for example that projects such as Crossrail or HS2 were to be used explicitly to help create new cities to meet strategic national imbalances, or less ambitiously that supportive land use policies are needed to deliver economic benefits? It is at least for discussion whether infrastructure projects lose part of their transformational potential without positive land-use planning to reinforce the market signals (Preston and Wall, 2008). But then there is no escape from evaluating the combined land use and transport plan.

6. COST BENEFIT ANALYSIS VERSUS GROSS VALUE ADDED METRICS

As noted above, current circumstances in Britain have led to a major emphasis being placed on the impact of transport projects on GVA rather than on full CBA, with the impact on GVA seeming to be many times the full social benefits of the project in a CBA. (see Laird and Mackie, 2010). In part these differences arise because of the measurement challenges faced in a CBA as we have discussed, but they predominantly occur because the baseline of the analyses differ. In particular:

Perspective/Geography This is often the main reason why the CBA and GVA measures differ. A CBA typically has a national perspective, assuming the study area is fit for purpose, while GVA impacts are usually calculated at local or regional level. This difference is crucial as redistribution of economic activity can result in substantial transfers of GVA at a local or sub-national level. If for example 90% of the GDP gain to a conurbation is displaced from adjacent sub-regions, the local perspective becomes a significant explanator of the disparity between the results of the CBA and GVA approaches. In the UK guidance from other Departments such as the Department for Communities and Local Government pay a lot of attention to the displacement assumptions in appraisal but this aspect has received less attention in transport thus far (English Partnerships, 2008).

Welfare benefits include impacts that GVA metrics do not. Transport CBA includes a measure of quality of life benefits such as non-work travel time savings, environmental externalities and unpriced elements of safety benefits which size of the economy metrics do not. These quality of life benefits are substantial contributors to welfare, often greater than 50% of total welfare benefits.

GVA and CBA metrics value the same impacts differently. For example a CBA typically attributes the marginal benefit of the triangle B in Figure 1 to the net social value of new resources taken into production. In contrast the gross value of the change in output and employment is included in GVA metrics (as Area E plus F[11]). For projects which have significant impacts on employment and output, this difference can be substantial.

Equity versus behavioural values. CBA in many countries uses standard or 'equity' values of non-working time and other benefit parameters. However these are averages. The use of such values for projects such as Crossrail and HS2 which are either located in high income locations or appeal to high income users will understate the benefits in a CBA and therefore produce a divergence with any GVA estimate.

Economic Potential. A CBA is an attempt to appraise the forecast actual impact of a transport project, relative to a reference case. Some studies of the impact on GVA also do this while others provide an estimate of what can be termed the *economic potential* of a transport improvement. In such studies, transport investment is viewed as the catalyst to a number of structural changes to the economy and is accompanied by complementary

[11] Area E plus area F represent the change in earnings, which along with business profits (which are zero in this example due to constant returns and perfect competition) represent the change in GVA in Figure 1. GDP can be calculated by summing the change in GVA with indirect taxes (the income based approach). Alternatively it can be calculated by calculating the change in output (Area D) which is the expenditure based approach. Areas E plus F and area D therefore double count each other.

investment often private sector developer driven which in turn generate the changes in output and employment. This creates two challenges for GVA appraisal--- the first is to account properly for the complementary investment and avoid the trap of attributing the combined effect to the transport project. The second is to find a way of forecasting what proportion of the potential will actually be taken up –here LUTI models which model the re-distribution of economic activity, but not usually any growth in the national economy, can be very useful at identifying how much of the change in economic activity occurs due to re-distribution and how much through endogenous growth (e.g. through changes in productivity). An assessment as to whether either of these is realistic can then be made.

7. CONCLUSIONS

Transport cost-benefit analysis is mature methodology used widely around the world by nations and lending agencies. The technical content of the British manual webTAG is in many ways an impressive achievement even if like Topsy it just keeps on growing.

Yet transport CBA is now under challenge as never before in the last fifty years. This is from a mix of factors—the feeling that CBA fails to capture the essence of transformational projects, the effect of the global financial crisis on stimulating the search for competitiveness and jobs, and institutional change such as the City Deal in the UK promoting a regional rather than national focus to appraisal and a cross-sectoral perspective in which the case for spending on transport will need to be compared with the returns on flood relief, the skills agenda and classic land regeneration schemes.

Partly, this reflects a simple change in priorities, with less attention being given to benefits to users and more to jobs and economic growth. But partly it is a technical challenge as to whether the techniques used in cost benefit analysis adequately measure the full economic impact of transformational transport projects. At the technical level, there are numerous challenges reviewed in this paper. Relative to incremental projects, appraisal of mega-projects such as Crossrail or HS2 and national policy studies such as airport capacity in the UK or the Road Pricing Feasibility Study of a decade ago is very demanding. They may have significant local or regional income effects. Almost certainly they will be expected to change the pattern of land use; indeed the very word 'transformational' implies that forecasting the future with and without the project is inherently difficult irrespective of the precise appraisal framework.

When it comes to the choice of appraisal method, our view is that for overall assessment of national value for money, the CBA framework remains the most coherent and robust available. Its emphasis on estimating the net impact of projects and avoiding double counting is a valuable defence against exaggerated claims. However, for mega-projects, CBA needs to develop, particularly when land uses change. A better account is required of the channels by which the primary benefits feed through via accessibility change into the final economy. The economists' story about how this is supposed to happen needs buttressing by evidence if it is to be fully convincing. At the same time better evidence about the overall effect on productivity of travel time savings is needed. New approaches to measuring the direct impact on productivity of transport improvements, as opposed to undertaking this through travel time valuation, may have a part to play as long as the danger of spurious correlation, because accessibility is so highly correlated with other determinants of productivity, is heeded.

Finally, we need to recognise that in a multi-actor world where both cities and nations are involved in promoting, funding and delivering very large projects within programmes which cross sector boundaries, economic impact studies using metrics such as Gross Value Added are likely to find a place alongside CBA. The challenge will be to understand and be able to explain the discrepancies between the CBA and GVA results. At the moment different methods for predicting economic returns on projects can give very different results and the reasons for this are not transparent, leading to potential for confusion and misinterpretation. Ultimately clarity, consistency and quality of analysis is required.

REFERENCES

Association of Greater Manchester Authorities and Greater Manchester Integrated Transport Authority (2011) Written evidence to the Transport Committee on Transport and the Economy. Available online at: <http://www.publications.parliament.uk/pa/cm201011/cmselect/cmtran/473/473vw40.htm> Accessed 9th December 2013,

Abrantes, P.A.L. and Wardman, M.R. (2011) Meta-analysis of UK values of travel time: An update. *Transportation Research Part A* **45** 1–17.

ACTRA (1977) *Report of the Leitch Committee for the Department for Transport*. London: HMSO.

Bates, J. (2006) Economic evaluation and transport modelling: theory and practice. In: Axhausen, K.W. (ed) *Moving through Nets. The Physical and Social Dimensions of Travel*. Selected papers from the 10th International Conference on Travel Behaviour Reseach. Elsevier, Kidlington/Amsterdam, pp279-352.

Boardman, A.E., D.H. Greenberg, A.R. Vining and D.L. Weimer. 2011. *Cost-Benefit Analysis Concepts and Practice*. Fourth Edition. Upper Saddle River: New Jersey.

Bröcker, J., R. Meyer, N. Schneekloth, C. Schürmann, K. Spiekermann, and M. Wegener (2004) *Modelling the Socio-economic and Spatial Impacts of EU Transport Policy.* IASON (Integrated Appraisal of Spatial economic and Network effects of transport investments and policies) Deliverable 6. Funded by 5th Framework RTD Programme. Delft: TNO Inro.

Cheng, Y, Loo, B and Vickerman, R (2013) High-speed rail networks and economic integration in China and Europe: a preliminary analysis. *World Conference in Transport Research, Rio de Janeiro.*

Cleary, E.J. and Thomas, R.E. (1973) The economic consequences of the Severn Bridge. Bath University Press.

Department for Transport (2005) (modified 2006) *Transport, Wider Economic Benefits and Impacts on GDP*. London: Department for Transport

Department for Transport (DfT) (2006) *Eddington Evidence Base*. Available online at <http://webarchive.nationalarchives.gov.uk/20100209071128/http://www.dft.gov.uk/about/strategy/transportstrategy/eddingtonstudy/pubeddingbase> (Accessed 31st August 2012).

Department for Transport (DfT) (2011) *High Speed Rail: Investing in Britain's Future. Consultation Summary*. February 2011. London: Department for Transport.

Department for Transport (DfT) (2012) *Economic Case for HS2: Updated appraisal of transport user benefits and wider economic benefits*. A report to Government by HS2 Ltd. January 2012. Available online at: < http://www.dft.gov.uk/publications/hs2-economic-case-appraisal-update/> (Accessed 26th October 2012).

Department for Transport (2013) *The Transport Business Cases.* London : January

Dodgson, J.S. (1973) External effects and secondary benefits in road investment appraisal. *Journal of Transport Economics and Policy*, **7** (2), pp 169-185.

Dodgson, J.S. (1974) Motorway Investment, Industrial Transport Costs and Sub-Regional Growth — a case study of the M62, *Regional Studies* **8** (1), pp 75-91

DP World (date unknown, unpublished) *London Gateway. Making the UK more competitive*. Available online at: http://www.londongateway.com/upload/environment/environment-overview/Making-the-UK-More-Competitive.pdf (accessed 13th September 2012)

Eddington, R. (2006) *The Eddington Transport Study. Main report: transport's role in sustaining the UK's productivity and competitiveness*. London: The Stationery Office.

Elhorst, J.P., and Oosterhaven, J. (2008). Integral Cost-Benefit Analysis of Maglev Rail Projects Under Market Imperfections. *Journal of Transport and Land Use*, *1*(1).

Eliasson, J. (2004) 'Car drivers' valuations of travel time variability, unexpected delays and queue driving', *Proceedings of the European Transport Conference, Strasbourg October 2004.* London: AET Transport.

Eliasson, J. and M. Lundberg (2012) Do cost–benefit analyses influence transport investment decisions? Experiences from the Swedish transport investment plan 2010-21. *Transport Reviews*, **32** (1), pp. 29–48

English Partnerships (2008) *Additionality Guide. A standard approach for assessing the additional impact of interventions*. English Partnerships. October 2008.

Fickling, R., Gunn, H., Kirby, H., Bradley, M., & Heywood, C. (2008). *The productive use of rail travel time and value of travel time saving for travellers in the course of work*. ETC

Proceedings. Available online at: <http://www.etcproceedings.org/paper/the-productive-use-of-rail-travel-time-and-value-of-travel-time-saving-for-tra-1> (Accessed 26th October 2012).

Flyvbjerg, B. (2006) Curbing Optimism Bias and Strategic Misrepresentation in Planning: Reference Class Forecasting in Practice. *European Planning Studies* 16(1) pp3-21.

Fowkes, A.S., Marks, P and Nash, C.A (1986) *The value of business travel time savings.* Institute for Transport Studies, University of Leeds, Working Paper 214.

Geurs, K. T., Van Wee, B., and Rietveld, P. (2006). Accessibility appraisal of integrated land-use-transport strategies: methodology and case study for the Netherlands Randstad area. *Environment and Planning B: Planning and Design*, *33*(5), 639-660.

Geurs, K., Zondag, B., De Jong, G., and De Bok, M. (2010). Accessibility appraisal of land-use/transport policy strategies: More than just adding up travel-time savings. *Transportation Research Part D: Transport and Environment*, *15*(7), pp382-393.

Gibbons, S., and Machin, S. (2005). Valuing rail access using transport innovations. *Journal of Urban Economics*, 57(1), pp148-169.

Gibbons, S., Lyytikäinen, T., Overman, H., and Sanchis-Guarner, R. (2012). *New Road Infrastructure: the Effects on Firms. SERC Discussion Paper No. 117*. September 2012. Spatial Economics Research Centre, LSE.

GMPTE (2010) *Network Rail Northern Hub Rail Study.* Report to Greater Manchester Integrated Transport Authority Policy and Resources Committee. Report dated 19th March 2010.

Graham, D.J. (2007) Agglomeration, Productivity and Transport Investment. *Journal of Transport Economics and Policy*, **41**(3) pp.317–343.

Graham, D.J., and Melo, P.C. (2011). Assessment of wider economic impacts of high-speed rail for Great Britain. *Transportation Research Record: Journal of the Transportation Research Board*, *2261*(1), 15-24.

Harrison, A.J. (1974) *The economics of transport appraisal*. Croom Helm, London.

Hensher, D.A. (1977) *Value of Business Travel Time*. Pergamon Press, Oxford.

Hensher, D. A., Truong, T. P., Mulley, C., and Ellison, R. (2012). Assessing the wider economy impacts of transport infrastructure investment with an illustrative application to the North-West Rail Link project in Sydney, Australia. Journal of Transport Geography, 24, 292-305.

High Speed 2 Ltd (HS2) (2012) *Updated Economic Case for HS2.* Report dated August 2012.

HM Government (2012) Unlocking growth in cities: city deals – wave 1. London: HM Government Cabinet Office. Report dated July 2012.

Jara-Diaz, S.R. 1986. On the Relation between Users' Benefits and the Economic Effects of Transportation Activities. *Journal of Regional Science*. **26**(2), pp.379-391.

Jong, G.C. de, Bakker, S., Pieters, M. and Wortelboer-van-Donselaar, P. (2004a): New Values of Time and Reliability in Freight Transport in the Netherlands, *Proceedings of the European Transport Conference, 2004*. Available online at: <http://www.etcproceedings.org/paper/new-values-of-time-and-reliability-in-freight-transport-in-the-netherlands > (accessed 9th November 2012)

Jong, G.C. de, E.P. Kroes, R. Plasmeijer, P. Sanders and P. Warffemius (2004b): The Value of Reliability, Proceedings of the European Transport Conference, 2004.

Laird, J.J., and Mackie, P. (2010). *Review of methodologies to assess transport's impacts on the size of the economy*. Institute for Transport Studies, University of Leeds: Report to the Northern Way. Report dated September 2010. Available online at: <http://www.northernwaytransportcompact.com/downloads/Evidence%20Base/Transport%20&%20the%20Economy/Review_of_Methodologies_to_Assess_Transports_Impacts_on_the_Size_of_the_Economy.pdf> (accessed 26th August 2013.

KPMG (2009, Unpublished) *Value for money from tackling overcrowding on northern city rail services*. Report to GMPTE. Report dated 17th December 2009.

KPMG (2013) *HS2 Regional Economic Impacts*. Report prepared for HS2 Ltd. September 2013.

KPMG (2010, Unpublished) *High Speed Rail in Great Britain: Consequences for employment and economic growth*. Report to Greengauge 21. Report dated 31 January 2010. Available online at: http://www.greengauge21.net/wp-content/uploads/consequences-for-employment.pdf (accessed 13th September 2012).

LAIRD, J.J. (2010) Transport welfare benefits in the presence of an income effect. In: HESS, S. and A. DALY (eds) *Choice Modelling: the State-of-the-Art and the State-of-Practice*, Chapter 18, pp.399-420. Bingley: Emerald.

Laird, J.J., J. Nellthorp, and P.J. Mackie (2005) Network effects and total economic impact in transport appraisal. *Transport Policy*, **12**, pp. 537–544.

Laird, J., C. Kelly, J. Nellthorp, S. Costantini, J. Carbajo, X. Mas, J. Leon, P. Richards, N. Macdonald, G. Oakes, J. Tindall, J. Arrand and K. Black (2012) Ex Post Appraisal: What lessons can be learnt from EU Cohesion funded transport projects. *European Transport Conference, Glasgow 8-10 October 2012. London: AET Transport*

Leeds City Region (LCR) (2012) *Proposal - A Leeds City Region Deal*. July 2012. Available online at: http://www.leedscityregion.gov.uk/LCR-Corporate/media/Media/Research%20and%20publications/LCR-Cities-Deal-2012.pdf?ext=.pdf. Accessed 9th December 2012.

Mackie, P.J. and Simon, D. (1986) Do Road Projects Benefit Industry? A Case Study of the Humber Bridge. *Journal of Transport Economics and Policy*, **20** (3) pp. 377-384

Mackie, P.J., and Nellthorp, J. (2001) Cost Benefit Analysis in Transport, in K.J. Button and D.A. Hensher. *Handbook of Transport systems and Traffic Control*, Pergamon, pp 143-174

Mackie P.J. and Preston J.M. (1998) Twenty One Sources of Error and Bias in Transport Project Appraisal *Transport Policy* **5** pp1-7

Martinez, F., and Araya, C. (2000). Transport and land-use benefits under location externalities. *Environment and Planning A*, *32*(9), 1611-1624.

Metropolitan Transport Research Unit (MTRU) (2008) *The Cost-Benefit Analysis of a Third Runway at Heathrow – an Independent Assessment commissioned by WWF-UK. Part One Economic Benefits.* Report dated April 2008.

Mohring, H. and H.F. Williamson (1969) Scale and "Industrial Reorganisation" economies of Transport Investments. *Journal of Transport Economics and Policy*, **3**(3) pp251-271.

Mohring H. (1976) *Transportation Economics*. Ballinger Press

McQuaid, R.W., Greig, M. Smyth, A. and Cooper, J. (2004): *The Importance of Transport in Business' Location Decisions*. Report to the DfT. DfT, London.

Mohring H. 1993. Maximizing, measuring and not double counting benefits: a primer on closed- and – economy cost benefit analysis. *Transportation Research* **27**(6) pp413-424.

Mouter, N., J.A. Annema, B. van Wee (2013) Attitudes towards the role of Cost–Benefit Analysis in the decision-making process for spatial-infrastructure projects: A Dutch case study. *Transportation Research Part A: Policy and Practice*, **58** pp1–14

Nilsson, J. E. (1991). Investment decisions in a public bureaucracy: A case study of Swedish road planning practices. *Journal of Transport Economics and Policy* **25**(2), pp163-175.

Network Rail (2010) *Prioritising investment to support our economy. A new approach to appraisal methodology.* Report dated September 2010.

Neuberger, H. (1971) User benefit in the evaluation of transport and land use plans. *Journal of Transport Economics and Policy*, **5** (1), pp 52-75

Noland, R.B. and Polak, J.W. (2002) 'Travel time variability: a review of theoretical and empirical issues' *Transport Reviews* 22(1) pp39-54

Nyborg, K. (1998) Some Norwegian politicians' use of cost–benefit analysis. Public Choice, 95, pp.381–401

Odeck, J. (1996)Ranking of regional road investment in Norway. *Transportation*, **23**(2), pp. 123–140

Odeck, J. (2010) What determines decision-makers' preferences for road investments? Evidence from the Norwegian road sector. *Transport Reviews*, 30(4), pp. 473–494

Odgaard, T., Kelly, C.E. and Laird, J.J. (2005) *Current practice in project appraisal in Europe – Analysis of country reports*. HEATCO Deliverable 1. HEATCO – Developing Harmonised European Approaches for Transport Costing and Project Assessment. Funded by the 6th Framework RTD Programme. IER Stuttgart, Germany. . Available online at: http://heatco.ier.uni-stuttgart.de/.

Oxford Economics (2012, Unpublished) *The value of aviation connectivity to the UK. March 2012*. A report prepared for BAA. Available online at: http://mediacentre.heathrowairport.com/imagelibrary/downloadmedia.ashx?MediaDetailsID=887&SizeId=-1 (accessed 13th September 2012).

Overman, H. (2013) *The Regional Economic Impacts of HS2*, Spatial Economics Research Centre Blog. Post dated 13th September 2013. Available online at < http://spatial-economics.blogspot.co.uk/2013/09/the-regional-economic-impacts-of-hs2.html>. Accessed 10th December 2013.

Peston, R. (2013) *What KPMG ignored when arguing for HS2*, Robert Peston Business Editor BBC News Blog. Post dated 11th September 2011. Available online at <http://www.bbc.co.uk/news/business-24047047> Accessed 10th December 2013.

Rouwendal, J. Indirect Effects in Cost-Benefit Analysis. 2012. *Journal of Benefit-Cost Analysis*. Volume **3**, Issue 1. Article 2.

SACTRA (1999) *Transport and the Economy.* London: HMSO.

Sheffield City Region Local Enterprise Partnership (2013) Introduction to the Sheffield City Region Investment Fund (SCRIF). Available online at: <http://www.sheffieldcityregion.org.uk/wp-content/uploads/2013/03/SCRIF-Overview.pdf>. Accessed 9th December 2013.

Simmonds, D.C. (2004) Assessment of UK land-use and transport strategies using land-use/transport interactrion modelling. *European Journal of Transport Infrastructure Research*, **4**, 273-293.

Simmonds, D.C. (2012) Advancing appraisal: from transport economic efficiency to land-use/transport economic efficiency. European Transport Conference, Glasgow, October 8th - 10th 2012. London: AET Transport.

Spatial Economic Research Centre (SERC) (2009) *Strengthening the economic linkages between Leeds and Manchester*. Report to Northern Way. Report dated November 2009.

Steer Davies Gleave (2009 Unpublished) *The Northern Way: Manchester Hub Phase 1 - Transport Modelling and Benefit Assessment*. Report to Northern Way. Report dated April 2009.

Sykes, J.B. (ed) (1978) *The Pocket Oxford Dictionary of Current English*. Oxford: Oxford University Press.

Venables, A.J. 2007. Evaluating urban transport improvements: cost-benefit analysis in the presence of agglomeration and income taxation. *Journal of Transport Economics and Policy*. **41**(2), pp. 173-188.

Wardman, M.R. (2004) Public Transport Values of Time. Transport Policy vol 11 pp 363–377

Wegener, M. (2011) Transport in spatial models of economic development. In: de Palma, A., R. Lindsey, E. Quinet, and R. Vickerman (eds) *A Handbook of Transport Economics*. Cheltenham: Edward Elgar.

Wong, C. and B. Webb (2014) Planning for Infrastructure: Challenges to Northern England. *Town Planning Review* (in this special issue – full details to be completed).

ACKNOWLEDGEMENTS

This paper is an output from research sponsored by the N8 partnership of universities into the regional impacts of infrastructure. We are grateful to Robert Cochrane, Tom Worsley, Mark Weiner, Stephen Glaister and two anonymous referees for comments on an earlier version.

Figure 1 Direct and indirect benefits of a freight related transport quality improvement in competitive conditions

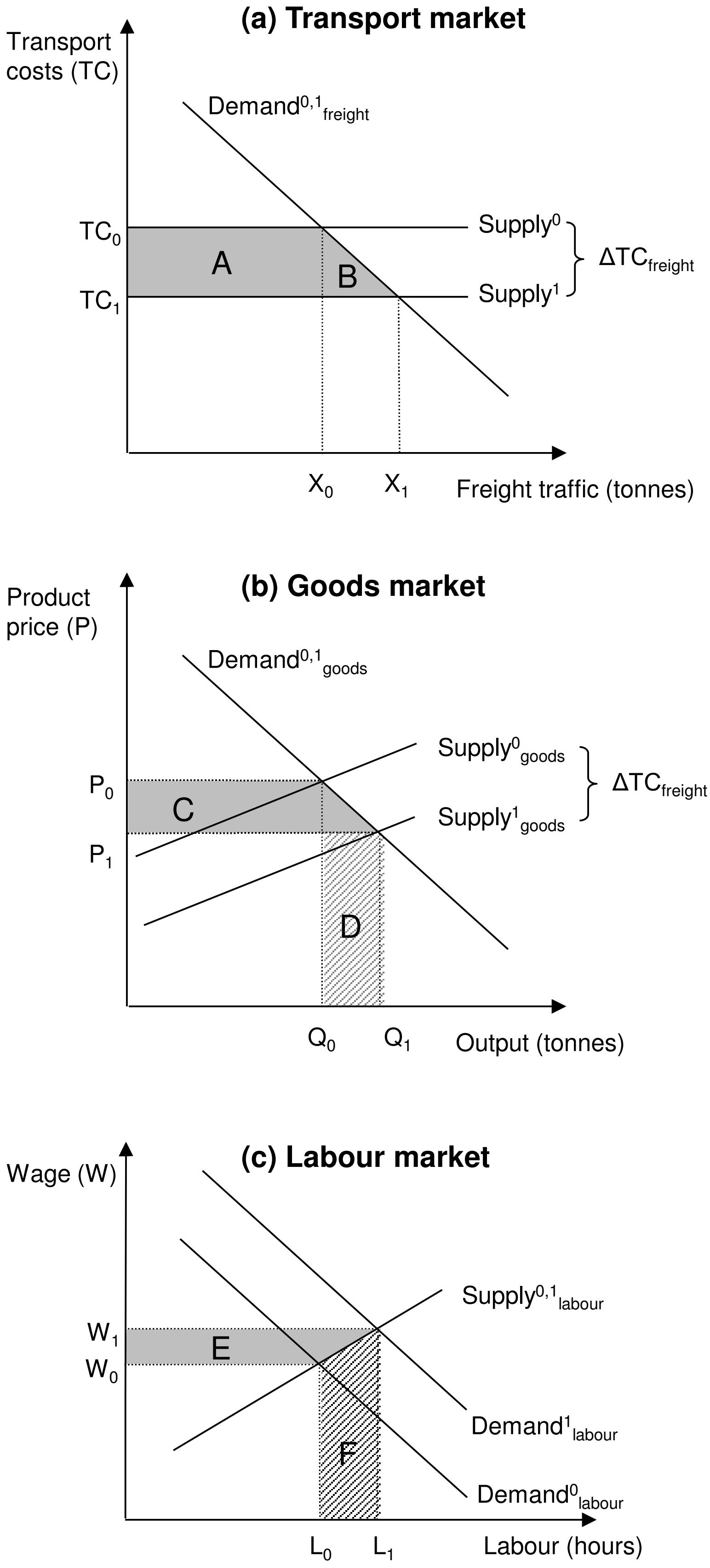

Table 1: Source of trips of passengers using HS2 services on the Y Network by mode

Passengers using HS2, 2037 (forecast)	
Switch from classic rail	65%
New trips	24%
Shift from air	3%
Shift from car	8%
Total	100%

Source DfT (2012 Table 3)