

9/10/14

**Transport investment and economic performance:
Implications for project appraisal***

Anthony J. VENABLE

James LAIRD

Henry OVERMAN

* Paper commissioned by UK Department for Transport. Thanks to referees, contributors to the seminar and the call for evidence, and staff of the Department for their inputs.

Transport investment and economic performance: implications for project appraisal

Executive summary and recommendations

Transport and economic performance

Transport is an essential input to income generation, and to consumption and wider domestic life. Estimates suggest that if all other drivers of growth were to increase by 10% and transport infrastructure were to stay constant, then realised growth in income would be just 9%, i.e. 1% point less than it otherwise would have been. Studies of particular projects or types of transport improvement point to positive impacts on a wide range of economic variables including city size and employment. The increases in land values associated with urban transport projects are well established. While these effects are well documented, the research literature has not been able to provide good estimates of the ex-post benefit-cost ratios (or rates of return) on particular transport investments that have been undertaken. This is partly because the benefits of a transport improvement can be quite diffuse, affecting many different individuals and firms, and partly because of the difficulty of establishing a good counterfactual; what would have happened if the project had not been built? Projected benefit cost ratios are generated by ex ante project appraisal, using techniques that are well-grounded in economic principles and empirics. For the UK, even taking a fairly narrow view of benefits, these indicate BCRs greater than two for more than 90% of projects undertaken.¹

The impacts of a transport improvement are wide-ranging, particularly for large projects. To understand their contribution to economic performance – and to have a framework for project appraisal – it is necessary to drop to a level of detail which identifies and assesses the impacts of particular projects. These impacts can be grouped into three types; user benefits, productivity effects, and investment and employment effects.

User-benefits:

User-benefits are the most direct effects and comprise the savings in time, vehicle operating costs and other elements of 'generalised travel cost' associated with better transport. They are calculated to include new journeys created and (for major projects) possible problems (such as congestion) created elsewhere in the network. The term 'user-benefit' is perhaps misleading; while the cost saving is best measured by its impact on users, the market economy transfers much of the benefit to others in the economic system. Commuters who see their travel times cut may end up transferring the benefit to their landlords in higher rent; firms whose costs fall may pass the benefit to consumers. These benefits are the principal impacts of a transport improvement and form the core

¹ And greater than four for more than 10%. Department for Transport, 2014.

of an economic appraisal. However, there is wide agreement that they fail to capture the full impact of major projects.

Productivity effects:

The second source of benefit is productivity gains accruing to firms and workers, including those that are not themselves necessarily users of the transport improvement. They arise because of the economic benefits of scale and economic density, both of which are known to lead to higher productivity. These productivity effects are one of the reasons why cities exist, and why central area employment in major cities reaches densities of 150,000 workers per km². High density leads to intense interaction between firms, partly in the form of competition, and partly through developing deep pools of knowledge and skills embodied in the local labour force. Part of the effect is within particular sectors (e.g. clusters of finance, software, or media) and part is more general (firms in other sectors also benefit as they are users of finance, software and media). This is an area where the research literature provides quite robust results, indicating that increases in city size (or other measures of economic density) have significant positive effects on productivity.

Transport is a necessary ingredient to securing these benefits, in several distinct ways. First, economic interactions between firms (and between firms and consumers) are better, the better the transport system. Firms can reach wider markets, enabling them to expand, gain scale economies and develop specialist skills; markets are more competitive as the natural barrier of distance is reduced and inefficiencies associated with monopoly and monopsony power are eroded.

Second, transport enables cities to specialise, developing sector specific advantages. Historically this was manifest in cities specialised in textiles, steel or cutlery. While some manufacturing clusters are still important, the phenomenon is now apparent in service sectors, particularly knowledge intensive activities. If better transport or communication enables some of the ancillary activities to be 'outsourced' to another city, it reduces costs and creates space for the high-value activities to further concentrate in the central cluster.

Third, transport is necessary to get workers into concentrated and productive centres of activity. This is most apparent in commuting into central business districts, but there is also evidence that firms outside these districts benefit from drawing on a wide catchment area of employees.

While there is a single underlying mechanism at work in each of these cases – concentration of economic activities leads to high productivity – the precise role of transport is different in each. Effects vary across transport projects (e.g. commuting versus inter-city links) and across the areas, and sectors likely to be affected.

Investment and employment.

The third causal mechanism through which transport affects economic performance is via altering patterns of private sector investment and consequent employment. Better transport generally makes a place more attractive for investment. There is evidence that transport links are one factor shaping the location decisions of firms, although only one amongst many (with availability of suitably skilled labour usually cited as the most important).

Transport's potential for attracting private investment and creating jobs might seem to be the most obvious source of benefit. It is often at the forefront of debate. However, these apparent benefits can be misleading; the topic is quite complex, potentially ambiguous, and lacking a good evidence base. To assess the effect on economic performance several questions have to be addressed. Is the private investment **additional**, or would it have taken place elsewhere in the absence of the transport improvement? Does the investment **displace** other activities and if so, are there particular reasons to think that the investment is of greater social value than activities displaced?

Additionality: A transport improvement may attract private investment to a place but possibly, absent the transport investment, the investment would have taken place elsewhere in the country. For projects whose output is not internationally tradable (e.g. retail) this is the likely outcome: transport induced investment is principally relocation and, from the perspective of the country as a whole, there is no additionality. For projects that are internationally mobile (e.g. the motor industry, producing products that are traded internationally) there is a much greater chance of additionality: the choice may be between sites in different countries so attracting investment is additional, at least from one country's perspective.

This issue is complicated further if the transport improvement affects several places. Is one more likely to gain investment than the other, or even at the expense of the other? And if so, which? Economists would usually expect lowering of transport costs (or other trade barriers) to be a force for economic convergence of areas. However, outcomes depend on a balance between cost differences and productivity differences between places, and can go either way. General predictions are hard to make and careful study of particular circumstances is needed.

Displacement and the social value of investment. Even if private investment stimulated by a transport project is additional from a national perspective it nevertheless uses resources – principally labour – that come from somewhere. This could be increased labour force participation, lower unemployment, migration, or from drawing workers away from other jobs and thereby displacing other activities. If it is the last of these – likely in a situation of long-run full employment – then new investment may be of no particular social value. Making the case that induced investment is of social value therefore requires a rigorous argument that there is some sort of market failure making the new activity more valuable than the alternative.

One such argument is to do with the labour market. If a region has structural issues of unemployment or low levels of participation (perhaps due to lack of jobs creating 'discouraged worker' effects) then displacement is small and investment is of net social value. Another argument arises if private investors cannot capture all the value associated with their investment. This can happen with large projects which have a significant impact on prices or wages in the area (e.g. if a project is large enough to significantly bid up local wages). It can also happen if there are significant complementarities between investment projects, so that one firm's investment plans are conditional on those of another. This can arise in the formation of a new cluster of activity, or in attempts to regenerate an area. The market system may not be effective in achieving the coordinated action needed to get such developments underway, in which case transport can be an important catalyst for development.

Pulling these investment and employment arguments together leads to the following conclusions. Business certainly benefits from better transport, and this is measured directly in 'user-benefits'.

There may then be changes in the pattern of investment and associated job creation, and it is possible that this is an additional source of gain. However this *possibility* has to be critically evaluated, project by project. Where is the investment likely to take place? Is it additional? Is it in areas where job creation is particularly highly valued? Are there reasons to think that transport is unblocking some market failure that is creating a barrier to efficient levels of private investment?

Finally, transport is just one of a package of policy measures that play a role in shaping the level and location of private investment, other policies range from land-use and planning policy through to skills and international trade policy. Its role should be seen in conjunction with such measures; if there are synergies, then its effect cannot be viewed in isolation.

Transport appraisal

Transport investments can deliver economic benefits over and above conventionally measured user-benefits. As suggested above, they arise as: (a) Transport fosters intense economic interaction that raises productivity; this can occur in clusters within narrowly defined areas or more widely by linking areas. (b) Transport shapes the level and location of private investment, potentially leading to higher levels of economic activity in some areas. Transport induced investments can interact with market failures including price-cost divergences, obstacles to efficient land use, and labour market imperfections (unemployment and low labour force participation).

Assessing these effects requires: (a) An appropriate analytical framework that captures effects and can ascribe social values to economic changes. (b) Good estimates of how transport changes quantities, i.e. journeys, patterns of investment and employment. (c) A robust evidence base combined with local and project specific knowledge that can inform judgements about whether such changes are additional (to a particular area and the country as a whole); whether they displace other activity; and how they interact with market imperfections thereby creating social value.

The Department for Transport appraisal guidelines provide a rigorous framework for appraising projects. Its assessment of user-benefits is well-grounded and it has been a world-leader in incorporating some of the wider impacts of transport improvements. The recommendations that follow are intended to inform discussion on how to extend and improve appraisal techniques in order to more fully capture (and critically evaluate) the economic impact of transport investments, while maintaining the Department's standards of rigour.

Recommendations

- 1) **Appraisal techniques are, in some cases, insufficiently context and project specific; they need to be informed by a clear narrative about likely economic impacts of the project.**

The DfT guidelines seek to provide a toolkit applicable to many different situations. This has advantages – uniform criteria are ultimately needed to rank projects. But it risks becoming overly

mechanical and thereby missing some impacts of a project, or placing undue emphasis on other aspects less relevant for the project under study. For example, both an inter-city road link and improved intra-urban commuting might have positive productivity effects, but through quite different mechanisms which cannot be readily captured by application of the same formula. To address this, appraisals need to be informed by a clear narrative about the likely effects of the project. This should inform the modelling and quantification work that is undertaken and the analytical work and empirical evidence that are brought to bear.

2) There should be a closer connection between the strategic and the economic cases for transport investment.

The strategic case provides the context specific narrative that should inform the focus of the economic appraisal. Equally importantly, the strategic case needs to be subject to the rigorous scrutiny provided by the economic case.

3) Appraisal of larger projects should direct more attention to impacts on private sector investment decisions and associated changes in employment and economic activity.

Appraisal techniques could be improved by greater engagement with the 'investment and employment' impacts of transport investments, i.e. the effects of the project on private sector investment decisions and consequent impacts on employment and economic activity. This is a difficult area where there are considerable uncertainties and the evidence base is quite weak. However, potentially important effects (e.g. large private developments that are brought forward by transport investments) should be addressed in appraisal. Critically, this is where much of the current policy debate takes place. Projections are put forward (often by scheme promoters or local interests) which shape this debate and which need to be rigorously assessed. The key questions – are investments additional, do they displace other activities, are there particular reasons for attaching social value to them? – are, at present, not being addressed in many appraisals. This is a significant gap in the appraisal system that should be addressed.

4) Land-use change (and more general changes in the level and spatial distribution of private investment) should be estimated and reported in a wider range of projects.

- a) This should be done in a manner that informs the debate about local impacts; a debate that will, in any case, take place.
- b) It should seek to identify the additionality of such changes and displacement effects that may be created.
- c) It should assess the likelihood that such investments interact with market failures and thereby create aggregate social benefit or dis-benefit
- d) Other parts of the appraisal should use these results, reporting benefit outcomes with and without land-use changes and in a consistent manner.

This is a challenging undertaking, as modelling such changes is both expensive and subject to a good deal of uncertainty. It should be undertaken selectively, on the basis of explicit criteria and informed by the narrative about the likely effects of the project. Techniques for predicting land use change and its effects need to be further developed, including:

- a) Greater use of detailed local and sectoral information to assess quantity changes and their interaction with the local economic environment.
- b) Application of techniques used by other government departments (e.g. BIS, CLG) for assessing additionality and displacement effects.
- c) Econometric and modelling methods are opening up possibilities for improving prediction and need to be developed further.
- d) The effectiveness of modelling techniques needs to be assessed by systematic comparison of ex ante estimates made using various techniques with actual ex post outcomes.

5) In some circumstances it will be appropriate to produce estimates for a range of different scenarios concerning private sector responses and related government policies.

Appraisal is subject to inherent uncertainties about the future state of the world and also complementary policy changes or investments that may or may not be made by the public and private sectors. It is important to produce scenarios (and rate of return or BCR estimates) corresponding to alternative assumptions about other investments or policy changes, particularly where there may be synergies between policies. These should make clear the assumptions made about possible changes in related policies or private sector actions. There are several benefits. One is greater understanding of the impact of the project. Another is that there will often be synergies between transport investments and other changes made by the private and public sector. Failure to recognise these synergies leads to fragmented decision taking and is a source of economic loss.

6) DfT should set best practise techniques and promote informed debate by encouraging transparency in appraisals done by others.

Appraisals will, as a matter of fact, be produced by a variety of bodies, private and public. An informed debate requires transparency, so that the reasons for diverse estimates can be understood and critically evaluated. The DfT sets best practise in many technical aspects of appraisal and can encourage reporting standards that facilitate the comparison of findings, are transparent and inform debate.

7) Component parts of DfT appraisals could be better integrated.

Component parts of DfT appraisals need, in some cases, to be better integrated; for example, the relationship between user benefits/ movement to better jobs/ productivity change. This would increase transparency and reduce the risk of incompatible assumptions or double counting. Work

could be undertaken to better place all aspects of an appraisal in an integrated and consistent spatial framework.

Table of contents:

1. Introduction

- 1.1 What does transport investment do?
- 1.2 Causal links and report outline
- 1.3 The evidence base
- 1.4 The social value of a transport improvement
- 1.5 Present appraisal techniques

2. User benefits and wider benefits

- 2.1 User benefits and total benefits.
- 2.2 Measuring user benefits
 - Traffic forecasts
 - Measuring generalised transport costs
- 2.3 Changing quantities and price-cost gaps
 - Labour market effects – increased labour supply
 - Labour market effects – move to more productive jobs
 - Output change under imperfect competition
- 2.4 Conclusions

3. Economic mass and productivity:

- 3.1 Access to economic mass and productivity: issues
- 3.2 Access to economic mass and productivity: evidence
- 3.3 Transport, access and productivity
 - Proximity: e.g. the Northern Way
 - Clusters: e.g. Crossrail
 - Department for Transport guidance: Lower Thames Crossing
- 3.4 Conclusions

4. Investment and employment

- 4.1 Transport and the location of activity
- 4.2 Valuing investment and employment
 - Social and private values of land use change
 - DfT approaches to land use change
 - Labour market displacement and the employment counterfactual
- 4.3 Transport and the location of activity; evidence
 - Econometric approaches
 - Case studies
- 4.4 Application: forecasting location effects
 - Econometric approaches
 - Bottom-up; local knowledge, local plans
 - Land use – transport interaction models
 - Spatial equilibrium models
- 4.5 Conclusions

5. Conclusions and recommendations

References and appendices

Chapter 1: Introduction

The necessity of transport infrastructure to the functioning of a modern economy is evident: London cannot be imagined without the underground, or business activity without a road network.

Improvements in transport infrastructure and services bring benefits to users, existing and new. They also change economic geography, enabling cities to be larger, better connected to each other and to their hinterlands, and better able to specialise and trade. Some areas become more attractive places for investment leading to a reorganisation of economic activity within a country, or within a wider regional or global economy. The reorganisation may bring productivity increases that spread beyond transport users, and it may create demand for labour, potentially raising wages.

This report investigates the impacts of transport investments on economic performance with a view to informing the appraisal techniques that are used in project selection. Like other types of public investment, transport investment is appraised using the Treasury's five business cases: the **strategic case** in which the case for change is made in the context of wider public policy objectives; the **economic case** which demonstrates value for money; the **commercial case** and **financial case** where commercial viability and financial affordability is assessed; and finally the **management case** in which the achievability of the investment is assessed. This report has particular relevance to the strategic and the economic cases.

Assessment of the effect of transport improvements on economic performance involves three broad steps. The first is to understand how a transport project impacts on the economy: what changes if a new transport link is built? This requires both a causal framework and empirical evidence. The second is: how should such changes be valued? Understanding of causal mechanisms has to be combined with criteria for placing a social value on the changes brought about by the project. The third is: how can the likely future effects of particular transport projects be estimated? Theoretical principles have to have a practical analogue if they are to be useful. Present appraisal techniques are based on answers to these questions; we assess the appropriateness of these techniques, suggesting changes in approach and emphasis in several areas.

1.1 What does transport investment do?

A transport improvement brings time and cost savings to users of the transport network.² The users are individuals and households in their work and leisure activity, and firms which need to move goods, services, and their staff. Time and cost savings change traffic flows in the network, leading to increased flows in some parts of the network and possibly less traffic elsewhere. These changes in costs and in flows are the subject of sophisticated modelling efforts and are the core of transport

² Throughout we focus on the effects of the completed project. We do not investigate the construction costs of projects, nor include the temporary economic activity created by construction.

appraisal. We follow practise in the transport literature and refer to these as the *user-benefits* of a project.

Beyond these direct effects in the transport network, transport investment can induce further changes in behaviour and economic performance. It enhances proximity, bringing firms and workers closer together (in economic terms). It may cause changes in the location of economic activity; households may move or change job and firms may relocate, changing the suppliers that they use or the markets to which they sell.

These proximity and location effects have impacts on economic performance at the local and national level. For example, much economic activity tends to cluster – London crams 150,000 workers into each square km of its central business districts. This happens because productivity is enhanced by the intense economic interaction that occurs in economically large and dense places. Evidently, transport is necessary for such high employment centres to function, suggesting that transport improvements can have a *productivity enhancing effect*.

At a wider spatial scale there may be changes in the level and distribution of investment, and hence in the spatial pattern of employment and incomes in the economy. Some locations become more attractive places in which to undertake investment and this can impact on job creation, wages and local income. We study these under the heading of *investment and employment* effects.

1.2 Causal links and report outline

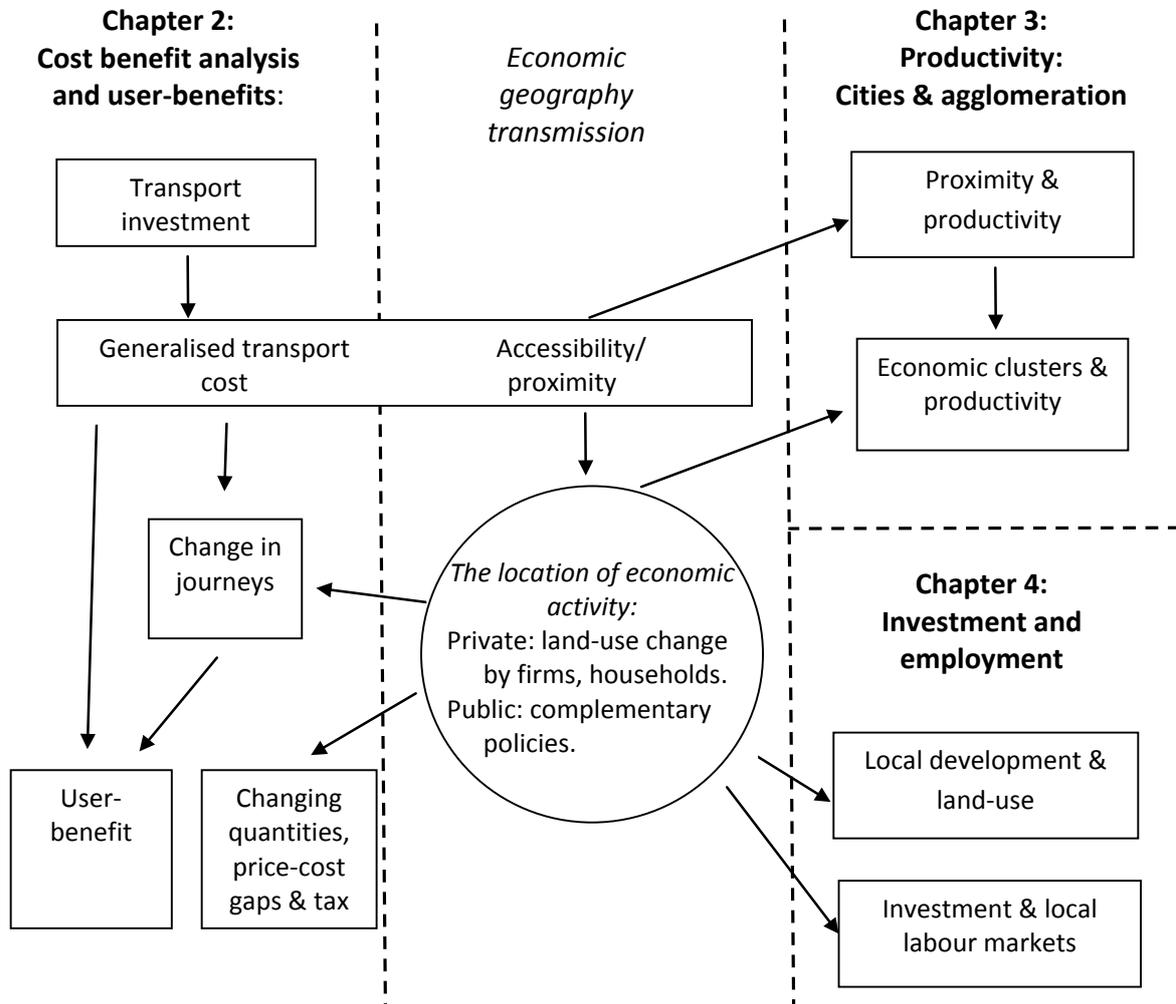
The report is organised around user-benefits, productivity effects, and investment and employment effects. For each we seek to understand the mechanisms that operate, review evidence about their magnitudes, and discuss appropriate ways to include them in project appraisal.

The key causal links and chapter structure of the report are illustrated schematically on figure 1. They start with the narrowly defined effects of transport given in the left hand column. The direct effects of a transport improvement follow the links down the left-hand side of this column. The costs of journeys (in monetary, time and other generalised transport costs, GTC) are reduced by an improvement. This creates user-benefit and induces changes in travel patterns; additional journeys are of value to those who make them, contributing a further source of user-benefit. These effects are at the centre of transport cost-benefit appraisals and are the entirety of a traditional approach. They form the core of chapter 2 of this report.

The indirect, but perhaps more fundamental, effects of a transport improvement arise as they shape the economic geography of the country. Lower GTC makes places more accessible, inducing changes in economic behaviour that go beyond transport decisions and often result in changes in the location of economy activity. These are generally investment decisions, some by households, some by firms and some involving policy changes by public bodies (central column of figure 1). They change the level and spatial distribution of economic activity, i.e. the quantities of output, employment and other economic variables generated at various places. (The transport literature often refers to these

changes in the location of activity as ‘land-use’ change, a term that we think too narrow to capture what is involved).

Figure 1: The effects of a transport improvement



What are the implications of these changes in accessibility and location? One implication is a feed-back into user-benefits. Accurate predictions of the change in journeys cannot be made without knowing about induced changes in the location of economic activity. Another is that the changes may create benefit through mechanisms such as changing tax revenue. These are addressed in the ‘wider economic benefits’ appraisals of the DfT, and we discuss them in chapter 2.

Changes in accessibility and location also have implications for the broader performance of the economy, divided into productivity effects (chapter 3) and investment and employment effects (chapter 4).

The productivity of workers in a place depends – amongst other things – on proximity to other workers. Spatially concentrated economic activity saves transport and communication costs thereby

facilitating interaction and giving firms better access to a wide range of specialist workers and skills. It raises the intensity of competition and promotes the exchange of ideas and creativity. At the extreme, this is manifest in the highly productive clusters of firms observed in the City of London, Cambridge, Silicon Valley, and Hollywood. More generally, there is evidence that better connectivity delivers some of these benefits to affected places. Chapter 3 asks two main questions. What is the evidence concerning the productivity impact of these changes? And what are the implications for project appraisal in practise? Notice that these agglomeration and productivity effects are driven by two distinct mechanisms (figure 1). One is simply that transport improvements make places more accessible so, for example, making business links between firms easier. The other is that there may be investment decisions shifting economic activity towards – or away from – various towns or cities. There is evidence that these productivity effects are sufficiently important for them to be included in transport appraisal, as is done in the wider benefits modules of current DfT practise. However, in order to be appropriately project specific, appraisal needs to pay more attention to the exact mechanisms and context of projects under study. Furthermore, there can be considerable divergence of results amongst practitioners in this area, requiring greater transparency in the techniques used in these appraisals.

Chapter 4 focuses on the spatial distribution of changes: what happens to investment in locations affected by a transport improvement, and how does this feed into employment and thence (together with productivity) into gross value added (GVA) at both the local and national level?³

Assessing these spatial investment and employment effects is challenging for several reasons. First, the economic arguments suggest that effects are, in some cases, ambiguous. While investment in a project focussed in one city is likely to have a positive effect on investment in that city, inter-city projects are less clear cut. Is there a positive impact on all places along the route, or just some? Do some places lose out relative to others? Chapter 4 outlines some of the arguments, recognising that outcomes depend on circumstances that are unlikely to be known to analysts undertaking transport appraisal. Predictions of these changes can be generated by computer based modelling techniques, by drawing on evidence from similar schemes, and by making the most of local knowledge. These are areas where further progress can and should be made.

Caution needs to be exercised in evaluating the social value of these changes; are they simply redistributions of investment and income around the country, or are they **additional**? Induced private sector investment incurs private costs and delivers private gains; under what circumstances do they also yield wider social benefits? Even if the investment is additional, jobs created may not be: workers may simply move between jobs of equal value, so other jobs are **displaced**. Chapter 4 reviews circumstances under which these investments create further net benefits, over and above the direct user-benefits accruing from the transport project. These are principally where there are market imperfections of various types, such that investors are unable to capture the full social value of a project they undertake.

³ Gross value added, GVA is reported at the regional level. GDP is the national sum of GVA, adjusted to be at market prices not factor cost.

One set of imperfections occurs in the labour market. In some circumstances the creation of new jobs will simply displace workers from other jobs, with no net gain. But in areas with structural unemployment or low participation, job displacement may be less than one- to-one so that net benefits are created by job creation. Imperfections can also arise for other reasons, particularly with large developments involving significant land-use change. For example, transport improvements may be a catalyst for regeneration or for establishing a new cluster of activity. Neighbourhoods can get stuck in low-level traps; it is not worthwhile for one property owner to invest in upgrading a property unless neighbours do the same. Better transport links can have an impact in such circumstances, attracting people and investment to the place, and thereby breaking the low level trap. Chapter 4 proposes and evaluates a number of arguments of this type, suggesting that significant sources of gain are possible.

These circumstances are all project and location specific, and evidence is correspondingly mixed. Importantly, the extent to which further benefits can be achieved depends not just on transport, but on a wider package of local measures. Is land made available for new warehouses, factories or offices? Do local travel networks link with a new, larger, scheme? Are local skills sufficient to attract investment or make the most of potential productivity improvements? To capture this range of possibilities appraisal needs to look at the local context of each project.

Analysing these transport induced changes in investment and employment is challenging. However, much of the policy discussion about transport is, and will be, about its impact on jobs and employment at the local as well as at the national level. There are local incentives for producing – and perhaps exaggerating – estimates of these effects. If informed debate is to take place then techniques in this area have to be improved, made more transparent and opened to scrutiny. DfT expertise and project appraisal is required to meet these challenges

1.3 The evidence base

Evidence on particular aspects of transport is reviewed in each chapter, and briefly summarised as follows.

The evidence base for measuring user-benefits is well established. Sophisticated traffic models are used to estimate the impact of transport investments on the generalised cost of travel and ensuing changes in traffic flows. We review the evidence on the accuracy of these predictions in chapter 2, suggesting that performance in practise has been rather mixed; in particular, for larger projects uncertainties to do with changes in land-use have been a problem. A cross-check on user-benefits is provided by estimates of land value uplift in affected areas. For example, studies of the Jubilee line and DLR extensions find that proximity to stations raises property prices by around 10%, a figure consistent with user-benefits (time savings) from proximity.⁴

⁴ Gibbons and Machin (2005)

Evidence for the productivity enhancing effects of ‘proximity’ (defined in economic, not just physical terms) is also well developed, and is reviewed in chapter 3. This has been an active research area, with work on different data sources for a number of countries. Rigorous statistical testing points to the importance of controlling for levels of skill and the occupational structure of different places but even so, evidence indicates that closer ‘proximity’ has a marked productivity effect. There are important sectoral and occupational differences, with business services and high-technology being the sectors that benefit most from clustering together. Applying these findings to transport appraisal poses some challenges. For example, a transport improvement will typically apply to just one transport mode; it can be difficult to assess the contribution of a change in one mode (e.g. a rail improvement) to a place’s overall measure of ‘proximity’, and to the sort of economic interactions that are important in raising productivity.

The effects of transport on investment, employment and GDP – nationally and broken down by area – are also widely researched, but the literature does not supply robust answers to many of the key questions. Establishing evidence is extremely demanding for two fundamental reasons. The first is that of the counterfactual; the outcome of a project is observed, but assessment of what would have happened in the absence of the project has to be inferred in some way. The second is that, even if this can be done with any accuracy for some set of completed projects, experience is only partially transferable to prospective projects.

Research on employment and GDP effects establishes findings at different economic levels. At the macro- level there are numerous studies establishing the relationship between measures of transport infrastructure and GDP. Estimates suggest that a 10% higher infrastructure stock is associated with around 1% higher income (given levels of other productive inputs).⁵ One way to interpret this is that if all inputs (including transport infrastructure) were to increase by 10% then GDP might be expected to also increase by 10%: but if transport infrastructure were to remain constant, then GDP would increase by only 9%.⁶ These macro-level studies, while confirming the importance of transport for GDP, offer little guidance about the level of transport investment needed in an economy, and no guidance about choice between transport projects.

Other studies look at the effects of specific projects, or types of project. They generally find positive effects of large transport projects on measures of economic performance such as local area employment or GDP, although effects for smaller projects are harder to tease out. For example, regeneration effects of local transit schemes appear to have been mixed. So too for studies of high speed rail, although positive effects are generally found for major stations. A new wave of literature finds that the positive impacts of transport are robust to rigorous statistical testing which seeks to establish that transport is causal to (not just correlated with) economic performance. Notable examples are studies of the impact of the US inter-state highway system and of UK road construction

⁵ Following the work of Aschauer (1989) and reviewed in chapter 4.

⁶ Precise numbers would also depend on returns to scale and technical change.

between 1998-2007.⁷ All of these studies struggle to provide convincing evidence on the extent to which positive effects felt locally are additional, and not just the consequence of activity relocating.

One of the largest questions surrounds the effect of transport on the spatial distribution of economic activity: does it tend to reduce spatial inequalities, or amplify them? There is little doubt that areas suffer from being isolated, and that integration into the world economy as a whole is good for economic performance, as evidenced by international experience. However, within the urban structure of a modern economy there is a delicate balance between larger and smaller cities. The former often experience higher productivity, but have the disadvantage of higher land and housing costs. Transport improvements change the relative attractiveness of different locations, affecting both productivity and costs, but the way in which this impacts across cities is hard to predict. We explore these issues in chapter 4, but note that there is little empirical guidance. Outcomes depend on a wide range of area specific factors, of which transport is just one.

It is in the nature of transport that each project is different and will not be replicated. Appraisal therefore has to build evidence on each of the mechanisms through which transport affects the economy and combine these elements – in a model – to get predictive power about likely effects of a particular project. The model may just be a conceptual framework, or a fully developed computer model, such as the Land-Use Transport Interaction (LUTI) models discussed in chapter 4. This approach inevitably has problems; the model in which elements are combined will be to some extent subjective, informed by the judgement of the analysts, and the evidence used in the model will be more or less accurate or appropriate. The appropriate combination of evidence and judgement is the subject of most of this report.

1.4 The social value of a transport improvement.

The changes outlined above affect the real incomes of individuals and thence of regions and the country as a whole. People will be interested in different aspects of these effects, and clarity is needed from the outset. There are several issues.

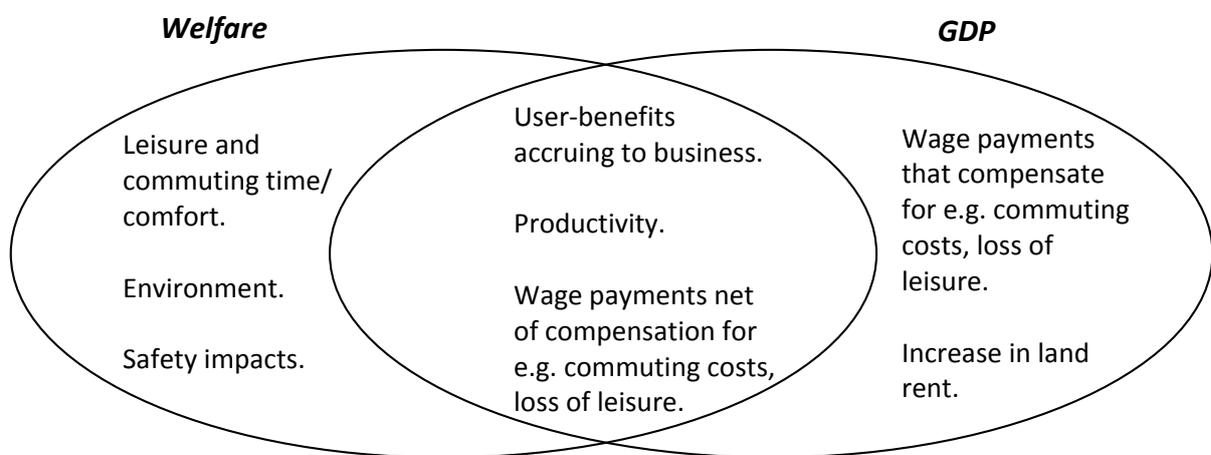
The first is the distinction between welfare and GDP (or GVA). GDP is the value of output (and expenditure) that goes through markets.⁸ But it does not include benefits that are unmarketed, and neither does it adjust for the fact that some expenditures are ‘defensive’, offsetting other costs. ‘Welfare’ makes these adjustments, some of which are given in figure 2. These distinctions are particularly important in the context of transport. Sitting in a traffic queue could raise GDP (expenditure on fuel, bringing forward your next car purchase) but it reduces welfare. Expenditure on commuting is a means to an end; a necessary cost of getting to a job, but not a benefit in its own right.

⁷ See chapter 4

⁸ Although the government can be a purchaser of services: the activity of the NHS is therefore marketed and in GDP.

Second, there is risk of double counting effects. As an example, consider the effect of a commuting improvement on someone using and living near the improved route. The user-benefit can be calculated directly (and correctly) as the reduction in generalised travel costs this person pays. However, some of this might be captured in higher property prices and rent. If the individual is renting her house this goes into GDP (although it doesn't if she is an owner occupier); however, since this has already been measured as part of the 'user' benefit it should not be counted again when transferred to the landlord.

Figure 2: Welfare and GDP measures



Third, whatever measure of value is used, the valuation requires comparison of situations with the project, and without it (the counterfactual). Value comes from activities that are additional and that do not displace other activities of similar value. The additionality criterion can be applied at different spatial levels – e.g. to the country as a whole, or to a particular city; an investment additional to a city may not be additional to the nation. We often hear that a transport improvement will lead to the creation of so many jobs. This can only be valued if we know what the workers would have been doing in the absence of the improvement, and whether other jobs have been displaced. Stating this more generally, the analyst needs an accurate measure of the opportunity cost of resources employed.

Finally, discussion throughout the report will be in terms of the effect of transport investments on the level of welfare and income, not on the rate of growth of these variables. In project appraisal, the time dimension over which a project operates is captured by computing the discounted present value of benefits and cost. Gains from a project may come through rapidly, as a step-change with a short-run impact on growth and a long-run effect on the level of income. Or they might increase through time, e.g. if, in the absence of the project, a bottleneck becomes increasingly costly. While a transport project may not change the long-run growth rate, in an economy in which the

fundamentals of productive capacity – technology and human skills – are improving, a sequence of transport improvements are typically needed. Thus, although a particular transport improvement may increase the level of income not the long-run rate of growth, a strategy of a sequence of such improvements will translate into an increase in the long-run rate of growth.

1.5 Present appraisal techniques

The core of appraisal techniques, including the Transport Analysis Guidelines (TAG) of the DfT, is the measurement of user-benefit, calculated as a welfare measure for the country as a whole (in present value, and often expressed, relative to costs, as the benefit cost ratio, BCR).⁹ In the core guidelines for appraisal this holds ‘land-use’ constant, i.e. switches off the location changes represented in the circle in the central column of figure 1. Restricting appraisal to this narrow measure has some powerful economic rationale, discussed in chapter 2. It also has practical advantage, as it does not require making estimates of the induced investment and location changes. However, by failing to capture spatial reorganisation effects it may miss some of the benefits that accrue to the national economy in aggregate, as well as failing to provide the local detail that is of interest to many stakeholders.

In addition to user-benefits, the TAG provides guidelines for analysis of a set of ‘wider impacts’. These effects and methodologies for measuring them are outlined in TAG Unit A2.1 and comprise three elements. The first of the wider impacts is agglomeration effects and consequent productivity change (TAG Unit A2.1 WI1). This came out of the context of Crossrail and a perception that growth of a highly productive cluster was being inhibited by inadequate transport links.¹⁰ The full assessment of the DfT’s approach to this and alternative methods is presented in chapter 3.

The other two wider impacts included in DfT appraisal are to do with valuation of changes in levels of employment and output. If there are gaps between the marginal benefits and costs of economic activity then changes in activity levels may yield a net benefit. One such gap arises as a consequence of income taxation. The wider impacts methodology includes procedures for valuing the changes in tax revenue that might follow from employment effects of a project such as increased labour force participation or workers moving to more productive jobs (WI3) Another is the presence of imperfect competition which enables firms to set price in excess of marginal cost: a methodology is included to capture this effect (WI2). Both of these are reviewed in chapter 2.

A recurrent issue in appraisal – and throughout this report – is the extent to which land-use changes (changes in the spatial pattern of investment and employment) are taken into account. As noted above, the benchmark position in England is that such changes are excluded, so that all arrows

⁹ Appendix 1 sketches appraisal methodologies used in other countries.

¹⁰ Notice that a partial assessment of productivity effects can be derived without estimates of investment and location effects. The upper left arrow in figure 1 is the proximity effect, capturing the fact that, even if nothing has moved, a transport investment improves accessibility and makes locations economically closer. This technique is used in some important appraisals, as discussed in chapter 3.

emanating from the circle in figure 1 are ignored. This is quite adequate for the majority of smaller schemes but, inevitably, paints a less than complete picture. Local effects are intrinsically important to local policy makers, particularly where they might unlock substantial amounts of private investment. They have wider national implications where they interact with failures in the labour market or the land market. DfT guidelines include provision for estimating location effects for some projects, particularly larger ones. Various techniques are employed to generate these estimates, typically Land Use-Transport Interaction (LUTI). The guidelines also have a discussion of how to handle 'dependent development' (where transport unlocks private investment) and regeneration. Chapter 4 addresses these issues, and makes a case for giving them fuller treatment in future appraisals.

2. User-benefits and wider benefits

The core of a transport cost-benefit analysis (CBA) is the measurement of user-benefits. This involves calculation of two changes. One is the generalised transport cost (GTC) reduction (including time savings and lower vehicle operating costs) associated with each journey made along affected routes. The other is the change in the number and pattern of journeys – on the route and elsewhere in the network – that follow from the project. This is typically based on a transport demand model which predicts traffic flows on the basis of generalised transport costs and route capacity. If parts of the route are congested these elements interact, as changes in traffic flow change costs which in turn change traffic flows, and so on.

There is a long established and rigorous process for calculating these quantity (i.e. traffic) changes, for placing values on them, and thence calculating user-benefits. This chapter does not seek to review all aspects of this, but rather to do three things.

The first is conceptual. Under what circumstances do user-benefits capture *all* of the social benefits of the project.¹¹ This is necessary groundwork for the investigation of ‘wider impacts’ that follows. The second is to outline current practise, briefly discussing its evolution and some issues that arise in the estimation and evaluation of user-benefits. Is there evidence of systematic over- or under-estimation of quantity effects, or over- or under-valuation of these changes? The third is to look at two contexts where this approach has been extended to include the wider impacts that occur when a transport improvement changes the quantity of an economic activity for which marginal benefits and costs diverge. One context is the labour market, in which income taxation creates such a divergence (TAG Unit A2.1, WI3); the other is the presence of imperfect competition in goods markets (TAG Unit A2.1, WI2). Productivity and broader issues surrounding the location of investment and employment are discussed in chapters 3 and 4 respectively.

2.1 User-benefits and total benefits.

Under a well-defined set of circumstances user-benefits (i.e. the cost reduction for existing and new traffic) capture the entire welfare effects of a transport investment.^{11,12} The conditions are that induced changes in the rest of the economy are quite small **and** that the rest of the economy is operating perfectly efficiently. This is a powerful statement. It means that, although a project will generally change many economic variables, under these conditions the narrow user-benefits approach accurately measures the welfare effect of the project. Cost benefit analysis can be quite

¹¹ The environmental and safety impacts of transport improvements are subject to a separate appraisal process and not covered in this report.

¹² Usually calculated by the ‘rule of half’.

tightly circumscribed and undertaken relatively easily, looking just at direct cost changes and changes in journeys.

To illustrate, a transport improvement will generally change some prices in the economy. This will affect people who are not themselves users of the project; however, under the assumptions above, such changes are simply transfers between individuals so net out in aggregate and can be ignored. The simplest example is that of housing at access points along the route. Houses become more desirable so there is land value uplift and an increase in rent and house prices. Should this benefit (perhaps accruing to the landlord, a non-user) be counted in the CBA? The answer is not if the benefits received by the user (i.e. the tenant) have already been counted. The market transfers these benefits to the landlord, but the rent increase is equal to user-benefit and to include it would be to double-count.¹³ Clearly, the argument rests on the social policymaker looking at aggregate benefit, not caring about its distribution between the tenant and the landlord. This is a questionable assumption, and in chapter 4 we suggest that policymakers might care about the spatial distribution of income.¹⁴

More generally, lower transport costs may induce many changes in behaviour; changes in investment and employment, plant location, place of shopping or place of residence. However, the private value of the change in behaviour cannot exceed the transport cost reduction that triggered it. If it did, the change would have been made anyway, without the transport cost reduction. Firms not directly impacted by the transport improvement may find themselves indirectly affected, e.g. by a change in demand for their product. They may then change their behaviour, perhaps increasing production. But there is no net social gain from this as the benefits of the extra production are matched by its costs. If the benefit exceeded the cost then firms would have been missing an opportunity to make money; in a perfectly functioning economy this does not happen. Colloquially, there are 'no dollar bills left on the sidewalk'.¹⁵ The implication is that to measure the net benefit of a project, appraisal can focus on user-benefits and does not need to track all the changes in the economy – since they are, under these conditions, of zero net value.

These conditions fail if there are 'distortions' or market failures that mean the economy is not functioning efficiently.¹⁶ Two of these are studied in section 2.3 of this chapter; they arise when there is a divergence between price and costs due to taxation or imperfect competition. Chapters 3 and 4 look at further arguments, suggesting that, particularly in a spatial context, the assumptions under which the user-benefit approach captures all social benefits do not hold. Important spatial interactions are not transmitted solely through perfect markets. There are multiple externalities and

¹³ A similar argument can be made for a reduction in firms' costs. This, in a competitive market, will reduce firms' price, so consumers of the product are the ultimate beneficiaries. The effect should only be counted once and this is most easily and accurately done on firms' cost reduction.

¹⁴ Distributional issues are important more widely. Society may value additional income accruing to poor people more than to rich, or to citizens more than to foreigners: the latter issue arises if land rent and land value uplift accrues to overseas landowners.

¹⁵ Dodgson, 1973, Jara-Diaz, 1986; Mohring, 1993; Boardman et al., 2011 p121

¹⁶ They may also fail if changes elsewhere are large enough, the general equilibrium effects, for example changing the economy's terms of trade, see chapter 4.

situations in which there is ‘coordination failure’: dollar bills **are** left on the sidewalk because it requires collective action to pick them up. Transport can act as a catalyst for such concerted behaviour (e.g. the development of cluster of activity or the regeneration of a neighbourhood).

In sum, the case for a narrow user-benefit approach is based on fundamental and powerful principles. The case for using a wider approach has to be very clear about why these principles do not apply. This will be the task of most of this report, but first we make a few observations about current application of the user-benefits approach.

Transport improvements and land values:

Numerous studies have looked at the impact of transport improvements on property prices. For example, Gibbons and Machin (2003) found that residential house prices in the vicinity of stations on the Jubilee Line extension and the Docklands Light railway increased by 9.3% compared to places unaffected by these infrastructure changes. This is consistent with estimates of the value of time savings from being close to a station. Banister and Thurstin-Goodwin (2011) estimated that the Jubilee Line Extension added £2.2bn to property values in the vicinity of stations.

These studies provide a useful ex-post check on appraisal. If the actual property value uplift is greater than the appraisal’s predicted benefit, then it is indicative that the appraisal underestimated benefits. However, the property market lens is not very useful for ex ante appraisal. An estimate of property uplift would usually be generated by capitalising user-benefits – in which case it adds nothing to using the user-benefit estimates in the usual way. Furthermore, while user-benefits might be spread over a narrow spatial area, wider benefits of a transport improvement could spread over a larger area. This makes it hard to associate changes in property values with particular transport improvements.

2.2 Measuring user-benefits:

The calculation of user-benefits and assessment of wider transport induced changes in the economy require accurate forecasts of traffic flows and the measurement and valuation of costs. Whilst not the primary focus of this report, we briefly review some of the issues that arise in predicting these variables.

Traffic forecasts

Much of the effort in practical transport appraisal involves predicting changes in the generalised costs of travel and associated changes in traffic flows in time and in space (in the peak, off-peak, this year and in future) and then aggregating the benefit over the life of the project. Although conceptually clear, this is quantitatively challenging, particularly in large urban areas. Travel demand substitution between routes, modes, destinations and time periods can all occur and new trips can be generated. These lead to a complex modelling process in which demands and costs need to be simultaneously determined (due to the presence of supply side constraints – such as congestion

costs) to give a set of consistent travel demands and costs between each origin-destination pair, by time period and mode, and a set of traffic flows and speeds/delays by link, junction, interchange, etc. Travel demand models that estimate all these effects in complex urban networks – such as a webTAG compliant model¹⁷ – can be onerous in terms of data and in operational costs.

There has been, and continues to be, a substantial research effort to improve modelling of travel demand and costs. In getting UK ‘best practise’ demand modelling to where it is today there have been several notable developments. The first considered the appraisal of urban road schemes which led to the standard use of network models (SACTRA, 1986), the second led to the adoption of variable demand modelling as standard – particularly in urban areas (SACTRA, 1994). In the rail industry similar efforts have been expended at setting out the evidence and good practise for demand and revenue forecasting. This has led to publications such as the Passenger Demand Forecasting Handbook (ATOC, 2013) and research streams aimed at improving the evidence base. Efforts appear slightly less co-ordinated in the bus sector, possibly due to its fragmented market structure, but nonetheless demand modelling guidance exists (e.g. Balcombe et al., 2002).

In order to form judgements about the accuracy of these predictions systematic ex post monitoring of projects is needed. The Highways Agency has such an ex post programme, Post Opening Project Evaluation (POPE). In a meta-analysis of 77 Highways Agency schemes Atkins (2013 pp47-63) found that 62% of the ex ante appraisals predicted traffic flows with +/-15% of ex post realised traffic flows,¹⁸ and about 85% of appraisals predicted traffic flows within +/-25%. They also found that traffic forecasting accuracy has shown some improvements over time. There does not appear to be significant variation in forecasting accuracy by road type, except that accuracy is somewhat worse for bypasses. The ‘successful’ ex ante forecasts all had good base year traffic models, well validated and of appropriate scope, as well as a good representation of how land uses in the vicinity of the schemes were expected to change and good prediction of expected traffic growth over time (through background economic growth). The less robust evaluations tended to be based on traffic models that arguably were weak (in terms of scope and model validation) and did not adequately capture external influences (i.e. developments, other transport schemes and background growth). Laird *et al.* (2012) made similar observations regarding the sources of traffic forecasting error in 10 EU Cohesion Fund funded transport projects. It is our view that with only 62% of forecasts being ‘successful’ there remains considerable scope for improvement in ex ante traffic forecasts. The observed errors from the model scope being too narrow and the model being poorly validated are avoidable, with the solutions having been part of good practise for a considerable time (see Mackie and Preston 1998).

¹⁷ Such a model would comply with DfT guidance on demand modelling and data. This guidance is contained in TAG units M1 to M5: M1 Modelling principles, M2 Variable demand modelling, M3 Assignment modelling (highway and public transport modelling), M4 Forecasting and uncertainty and M5 Advanced modelling techniques (park and ride and smarter choices) (DfT, 2014) <https://www.gov.uk/transport-analysis-guidance-webtag#guidance-for-the-modelling-practitioner>.

¹⁸ +/-15% is considered to be an acceptable degree of error when developing a network demand travel model.

Atkins (2013) also identify that in 10% of the appraisals (i.e. about 25% of the appraisals where traffic flows have not been estimated at a good level of accuracy) the incorrect incorporation of land use change (in particular, new developments) was part of the cause. Even with a land-use model (see chapter 4) land-use change is hard to predict, although risk assessments can be undertaken. Similarly poor quality estimates of background growth in traffic levels is relevant to 22% of the appraisals (more than half of the appraisals where traffic flows have not been estimated at a good level of accuracy).

The importance of accurate forecasts of travel flows is emphasised by recent econometric work showing that, in heavily congested and car dominated cities in the US, road improvements have induced so much traffic that vehicle kilometres travelled have increased one for one with the increase in lane kilometres (Duranton and Turner, 2011) and volume to capacity ratios have not been altered by the transport investment (Graham, 2013). Land-use change is one of the reasons for this. Cities that have received road investments have grown as a consequence and also specialise in the export of heavy goods (Duranton and Turner, 2011; 2012; Duranton, Morrow and Turner, 2013). Clearly these findings are location and context specific, but they serve to illustrate how essential an understanding of land-use change is to predicting future traffic flows. SACTRA (1994) in their report on generated traffic to the Department for Transport also considered this to be the case.

Two conclusions follow from this. One is the need to further assess the extent to which current forecasts fail to adequately predict traffic flows. This requires systematic ex post evaluation and careful comparison of these with ex ante predictions. While already undertaken for Highways Agency schemes through the POPE programme, this is not routinely done for other sorts of projects (such as rail, local transport, cycling and walking).¹⁹ Contingent on this, there may be a case for reviewing the set of projects for which land-use changes are forecast. The benchmark is that this is not done.²⁰ We return to this throughout the report and in conclusions.

Measuring Generalised Transport Costs

Along with changes in traffic flows, appraisal requires predictions of changes in user-costs. The generalised cost of transport contains monetary elements and non-monetary, such as the value of time and of reliability. There are two issues: prediction of how elements of cost are affected by a transport investment and the valuation of these changes.

Travel time savings are the major component of the change in generalised transport costs for infrastructure projects that increase capacity. For example in a package of UK highway improvements appraised for the Eddington study (Eddington, 2006), travel time benefits accounted for 72% of all monetised benefits including reliability and wider impacts. Time savings also form half

¹⁹ TAG Unit A1.1 Cost Benefit Analysis (p3) and TAG Unit A2.3 Transport Appraisal in the Context of Dependent Development. The DfT has recently published a programme for improving its monitoring and evaluation, <https://www.gov.uk/government/publications/dft-monitoring-and-evaluation-programme-2013>.

²⁰ We find the DfT's position on fixed land uses slightly confusing. This is because whilst the guidance advocates that land uses should remain fixed, it provides a guidance note on LUTI models and includes what it terms move to more productive jobs (see discussion later in this chapter) as part of its wider impacts guidance.

of all user-benefits predicted for the proposed London to West Midlands high speed rail line (HS2) (DfT, 2012 Table 10 p42). Despite business use of the road network (including for freight) being a small share of total use,²¹ benefits to business tend to be as important as non-work related benefits due to their high economic value. Thus for the Eddington package of highway improvements referred to above 54% of the time savings benefit accrued to freight and cars on employers' business trips. For HS2 aggregate business time savings comprise almost three times the aggregate value of non-work time savings.

Better reliability is also important, reducing the amount of contingency time that has to be built into journeys. Punctuality of train services and variability of journey times by road are frequently cited as areas of concern by transport users. For freight some estimates suggest that improvements in reliability are more important to businesses than time savings (Significance et al., 2013).

For road improvements the impacts on travel times are typically estimated simultaneously with travel demands due to the interaction between demand and travel times in congested networks. The Atkins ex post analysis of Highways Agency trunk road improvements includes an analysis of travel time savings (Atkins, 2013 pp63-68). They find that inter-peak travel times are reasonably well predicted ex ante, but that time savings realised in the peak are on average 21% less than those forecast²². This difference between the peak and off-peak is attributed to the differing levels of congestion – at higher levels of congestion small changes in demand can lead to large changes in travel times, requiring a much higher degree of accuracy in the demand modelling at the peak. Three reasons for the divergences between the ex ante and the ex post time savings are given: traffic flows are not predicted with sufficient degree of accuracy, lower speed limits have been imposed than were anticipated ex ante, and the ex ante transport model contained junction coding errors. The issue of speed limits is an example of policy change rendering the appraisal inaccurate (see Mackie and Preston 1998 for similar issues related to operation of public transport schemes). No comparison on predicted versus realised changes in reliability are presented in the Atkins work – as ex ante predictions of reliability are not contained in the ex ante reports. Atkins do however find that reliability has improved as a consequence of the transport investments.

Bringing the demand forecasts and the journey time saving aspects of the ex post analysis together, Atkins found that only 19% of the appraisals obtained journey time benefits within +/-15% of outturn benefits, whilst 78% of schemes had them within +/-50%. The majority of the ex ante appraisals over-estimated travel time benefits – though Atkins note that their methodology for measuring ex post total travel time savings gives conservative estimates when the benefits are

²¹ Less than 30% of traffic by distance. For the average road in the UK goods vehicles and light vans combine to form 19% of traffic flows by distance, whilst 13.1% of cars are making business related trips (weighted by distance); cars form 79.4% of all vehicles on the road network. Source webTAG Table A1.3.4 and NTS Table TRA0104.

²² When Atkins regress ex post travel time savings on ex ante time savings a coefficient on the ex ante time saving of 0.79 is found in the peak – implying the realised time savings are on average 21% lower than the ex ante expected time savings – and a coefficient of 1.02 is found for the inter-peak (implying the inter-peak travel time predictions are on average fairly accurate).

spread over a large area.²³ These statistics do not strike us as particularly re-assuring, and would suggest that there exists a large source of error in the ex ante predictions of user-benefits. We see that an important part of efforts to improve the accuracy of transport investment appraisal involves the use of ex post evaluation programmes which should extend beyond Highways Agency schemes and include before and after measures of changes in reliability.

The monetary values applied to travel time savings and other non-marketed components of generalised transport costs remain the subject of debate. A consensus has been reached on the valuation of non-work time savings and there is a substantial body of evidence on this. There remains debate regarding the most appropriate way to value business time savings (Wardman et al., 2013) and whether freight time savings should reflect the type of load that is being carried as well as the treatment of small time savings (Batley et al., 2010). The DfT continues to be active in this field of research and is commissioning a new study of business and non-work valuations of peoples' travel time (excludes freight). Unlike the ex post work by Atkins referred to above there is no observable benchmark against which the values used in appraisal can be assessed.²⁴ It is therefore hard for us to offer comment on the values in use beyond noting that whilst some consensus has developed there remain areas of controversy, and continued research in these areas is needed.

One final point worth emphasising is that the transport modelling and appraisal literature distinguishes between behavioural and appraisal valuations. Behavioural values are used for modelling changes in behaviour (primarily demand), whilst the appraisal values are those used in the ex ante CBA. Behavioural values are adjusted for use in CBA principally for equity reasons;²⁵ since valuations vary by income, time savings are implied to be more valuable in high income areas of the country. To avoid this, national averages of the time savings and other non-market components of GTC are typically used in appraisal. When modelling transport and economy impacts therefore it is important that behavioural values are used rather than appraisal values.

2.3 Changing quantities and price-cost gaps.

User-benefits are the entirety of gain if the benefit of induced changes elsewhere in the economy equals their cost (at the margin); induced changes are then of zero net value.²⁶ There are numerous situations where this is not true, arising when some sort of market failure or 'distortion' means that the price system fails to align benefits with costs. Three of these are part of the DfT's 'wider benefit' appraisal modules. One applies in the labour market, where income tax places a wedge between pre- and post-tax earnings. Another is in product markets, where distortions due to monopolistic

²³ The methodology employed by Atkins measures travel time changes on key routes only. When time savings are spread over a wider area this means that the time saving benefits are underestimated.

²⁴ Values for the non-market components of generalised transport costs cannot be observed. They need to be inferred from behaviour, often in the form of stated preferences. Revealed preferences (i.e. observations on actual behaviour) are usually used as a form of validation on these stated preferences.

²⁵ There is also a technical change on business valuations to account for indirect taxation and adjust them from factor prices to market prices.

²⁶ Applicable for relatively small changes.

behaviour or other types of imperfect competition have similar effects. The third is agglomeration and productivity, additional to user-benefits and the subject of chapter 3. The remainder of this chapter reviews the logic underlying the first two of these cases and their WebTag implementation.

Labour Market Effects - Increased Labour Supply

When deciding whether or not to work an individual weighs up the costs of working (including commuting costs), against the wages earned from a particular job. By reducing the cost (in time and money) of getting to work, a transport investment is likely to increase the returns to working; some people, for whom the net returns to entering the labour market were initially not worthwhile, may decide to enter.

An increase in labour supply and employment raises GVA but, in the simplest circumstances, does not increase welfare. Initially, the individual was not working because the utility from leisure exceeded that from working, net of commuting costs.²⁷ If a transport improvement triggers work, the benefit to the individual cannot be greater than the user-benefit received, and this is already counted in the valuation of journeys undertaken. However, the situation changes if there is an income tax wedge (or loss of state benefits). In the case of income tax, the individual does not receive the full value of work undertaken because a fraction of it accrues to government. The full gain from entering employment is then the user-benefit plus tax revenue paid (or benefits not received).²⁸

In WebTAG unit A2.1 this is calculated by working out the change in the generalised cost of commuting; then estimating how this increased return to working affects the amount of labour supplied, and hence calculating how much more income is generated and how much of this accrues as income tax (or benefits not paid). The first stage of this is done by estimating the average generalised costs for each worker of commuting from home to employment, with and without the schemes. This is averaged across workers in the area and expressed as a proportionate change in their net earnings. The response of the labour force participation rate to this increase is found by multiplying by the elasticity of labour supply with respect to earnings (the estimated responsiveness of labour supply to net earnings) set at value 0.1. This predicted change in employment is multiplied by the median wage for unemployed people re-joining the labour force (these workers are assumed to be less productive than the average worker). This process is repeated for all home and employment zone pairs, to give the total annual output change from the additional labour supplied.

²⁷ Chapter 4 looks at situations where unemployment is involuntary.

²⁸ For example, the wage is £100 per day, commuting costs £12 and utility of leisure £90 so the individual does not work. Reducing the commuting cost to £8 causes the individual to work giving net benefit of £2 (=£100-£8-£90). If income tax is £50 a day and the wage, net of tax, is £100, then the same calculation goes through although in this new example the individual is assumed to be more productive (pre-tax wage £150 giving post-tax wage of £100). The government (and society) receives £50 a day from the increase in labour supplied so the full net benefit is £52 not £2.

By the argument above, only the tax raised (or benefit saved) by the additional employment and output is included as an additional benefit from the scheme; the tax rate is taken to be 40%.²⁹

While the logic of including these effects is correct, a point needs to be made concerning their application. In most appraisals the labour supply effect is created without any reference to estimates of actual jobs likely to be created. Instead, it comes from applying a common national value of the elasticity of labour supply with respect to net earnings. This has the advantage of simplicity, but needs to be cross-referenced against likely employment effects. It appears that, where these have been calculated (e.g. through a LUTI model), no attempt is made to reconcile or compare numbers coming from the two sources.³⁰

Labour Market Effects - Move to More Productive Jobs:

A similar logic underpins the calculation of the value of a transport improvement which causes not just a move from non-participation in the labour force to participation, but also causes people who are employed to move to more productive jobs. The Crossrail appraisal provides a good illustration of the argument.

The appraisal projected that Crossrail would enable central London employment to be 33,000 greater than it otherwise would have been (by 2026), with these jobs assumed to have average wages £10-12k higher than jobs elsewhere. This increases GDP by around £350 mn pa. However, much of this is not a welfare benefit, because accessing the jobs requires that workers pay the commuting costs of reaching central London. The full cost of this commuting is revealed by the fact that some people were initially indifferent between commuting to central London or working elsewhere. However, their calculation of the net gain from switching jobs is based on post-tax income, not the pre-tax wage. 30% of the wage gap accrues to the exchequer (the figure used by DfT as the marginal tax rate in this context), and it is this that constitutes the net social benefit. The appraisal included this effect, with present value (allowing for the time profile of job moves) of £3.2bn (2002 prices).³¹

As is clear from the Crossrail example, calculation of this effect requires information on jobs created and displaced, the wage and productivity levels of each, and a narrative indicating why, in the initial situation, workers were not taking the higher wage and productivity jobs (i.e. why comparable jobs with different wages could co-exist).³² These elements were all present in the Crossrail appraisal, with commuting capacity the barrier to taking the jobs, and the project increasing this capacity.

Application of these principles to other projects is undertaken using methods set out in TAG Unit A2.1 which recommends calculation of these effects only when forecasts of job creation have been

²⁹ The rationale for such a high rate is not made clear. Presumably, the marginal rate of income tax on such workers is low but the number also captures reduction in benefits paid.

³⁰ For example, Review of Lower Thames Crossing options; final review report appendices, Department for Transport 2013.

³¹ See Venables (2007) for this argument. The fact that income taxation captures some of the benefits of urban productivity has been used to argue that cities are too small, see Eeckhout and N. Guner (2014).

³² 'Comparable' such that other obstacles – such as skill requirements – could be ignored.

produced, i.e. a LUTI model or similar has been used to forecast changes in the location of activity. Given forecasts of job creation by employment zone, judgements have to be made about productivity differences between jobs created and jobs vacated. The TAG guidance recommends doing this using average GDP per worker in each of the zones affected. Thus, additional GDP created is calculated by multiplying the change in employment in each area due to the scheme (derived from the LUTI model), by the GDP per worker in that area. The welfare calculation is to take 30% of this change in GDP as net welfare increment.

We doubt that the use of area average GDP per worker is a good guide to the actual productivity differentials between jobs created and displaced. One can imagine it producing perverse results. For example, consider a project that causes the total number of high productivity jobs to increase, and as this happens they spread out into a lower wage area. Using historical average GDP per worker, these new jobs created in the lower wage area are assumed to be low productivity, so they appear as a negative value in appraisal, from what is in fact an expansion of high productivity employment.³³ The problem is that an historical area average does not control for the composition of the labour force and compositional changes that will occur.

Once again, the logic underlying the inclusion of these effects is sound, but implementation is mechanical rather than context specific. Satisfactory implementation of this quantitatively important effect needs to be based on a context specific narrative which explains why there is a productivity differential between jobs created and displaced, and a context specific quantification of these productivity differences.

Output Change under Imperfect Competition

When the level of competition to which firms are exposed is weak they may set higher prices, and sell less output, than they would be forced to in a perfectly competitive market. Transport costs can act as a barrier to competition, insulating firms from their competitors. Lower transport costs open up such areas to more competition, enhancing firms' ability to challenge in protected markets.

The welfare impact of such changes depends on the magnitude of the quantity change (the increase in firms' output and supply attributable to the transport improvement) and the price-cost margin applicable to the sector. The welfare gain is the product of the two. TAG guidance recommends approximating this by adding a 10% uplift on business user-benefits (see DfT 2005).³⁴

This approach has the advantage of simplicity and can be rationalised as the outcome of the interaction between the cost reductions associated with user-benefits, the price elasticity of demand, and firm's price-cost margin. The effects are relatively modest, but context- and project-specificity is once again a concern. Projects impact on different sectors in different ways and, as some sectors expand, others may contract. Arguably, the approach should be applied only where

³³ This seems to have arisen in the Lower Thames Crossing study.

³⁴

<http://webarchive.nationalarchives.gov.uk/+/http://www.dft.gov.uk/pgr/economics/rdg/webia/webmethodology/sportwidereconomicbenefi3137.pdf>

there is reason to believe that expanding sectors are those with particularly high price-cost margins, or where transport improvements can markedly increase competition in spatially segmented markets.

2.4 Conclusions.

i) We recognise the logical force of the user-benefit approach and the practical merit of not attempting to calculate location effects (land-use change and other investment and employment effects) in a wide range of cases. We note that approximations to some of the wider impacts can be calculated without requiring estimates of location effects (changes in labour force participation being estimated from commuter user-benefits, and imperfect competition effects from business user-benefits).

ii) The user-benefit approach rests on the robustness of the user demand and generalised transport cost estimations, and there is room for improvement in how these are derived. There is some evidence that a part of the inaccuracy in estimates of traffic flows and user costs is attributable to failure to include land-use change effects. This (together with other arguments to be developed later in the report) suggests a case for reviewing circumstances under which estimates of location and land-use change are generated.

iii) The presence of divergences between price and marginal cost make it appropriate that quantity changes (numbers of workers in the labour force or in particular jobs, the output of firms in imperfectly competitive markets) are valued and added to the benefit calculation. The approach taken by DfT is logically correct, but application lacks context specificity and risks significant errors. In particular, the 'move to better jobs' module is not sufficiently grounded on actual productivity differences. From applications we have looked at, it is not clear that the LUTI estimates of job change and the assumed (area wide) productivity differences are consistent.

Chapter 3. Economic Mass and Productivity

Economic and social activity tends to cluster geographically. This is manifest in the existence of cities and of a central business district and specialised ‘quarters’ within cities. The reasons are partly to do with access to amenities and social networks, and partly to do with productivity. A concentration of economic activity brings a combination of scale and density that can make workers and firms more productive and, in many cases, more innovative. A summary measure of a location’s potential to achieve these benefits is its *access to economic mass*; how easy it is for firms and workers to communicate, compete, and trade with a large mass of other firms, workers, and consumers.

Transport plays a key role in supporting these high productivity environments. Within large cities millions of workers are in close proximity: the central business districts of London, New York and Hong Kong have employment densities in excess of 150,000 workers per square kilometre, attainable only with good intra-urban transport systems. As well as enabling workers to get to work, transport systems allow firms to interact with other firms across the city. They also connect towns and cities to the rest of the world – creating access to markets, sources of supply, and to other cities specialised in complementary activities.³⁵

It follows from this that transport improvements, by facilitating these interactions, have the potential to raise productivity. Typically the interactions that support high productivity in economic clusters are not just mediated through perfect functioning markets but also involve many non-market interactions or ‘externalities’. These productivity benefits are therefore additional to the user-benefits of the previous chapter, and they are included in the wider impacts methodology of DfT appraisal.

In this chapter we set out the evidence and the way in which to quantify these effects. We do this in some detail, partly because these effects are quantitatively important in some DfT appraisals, and also because effects can operate through quite different channels in different contexts. It is important to distinguish between cases and to use appraisal techniques that are tailored to these distinctions, rather than a one-size-fits-all approach.

Conceptually, we split the productivity impact of transport into two steps. The first is that transport is one of the determinants of access to economic mass, and the second is that access to economic mass is one of the determinants of productivity. The next two sections discuss the second of these links: what are the mechanisms through which access to economic mass influences productivity, and what is the evidence? Section 3.3 adds the first link, that between transport and access to economic

³⁵ A useful distinction about the effects of better transport connectivity is drawn by historian Tim Leunig: “What history teaches us is that transport matters when it connects up two places that are synergistic, or when it allows a confined place to grow. The creation of the Silk Road, the discovery of the New World, and connecting the Midwest to the East Coast all come in the former category. Expanding the City of London falls into the second” (Leunig 2011).

mass. Together, these give the framework for assessing the effect of transport improvements on productivity.

We argue that there is sufficient evidence on the quantitative importance of these effects for them to be included in appraisal. However, judgement has to be exercised about how a particular appraisal should be designed in order to adequately capture the specific context of the project. There is a risk that use of a standard approach, as recommended by WebTag, can miss key aspects of the project; tools to develop this judgement in a context specific manner are needed. Appraisals (by the DfT and by other agencies) will differ in their level of detail and in other technical aspects. To enable informed debate it is necessary that key aspects of each appraisal are laid out in a clear and transparent manner, stating exactly what steps have been followed. We outline a checklist (appendix 3.1) as a possible basis for this.

3.1 Access to economic mass and productivity: issues

Why is economic activity spread unevenly across space and why does productivity tend to be higher in larger cities? Economists and geographers have debated these questions for over a century and we briefly outline the main issues and causal mechanisms that have been put forward.

A simple explanation is that proximity to customers, suppliers or workers saves on transport costs as goods and services can be obtained and delivered more cheaply. Proximity may bring benefits in terms of better reliability and greater speed. In turn, cheaper, more reliable and faster transport may allow firms to change the way in which they organise their logistics (e.g. use one or several distribution centres) or production (e.g. just-in-time manufacturing technologies). These gains are principally user-benefits, and are accounted for in calculation of those benefits.

Second, scale and density together create an environment where workers and firms can develop highly specialised skills. These are typically inputs to firms – the specialist engineers, lawyers, finance experts who may be necessary to efficient operation of a firm.³⁶ There are spillover effects (externalities) in this process. A new specialist supplier will set up once the market is big enough, and the presence of the new supplier will make the city more attractive as a location for other firms that use the product or service. This is the classic process of cluster formation, such as an auto-industry cluster of assemblers and suppliers or a film industry cluster of directors, actors and technicians. Indivisibilities or increasing returns to scale mean that a service, skill, facility or product will only be supplied if the market is big enough; but the supplier is generally unable to capture all of the benefit, so there is a positive net effect created for others in the cluster.

Related to this, competition is likely to be intense in a large and dense cluster and monopolistic pockets of inefficiency are less likely to survive. Monopsonistic behaviour, occurring where there

³⁶ The economics literature often models this as the presence of a large ‘variety’ of intermediate inputs. Each variety yields consumer surplus that is not captured by the supplier (i.e. the supplier cannot perfectly price discriminate).

are few potential purchasers for a product or skill, can deter investment; this too is less likely to be a problem in a large and dense cluster.

The mechanisms may operate within particular sectors, and across sectors and the city as a whole.³⁷ Within sector productivity effects create a force for sectorally specialised clusters, and possibly specialised cities. Importantly, the strength of the mechanisms is likely to be quite different in different sectors. This has changed through time. In manufacturing it led to specialisations such as Sheffield in cutlery, Birmingham in light engineering, and so on. In the modern economy it is still manifest in some sectors such as automotive clusters,³⁸ and has become important in service and knowledge intensive activities. Business services such as finance, law, media or high-tech, seem to be particularly prone to clustering. Both the diffusion and creation of knowledge work particularly well in clusters of activity, and a large body of literature points to the spatial concentration of innovative activities (Audretsch and Feldman 2004, Glaeser & Gottlieb 2009). Across US cities, a doubling of employment density is associated with a 20% increase in patents per capita (Carlino et al. 2007).

For purposes of transport appraisal, several features of these agglomeration and productivity effects are particularly important. First, these mechanisms have in common the fact that presence of a firm or individual in a cluster creates benefit to other firms (and workers) in the cluster. This is an externality or market failure, so creates benefits additional to user-benefits. Second, a particular transport improvement may only be used by a small proportion of workers and firms in the cluster. However, if it serves to bring more firms and workers into the cluster, then it may generate productivity gains that are felt throughout the cluster. Since many times more workers may receive the productivity benefit than use the transport improvement, the value of the improvement is potentially large.

Transport plays two distinct roles in supporting these agglomeration and productivity effects. One we term the *proximity effect*. Given the location of activity, transport reduces effective distance between places. This facilitates communications, trade and business links between firms, thereby increasing the sort of interactions that raise productivity. The second we call the *cluster effect*: this arises as transport enables activity (particularly employment) to locate in a spatially concentrated way. For example, an improvement in commuting enables more workers to reach a business district so enabling a dense cluster of activity to expand. Transport links that enable cities to specialise also have the effect of allowing firms in particular sectors to concentrate, i.e. to locate where they can better achieve the benefits of clustering with closely related firms.

The research literature and appraisal techniques use summary measures of access to economic mass to capture these effects. This has been an important contribution to quantification but, we will suggest below, has not offered a sufficiently context specific framework for transport appraisal.

³⁷ These are sometimes referred to as localisation (or Marshallian) economies, and the broader cross-sectoral effects referred to as urbanisation (or Jacob) economies.

³⁸ And, in developing economies, clusters of garment production such as Dhaka: the city of Qiaotou produces 200,000km of zippers per year.

Some sorts of transport projects create proximity effects (as when neighbouring cities become better connected) and other generate cluster effects (enabling growth of activity in a particular place). It is important to distinguish between these cases.

Finally, before turning to empirics, we note that while the agglomeration/ productivity mechanisms suggest that larger cities tend to have higher productivity and wages, the benefits of scale are (at the margin) countered by urban dis-benefits. Chief amongst these is the expense and time of commuting.³⁹ It follows that overall efficiency is maximised by a system of cities and towns, rather than complete concentration of economic mass in one place.

3.2 Access to economic mass and productivity: evidence

How large are the productivity increments associated with good access to economic mass? A substantial econometric literature addresses this question, initially in the context of the relationship between city size and productivity. An authoritative survey of the literature finds that ‘In sum, doubling city size seems to increase productivity by an amount that ranges from roughly 3-8%’ (Rosenthal and Strange 2004, p2133). This means that the elasticity of productivity with respect to city size is in the range 0.05- 0.11.⁴⁰ This is a large effect in the cross-section, suggesting that productivity in a city of 5 million is between 12% and 26% higher than in a city of ½ million. A meta-study (Melo et al. 2009) suggested that the mean estimate of this elasticity across several hundred studies is somewhat lower, at 0.03, although pointed to considerable variation according to sector, country, and technique employed by researchers.

Much work has been done to refine these estimates, particularly to consider questions of sectoral and geographical scope, to better control for other factors that determine productivity (above all skill) and to address concerns about reverse causality (does city size drive productivity, or vice versa). We briefly discuss some of these issues before summarising the results that researchers have found.⁴¹

To capture these effects researchers and policy analysts construct a measure of access to economic mass (or effective density) for each place, and then empirically establish the effect of this on the place’s economic performance (in particular, its productivity). This measure adds together economic activity (typically measured by employment) in the place and in other areas, with declining weights the further away are the other areas. Formally, location i ’s access to economic mass, $ATEM_i$ is,

$$ATEM_i = \sum_j f(d_{ij}) Emp_j$$

³⁹ Another is high property and land prices, although this is not a real resource cost; rent is a transfer from tenant to landlord. The balance between cost and benefit occurs at the margin, leaving intra-marginal surplus.

⁴⁰ Elasticities are therefore in the range 0.05-0.1 since $2^{(0.05)}=1.03$ and $2^{(0.11)} = 1.08$. Other numbers in this paragraph use these elasticities.

⁴¹ The reverse causality issue is addressed in chapter 4.

The right-hand side of this expression adds employment in all districts (indexed j), weighted by some decreasing function, f , of their economic distance to i , d_{ij} . If a place is near to lots of other places with high employment then it will have high *ATEM*. If a place is remote from centres of employment it will have low *ATEM*. A transport investment can change this measure in two distinct ways, corresponding to the distinction between proximity and cluster effects made in the preceding subsection. There may be a *proximity effect* as a transport improvement changes the matrix of economic distances between places, d_{ij} . This quantifies the idea that transport makes places better connected. There may also be *cluster effect*, as the transport improvement changes activity levels in various places, the terms Emp_j . We return to this point in more detail in section 3.3.

There are numerous different ways in which this measure of access to economic mass can be constructed and its relationship to productivity investigated, several of which need mention.

Sectoral level: The measure can be produced at an aggregate level, based on total employment in each place, to capture overall and cross-sectoral effects. Or, to capture sectoral effects, the measure and the variables contained in it can be sector specific – e.g. employment in finance, rather than employment in all activities. The relationship should then be estimated separately for each industry (see Graham et al. 2009). The productivity/ *ATEM* relationship may operate with differing strength in different sectors (some types of activity benefit more from agglomeration than others); the appropriate distance weighting may also be activity specific, both in the rate of spatial decay, and the mix of transport modes used to construct a measure of economic ‘distance’, d_{ij} . The researcher might also want to allow for the possibility that productivity is affected by both the concentration of sectoral and overall economic activity.

Geographical scope: The spatial range over which productivity effects operate will depend on how ‘distance’ is defined and how it is weighted in the calculation of *ATEM*. Distance can be measured as a geographical distance or using generalised travel costs (GTC). Generalised travel costs vary according to travel mode, important for application in the transport context, as we discuss further in the next section. The spatial weighting, i.e. the rate at which effects are curtailed by economic distance, can be imposed by the researcher or econometrically estimated. The simplest possibility is to use inverse distance or GTC (i.e. $f(d_{ij}) = 1/GTC_{ij}$). A further possibility is to let the data reveal the rate of spatial decay, either by estimating a decay parameter or by working with a series of distance bands (Graham et al. 2009, Rice et al 2006)

Place or people? occupation and skills: Productivity differences between locations arise for many reasons, of which *ATEM* is only one, and the influence of these other factors needs to be taken into account when establishing the link between productivity and *ATEM*. In particular, cities vary in their occupational structure and the skill mix of their population, both important determinants of output per worker. Controls for this and other factors have to be included in the econometric analysis if it is to properly capture the link between productivity and *ATEM*.

Table 3.1 reports some results from this research literature. It is not intended as a definitive statement of parameter values, but is indicative of the magnitudes and illustrative of the issues.

Table 3.1: Accessibility and productivity:

Unit of observation: Places	Elasticity of productivity with respect to ATEM	Controls		Distance measure: Spatial decay
Rosenthal & Strange (2004)	0.05 - 0.11	--- Survey article ---		
Ciccone & Hall (1996)	0.03	Education level		Fixed
Rice, Venables & Patachini (2006)	0.04	Occupation, skill		Travel time. Estimated.
Unit of observation: Firms				
Graham et al. (2009)	Econ average: 0.043 By sector: Manuf: 0.021 Construction: 0.034 Cons. servs: 0.024 Bus. servs: 0.083	Firm characteristics (e.g. firm age)		Geographical distance. Estimated.
Unit of observation: Workers		Observable (occupation, age, skill, experience) ²	Unobservable (individual fixed effects) ²	
Combes et al (2008)	0.035 0.024	√ X	X √	Fixed
Puga & Roca (2012)	0.046 0.023	√ √	X √	Fixed
SERC (2009) ¹ Car	0.08 (not signif) 0.05 (not signif) 0.07	X √ √	X X √	GTC car. Fixed, reciprocal
SERC (2009) ¹ Rail	0.258 0.17 0.05	X √ √	X X √	GTC rail Fixed, reciprocal

1: SERC 2009, columns 1, 5, 6 table 8 p49.

2: √, control included: X, control not included.

In the first block of the table the units of observation are places. Results are reported for the US (Ciccone & Hall 1996, and the survey article) and the UK (Rice et al. 2006). Controlling for skill and, in Rice et al. also factoring out differences in occupation structure, researchers find elasticities in the range 0.03- 0.04. Rice et al. also estimate, rather than impose, the rate of spatial attenuation of effects; they tail off sharply beyond about 45 minutes driving time, i.e. are concentrated within travel-to-work distances.

The second block is representative of studies that take a different approach, based on firm level data (for the UK, plants from the Annual Respondents' Database). The study by Graham et al. (2009) estimates productivity relationships by sector, using an *ATEM* computed for the location and sector of plants and offices. Productivity elasticities of similar magnitude are derived from this work

although there is considerable heterogeneity, with effects largest in business services. The spatial decay factor was also estimated separately for each sector and is largest in service activities, suggesting the incentive for tightly concentrated service clusters. This study provides the elasticities generally used in DfT appraisals.

The third block of table 3.1 reports results of estimating wage equations, i.e. looking at the determinants of the earnings of individual workers. The three studies indicated are for data from France, Spain and the UK. Working with individual data makes it possible to address the issue of 'people versus place' by using a fine level of worker level controls – generally skills, age and experience. Once again, elasticities of productivity are of similar size, with those for France (Combes et al) and Spain (Puga & Roca) at 0.046 and 0.05 respectively.

The studies in the third block contain two important extensions. One is that while some characteristics of individual workers are observable – their age, skill and experience – others, such as innate ability, are not. It could be the case that people with high innate ability are more likely to move to large cities. If so, city productivity would be high because of this selection effect, although the individuals might be equally productive wherever they work. Controlling for this is difficult – innate ability is not observable. However, it can be done by tracking individuals who move; when they move between cities their innate characteristics do not change, so any change in their wages must be due to the effect of the city on productivity. Estimates of this type are presented in the final row of each of these studies and in most cases markedly reduce the productivity elasticity. For Combes et al. (2008) and for Puga & Roca (2012) including these individual effects approximately halves the elasticity, although still leaving it within the range put forward in earlier studies.

The second extension is that the work by SERC (2009) has richer modelling of access to economic mass, constructing *ATEM* measures separately for two different modes of transport (car and rail) and estimating the joint effect of both measures on wages.⁴² Consistent with the results above, they find that controlling for the observable characteristics of individuals (and jobs) reduces the effect of access to economic mass (by somewhere between a quarter and a third). The effect of controlling for unobservable characteristics depends on whether one is considering the impact of accessibility by car or by train. For accessibility by car, allowing for sorting on the basis of unobserved characteristics actually increases the estimated effect (and turns it significant). In contrast, for accessibility by train allowing for sorting decreases the estimated effect by a factor of 3 (larger than the reduction found in studies that do not split by mode).

Conclusions: Several messages come from this overview of the relationship between economic mass and productivity. First, using quite different data and increasingly sophisticated econometric techniques, studies consistently find a positive relationship. Furthermore, the relationship is quantitatively important, as suggested by the discussion at the beginning of this section.

Second, the estimates by sector suggest that a significant part of the productivity effect is driven within sector. This is important because, as we will discuss below, transport can facilitate

⁴² That is, they run a multivariate wage equation with both measures included.

specialisation, enabling a city to grow a particular sector even if the city as a whole does not change effective size. The variation in elasticity across sectors can point to circumstances in which enabling sectoral expansion is particularly important.

Third, controlling for worker characteristics (in particular by means of worker fixed effects) reduces, but does not eliminate the productivity effect. Economists would generally consider results that control for both the observed and unobserved characteristics of individuals as providing the best estimate of the relationship between city size and wages controlling for composition. However, it is possible that controlling for skills or occupations in this way might create a *downwards* bias in the estimated elasticity. Skills are not exogenous, and workers might have acquired the skill *because of* the accessibility of the place. There is some evidence linking educational outcomes to access to economic mass, although the causal effect is not large. Similarly, productivity in a location depends on occupational structure, but this in turn might depend on the accessibility of the location. The different estimates presented in the third block can best be thought of as bounds on the relevant elasticity, with the lower numbers now regarded as providing lower bound estimates of the relevant causal impact.

Finally, where the spatial decay of these effects is estimated, they are found to attenuate quite rapidly. Nevertheless, in a relatively small country such as the UK effects are large enough to extend across neighbouring cities.

3.3 Transport, access, and productivity

Having discussed the relationship between access to economic mass and productivity, we now turn to the first stage in the causal chain. How does a transport improvement affect access to economic mass?

Recall that access to economic mass is constructed as the sum of activity in areas weighted by a measure of economic distance, $ATEM_i = \sum_j f(d_{ij}) Emp_j$. A transport improvement can change this in two ways. There is a *proximity effect* as a transport improvement changes the matrix of economic distances d_{ij} between places. This quantifies the idea that transport makes places better connected. There may also be a *cluster effect*, as the location of economic activity – the Emp_j variables in the equation – may change. This arises as a transport improvement may also be expected to change the spatial pattern of employment (in aggregate or by sector), perhaps by reducing the cost of commuting or by enabling places to specialise and develop sectoral clusters.

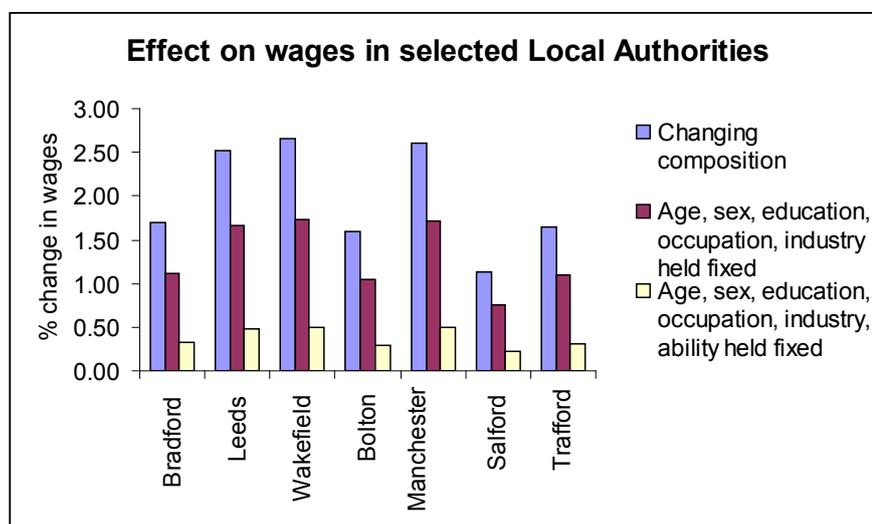
A notional ideal appraisal would have estimates of both of these effects, each sector specific and transport mode specific. In practise, appraisals have focussed on just some of these elements, ignoring (i.e. implicitly holding constant) other effects. We first illustrate with a study that focuses on proximity effects, and then turn to some that include cluster effects.

Proximity: e.g. the Northern Way

The effect of improved links between northern cities in the UK was analysed by SERC (2009) in its **Northern Way** study. Elasticities of productivity with respect to *ATEM* were generated by their own econometric work and have already been discussed (bottom block of table 3.1). Using these elasticities, they investigated the effect of various transport improvements on GTC between locations. One experiment was a 20 minute reduction in train journey times between Leeds and Manchester. This had a large impact on the rail *ATEM*, increasing it for each of these cities by approximately 10%. The impacts on productivity (measured by wages) in various places affected by the improvement are given in figure 3.1.

The tallest bar in the figure – indicating wages increases of over 2.5% in the most directly affected places – comes from a measure of the elasticity that does not control for any differences in the skill levels or occupational composition of places. The second set of bars, indicating wage increases in excess of 1.5%, controls for the skill, age, sex, and occupational mix of places (using the elasticity of 0.17 reported in table 3.1). The final set of bars is estimated with individual fixed effects (the elasticity of 0.05), yielding wage increases of up to 0.5%.

Figure 3.1:
Productivity effect of a 20 minute reduction in Leeds-Manchester rail journey time



Columns 1, 5, 6 of SERC 2009, table 12 p55: no controls, controlling for age, sex, education, occupation, industry and finally adding individual fixed effects.

Several messages come from this work. First is the quantitative importance of effects: even with the lower bound estimates there is an average productivity increase (up to 0.5%) for **all** workers in affected cities. However, the magnitude of the effect clearly depends on what is held constant (i.e. controlled for in the regression analysis). If transport improvement changes skill levels and

occupational structure the effects are several times larger although, as the SERC report makes clear, such changes will require additional investments and may be additional for the local area but not for the UK as a whole.

Second, it is important to be clear about the mode of travel that is improved. In the SERC study changes in rail access have a larger effect than road access. Other studies go further in splitting travel mode. For example, the KPMG report for HS2 Ltd (HS2 2013)⁴³ split by road and rail access and by access to workers and to business. Following this approach is difficult however, because high correlation between the different measures of *ATEM* make it difficult to obtain robust estimates of the elasticity of productivity with respect to each.⁴⁴ Not using multivariate regression (but instead estimating each separately, as done by KPMG) makes it likely that too large an effect is attributed to each mode.

Third, this study looked only at proximity effects, holding employment (by sector and in aggregate) in each place constant. This is probably appropriate for inter-city links, the focus of the study. However, by excluding location change and the potential role of transport in facilitating the emergence of clusters and specialisation, it probably offers a lower bound estimate. The next example has the opposite focus.

Clusters; e.g. Crossrail

In general, the scale of activity of each sector in each location may change, and these changes in the Emp_j terms in the expression for *ATEM* should be taken into account. In practise this will be difficult – it requires detailed predictions of land-use change and other quantity effects, which we discuss further in chapter 4. However, there are particular contexts where the effects are likely to be large and relatively easy to predict. This is for intra-urban transport schemes, principally commuting, that deliver more workers to a location where there is a cluster of economic activity.

The appraisal of Crossrail is an example of this approach.⁴⁵ It focuses on the project enabling more workers to access central London, this causing a well defined increase in employment in an area and sector where agglomeration effects are believed to be important. In detail, the study assumed that effects were limited to areas in the City of London, Westminster and the Isle of Dogs, and *ATEM* changed purely because of job growth in these areas.⁴⁶ With Crossrail assumed to enable 32,600 extra jobs in these areas (by 2027), an elasticity of productivity with respect to employment of 0.06, and central London GDP per worker at £56,900 (2002 levels and prices), the increase in productivity

⁴³ HS2 (2013) Regional Economic Impacts, <http://assets.hs2.org.uk/sites/default/files/inserts/HS2%20Regional%20Economic%20Impacts.pdf>

⁴⁴ Multivariate regression is needed, but colinearity problems arise. Estimating each mode separately risks severe upwards bias.

⁴⁵ The effects described here are additional to those discussed in chapter 2. This draws on material from DfT 2005.

⁴⁶ Formally, $f(d_{ij})=1$ for i the union of the areas above, $f(d_{ij})=0$ for links outside this set, so $ATEM_i = Emp$ in the selected areas.

of those working in the sectors was calculated as approximately £100m pa (employment being assumed to increase slowly over a long period), with present value of over £3bn.⁴⁷

This study used the same broad methodology as that of the Northern Way (going from transport improvement, to access to economic mass, to productivity), but tailored in a quite different and context specific way. For the Northern Way study, the transport improvement to ATEM link operates via the proximity effect, not by changes in total or sectoral employment in each place. For Crossrail, the transport improvement to ATEM link operates via the cluster effect, with the predicted change in employment informed by design of the project. This focus is underpinned by a view of the sectors involved and their propensity to cluster in a small spatial area.

DfT guidance: e.g. Lower Thames Crossing

Agglomeration and productivity effects are captured in DfT project appraisal as outlined in TAG unit A2.1 (and, for greater detail, see also unit 3.5.14c). In broad terms, it follows the methodology described above. Access to economic mass (or, equivalently, effective density) is calculated for each affected place, in the initial situation and with the project in place. This is done for five different sectors, with 'distance' captured by the average generalised cost of travelling between the relevant home and employment zones. The elasticities of productivity with respect to ATEM and the spatial decay factors are sector specific (based on Graham 2009). The benchmark approach assumes that land-use and the location of activity are unchanged. Effects are then derived from the impact of the project on proximity, as measured by the change in the GTC. However, for projects where a LUTI has been used, guidance allows the effect of employment and residential location change to be presented as a sensitivity check.

It is worth noting some points of detail in the approach. GTC distinguishes journeys by mode, e.g. the Lower Thames Crossing study calculates it separately for public and private transport. However, GTC is calculated as an average over **all** journeys, i.e. business and commuting and (in some cases) freight, with no distinction between sectors. In the calculation of ATEM, employment in **all** sectors is used. However, spatial decay functions and elasticities of productivity with respect to ATEM are sector specific. In the benchmark, the effect of the transport improvement is calculated only from the proximity effect, holding location, employment levels and land-use constant. For the Lower Thames Crossing study estimates of employment change are available from a LUTI study, but these appear not to be used in the productivity calculations.

These modelling assumptions do not sit well together. Why should leisure journeys affect productivity? Why should aggregate employment be used with sector specific elasticities? Should employment change and cluster effects enter or not? A subset of these assumptions may be appropriate for a particular project, but together they conflate some possible effects and ignore others.

⁴⁷ The final estimate is proportional to each of three numbers; extra jobs, elasticity of productivity and average wage.

Each of these points is a symptom of a deeper problem arising in application of fundamentally sound methods. Application is not sufficiently attuned to the specific project that is being studied. We described the Northern Way (inter-city, principally proximity effect) and Crossrail (intra-city principally cluster effect) studies as examples of how this can be done. For other projects, the cluster effect might work by improving inter-regional links which facilitate specialisation and the growth of sectoral clusters. However, each of these cases requires that a narrative be formed about the principal impacts of each project and the key causal mechanisms that are likely to operate. Modelling judgements should follow from this, rather than from a set approach.

3.4 Conclusions:

The productivity effects of transport improvements are large enough and well enough grounded to merit inclusion in transport appraisal. There is, in broad terms, an accepted and appropriate methodology for estimating these effects, although application of this methodology can vary widely.

Application of the methodology needs to be context specific; there is no single correct encompassing method, and project specific judgements have to be made about: (i) the focus of modelling efforts – what are the key issues that matter for a particular project? (ii) the proportionality of different approaches: (iii) various detailed aspects of the techniques employed.

To address (i), a clear narrative needs to be offered about the range of likely effects of a particular transport improvement. This will distinguish between projects that are e.g. primarily about commuting or about inter-city freight transport, but also drop down to a finer level to do with mode of travel, constraints on affected places, and sectoral effects. Given that agglomeration/ productivity effects are strongest in particular sectors, more attention needs to be paid to the role of particular projects in enabling the formation or growth of regional clusters. The narrative will identify the key channels through which the project is likely to affect productivity and inform the choice of modelling focus.

An important decision concerns whether or not cluster effects – changes in land-use and employment – should be captured. Undertaking this (e.g. by LUTI modelling) should depend on the scale of the project, and also informed by the narrative about key causal effects; in some cases significant changes in sectoral or total employment may be likely, in others not. Where such work is undertaken, it should be used in calculating productivity estimates (to be reported with and without these effects) and consistent with other parts of the appraisal.

There will be considerable differences in detail between different studies (including those done by private sector). Transparency is required if there is to be informed debate, and could be improved by reporting a summary checklist of the approach being followed. An example of such a checklist is given in the appendix to this chapter.

4. Investment and Employment

Much of the debate around transport improvements centres on their impact on job creation.⁴⁸ Transport improvements can trigger private sector investments which change the spatial distribution of economic activity, employment, and GVA. Care needs to be taken in assessing these spatial location effects and many would argue that they should not be included in transport appraisal. Creating one job may displace another so all that is being achieved is a shuffling of workers between jobs, sometimes within a region, sometimes between regions.

Arguments for analysing these location specific investment and employment effects as part of an appraisal have already cropped up in preceding chapters. They can improve traffic forecasts, are necessary to calculate moves to more productive jobs, and to inform cluster effects that can drive agglomeration and productivity. In this chapter we suggest that, for some projects, impacts on regional investment, employment and GVA should be presented as part of the appraisal process, and considered in parallel with the appraisal techniques outlined in the previous chapters. In addition to arguments from earlier chapters, there are several further reasons.

First, these changes are part of understanding the effect of a transport project. They are of interest in their own right and the narrative about the effect of the project is incomplete without them.

Second, the political economy of debate and decision taking often focuses on these variables. Local investment and employment effects are likely to be the prime concern of local decision takers. Numbers will be put forward and debated, and it is appropriate that transport appraisal should seek to raise the quality of such work and create the framework where arguments can be rigorously tested. Furthermore, there is risk that areas engage in a negative sum game, seeking to produce estimates of these effects with a view to attracting public funds for their projects. A central referee is needed to evaluate and challenge such estimates.

Third, regional impacts of a transport scheme may interact with particular features of the local economy in important ways that are not covered in present appraisal techniques. Local employment conditions may create a value to job creation over and above those used in current appraisal. There may also be local development and regeneration opportunities in which transport plays a role.

Related to this, transport improvements are often part of a wider package of (typically local) policy measures. These may include local planning policies, related local transport improvements, and wider aspects of local development plans. There will generally be synergies between these elements of the policy package. Transport appraisal then needs to be undertaken in conjunction with appraisal of these other policy changes. If there are synergies between measures then the value of

⁴⁸ Discussion does not address job creation during project construction; we focus on job creation due to the completed project.

the investment is conditional on other measures taken, so appraisal needs to be undertaken for the package as a whole, or explicitly conditioned on alternative combinations of other policies.

Undertaking appraisals of this type requires a good deal of information. First, there have to be credible estimates of the location effects, i.e. the changes in the level and spatial distribution of activity. Is investment simply moved from region to region, or is there additional investment for the country as a whole? This is technically difficult: modelling is expensive and results are, inevitably, subject to a good deal of uncertainty. The evidence base is correspondingly weak. Second, there has to be valuation of changes for the region and the country as a whole. Are there reasons for placing particular value on job creation in one region rather than another? Finally, there has to be a practical methodology for capturing the evidence and applying it in appraisal: as yet there is no settled practise for doing this, as there is for the productivity effects of the preceding chapter.

The chapter discusses these issues in several stages. We start (section 4.1) with a discussion of the issues and the mechanisms that shape the impact of transport on the location of activity. The key question here is whether investment and job creation associated with better transport is **additional** to the country or is relocation from elsewhere in the country. Section 4.2 looks at reasons why such investment may (or may not) create net social benefits. Even if a new investment project is additional it draws its workers from some alternative activity and may therefore **displace** other activities in the same region. We suggest that, despite this, there are a number of reasons why additional investments can create net social benefit; development projects involving significant land-use change frequently lead to private returns that diverge from social benefits. Section 4.3 reviews evidence on location effects, section 4.4 discusses techniques that can be used to predict them, and a final section concludes.

4.1 Transport and the location of activity

How do transport investments change the location of economic activity? A transport improvement, other things equal, makes affected locations more attractive destinations for investment. Access to markets and to sources of supply (such as intermediate inputs) becomes cheaper and possibly faster and more reliable. Staff may find it easier to travel to work and firms may be able to draw on a larger catchment area of workers. This suggests a positive effect, with affected regions tending to attract investment and thereby open new jobs.

Unfortunately, assessing these effects is complicated by the usual issue of the counterfactual. Absent the transport improvement, would the private investment have taken place elsewhere in the country? If so, the transport improvement has simply changed the spatial distribution of investment but not its total. Or is the investment **additional** from the perspective of whatever spatial unit the policy maker is concerned with, perhaps drawing in investment that would otherwise have taken place abroad?

For investments devoted to serving the domestic market, producing goods or services that are internationally non-tradable (or traded little), investment is unlikely to be additional. It will take

place somewhere in the UK, and expansion in one place will be matched by the sector contracting somewhere else. An obvious example is retail: out of town shopping centres have benefitted from improved accessibility at the edge of cities at the expense of their city centre counterparts.

However, to the extent that investment is globally mobile, producing output that is sold internationally, investment attracted by better communication may be additional. Better transport enables places to attract this foot-loose investment from elsewhere in the world, not just elsewhere in the UK. This might be foreign direct investment, but need not be.⁴⁹ If a UK company expands its production for world markets it is unlikely to displace another UK company in the sector also supplying the global market. (The motor industry is an obvious example).

A complex twist arises for transport improvements that affect several locations – e.g. an inter-city link. Reducing transport costs between centres will generally make both places more attractive locations for investment, but may have greater impact on one location than the other. The *relative* impact is then important, potentially drawing investment into one of the linked locations at the expense of the other.

This ‘two-way road’ problem raises difficult issues, but can be explored through some thought experiments. Suppose that a transport improvement links two cities, one large and central, the other small and peripheral. Do both attract investment or does one attract it at the expense of the other, and if so which? For example, does a firm need to operate separate regional offices or can it amalgamate in one city? Simple reasoning suggests that, if transport and communication costs are very high, the firm has to operate one office in each city to reach customers. If they are moderate, it serves both cities from one office, and this will tend to be the larger city where most of its customers are. But if transport/ communication costs become extremely low, then the cost of reaching customers becomes irrelevant compared to other elements of costs: it will run its single office from whichever city is cheaper. If the small/ peripheral city is the cheaper place to do business, with lower costs of land and perhaps also labour, then this suggests a process of regional divergence followed by convergence. Reducing transport/ communication costs from very high levels to intermediate ones is associated with regional divergence (as the branch office is closed and activity concentrated in the centre). Reducing them from intermediate to low brings convergence, as activity moves to the periphery where land and labour is cheapest.⁵⁰

This is a simple thought experiment and in practise other considerations matter, particularly in determining the cost differentials between locations. The peripheral location may have lower wages, but does it also have lower productivity? There may be difference in skills and productivity

⁴⁹ If it is foreign direct investment, then there is some empirical evidence suggesting that additional benefits of high productivity, good management and technology transfer can spill over to neighbouring local firms. See Barba Navaretti and Venables (2013) for a review. We do not pursue these effects here.

⁵⁰ This argument is often made at the global level. Economic historians refer to the ‘great divergence’ in the world economy from the late 18th century until the current era of globalisation; international inequalities increased for more than 200 years as manufacturing concentrated in Europe and the US. Globalisation reverses the process as low cost emerging markets engage with the world economy. See Fujita et al (1999) for formalisation of this argument.

that overturn the argument above. It is unlikely that reducing transport costs will unravel a strong existing cluster with its productivity advantages, although it could lead to ancillary activities (e.g. backroom operations) or sectors with less powerful agglomeration benefits moving to the periphery.^{51, 52} This can reinforce or create a pattern of regional specialisation, possibly bringing the cluster and productivity effects discussed in chapter 3.

Sketching these arguments illustrates the sensitivity of outcomes to particular circumstances; the nature of the investment, levels of transport costs, and the productivity and cost differentials between cities in various sectors are all important factors in determining how a particular transport investment is likely to change the location of activity. Ex-ante predictions of effects are therefore subject to considerable uncertainty.

4.2 Valuing investment and employment

Given that a transport improvement has impacts on private sector investment and local job creation the next question to be addressed is, are there any reasons to think that such changes are of social value? The first test of this is additionality, as outlined above; while an investment may be additional to the area in which it takes place, it may not be to a wider area or to the country as a whole. But even if a new investment is attracted to the country, it does not necessarily follow that it creates net social benefit. Private investments use resources and earn income. Absent the investment, how would the resources (such as labour) have been used? It is possible that a new investment project simply *displaces* some other activity. If so, is there any reason to think that there is particular social value attached to investments attracted by transport improvements, compared to what is displaced?

To explore these issues we proceed in two stages, looking first at the social and private values of new investments (in this context, land-use change), and then at the labour market impact of investments.

Social and private values of land-use change.

It is often suggested that one of the main impacts of a transport investment scheme is that it unlocks land for development; an office or housing development will not proceed unless transport links are improved. Such effects may have wide ramifications; an improvement in transport might lead to an increase in the number of people visiting a city centre, leading to new businesses opening and making the city centre a more desirable place to visit. It has been suggested that this creates benefits over and above those captured by conventionally measured user-benefits.⁵³

⁵¹ In the international context established clusters did get undermined, but by new competitors with much larger cost advantages than exist between regions of the UK.

⁵² Duranton and Puga (2001).

⁵³ See Neuberger (1971), Martinez and Araya (2000), Bates (2006), Geurs et al. (2006, 2010).

This argument needs careful examination in order to pin-point precise sources of any additional benefits (or losses). As we saw in chapter 2, the fact that transport improvement leads to other changes in the economy does not create a case for adding (or subtracting) benefits to a transport appraisal, unless private sector decisions are distorted away from social efficiency. There is additional benefit only if transport investment unlocks an economic surplus that was previously not being tapped (i.e. dollar bills that the market system leaves on the sidewalk).

One possible reason for such divergence between private and social values arises from constraints created by other policies, and we look at the impact of planning controls in the next subsection. However, there are a number of arguments suggesting that private and social values of large investment projects may diverge, particularly for land-use developments. These have not been systematically addressed in transport appraisal, and the remainder of this sub-section sets out possibilities. It turns out that the divergence is highly context specific and can go in either direction. We present a simple analytical framework and a series of examples, with reasoning presented more rigorously in appendices to this chapter.

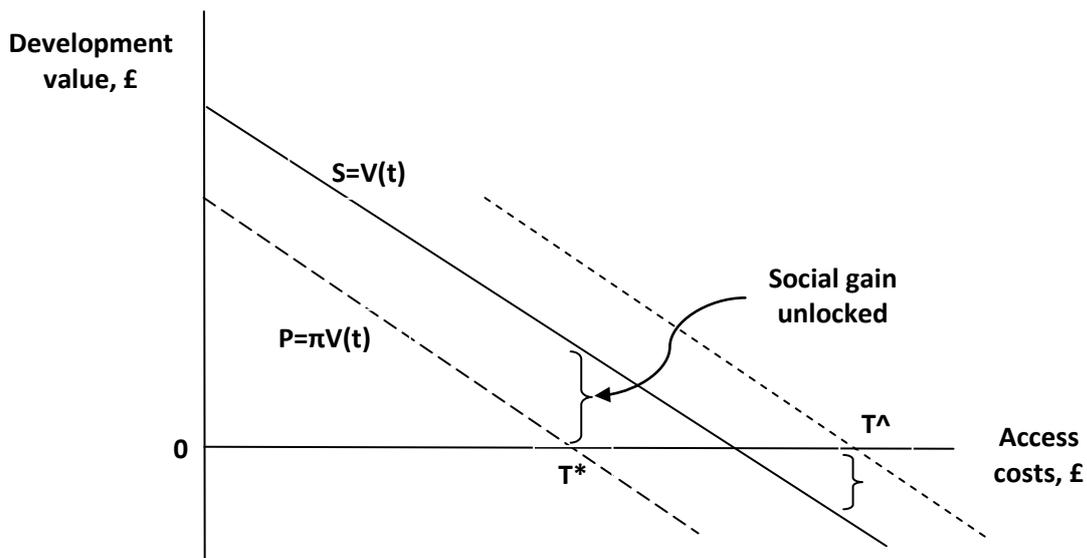
The framework for thinking about these issues is given in figure 4.1. This focuses on development of a particular site that is directly affected by a transport improvement.⁵⁴ The horizontal axis is the cost of accessing a particular piece of land (e.g. the transport costs of workers, shoppers or firms visiting or servicing the site). The vertical axis gives the benefit arising from developing the site, which we denote $V(t)$; this benefit is greater the lower the costs of access, i.e. the better the transport infrastructure, giving the solid downward sloping line.

The first question is: *whose* benefits are represented by the downward sloping line? We construct the example so that the solid line illustrates full social benefits, so $S = V(t)$. However, the decision to develop is taken by private developers, who may have a different benefit (i.e. profit) schedule, illustrated by the long-dashed curve, $P = \pi V(t)$, where π denotes the share of the social gain that is captured by the private developer. As illustrated in the figure, the land will not be developed if transport costs are greater than T^* , since the private development value is negative. A transport improvement that reduces access costs below T^* causes development to take place, as profits become positive.

The key point from this figure is that if the private benefit (profit) schedule lies below the social benefit line then, a transport improvement which reduces access costs from a value above T^* to a value below it causes the development to take place, and thereby creates social benefit of value given by the gap between the private and social values. This is additional to user-benefit, and should be added to transport appraisal.

⁵⁴ The general equilibrium concerns of whether this development is 'additional' are left on one side in order to focus on issues in the immediate location of the site.

Figure 4.1: Transport improvement unlocking land-use change.



The configuration of these curves is project and context specific. In a case in which the private and social benefit lines coincide there is no additional source of social gain (the vertical gap is zero), so the usual user-benefit measure captures everything. In a situation in which private benefits from development exceed social benefits (short-dashed line) then private incentives to undertake investment are too large. The development will go ahead at relatively high trade costs (T^\wedge), and a transport improvement that reduces access costs from above T^\wedge to below will cause land-use change that brings a social loss (negative gap between curves) which should be *deducted* from the appraisal.

Under what circumstances and in what direction do social and private values to diverge? We give several examples, the first being a case in which private benefits exceed social.

'Business-stealing' and non-additionality. The first example captures the fact that some private investments derive profits principally from attracting customers away from other firms. This 'business stealing' investment gives private benefits to the developer that are greater than social benefits. For example, suppose that a transport improvement enables development of a retail store in a new location. For some groups of consumers the store is more convenient than existing ones, and this brings user-benefits as conventionally measured in transport appraisal. Some of the store's profits derive from this convenience value, but some are derived at the expense of existing stores; profits of the new store come at the expense of lower profits for others. While the new store is additional, its customers and the economic activity it supports are not, as they are drawn from existing stores.⁵⁵

⁵⁵ Notice that changes in land values would be an extremely poor indicator of social value in this case. The econometrician would be likely to pick up a large increase in land value at the new store compared to similar places, but this is partly because of a reduction in value at existing stores.

This case is referred to in the economics literature as ‘business stealing’ and the literature points to the fact that private incentives are such that too much entry will occur (i.e. too many stores will be established).⁵⁶ In the current context, the private value curve lies above the social, so that if a transport improvement is expected to cause a private investment to take place, a *negative* value should be included in the appraisal. Of course, one way to rectify the situation is to impose some sort of charge on the developer to reduce the private incentive.

Price change and transfer of surplus. An alternative case can be illustrated by the example of a large office development, construction of which is dependent on transport improvement. The development is ‘non-marginal’ in the sense that it changes prices in the area; this may be a reduction in office rents and perhaps also an increase in local wages.⁵⁷ In this case some of the economic benefit created by the development is not captured by the developer but is instead passed to companies that use the offices (in the form of rents being lower than they otherwise would have been) or to workers (in the form of higher wages). Since the developer’s private benefit (profits) are less than the full benefit (private curve below social on figure 4.1) there is a case for attaching an additional value to appraisal to capture this. A diagrammatic analysis of this case is given in appendix 4.1.

What is the fundamental difference between these cases? In the case of the store there is (assumed to be) little change in the total volume of sales and the new development is profitable because it shifts some business away from existing stores. In the case of the office development there is an addition to the quantity of office space used and rents fall in order to substantially fill the additional space. Rent is lower than it otherwise would have been (this transferring income from existing office owners to office users) such that some of the benefit of the additional office capacity is passed to its occupants rather than its owner.⁵⁸ Evidently, these are fine differences that can only be addressed by detailed knowledge of the circumstances of particular developments.

Coordination failure and industrial location: A third example considers the location decisions of firms that are in a complementary rather than a competitive relationship, such as a firm and its supplier. Suppose that these firms are initially both located in a high cost area. Movement to a lower cost area (perhaps a relatively remote region with lower land prices and wages) would be profitable for both firms if *both* were to move. However, it is unprofitable for just one firm to move, as supplies then have to be shipped between regions. There is ‘coordination failure’ as neither firm wants to risk the move, not knowing whether the other will also move; this creates an economic inefficiency. In terms of figure 4.1 the social benefit is the profits of both firms but decisions are taken on the basis of the profits of just one (the lower curve with $\pi = \frac{1}{2}$). A transport improvement

⁵⁶ See Mankiw and Whinston (1986) for a general statement and Salop (1979). A simple model is laid out in appendix 4.1.

⁵⁷ For a marginal change, the price does not fall so the developer gets the entire benefit and pays the entire cost. This example supposes that, for commercial or technical reasons you don’t build a single office, you build a complex of towers.

⁵⁸ The former case is price competition with an inelastic total demand curve; the latter is quantity competition.

could be one way (although not the only or the best way) of breaking this low level trap and inducing movement (see appendix 4.2). It brings with it social benefit over and above user-benefits.

Coordination failure: regeneration and low-level traps: A two-firm example of coordination failure is contrived (why can't they get together to coordinate a move?) but illustrates a wider problem of coordination failure in spatial relationships. These situations are variously referred to as low-level traps, coordination failures, or simply vicious circles. Starting a new cluster of economic activity is extremely hard because no firm wants to be the first-mover. Skill acquisition could also be held back by a low-level trap: workers don't acquire skills because there are few jobs, and employers don't enter the region because workers are unskilled. There are different ways of getting out of these traps; transport is not the prime one, but it has been argued that it can have a role in some contexts. A transport improvement can be a catalyst that, by affecting many firms and households simultaneously, serves to coordinate behaviour.

Coordination failure of this type can also occur in the context of regeneration of a run-down area. Here, a low quality building stock and low level of economic activity create a trap in which no individual is willing to invest in improvement because of uncertainty as to whether their neighbour will act similarly. A transport improvement, such as a new station providing a link to an area of higher economic activity and with positive impacts on traffic flows and land values, affects the neighbourhood collectively. It can, potentially, provide the way out of the trap as private investors have raised expectations about prospects for the district and about actions to be taken by other investors.

Of course, it is important to relate changes in a particular site to accompanying changes elsewhere – the usual additionality arguments. In this context, a concern is that regeneration of one place simply moves disadvantaged people to another low quality (and poor access) area.

DfT approaches to land-use change

DfT's wider economic impacts guidance includes a method for calculating benefits of land-use change where it can be shown that a development would not take place in the absence of the scheme due to the existing transport infrastructure being unable to supply a reasonable level of service to the existing and/or new users.⁵⁹ The approach focuses on housing development and has several elements. One is a series of tests for whether the scheme is truly dependent on the transport improvement. The second is to undertake a conventional user-benefit appraisal. The third is to compute an estimate of planning gain and, to quote: *'the analysis ...is likely to result in a large estimated value for the benefits of the dependent housing. This is because the surplus of value of land in residential use over land in, (for example), agricultural use, is typically large. This surplus is a major component of the welfare gain to society that arises from a planning decision in favour of*

⁵⁹ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/275350/webtag-tag-unit-a2-3-transport-appraisal-in-the-context-of-dependent-development.pdf

residential use.' The guidance recommends that this number not be reported in the BCR, but separately in the economic appraisal report.

Several comments are in order. First, the approach is based on the assumption that planning controls are tighter than is socially efficient (i.e. the social value of land, including full valuation of amenity and landscape, varies across different uses to which land is put). While this may be believed to be true in many contexts (particularly given the spatial variation in planning gains) it is not universally so. The onus should be on the appraiser to establish that private and social benefits diverge. In principle, the appraisal should look at the change in land value net of the costs (environmental, congestion) that provide the rationale for planning controls.

Second, the DfT analysis is applied to housing development but, as we have seen in the preceding sub-section, divergence between social and private values of land-use change are likely to be a widespread phenomenon, arising not just from the planning system but from a range of important market failures. These include commercial as well as housing development. An integrated approach to these issues is needed.⁶⁰

Labour market displacement and the employment counterfactual:

A further source of divergence between private and social values can arise in the labour market. If new jobs are created in one place, where do the workers come from? Or, more accurately, what would they be doing in the counterfactual situation, and hence what is the opportunity cost of their taking a new job? Broadly speaking, there are three alternatives: they could be employed in some other job; economically inactive; or unemployed. We discuss each in turn.

Full employment: The conventional position is that jobs created by new investments simply draw labour from other productive activities. If the labour market is working efficiently it follows that job creation is of no value – workers are simply shuffled between similar value jobs. Using this argument, a conventional appraisal does not need to consider job creation; if there is any, it is of no net social value.

This position needs modification if the amount of job creation is large enough to bid up wages in the area affected or more broadly. Given the level of productivity, an increase in wages must be financed either by a reduction in profits (or more generally, payments to other inputs), or by an increase in prices. The increase in wages is therefore just a transfer, of no value to aggregate income, unless the people paying for it (consumers and recipients of profits) are, for some reason, people that we do not value. A standard approach would be to suggest that benefit arises to the extent that the increase in price is paid by foreigners, i.e. represents a terms of trade improvement for the UK, able to sell its exports at higher price. Of course, the same argument could be made at a regional level, albeit with a different definition of who is 'foreign'.

⁶⁰ From the economic theory of the second best, correcting some imperfections while not addressing others in closely related markets risks making matters worse.

Inactivity: A second alternative is that workers are drawn into the labour force from voluntary inactivity. The social value of such a change is its tax/benefit impact, as discussed in the context of labour force participation in chapter 2. However, in that context workers were drawn into the labour force just by a reduction in travel costs. Here the mechanism is broader, including a reduction in the discouraged worker effect. Job creation following a transport improvement might reduce the number of 'discouraged' workers who drop out of the labour force because no jobs are available, and the social value of this is its tax/benefit savings.

Unemployment: The third alternative is that workers come from involuntary unemployment. In the long run context of transport investment this would apply to structural unemployment, due perhaps to a regional problem. The net benefit of job creation is then much larger than in the previous cases. A full analysis of the causes of structural employment goes well beyond the scope of this report and its application to public policy is covered in the Treasury's Green Book.

Valuing investment and employment; concluding comments:

Changes in investment and in land-use are of interest to affected locations and, as we have seen, may also release aggregate gains for the nation as a whole. However, these are highly context specific, depending on a long list of conditions: additionality, displacement, planning regimes, and details of the market situation and the nature of interactions between firms. Several points follow.

First, using transport policy to support private investment and effective land-use is sufficiently important for the effects described above to be included in transport appraisal, at least for some projects. We recognise that this is complex, so will require further work. Second, in some cases, appraisal can usefully present alternative estimates, each conditional on a range of private investments taking place or other policy measures being adopted; the treatment of planning gain in dependent housing development is a case in point. Third, it is likely that some of the issues discussed above cannot be readily captured in the economic appraisal and belong primarily to the strategic case made for transport investments. This points to the importance of cross-referencing between the economic appraisal and the strategic case, and of making explicit what is included and what is not included in the appraisal.

Finally, we note that in addition to interactions between transport improvements and private investment, there is also considerable inter-dependency between transport and other public projects and policies. There are clear synergies across transport projects, each with implications for private development. The Docklands Light Rail and then the Jubilee Line Extension were intrinsically linked with continuing development at Canary Wharf. The route of the high speed link to the Channel Tunnel was altered to assist in the re-development of Stratford whilst the 67 acre development at Kings Cross⁶¹ is explicitly linked to the upgrading of the railway stations there and the high speed rail line to Europe. Looking to the future there are concerted efforts to maximise the impact of the proposed High Speed 2 rail line by co-ordinating land-use investment strategies near

⁶¹ <http://www.kingscross.co.uk/>

proposed stations. The proposed Atlantic Gateway⁶² has substantial investment in land centred along the Manchester Ship Canal with enhanced port facilities, freight interchanges and rail, road and air access as part of the package. Synergies extend not just across transport projects and associated private development, but also across government policies. The value of a transport project depends on land-use policy, and on wider urban and regional development measures. It is important that transport appraisal recognises potential synergies arising from interaction between policies.

4.3 Transport and the location of activity: evidence

What evidence is there on the impact of transport investments on the level and spatial distribution of investment, employment and GDP? Evidence comes from multiple sources, each focussing on somewhat different questions and using different data and techniques. In this section we give a brief review of evidence, focusing on the different approaches, the main messages, and their applicability to the appraisal of particular projects.

Econometric approaches:

There is an extensive literature on the effect of transport infrastructure on private output, stemming from Aschauer's (1989, 1990) seminal work. These studies look at the stock of public capital or, data permitting, the stock of infrastructure or transport capital, and ask how variations in this stock across time and across regions or countries is related to GDP. Findings indicated a substantial output response, with elasticities of GNP with respect to infrastructure as high as 0.25 being found in some cases. Melo, Graham and Braga-Ardao (2013) present an international meta-analysis from this literature. This suggests an average elasticity of private output with respect to road investment of 0.088. Thus a 10% increase in the stock of roads would increase private output by 0.88%. They find lower elasticities for other modes (0.028).⁶³ The estimates they find may be biased upwards by the presence in the dataset of early estimates of elasticities that do not correct for omitted variables and unobserved heterogeneity. While this literature points to orders of magnitude of effects, it is not for appraisal purposes sufficiently specific about how output response varies with characteristics of the region or of the particular transport project.

A more focussed approach looks at the impact of accessibility on particular variables of interest, rather than on output as a whole. One strand of literature studies the location decisions of firms. This is surveyed by McQuaid et al (2004) who suggest that transport improvements are unlikely to cause firms to move but, if they are moving for other reasons, then accessibility is one of the factors influencing their choice of new location. Access to labour is a prime determinant of location and transport facilitates this by enlarging travel to work areas. Effects vary across types of activity and

⁶² <http://www.atlanticgateway.co.uk/>

⁶³ An alternative way to interpret this is to suppose that all other inputs increase by 10%, holding transport infrastructure constant. Then output would increase by just over 9%, as compared to 10% output growth if transport infrastructure increased in line with other inputs.

have become important for business communication. For example, Strauss-Kahn and Vives (2009) find that good transport links are one of the main factors attracting office head-quarters to second-tier US cities.

Another line of research calculates accessibility measures of different places in order to look at the effect of accessibility on employment. For example, Berechman et al. (2006) use county level data from New York/New Jersey to calculate a measure of accessibility between each combination of residential and employment locations. This measure depends on public transit and car travel times, and their study indicates that 10% better accessibility is associated with 0.46% higher employment in a place. A similar analysis (Berechman and Paaswell 2001) focuses on the impact of changes in accessibility on employment in the low income South Bronx area of New York. They find that a 10% better level of accessibility is associated with employment higher by 0.44%. In a cross-US city study, Rice (2001) examines the impact of public transit route density on individual's probability of employment and finds that the density of public transit routes has a positive effect on the probability of employment for the low education population, although no significant effect for the overall population.

While these papers point to important correlations between transport and local economic activity, the econometric challenge in establishing quantitatively accurate causal effects of transport investments is formidable. Recent work addresses this by careful comparison of places affected by transport improvement with other areas. Comparing outcomes for areas connected to the transport project with areas distant from it, each observed before and after the project, it is possible to econometrically estimate the effects of the investment. Identifying causal effects is difficult, because of the difficulty in defining the counterfactual; did a region boom because of the road, or was the road built because of an actual or anticipated boom? Modern econometric techniques are able to make considerable progress on unravelling this and a number of recent studies point to the significant local impact of transport infrastructure.⁶⁴ Some studies have taken historical examples: for example, Donaldson (2013) finds that the arrival of the railways in colonial India raised real income in connected villages by 16%. The Chinese infrastructure boom has proved fertile ground for researchers. Several (e.g. Faber 2013) point to positive impacts on growth in the major connected cities, although negative effects on smaller towns along the route. For the US, Duranton and Turner (2012) look at the impact of the US inter-state highway system on cities with varying degrees of access to the system. They find that local access to 10% more highway miles resulted in 1.5% more urban employment. Highways are also a causal factor in shaping cities patterns of specialisation, cities with more highways tending to specialise in sectors producing heavy goods (Duranton, Morrow and Turner, 2013). For the UK, Gibbons et al. (2012) investigate the effect of road construction during the period 1998-2007 and find substantial positive effects on employment and numbers of plants for small-scale geographical areas (electoral wards). In contrast, for firms already

⁶⁴ Redding and Turner (2014) survey some of this literature. Methodologically there is a parallel with drug trials: some areas are 'treated' by having investment, others form the control group. However, it is not generally the case that assignment of areas for treatment is random, as it would be with individuals in a drug trial. Instrumental variables are used to address this problem.

in the area they find negative effects on employment coupled with increases in output per worker and wages. A plausible interpretation is that new transport infrastructure attracts transport intensive firms to an area, but this displaces some employment in existing businesses.

Case studies

There are numerous case studies of particular transport investments. They vary widely in the technique employed, in particular the issue of how to construct the counterfactual. One approach is to construct and quantify a fully detailed alternative history; the prime example of this approach is the work of Fogel (1964) on US railroads, in which the outcome (railway construction) was compared with a counter-factual (expansion of the US canal network). Another is econometric, as discussed above, in which areas 'treated' by a transport improvement are compared with a control group. A third is more descriptive, making less rigorous attempts to separate out causal effects of the transport project. We do not attempt a comprehensive review of case studies, instead just flagging studies in two contexts.

Intra-city and regeneration: Do transport improvements play a role in urban regeneration? The literature paints a picture of very mixed experience, with outcomes varying widely across schemes.⁶⁵ For example, studies of commuter rail systems have generally found little impact on land-use. In West Yorkshire, there was some rise in population around the new stations compared with similar areas elsewhere. A study of Newcastle suggests that the additional city centre bound shopping trips generated may have strengthened the city centre relative to other retail locations. NAO (2004) considered that light rail helped regenerate run down areas in Manchester, Birmingham and Croyden, but Dabinett et al (1999) found no such evidence for Sheffield; nor did Davoudi et al (1993) for Newcastle. Millward Brown (2006) surveyed firms in central Dublin following the opening of the light rail system but they found that the labour market and other benefits they had received to be very small. The impact of these schemes obviously depends crucially on local circumstances. Perhaps the main message from these studies (and those of London) is that transport improvements are, unsurprisingly, more successful where they are a response to demand for transport.

High-speed rail: The impact of new high speed rail links is found to be similarly mixed. For the Shinkansen, there is evidence that regions with a station experienced faster population growth, per capita income growth and employment growth, particularly in sectors classified as 'information exchange industries'. Effects were particularly strong for cities with both an expressway and a Shinkansen station (Nakamura and Ueda 1989).⁶⁶ New research also suggests that it has increased business links, with firm-to-firm trade enhanced by proximity to Shinkansen stations (Bernard et al. 2014). For the TGV the impact has been varied. "Development has been inconsistent across station locations, as impacts have been variable and highly localised. The extent of development has

⁶⁵ Studies of commuter transport include: Glasgow (Gentleman et al, 1983), Newcastle (Davoudi et al, 1993), Manchester (Forrest et al 1996), Sheffield (Dabinett et al 1999), Dublin (Mayor et al, 2008). Studies on the impact of new stations include West Yorkshire (Blainey and Preston, 2010) and high speed rail stations (Cascetti et al, 2010; Pagliana et al, 2010, Ahlfeldt and Feddersen, 2009).

⁶⁶ For this relatively old study, questions remain about the direction of causality.

depended on the overall economic strength of the local economy and the presence of service sector firms requiring access to Paris” Bannister and Berechman (2000 Chapter 10). For Germany, there is evidence of increased economic activity at intermediate stations along the Cologne – Frankfurt high speed line (Ahlfeldt et al, 2010).

4.4 Application; forecasting location effects.

The preceding sections suggest that the effects of transport improvements on regional investment and thence employment are the outcome of a delicate balance between different economic forces. There is, unsurprisingly, evidence that transport has effects, but the evidence base does not (yet) provide clear guidance as to how this balance is likely to play out in various types of project, much less in any specific project. Appraisal needs to offer robust ex ante predictions, and this is clearly hard to do in this context. A number of approaches have been – or could be – followed, and they are discussed below. We do not seek to undertake a comprehensive review, but rather to draw out issues that are relevant for possible application of alternative approaches.⁶⁷

To do this we categorise approaches as follows: econometric based models; bottom-up local knowledge and regional plans; LUTI (Land-use Transport Interaction) models; and Spatial Computable General Equilibrium model (SCGE) and other General Equilibrium (GE) models. We note that there is tremendous variety within each category – particularly within that of LUTI and SCGE and GE. Bespoke model applications or proprietary modelling software may often mix and match different approaches. Models operate at different spatial levels and with different disaggregations of firm and household behaviour. In modelling transport-economy interactions it is also necessary to interface the transport model and the regional economic model. This can be complicated, particularly in the treatment of personal travel (Bröcker and Mercenier, 2011; Tavasszy et al., 2011).

Econometric approaches

The previous section indicated that progress is being made in econometrically establishing the effects of transport investments on a range of local economic variables. For example, the production function approach that followed the work of Aschauer gives estimates of elasticities of output with respect to transport investment. Whilst these are ‘broadbrush’ estimates their application is straightforward. We therefore find it surprising that our literature search has not identified any studies that have used the elasticities from this part of the literature to estimate changes in GVA – even as a benchmarking exercise or as a validation for other model results.

Other econometric studies contain information broken down by type of activity and at a finer spatial level. Transport investment changes the accessibility of places in a well-defined way and the empirical literature can (potentially) offer elasticities that indicate the effect of accessibility on local

⁶⁷ For reviews see Vickerman, 1991; Rietveld and Bruinisma, 1998; Oosterhaven and Knaap, 2003; Wegener, 2011; MVA/ITS, 2013.

investment or employment. A procedure analogous to that followed in estimating productivity effects could therefore be employed. However, research has not yet reached a stage where this can be done with high levels of confidence. The research literature is not yet sufficiently deep or mature to offer a consensus view on these effects (in contrast to that on productivity estimates). Furthermore, effects are perhaps inherently more ambiguous – as in our discussion in the first section of this chapter. It will be difficult to reach a point where sufficiently robust techniques and estimates are in place, but we think that this is an important area for future development.

Bottom-up: local knowledge, local plans

Forecasts of the local or sectoral impact of policy measures are commonly used for the assessment of a wide range of local and national government interventions. These are generally based on local knowledge -- what we term the bottom-up approach.

Bottom-up approaches to assessing the economic impact of transport projects are common forms of impact assessment, particularly in non-transport related sectors. The guidance followed is that issued by the Department for Business Innovation and Skills and the Office of National Statistics (BIS, 2009, ONS, 2010). The DfT's guidance on assessing impacts in regeneration areas (webTAG A2.2) is consistent with BIS guidance. A good example of this approach to a transport investment is that proposed by the Airports Commission to analyse the local economy impacts of airport capacity expansion (Airports Commission, 2014 pp41-49).

The primary interest in these methods is to identify the local economic impact and to establish what is 'additional' at the national level. In the main, public sector investment in transport and other sectors (e.g. business start-up or expansion grants) is viewed as displacing economic activity – e.g. from one locality to another. Where additionality at the national level is anticipated, this has to be demonstrated through both a narrative and some empirical analysis. A multi-angled approach is usually adopted. There is a need to understand the market in which the different businesses operate, in terms of the cost base and the contribution of transport to that, where the majority of customers are and where the businesses' competitors are located. The ability of businesses to grow needs to be assessed both in terms of land/premises availability, the need for further investment and most importantly the ability to expand the workforce – are there workers with the correct skills in the locality?

The economic impact analysts therefore need to draw data from published sources and also undertake primary research including interviews with producers, consumers and sometimes competitors. An understanding of the markets in which the affected businesses operate is essential to a good quality impact analysis – hence the use of local knowledge and local plans. Supply chain effects and the impacts of the additional wages received by increased levels of employment are often estimated using multipliers derived from input-output tables. These multipliers give a relationship between output and employment, as well as indicating how the expansion of output/employment in one sector will expand output and employment in other sectors. A risk assessment on the probability of the economic impacts being realised should also be made.

The strength of these methods is that they are well grounded in the problems that a local economy faces and how transport (or other policy interventions) will address them. Another key strength is that they can be well suited to the smaller schemes, where the principle of proportionality would suggest that less resource intensive methods of appraisal should be adopted. On the con side it is often a judgemental decision on the part of the analyst regarding the level of transport dependent development that is expected to occur and the level of additionality that will be generated. This can obviously lead to biases in the assessment, which may be 'optimism bias', or may be strategically motivated.

In terms of the economic outcomes that we are interested in, these methods can give estimates of changes in employment at a local level and are inputs to an assessment of the extent to which employment is displaced or additional. These methods are best applied to schemes where impacts are expected to be quite localised – train stations, ports and airports are good examples. Schemes where the impacts are expected to be spread over a larger geographic area are harder to analyse due to the fact that the beneficiaries are hard to identify. Such schemes could include incremental changes to major inter-urban routes (e.g. motorways). This method is therefore better suited to some transport investments than others.

Land-use transport interaction models

Land-use transport interaction (LUTI) models have a long history dating back to the 1950s and have been extensively used in transport appraisal.⁶⁸ The DfT has its own guidance on LUTI models⁶⁹. The term covers a wide range of models differing in numerous respects. Some LUTI models focus on the urban environment (an intra-regional model), whilst others model impacts at a regional level (inter-regional). Some operate at both levels of spatial detail.

At the inter-regional scale, LUTI models will either use a multiple region input-output framework to model economic impacts and substitution between regions or some form of production function method. The classic multi-regional input-output framework (Leontief, 1966), is one where inter-industry and interregional trade flows are a function of input-output coefficients and transport costs. Models that utilise this framework often treat final demand as exogenous (i.e. transport investment cannot grow the overall size of the economy), instead transport investment affects growth at a regional level (i.e. it affects the spatial distribution of activity). In contrast modern regional production function models with a transport application will use regional inputs of capital, labour, land and other location specific factors such as infrastructure and in more recent applications accessibility and other 'soft' location factors.

At the intraregional or urban level, three genres for modelling industry location exist (Wegener, 2011). These are: location models which take changes in trade flows from an input-output framework as an indicator of changes in industry location; bid-rent location models that have firms

⁶⁸ For fuller reviews see Wegener (2004), Wilson (1998).

⁶⁹ DfT (2014) *Supplementary guidance. Land-use/Transport Interaction Models*. London: Department for Transport.

acting as profit maximisers choosing locations given land prices (where land prices are endogenous to the model); and utility-based location models which are similar to bid-rent models, but include multiple location factors and convert them to a utility scale, with firms choosing locations to maximise utility. Recent innovations in this field include the application of micro-simulation methods.

The strength of the LUTI model is the internal consistency brought by a fully specified mathematical model. For example, placing overall resource constraints on the model means that employment displacement is captured along with job creation. Their geographical structure enables predictions about the locations from which economic activity is displaced. Interaction effects can, in principle, be fully captured and double counting avoided. Estimates of a wide range of variables – investment, employment, GVA and welfare – can be computed at whatever level of spatial disaggregation the model is running. Arguably, the models are less prone to strategic biases compared to bottom up approaches.

On the downside LUTI models are typically quite expensive, although simpler versions (with large zone sizes and a simplified representation of the transport network) offer cheaper alternatives. They are data intensive, which is a particular issue given the absence of UK data on inter-regional trade flows.⁷⁰ They also contain numerous modelling judgements, the implications of which may not be transparent. One such assumption is that total employment in the area under study is assumed to be fixed, so all employment changes have displacement effects within the region. Judgements are incorporated in the form of key behavioural and economic relationships and in values of key parameters, such as the elasticities linking change in one variable to that in another. These values are, in many cases, not based on empirical evidence that directly pertains to their use in the model.

Spatial equilibrium models

The principal advantage, compared to other models, of a general equilibrium model (or spatial computable general equilibrium model, SCGE) is that they contain a richer modelling of prices and of response to economic changes initiated by some 'shock' to the economic system. The ripple effect of changes in demand in one sector on other sectors is therefore captured, as in some LUTI models and in the input-output analysis, but these effects can be partially crowded out through price adjustments reflecting supply side constraints. Such models therefore have the ability to capture additionality in output and employment. The limitations of such models are that they typically operate at a broad spatial scale and simplifications in the representation of which sectors are represented and how different markets are assumed to operate are often made to make the model tractable. The interaction of these models with transport models can also be problematic.

In the UK context transport applications of SCGE and general equilibrium models is limited. Examples include the use of models by Oxford Economics, HMRC and PwC to investigate the cost of

⁷⁰ Inter-regional trade flows have to be synthesised from regional output/employment and accessibility costs or collected through primary research.

capacity constraints at Heathrow Airport. Zhu et al. (2012) at the University of Cambridge developed and applied an SCGE model to land-use and transport plans around London. Elsewhere, SCGE models have been used on transport schemes in the Netherlands, Denmark, Norway, Germany, New Zealand and Australia. There is also a European wide model – CGEurope.

The advantages and disadvantages of these models are similar to those of LUTIs. However, greater complexity and cost means that they are only candidates for application to the largest transport projects. Further discussion of differences between models – and their implications for model results – is given in appendix 4.3

Modelling techniques: summary

There is no single best approach to capturing all the location change and quantity effects induced by a transport improvement. Different methods are applicable to different contexts, and these choices should be informed by the narrative of what the most important impacts of the project are likely to be. Computer simulation models are a valuable tool, although dogged by the difficulty of understanding (and assessing) what key elements of the model exactly drives their results. They need to be complemented by fuller use of ‘bottom-up’ local information and econometric approaches. The former are susceptible to strategic manipulation and require quality control. The latter are not yet at a stage where they can give sufficiently project specific results, although rapid progress is being made. Nevertheless, they provide a way of assessing the plausibility of results obtained by other means.

4.5 Conclusions

The case for calculating the impact of transport on the spatial pattern of activity rests on several arguments.

First, it is important for local stakeholders. Local authorities and development bodies are likely to produce estimates of these effects that will influence the public debate and decision-taking process. It is important that the DfT sets the quality standard for such estimates and thereby provides a discipline against exaggerated claims.

Second, such results will improve aspects of appraisals that are, in any case, undertaken. As we saw in earlier chapters, transport forecasts, assessments of job changes and estimates of agglomeration productivity and agglomeration effects all require estimates of changes in the location of activity.

Third, there is a range of local circumstances – large scale land-use change, regeneration, dependent development and labour market failures – where local changes in economic activity can release significant aggregate benefit. These effects are highly context specific (and are possibly negative), but work needs to be done to develop ways to incorporate these effects in appraisal. There is a risk that project-by-project appraisal is too fragmented and misses synergies. In some cases this can be addressed by explicitly producing a range of estimates conditional on other policy change. In other

cases economic appraisal should – using the narrative surrounding the project – be explicit about potential effects not covered.

Calculation of location change effects is difficult. Simulation models are an important tool, but more can be done to foster the development of econometric approaches. The use of local data and knowledge is important, particularly in view of the need to place transport appraisal in the context of local circumstances and other local policy initiatives. Both of these approaches would benefit from some ex post evaluation of the accuracy of their predictions (similar to the evaluations of forecast traffic flows that were discussed in chapter 2).

5. Conclusions and recommendations

Transport investments can deliver economic benefits over and above conventionally measured user-benefits. As suggested above, they arise as: (a) Transport fosters intense economic interaction that raises productivity; this can occur in clusters within narrowly defined areas or more widely by linking areas. (b) Transport shapes the level and location of private investment, potentially leading to higher levels of economic activity in some areas. Transport induced investments can interact with market failures including price-cost divergences, obstacles to efficient land use, and labour market imperfections (unemployment and low labour force participation).

Assessing these effects requires: (a) An appropriate analytical framework that captures effects and can ascribe social values to economic changes. (b) Good estimates of how transport changes quantities, i.e. journeys, patterns of investment and employment. (c) A robust evidence base combined with local and project specific knowledge that can inform judgements about whether such changes are additional (to a particular area and the country as a whole); whether they displace other activity; and how they interact with market imperfections thereby creating social value.

The Department for Transport appraisal guidelines provide a rigorous framework for appraising projects. Its assessment of user-benefits is well-grounded and it has been a world-leader in incorporating some of the wider impacts of transport improvements. The recommendations that follow are intended to inform discussion on how to extend and improve appraisal techniques in order to more fully capture (and critically evaluate) the economic impact of transport investments, while maintaining the Department's standards of rigour.

Recommendations

- 1) **Appraisal techniques are, in some cases, insufficiently context and project specific; they need to be informed by a clear narrative about likely economic impacts of the project.**

The DfT guidelines seek to provide a toolkit applicable to many different situations. This has advantages – uniform criteria are ultimately needed to rank projects. But it risks becoming overly mechanical and thereby missing some impacts of a project, or placing undue emphasis on other aspects less relevant for the project under study. For example, both an inter-city road link and improved intra-urban commuting might have positive productivity effects, but through quite different mechanisms which cannot be readily captured by application of the same formula. To address this, appraisals need to be informed by a clear narrative about the likely effects of the project. This should inform the modelling and quantification work that is undertaken and the analytical work and empirical evidence that are brought to bear.

2) There should be a closer connection between the strategic and the economic cases for transport investment.

The strategic case provides the context specific narrative that should inform the focus of the economic appraisal. Equally importantly, the strategic case needs to be subject to the rigorous scrutiny provided by the economic case.

3) Appraisal of larger projects should direct more attention to impacts on private sector investment decisions and associated changes in employment and economic activity.

Appraisal techniques could be improved by greater engagement with the ‘investment and employment’ impacts of transport investments, i.e. the effects of the project on private sector investment decisions and consequent impacts on employment and economic activity. This is a difficult area where there are considerable uncertainties and the evidence base is quite weak. However, potentially important effects (e.g. large private developments that are brought forward by transport investments) should be addressed in appraisal. Critically, this is where much of the current policy debate takes place. Projections are put forward (often by scheme promoters or local interests) which shape this debate and which need to be rigorously assessed. The key questions – are investments additional, do they displace other activities, are there particular reasons for attaching social value to them? – are, at present, not being addressed in many appraisals. This is a significant gap in the appraisal system that should be addressed.

4) Land-use change (and more general changes in the level and spatial distribution of private investment) should be estimated and reported in a wider range of projects.

- a) This should be done in a manner that informs the debate about local impacts; a debate that will, in any case, take place.
- b) It should seek to identify the additionality of such changes and displacement effects that may be created.
- c) It should assess the likelihood that such investments interact with market failures and thereby create aggregate social benefit or dis-benefit
- d) Other parts of the appraisal should use these results, reporting benefit outcomes with and without land-use changes and in a consistent manner.

This is a challenging undertaking, as modelling such changes is both expensive and subject to a good deal of uncertainty. It should be undertaken selectively, on the basis of explicit criteria and informed by the narrative about the likely effects of the project. Techniques for predicting land use change and its effects need to be further developed, including:

- a) Greater use of detailed local and sectoral information to assess quantity changes and their interaction with the local economic environment.

- b) Application of techniques used by other government departments (e.g. BIS, CLG) for assessing additionality and displacement effects.
- c) Econometric and modelling methods are opening up possibilities for improving prediction and need to be developed further.
- d) The effectiveness of modelling techniques needs to be assessed by systematic comparison of ex ante estimates made using various techniques with actual ex post outcomes.

5) In some circumstances it will be appropriate to produce estimates for a range of different scenarios concerning private sector responses and related government policies.

Appraisal is subject to inherent uncertainties about the future state of the world, and also arising from uncertainty about complementary policy changes or investments that may or may not be made by the public and private sectors. It is important to produce scenarios (and rate of return or BCR estimates) corresponding to alternative assumptions about other investments or policy changes, particularly where there may be synergies between policies. These should make clear the assumptions made about possible changes in related policies or private sector actions. There are several benefits. One is greater understanding of the impact of the project. Another is that there will often be synergies between transport investments and other changes made by the private and public sector. Failure to recognise these synergies leads to fragmented decision taking and is a source of economic loss.

6) DfT should set best practise techniques and promote informed debate by encouraging transparency in appraisals done by others.

Appraisals will, as a matter of fact, be produced by a variety of bodies, private and public. An informed debate requires transparency, so that the reasons for diverse estimates can be understood and critically evaluated. The DfT sets best practise in many technical aspects of appraisal and can encourage reporting standards that facilitate the comparison of findings, are transparent and inform debate.

7) Component parts of DfT appraisals could be better integrated.

Component parts of DfT appraisals need, in some cases, to be better integrated; for example, the relationship between user benefits/ movement to better jobs/ productivity change. This would increase transparency and reduce the risk of incompatible assumptions or double counting. Work could be undertaken to better place all aspects of an appraisal in an integrated and consistent spatial framework.

References:

Ahlfeldt, G. and Feddersen, A. (2010) From Periphery to Core: Economic Adjustments to High Speed Rail, processed LSE

Ahlfeldt, G. (2009) The train has left the station: Do markets value intra-city access to inter-city rail connections? University of Hamburg, <http://mpa.ub.uni-muenchen.de/13900/>.

Ahlfeldt, G.M., Redding S.J., Sturm, D.M. and Wolf, N. (2012) The economics of density: Evidence from the Berlin Wall. CEP Discussion Paper No. 1154, London School of Economics.

Airports Commission (2013) Airports Commission: Interim report. Report dated December 2013.

Airports Commission (2014) Airports Commission: Appraisal Framework. Report dated April 2014.

Aschauer, D.A. (1989) Is public expenditure productive, *Journal of Monetary Economics*, 23, 177-200.

Aschauer, D. A. (1990) Highway capacity and economic growth. *Economic Perspectives*, 14, 14–24.

Association of Train Operating Companies (ATOC) (2013). Passenger Demand Forecasting Handbook (PDFH) 5th Edition. London: ATOC.

Atkins (2013) Post Opening Project Evaluation of Major Schemes Meta-analysis 2013: Main Report. Report to the Highways Agency.

Audretsch, D.B. and M.P Feldman (2004) 'Knowledge spillovers and the geography of innovation' in *Handbook of Urban and Regional Economics*, Vol. 4, ed. Henderson, J. V. and Thisse, J. F. New York: North-Holland.

Balcombe, R., Mackett, R., Paulley, N., Preston, J., Shires, J., Titheridge, H., Wardman, M. and White, P. (2002) The demand for public transport: a practical guide. TRL report 593. Crowthorne: Transport Research Laboratory.

Banister, D. and Thurstain-Goodwin, M. (2011) Quantification of the non-transport benefits resulting from rail investment. *Journal of Transport Geography* 19: 212-223

Banister, D. and Berechman. (2000) Transport investment and economic development. University College Press, London

Barba Navaretti, G. and A.J. Venables (2013) Multinationals and industrial policy, *Oxford Review of Economic Policy* , 29, 361-82.

Bates, J. (2006) Economic evaluation and transport modelling: theory and practise. 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 Research.* Elsevier, Kidlington/Amsterdam, pp279-352.

Baum-Snow, N. (2007) Did highways cause suburbanization? *Quarterly Journal of Economics* 122(2): 775–805.

Baum-Snow, N., Brandt, L., Henderson, J.V., Turner, M.A. and Zhang, Q. (2012) Roads, railroads and decentralization of Chinese cities. Processed, University of Toronto.

Baum-Snow, N. and Kahn, M.E. (2005) Effects of urban rail transit expansions: Evidence from sixteen cities, 1970-2000. *Brookings-Wharton Papers on Urban Affairs*: 2005 1(4): 147–197.

Bernard, A.B., A. Moxnes and Y. Saito (2014) Production networks, geography and firm performance. Processed, Tuck School, Dartmouth.

Berechman J and R. Paaswell (2001) Accessibility improvements and local employment; an empirical analysis, *Journal of Transportation Studies*, 4, 49-66

Berechman, J., D Ozmen, and K. Ozbay (2006) Empirical analysis of transportation investment and economic development at state, county and municipality levels *Transportation* 33, 537-55

Blainey, S. and Preston, J. (2010), Gateways to Prosperity? The Long Term Impacts of New Local Railway Stations. Transportation Research Group, University of Southampton (Incomplete Draft).

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

Bonnafous, A. (1987) The Regional Impact of the TGV. *Transportation* 14: 127-137.

Bröcker, J., Meyer, R., Schneekloth, N., Schürmann, C., Spiekermann, K. and Wegener, M. (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. Kiel/Dortmund: Christian-Albrechts-Universität Kiel/Institut für Raumplanung, Universität Dortmund.

Bröcker, J. and Mercenier, J. (2011) General Equilibrium Models for Transportation Economics. In: de Palma, A., Lindsey, R., Quinet, E. and Vickerman, R. (eds) *A Handbook of Transport Economics*. Chapter 2 pp21-65. Cheltenham: Edward Elgar.

Carlino, G.A., Chatterjee, S. and Hunt, R.M. (2007) Urban density and the rate of invention. *Journal of Urban Economics*, Elsevier 61(3): 389-419, May.

Cascetta, E. et al (2010) Evaluating Regeneration Impacts of the Channel Tunnel Rail Link. 12th WCTR (11-15 July 2010).

Chandra, A. and Thompson, E. (2000) Does public infrastructure affect economic activity? Evidence from the rural interstate highway system. *Regional Science and Urban Economics* 30(4): 457–490.

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.

Ciccone, A. and Hall, R. (1996) Productivity and the Density of Economic Activity. *American Economic Review* 87, 54–70.

Combes, P-P., Duranton, G. and Gobillon, L. (2008) Spatial wage disparities: Sorting matters! *Journal of Urban Economics* 63(2):723–742.

Dabinett, G. et al (1999) Transport regeneration and investment – Sheffield: 1992-1997, Transport Policy 6 (1999) 123–134.

Davoudi, S. et al (1993), The Longer Term Effects of the Tyne and Wear Metro. Report for Transport Research Laboratory.

Department for Business, Innovation and Skills (BIS) (2009) RDA evaluation: Practical Guidance on Implementing the Impact Evaluation Framework. December 2009. London: BIS.

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

Department for Transport (2005) Transport, wider economic benefits and impacts on GDP. DfT discussion paper July 2005, p38.

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) (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 (DfT) (2014) Annual report and accounts, 2013-14, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/324031/dft-annual-report-2014-web.pdf

Dodgson, J.S. (1973) External effects and secondary benefits in road investment appraisal. Journal of Transport Economics and Policy, 7 (2): 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): 75-91.

Donaldson, D. (2013) Railroads of the Raj: Estimating the impact of transportation infrastructure. American Economic Review, forthcoming.

Duranton, G. and Turner, M.A. (2011) The fundamental law of road congestion: Evidence from US cities. American Economic Review 101(6): 2616–2652.

Duranton, G. and Turner, M.A. (2012) Urban growth and transportation. Review of Economic Studies 79(4): 1407–1440.

Duranton, G., Morrow, P. and Turner, M.A. (2013) Roads and trade: Evidence from the US. Discussion paper DP9393, March 2013. Centre for Economic Policy Research.

Duranton, G., and D. Puga (2001) Nursery Cities: Urban Diversity, Process Innovation, and the Life Cycle of Products, American Economic Review, 91(5), 1454-1477

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

- Eeckhout J. and N. Guner (2014). 'Optimal Spatial Taxation: Are Big Cities too Small?' processed.
- Faber, B. (2013) Trade integration, market size, and industrialization: Evidence from China's national trunk highway system. Processed, University of California at Berkeley.
- Fogel, Robert. (1964) Railroads and American Economic Growth: Essays in Econometric History. Baltimore (MD): Johns Hopkins University Press.
- Forrest, D. et al (1996) The Impact of a Light Rail System on the Structure of House Prices. *Journal of Transport Economics and Policy*, 30(1): 15-29.
- Fujita, M, P. Krugman and A.J. Venables (1999) *The spatial economy: cities, regions and international trade*, MIT press
- Gentleman, H. et al (1983) *The Glasgow rail impact study: Summary Report*. Transport and Road Research Laboratory Supplementary Report 800.
- Geurs, K. T., Van Wee, B., and Rietveld, P. (2006) Accessibility appraisal of integrated landuse-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 landuse/transport policy strategies: More than just adding up travel-time savings. *Transportation Research Part D: Transport and Environment*, 15(7): 382-393.
- Gibbons, S. and S. Machin, (2003) *Rail Access and House Prices, An Evaluation of the Wider Benefits of Transport Improvements, and Employment and Rail Access, An Evaluation of the Wider Benefits of Transport Improvements*, reports for the Department of Transport, November 2003.
- Gibbons, S., and Machin, S. (2005) Valuing rail access using transport innovations. *Journal of Urban Economics*, 57(1): 148-169.
- Gibbons, S. and Machin, S. (2006) *Transport and Labour Market Linkages: Empirical evidence, implications for policy and scope for further research*, background paper for the Eddington report to the Department of transport, January 2006.
- Gibbons, S. and Overman, H.G. (2009) *Productivity in transport evaluation studies*, Report for Department of Transport, April 2009.
- Gibbons, S., Lyytikäinen, T., Sanchis-Guarner, R., Overman, H.G. and Laird, J. (2010) *Evaluating the Productivity Impacts of Road Transport Schemes*, Report for Department for Transport, August 2010.
- 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. 32.
- Glaeser, E. L., and Gottlieb, J. D. (2009) The Wealth of Cities: Agglomeration Economies and Spatial Equilibrium in the United States. *Journal of Economic Literature*, 47(4): 983-1028.
- GMPT (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. (2005) Wider economic benefits of transport improvements: link between agglomeration and productivity, Stage 1 report. DfT: London.

Graham, D.J. (2006) Wider economic benefits of transport improvements: link between agglomeration and productivity, Stage 2 report. DfT: London.

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

Graham, D.J. (2013) Quantifying causal effects of road network capacity expansions on traffic volume and density via a mixed model propensity score estimator. Working paper, Imperial College, London.

Graham, D. J., Gibbons, S. and Martin, R. (2009) Transport investments and the distance decay of agglomeration benefits. Draft report for the Department of Transport.

Graham D., Gibbons, S., Martin, R. (2010) The spatial decay of agglomeration economies: estimates for use in transport appraisal. Report for Department of Transport, October 2010.

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.

Grimes, A. and Laing, Y. (2010) A Bridge to Somewhere: Valuing Auckland's Northern Motorway Extensions. *Journal of Transport Economics and Policy* 44(3): 287-315.

High Speed 2 Ltd (HS2) (2012) Updated Economic Case for HS2. Report dated August 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): 379-391.

Jones, P., Evers, T., Bray, J., Georgeson, N., Powell, T., Paris, J. and Lane, R. (2004) The Jubilee Line Extension Impacts Study Main Findings and lessons learnt. European Transport Conference. London: AET Transport.

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

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).

Laird, J.J. (2010) Transport welfare benefits in the presence of an income effect. In: Hess, S. and Daly, A. (eds) Choice Modelling: the State-of-the-Art and the State-of-Practise, Chapter 18: 399-420. Bingley: Emerald.

Laird, J.J., Nellthorp, J. and Mackie, P.J. (2005) Network effects and total economic impact in

transport appraisal. *Transport Policy*, 12: 537–544.

Laird, J., Kelly, C., Nellthorp, J., Costantini, S., Carbajo, J., Mas, X., Leon, J., Richards, P., Macdonald, N., Oakes, G., Tindall, J., Arrand, J. and Black, K. (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.

Lakshmanan, T. R. (2011). The broader economic consequences of transport infrastructure investments. *Journal of Transport Geography*, 19(1): 1-12.

Leontief, W. (1966) *Input-Output Economics*. Oxford: Oxford University Press.

Leunig, T (2011), 'Cart or Horse: Transport and Economic Growth', International Transport Forum Discussion Paper 04

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): 377-384.

Mackie P.J. and Preston J.M. (1998) Twenty One Sources of Error and Bias in Transport Project Appraisal. *Transport Policy* 5: 1-7.

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., Graham, D. and Laird, J. (2011) The direct and wider impacts of transport projects; a review. in A. de Palma, R. Lindsey, E. Quinet and R. Vickerman (eds) *A Handbook of Transport Economics*, Edward Elgar, Cheltenham.

Mankiw N.G. and M. *Whinston* (1986) Free Entry and Social Inefficiency. *Rand Journal of Economics*. 17, 48-58.

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

Mayor, K. et al (2008) A Hedonic Analysis of the Value of Rail Transport in the Greater Dublin Area, ESRI Working Paper No. 264.

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.

Melo, P.C., D.J. Graham and R.B. Noland (2009) A meta-analysis of estimates of urban agglomeration economies, *Regional Science and Urban Economics*, 39, 332-342

Melo PC, Graham DJ, Brage-Ardao R, 2013, The productivity of transport infrastructure investment: A meta-analysis of empirical evidence, *Regional Science and Urban Economics*, 43,695-706.

Millward Brown, I.M.S. (2006) LUAS 'After' Study – Employers & Retailers. Report for Dublin Transportation Office.

Mohring, H. (1993) Maximizing, measuring and not double counting benefits: a primer on closed- and – economy cost benefit analysis. *Transportation Research*, 27(6): 413-424.

MVA/ITS (2013) Assessment of Methods for Modelling and Appraisal of the Sub-National, Regional and Local Economy Impacts of Transport. Report to the Department for Transport. September 2013.

Nakamura, H. and T. Ueda. 1989. The Impacts of the Shinkansen on Regional Development. In the Fifth World Conference on Transport Research, Yokohama, 1989, Vol 3, Ventura, California: Western Periodicals.

National Audit Office (2004) Improving public transport in England through light rail. HC 518 Session 2003-2004.

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

Office for National Statistics (ONS) (2010) Measuring the economic impact of an intervention or investment. Paper Two: Existing sources and methods. London: ONS.

Oosterhaven, J. and Knaap, T. (2003) Spatial Economic Impacts of Transport Projects. In: Pearman, A., P. Mackie, J. Nellthorp and L. Giorgi (eds) *Transport Projects, Programmes and Policies: Evaluation Needs and Capabilities*. Chapter 5. Aldershot: Ashgate.

Overman, H., Gibbons, S., D'Costa, S., Mion, G., Pelkonen, P., Resende, G. and Thomas, M. (2009) Strengthening the economic linkages between Leeds and Manchester. Report to Northern Way. Report dated November 2009.

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).

Pagliara, F. et al (2010) High Speed Rail Accessibility Impact on Property Prices: Evidence from St Pancras International Station in London, XVI PANAM July 2010.

Rietveld, P. and Bruinisma, F. (1998) *Is transport infrastructure effective? Transport Infrastructure and Accessibility: Impacts on the Space Economy*. Springer Verlag: Berlin.

Puga, D. and J. de la Roca (2012) Learning by working in big cities' CEPR dp no 9243

Redding, S.J. and M. Turner (2014) *Transportation costs and the spatial organisation of economic activity*, processed, Princeton

Rice, P.G., A.J. Venables and E. Patachini (2006) Spatial determinants of productivity; analysis for UK regions, *Regional Science and Urban Economics*, 36, 727-752

Rosenthal, S. S. and Strange, W. C. (2004) Evidence on the Nature and Sources of Agglomeration Economies. *Handbook of Urban and Regional Economics*, Vol. 4, ed. Henderson, J. V. and Thisse, J. F. New York: North-Holland.

Salop, S. (1979). Monopolistic competition with outside goods. *Bell Journal of Economics* 10, 141–156.

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

SAHA (2010). Roads of National Significance Economic Assessments Review. Report to NZTA. Report dated July 2010.

Simmonds, D.C. (2012) Advancing appraisal: from transport economic efficiency to landuse/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.

Standing Advisory Committee on Trunk Road Assessment (SACTRA) (1986) Urban road appraisal. London: H.M.S.O.

Standing Advisory Committee on Trunk Road Assessment (SACTRA) (1994) Trunk Roads and the Generation of Traffic. London: H.M.S.O.

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.

Strauss-Kahn, V, and X Vives, X. (2009) Why and where do headquarters move?, *Regional Science and Urban Economics*, 39, 168-186.

Tavasszy, L. A., Thissen, M. J. P. M. and Oosterhaven, J. (2011) Challenges in the application of spatial computable general equilibrium models for transport appraisal. *Research in Transportation Economics*, 31(1): 12-18.

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): 173-188.

Venables, A.J. (2013) Expanding cities and connecting cities: the wider benefits of better communications. Processed, Oxford.

Vickerman, R. (ed.) (1991) *Infrastructure and Regional Development*. Pion: London.

Wegener, M. (2004) Overview of land-use transport models. In: Hensher, D.A. and Button, K.J. (eds) *Transport geography and spatial systems. Handbook 5 of handbook in transport*. pp 127–146. Kidlington: Pergamon/Elsevier Science.

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.

West Yorkshire Passenger Transport Executive (WYPTE) (2014) West Yorkshire and York LTB Priority Core Package of Schemes and GVA and BCR Measures.

Wilson, A.G. (1998) Land-Use/transport Interaction Models: Past and Future. *Journal of Transport Economics and Policy* 32(1): 3-26.

Worsley, T. (2011) The evolution of London's Crossrail Scheme and the development of the Department for Transport's economic appraisal methods. Discussion Paper No. 2011-27 International Transport Forum, Paris.

Zhu, J., Ying, J. and Echenique, M. (2012) Application of a new spatial computable general equilibrium model for assessing strategic transport and land use development options in London and surrounding regions. ERSA congress 2012, August 2012, Bratislava.

Appendix 1.1: Transport Appraisal – How the English approach compares with other countries’?

DfT recently commissioned a report (Mackie and Worsley 2013), which reviewed recent developments in economic appraisal of the transport sector and the use of appraisal in the decision-making process. The report compared the English approach with that in; Germany, Netherlands, Sweden, USA, Australia, and New Zealand. The project also included individual country reports which are available online.

The report found no radical alternative frameworks in use by any of the above countries. The evidence base in England is comparable in quality with best practise elsewhere. It is worth noting that in the US transport appraisal is conducted at the state level, so a range of approaches are employed, rather than having a unified approach. The English approach has gone further than most in its application than just road and rail, to policy areas from walking and cycling, to aviation, and dimensions such as distributional impacts. WebTAG remains the leading model.

Some of the key values in WebTAG such as those for travel time savings and safety benefits are based on studies which are almost 20 years old, most of the comparator counties were using more up to date studies. However, DfT is currently undertaking research to update its values of time, and this study will be able to benefit from the more up to date international evidence available.

There is most variation in the approach to wider economic impacts. There are two key approaches. The first argues that the presence of tax wedges and agglomeration effects means that improved accessibility leads to benefits external to the traveller which are not picked up in the standard estimate of user benefits. The UK has led the way in this approach, but it is also used in Australia, New Zealand, and Sweden. The second approach focusses on inter-industry linkages, using regional input/output models or CGE models. The USA considers a range of impact pathways beyond commuting, such as logistics and supply chain impacts, connectivity to corridors and gateways, and intermodal interchanges.

No other country publishes the same quantity of information as DfT, on the way cost benefit analysis informs the decision-making process. The DfT publishes both WebTAG, which details all of the requirements for the economic appraisal of a scheme, and information in its Value for Money Guidance on the process used by decision-makers for determining priorities between options which have been appraised. Nor to our knowledge do other countries set objectives for and publish information about the performance of the transport schemes that they approve which is the equivalent of the DfT’s value for money input indicator.

The DfT guidance on the Transport Business Case goes further than other countries in setting out the overall requirements but delivering them consistently is demanding. For example, delivering economic growth is one of the Department’s objectives so the impact on the economy is to be considered in the strategic case. However, there is currently no guidance on how this impact should be measured or reported. If methods are developed to include the impact on the economy, measured by the change in GDP or GVA, as part of the strategic case careful consideration will have to be given to how it meshes with the economic case (an issue discussed in more detail in this report). Similar issues arise in other countries, especially the USA where there is more experience of Economic Impact Assessment.

Appendix 3.1:

A technical checklist for agglomeration effects

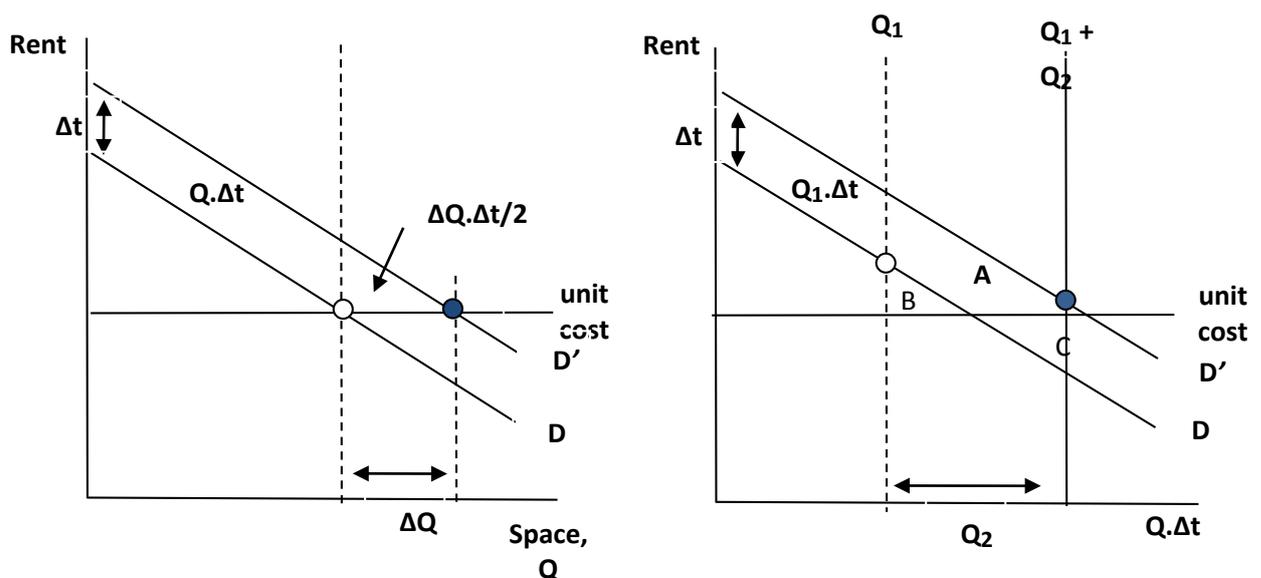
Checklist:	<i>E.g.:</i> Northern way (SERC 2009)
Measurement of ATEMs:	
- What activity variable:	Employment
- What sectors	Aggregate
- What 'distance' measure:	
o Distance, GTC.	GTC
o By mode of transport	Road, rail
- What spatial decay	
o Spatial unit	Wards
o exponent, bands.	Imposed, reciprocal
Relationship ATEM and productivity:	
- Productivity measure	Wages
- Source for elasticities	Own estimation, workers, NES/ ASHE
o Conditional on?	Alternatives including: Skills, occupation, individual fixed effect
o Based on multivariate regression	Yes
- What sectors	Aggregate
Transport project impact on ATEM:	
- Proximity effect: change in distance weighting	
o By mode	Changes GTC by mode
o By sector	Aggregate
- Location effect: Change in activity variables	Held constant
o By sector	o
Reporting of results	o
- Distinguish by national/ local Additionality Further investments needed	o

Appendix 4.1: Dependent development

Figure 4.1 below can be thought of as a simple description of the rental market for office space in a particular place. The standard analysis is the left hand panel. The horizontal axis is numbers of workers accommodated (equal to the number of journeys made), and the unit cost of building office space (per worker) is as illustrated. The demand curve is labelled D , and the initial equilibrium point is given by the empty circle. A transport improvement raises demand (more workers can access the office, given wage rates), the size of the vertical shift being the user-benefit Δt (expressed per unit office space / worker). If there is no land-use change the price of office space increases and the benefit is $Q \cdot \Delta t$. If land-use changes ΔQ new units will be constructed, giving the new equilibrium at the solid circle. This brings additional benefit equal to the triangle $\Delta Q \cdot \Delta t / 2$. This is the standard user-benefit approach. The land-use change is 'dependent' on the transport improvement, and the quantity estimate (journeys created and extra workers accommodated) needs to incorporate the land-use change. However, it calls for no modification of approach.

Dependent development projects are often large schemes where non-marginal changes occur, and this can be a source of surplus. For example, an office or shopping development might, for commercial or technical reasons, need to be undertaken at scale. This is illustrated on the right hand panel of figure 4.1. Initially quantity of space available is fixed at Q_1 and, as the example is constructed, rents exceed unit building cost. However, a new development is of minimum scale Q_2 ; undertaking this without the transport improvement would lead rents to fall below unit cost, so the development is not profitable. As illustrated, the transport improvement (shift in demand curve) is large enough to make the development profitable, at equilibrium indicated by the solid circle. The benefit of the improvement is $Q_1 \cdot \Delta t + A + B$, whereas the standard user-benefit rule (with $\Delta Q = Q_2$) would give $Q_1 \cdot \Delta t + Q_2 \cdot \Delta t / 2 = Q_1 \cdot \Delta t + (A + C) / 2$. Evidently, the former may (although need not?) exceed the latter, suggesting that the user-benefit approach underestimates gains. Fundamentally, the issue is that the office developer is unable to capture the entire surplus created, because of the non-marginal effect of the project. The transport investment unlocks this, creating further aggregate gain.

Figure 4.2: Land-use and dependent development.



Appendix 4.2: Transport resolving a coordination failure

Firms' location decisions may be inter-dependent and – absent some mechanism to coordinate them – may be inefficient. This can be illustrated by a numerical example. Each firm, 1, 2, can choose either location A or B. In location A each firm makes 100, plus a further benefit c if the other firm is also in A. Location B gives profits to each firm of 130, minus transport costs t ; for example B has lower land rent but is remote from customers. There are further profits of c if both firms are in B.

Initially both firms are in A. When will they move to B, and what is the payoff from so doing? The payoff matrix below illustrates the game.

If $c = 0$ firm 1 will choose B in preference to A if $t < 30$, and the gain from so doing is $30 - t$. Suppose t drops from 35 to 25. This triggers the move, and the gain is $30 - 25 = 5$; this is less than the reduction in t ($= 10$), illustrating the user cost argument.

Alternatively, suppose that $c = 10$. Then firm 1 will choose B in preference to A if $t < 20$. The fact that it takes a lower level of t to trigger the change illustrates the point of 'lock-in'; if $t = 25$ both firms would gain from moving from A to B but, acting independently, neither will choose to move. Now suppose that a transport improvement reduces t from 25 to 15. This triggers the move for both firms, and the gain for each is $30 - 15 = 15$: this is greater than the reduction in t ($= 10$).

Pay-off matrix:		Firm 2	
		Locations	A
Firm 1	A	$(100 + c, 100 + c)$	$(100, 130 - t)$
	B	$(130 - t, 100)$	$(130 + c - t, 130 + c - t)$

An example with just two firms is contrived (could they not cooperate in some way to coordinate their choices?). The real world examples arise as benefits of co-location come from the interaction of many hundreds of firms and thousands of workers in economic clusters.

Appendix 4.3: Variation in economic outcomes by modelling method

Different economy models can give substantially different predictions of the effect on the economy of transport schemes (e.g. Lakshamanan, 2011). Our survey of transport-economy studies confirms this. It is hard to make comparisons as it is rare that different modelling methods are applied to the same scheme appraisal simultaneously. Invariably there are subtle but important differences between the scenarios that are being examined.

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 as estimated with a reduced form model. Overman et al. (2009 Chapter 6) find benefits just under half of that at £7 billion (2006 prices) estimated with a general equilibrium model – albeit for a scheme that reduces journey times from only Manchester and Leeds. 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) – a large proportion of which will not be business related. 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) would be reduced by £8.5 billion each year and employment would be lower by 141,400 (compared to an unconstrained case) as estimated with a general equilibrium model (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 from the cost benefit analysis for all airport capacity constraints across the UK is estimated to be £18 to £20 billion, whilst a 60 year present value of benefit estimated from two different SCGE models is in the region of £30 to £45 billion (Airports Commission, 2013 p100).

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 £2.1 billion in GDP for the North of England using a reduced form model. Of this £0.9 billion is additional to the UK economy (GMPTE, 2010). 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 (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.

The £1 billion West Yorkshire Transport Fund has an estimated regional GVA impact of £1.23 billion creating about 20,000 jobs by 2036. 46% of this gain is estimated to be additional at the national level. This has been estimated using the Urban Dynamic Model, a simulation model that can be regarded as a LUTI model. In contrast the CBA only has a benefit cost ratio of 4.9 (WYPTE, 2014). That is the benefit from the CBA (including non-business related benefits) is only 4 times a single years regional GVA impact and just under 8 times the additional impact at a national level.

In New Zealand SAHA (2010 appendix D) used a CGE model to study the impact of upgrades to strategic roads of national significance, showing that total benefits could be 80% above user-benefits if investment in other industries was to be undertaken in response to the higher expected rate of return. In contrast a study by SAHA (2010 appendix C), employing add-on techniques to the standard CBA analysis to capture agglomeration and labour supply effects, estimated the wider economic benefits of the same strategic roads to be 40% of the user-benefits. Note these two estimates not only vary in magnitude but they measure different impacts: the CGE model picks up allocative efficiencies, but has no agglomeration effects and any employment impact comes through wage changes; whereas SAHA picked up higher productivity arising from agglomeration and higher employment.

At a much smaller scale the upgrade of the A82 to Fort William in the Scottish Highlands is expected to generate a £152 million increase in regional GDP (30 year PV) of which £113 million is additional at the national level. This has been estimated using the bottom-up approach discussed in chapter 4. The additionality is created as the road serves an export orientated sector (fish farming). The CBA in contrast only has £52.5 million of business and freight user-benefits.

The above examples are in the main comparisons between an economy modelling method (e.g. reduced form) and the use of CBA outputs as a proxy for economy impacts. This is because it is hard to find examples where two transport-economy modelling methodologies are employed simultaneously for the same set of projects using exactly the same set of inputs. The only study we have identified is that undertaken as part of the IASON research project (Bröcker et al., 2004). The results from the comparison between the economy modelling of these trans-European projects using a regional production function model (SASI) and a spatial computable general equilibrium model are reproduced in Table 4.1 for 13 different investment and transport policy scenarios. The second column represents the degree of correlation between the two models' results for changes in GDP/capita at a NUTS3 regional level. As can be seen this is not particularly high, but they do show broad agreement in terms of the direction and spatial location of change. The right hand column represents the average difference between GDP/capita changes forecast by the two models. Taking scenario A1, implementation of all Trans-European Network (TEN) priority projects (Essen list), a

value of 5.05 means that the SASI model suggests GDP/capita growth 5.05 times that predicted by CGEurope. However it is clear that there is no consistency between the scenarios – with SASI predicting a 9.1 times larger GDP/capita growth in one scenario, and at the other extreme CGEurope predicting a GDP/capita growth 3.3 times that predicted by SASI (=1/0.30). This is indicative of the divergence between what one would expect to be two fairly sophisticated modelling methods.

Table 4.1. Comparison of GDP/capita impacts between a regional production function model (SASI) and a Spatial Computable General Equilibrium model (CGEurope) across multiple European transport investment scenarios

Scenario		Relative Change of GDP Per Capita	
		Coefficient of Correlation between SASI and CGEurope results	Regression Coefficient of SASI results on CGEurope results
A1	Implementation of all Trans-European Network (TEN) priority projects (Essen list)	0.47	5.05
A21	Implementation of all high-speed rail priority projects (Essen list)	0.70	9.10
A22	Implementation of all conventional rail priority projects (Essen list)	0.68	4.64
A23	Implementation of all road priority projects (Essen list)	0.80	1.76
A24	Implementation of all rail priority projects (Essen list)	0.62	8.17
A3	Implementation of all TEN and TINA projects	0.50	5.62
A4	Implementation of all TEN projects	0.56	5.10
B1	Social Marginal Cost pricing applied to road freight	0.08	0.30
B2	Social Marginal Cost pricing applied to all modes (travel and freight)	0.73	2.36
C1	Implementation of all TEN priority projects (Essen list) plus Social Marginal Cost pricing applied to all modes (travel and freight)	0.69	1.87
D1	Dedicated rail freight network	0.46	3.64
E1	TIPMAC business-as-usual scenario	0.52	5.80
E2	TIPMAC fast implementation scenario	0.70	0.89

Source: Bröcker et al. (2004 Table 5.1 p168)

Ex post studies can act as a form of validation on modelling methods. Unfortunately appropriate ex post studies are limited, and where they exist there are not always modelling studies against which they can be compared. There are two examples where economic outcomes in terms of GDP have been compared against cost benefit analyses. The first is that of the Jubilee Line Extension, where Jones et al. (2004) concluded that it was responsible for adding some £9.6billion to GDP (2003 prices present value over 60 years from 2000 to 2060) through attracting jobs to the area and through agglomeration benefits. Other work identified that the ex post CBA benefit cost ratio was 1.75 (Bartlett School of Planning, undated) and the final scheme costs were £3.5billion (Worsley, 2011). That is the gain to the economy exceeds the CBA benefits even though the CBA benefits include non-GDP impacts (non-work time savings, accident savings, etc.). A similar finding was found for the extension of the Northern motorway in Auckland; after taking into account reductions in property values elsewhere in Auckland, the motorway developments led to an increment in land values such that the scheme had generated a GDP benefit to cost ratio of 6.3. This exceeded the benefit to cost ratio from the CBA (Grimes, Arther and Liang, 2010).