USE OF INTEGRATED TRANSPORTATION LAND USE MODELS IN THE WIDER ECONOMIC BENEFITS CALCULATIONS OF TRANSPORT SCHEMES

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ABSTRACT

A set of suggested methodologies for appraisal of Wider Economic Benefits was published by the UK Department for Transport covering a range of welfare and GDP benefits including Agglomeration Economies - increases in productivity resulting from higher densities of employment; More people working - the increase in output arising from better transport encouraging more people into work; Move to more productive jobs - the increase in productivity identified as resulting from jobs relocating into higher productivity areas; Increased output in imperfectly competitive markets - the increase in production expected to result from transport improvements; Increased competition - benefits arising from increased competition as a result of transport improvements and the Wider benefits from the exchequer consequences of the GDP related effects.

MVA Consultancy and David Simmonds Consultancy were commissioned to undertake a study of these wider economic impacts of transport interventions using a land-use and transport interaction model in combination with the DfT's new method for identifying and quantifying wider economic impacts. The aim of the study was to look at the likely impacts of a range of transport interventions, with a view to helping to draw some broad conclusions as to which interventions given particular characteristics of the area are likely to provide an effective contribution to the economy. This paper presents the Wider Economic Benefit methodology, describes the South and West Yorkshire Strategic Model - a Land-Use Transport Interaction Model used in this study, and reports on the results obtained.

1 INTRODUCTION

1.1 Methodological context

The standard methods for economic evaluation of transport schemes have developed over many years – from as early as the 1840s. The major component has traditionally been that of changes in consumer surplus, which for most transport infrastructure schemes in developed countries are closely related to the monetary valuation of the time savings which are forecast to result from the investment. Reductions in accident costs also feature strongly in many economic analyses of transport improvements.

More recently, the environmental impact of the provision and use of transport infrastructure has been given increasing attention, firstly by identifying these impacts and then in some cases by attaching monetary values to them, converting them into the same units as the conventional costs and benefits. The present state of practice is therefore one which merges important themes from welfare economics and from environmental economics. The environmental concerns have generally started with the most immediate (eg the loss of habitat under a road in a rural area, or levels of air pollution beside urban roads) and moved to include the more distant (eg the climate changes impacts of changes in greenhouse gas emissions).

In many cases it has been conventional to assume, in the formal analysis, that it was sufficient to estimate the welfare and resource impacts on the individuals, firms and government sectors directly affected; it was assumed that the workings of the economy might result in benefits (or costs) being transferred between these groups, or between people and firms, but that these transfers would not affect the overall level of benefits.

This view has more recently been called into question, the key theoretical argument being that imperfections in the market economy may mean that there will be wider gains (or losses) to the economy beyond those measured in conventional appraisal.

1.2 Study context

The UK Department for Transport (DfT) and HM Treasury (HMT) have been seeking a better understanding of the potential wider economic effects of transport strategies. A set of methods for appraisal of such benefits was published by DfT (2005). These methods require a multi-modal transport model of a substantial region, integrated with a land-use/economic model to forecast the changes in employment and population location resulting from the transport interventions. As part of the work for a major review of UK transport policy - the Eddington Study - MVA Consultancy, Mouchel Parkman and David Simmonds Consultancy (DSC) were commissioned to apply these methods using the South and West Yorkshire Strategic Model (SWYSM). This paper is based upon that work; the full report was published as ETSR (2006).

The structure of this paper is that following this introduction, the second section introduces the Department's suggested methodologies. The third describes their application using the SWSYM model. The fourth section outlines the results of a range of transport interventions, and the final section draws some conclusions.

2 METHODS AND MODEL APPLICATION

2.1 Introduction to the methodology

The DfT methodology identifies a number of types of potential welfare benefits (WB) which are either missing or only partly counted in the current standard approach to transport appraisal. These are:

- Agglomeration Economies (WB1): these describe the productivity benefits that some firms derive from being located close to other firms;
- Benefits from Increased Competition (WB2): the DfT guidance is that this is not normally expected to be significant in the UK situation.
- Increased Output (WB3): the argument here starts from the conventional transport policy objective of (inter alia) reducing the costs of business travel and goods haulage, by reducing the time taken (and hence reducing wage and vehicle costs) or more directly by offering cheaper alternatives. Firms are expected to respond to such cost savings by reducing prices and increasing output. The benefits of reduced prices and increased output accrue to the customers of the firms affected by the transport improvement; the argument is that the benefits to these customers have not been sufficiently taken into account;
- Wider benefits arising from improved labour supply (WB4), which can arise from:

  - improved travel for commuters leading some people to work who would otherwise choose not to work;

  - improved travel encouraging other people to work longer hours (because they spend less time commuting)

  - moves to more productive jobs. The DfT approach argues that certain areas display higher productivity than other areas, and hence that, if the effect of a transport intervention is to move jobs from a lower-productivity area to a higher-productivity one, there is an additional economic gain.

The welfare benefits WB1-3 are also increases in GDP, as are the moves to more productive jobs until WB4. The other components of WB4, involving increased working, will have bigger impacts on GDP than on welfare, since the welfare gain to the individual who becomes a worker rather than a non-worker, or who chooses to work longer hours, will in most cases be offset by some loss of leisure time. The wider economic benefits need to be considered in both welfare and GDP terms. Welfare (also called “social welfare”) effects measure changes in the total well-being of society. GDP measures the overall performance of the economy. The two views of wider economic benefits are closely related but not identical; they must both be considered but cannot be added together (to do so would be double-counting).

The following sections describe the different categories of wider benefits in turn.

2.2 WB1 Agglomeration economies

Agglomeration benefits are an alternative way of describing what were traditionally known as *external economies of scale* - the fall in a firm's average costs of production due to their proximity to other firms in the same or other industries. When scale effects are external to the firm, average costs decline as local industry output increases.

The existence of agglomeration economies was recognized by classical economists such as Weber (1909) and Marshall (1920). According to Marshall, the agglomeration economies are economies which are independent of a single firm, but they accumulate to all of the firms in the same location. As the scale and density of urban and industrial agglomeration increase, we expect to find an increase in the external benefits available to firms. The existence of such benefits can explicate the formation and expansion of cities and industrial sites.

Nevertheless, it does not necessary follow that just due to an increase in perceived importance of these agglomeration phenomena, there has actually been any substantial recent change to the economic conditions faced by firms or economies. For instance, there have been extensive technological alterations which appear largely to have decreased some transactions costs, thus potentially diminishing the significance of proximity. Another argument is that large cities and industrial locations have been an established attribute of our economic system and unequal distribution of activity may be a natural outcome of a random process (see Ellison and Glaese, 1997), not related to arguments about economies of scale (Gabaix 1999a, b).

The following sources of the economies of scale are recognised (see McCann,2001):

- information spillovers – "proximity maximises the mutual accessibility of all individuals within the cluster, thereby improving the information available to all local participants";
- local non-traded inputs (to distinguish from consumed inputs) – some specialist inputs can be offered to the groups "in a more efficient manner than would be the case if all of the firms were dispersed"; and
- local skilled labour pools – "the existence of specialised local labour pool" which "allows firms to reduce their labour acquisition costs".

There is a natural relationship between transport and externalities of agglomeration. Transport costs are essential in generating tendencies towards spatial concentration. This is due to the fact that transport networks to certain degree define the ease of access to other firms and to labour markets, and transport improvements or worsening can significantly change employment densities.

Taking all this into account, it is apparent that there may be effects of transport investment that relate specifically to agglomeration. If there are increasing returns to spatial concentration, and if transport in partly influences the density level experienced by firms, then investment in transport may encourage some shift in the productivity of firms via the externalities of agglomeration. These effects of transport investment are known as wider economic benefits as they correspond to market imperfections that are not accounted for in a standard cost-benefit analysis.

To identify the scale of the likely wider economic benefits of transport investment we need quantitative estimates of the returns to agglomeration, namely, the empirical confirmation of the existence and scale of the relationship between employment density and productivity. Ideally this relationship should be estimated separately for different economic sectors due to the fact that some sectors are more urbanised than others and as a result they are likely to gain more from rising densities.

Different econometric techniques have been developed over the last decade to capture agglomeration. Some of those techniques are non-spatial in their approach (see for example, Glaeser et al, 1992; Ellison and Glaeser, 1997), the others are extremely spatial (for example Fingleton, 2003). Despite considerable attention from the research community in the mechanisms underlying agglomeration economies remain contested and in many respects a "Black Box" (see Doring and Schnellenbach (2006) and McCann and Shefer (2004, 2005) for overviews) with considerable overlap between potential causes of the empirically observed relationship between productivity and density.

The methodology proposed (DfT, 2005) is based on the observed correlation between density of employment and productivity. Employment density is, in effect, a measure of accessibility to jobs, and the level of urban or industrial density in a particular location is to a certain extent dependent on the nature of transport systems availability. Density in this situation is most appropriately understood in terms of the cost of accessing other jobs both in the study zone but also in adjacent and more distant areas. Research by Dr Dan Graham (Graham, 2005) into the relationship between employment density and productivity in the UK has produced estimates of elasticities between the 'effective density' of a location (the employment in and around an area weighted by proximity, i.e. generalised cost of access) and productivity, GDP per worker.

The formula for calculating agglomeration economies is shown below.

$$WB1 = \sum_i \left[\left[\left(\frac{d_i^A}{d_i^{B_0}} \right) \wedge e(WB1) - \left(\frac{d_i^B}{d_i^{B_0}} \right) \wedge e(WB1) \right] \times h_i \times E_i^A \right]$$

where $WB1$ are the agglomeration benefits of the alternative situation (A) compared with the base (B), to be calculated; i is a zone for which agglomeration benefits are being calculated - all of the modelled zones are included in the summation; d_i^A, d_i^B are the effective densities of zone i in the alternative situation A and base situation B respectively, calculated as shown below; $d_i^{B_0}$ is effective density of zone i in the base year (all other values are for the forecast year), likewise calculated using the formula shown below; $e(WB1)$ is the elasticity of productivity with respect to effective density (Graham, 2005); h_i is GDP per worker in i (see below); E_i^A is employment (in the alternative case) as predicted by SWYSM.

Effective density is a measure of the accessibility of zone *i* to jobs in all zones, calculated (in the base case) as

$$d_i^B = \sum_j \left\{ \frac{E_j^B}{g_{ij}^B} \right\}$$

where g_{ij}^B is the generalised cost of travel from *i* to *j* in the base case B. All the modelled zones *j* are considered in the calculation, as is the intrazonal pair (*i*=*j*); E_j^B is the employment in zone *j* in the base case B.

The form of the employment density function - dividing employment in each zone by a measure of the generalized cost of reaching that employment from the zone being considered - was that selected by DfT. The calculations made in this project therefore produce agglomeration benefits (or disbenefits) from changes in the ease or difficulty of getting from place to place, as well as from the changes in where jobs are located.

The generalized cost used is a weighted average over:

- passenger travel (commuter and in-work purposes) and goods movement;
- traveller modes or goods vehicle types;
- car-ownership levels, for passengers; and
- times of day, routes and public transport sub-modes.

The weights used in these steps are the numbers of trips (persons or goods vehicles) by mode and purpose in the base case. These weights are based on the numbers of trips between the pair of zones considered in each calculation.

2.3 WB2 Increased competition as a result of better transport

Benefits arising from increased competition as a result of transport improvements (WB2) - was identified by DfT as theoretically possible. However there is little evidence to be found on the relationship between transport and competition and on the basis of that available, DfT does not expect that there will be significant wider benefits owing to increased competition. This category has accordingly not been considered further in the present study.

2.4 WB3 Increased output in imperfectly competitive markets

“Where there is imperfect competition in a market, we’ve seen that the value placed on additional production, the price, is normally higher than production costs. Firms and consumers would therefore be jointly better off if firms were to increase production. If better transport induces firms to increase production there are precisely such benefits … the value attached to time savings would underestimate the true benefits.” (DfT, 2005)

As set out by the DfT (2005) WB3 is calculated on the basis of an uprate factor (10%) applied to the savings to business travel.

2.5 WB4 Wider benefits from consequences on the exchequer

The Department's work identifies three labour market effects which could have consequences for GDP and which may contribute to welfare benefits through the tax take. These are referred to as:

- GP1: More people choosing to work as a result of commuting time savings (because one of the costs of working – commuting costs – has fallen);
- GP2: some people choosing to work longer hours (because they spend less time commuting);
- GP3: relocation of jobs to higher-productive areas (because better transport makes the area more attractive to firms and workers).

WB4 is the sum of the tax consequences of these effects. The DfT suggests that given the differences between effects GP2 and GP3, which are applicable to existing workers attracting a marginal increase in taxation as they become more productive, and GP1, which relates to the tax on any additional average workers and also reductions in benefit payments, the relevant tax rates for the benefits should be 30% for GP2 and GP3 and 40% for GP1.

Thus:

$$WB4 = 40\% \times GP1 + 30\% \times (GP2 + GP3)$$

The increase in GDP from **more people working** (component GP1) is calculated as

$$GP1 = -\sum_i \left[\left\{ \frac{\sum_j W_{ij}^A \times (g_{ij}^{WA} - g_{ij}^{WB})}{\sum_j W_{ij}^A \times y_j} \times \sum_j (m_j \times W_{ij}^A) \right\} \times e(GP1) \right]$$

where $GP1$ are the more-people-in-work benefits of the alternative situation (A) compared with the base (B), to be calculated; *i* is a residential zone for which benefits are being calculated - all of the modelled zones are included in the summation; j is a workplace zone; g_{ij}^{WA}, g_{ij}^{WB} are the generalised costs of travel-to-work (commuting, purpose W) from zone *i* to zone *j* in the Alternative and the Base case respectively, as forecast by the model; W_{ij}^A is the number of workers living in *i* and working in *j* (in the Alternative case) as forecast by the model; y_j is the average wage of workers employed in zone *j;* m_j is the GDP per worker entering the labour market in zone *j* in 2006; $e(GP1)$ is the elasticity of labour supply with respect to wages.

Benefit GP2, arising from people working longer hours in their current job, is assumed to be zero.

The calculation of the GDP effect of the **move to more productive jobs** (GP3) is based on the change in number of jobs in each area multiplied by the average GDP per worker for the Reference case and by the index of productivity per worker in each area. Therefore the benefit from people moving to more productive jobs is calculated as

$$GP3 = \sum_i (E_i^A - E_i^B) \times PI_i \times k^B$$

where $GP3$ is the move to more productive jobs benefit of the alternative situation (A) compared with the base (B), to be calculated; *i* is a zone for which benefits are being calculated - all of the modelled zones are included in the summation; PI_i is index of productivity per worker in zone i; k^B is the modelling area average GDP per worker in the reference case; E_i^A, E_i^B are the employment levels for zone *i* in the base and alternative situations.

PI_i, regional productivity differentials estimate the regional productivity relativities after accounting for factors such as differences in occupation distribution, industrial structures and worker qualification levels and are currently assumed to be constant for the whole appraisal period.

3 OPERATIONALISING WIDER BENEFIT CALCULATIONS

3.1 Overview of SWYSM

SWYSM (see Simmonds and Skinner, 2003) is a land-use/transport interaction model of South and West Yorkshire and adjoining areas (see Figure 1), based on DSC's land-use/economic model package DELTA and MVA's strategic transport model START. SWYSM can be used

- as a strategic multi-mode transport model, running START alone for a chosen year (Transport-SWYSM); and
- as a land-use/transport interaction model using DELTA and START dynamically (LUTI-SWYSM).

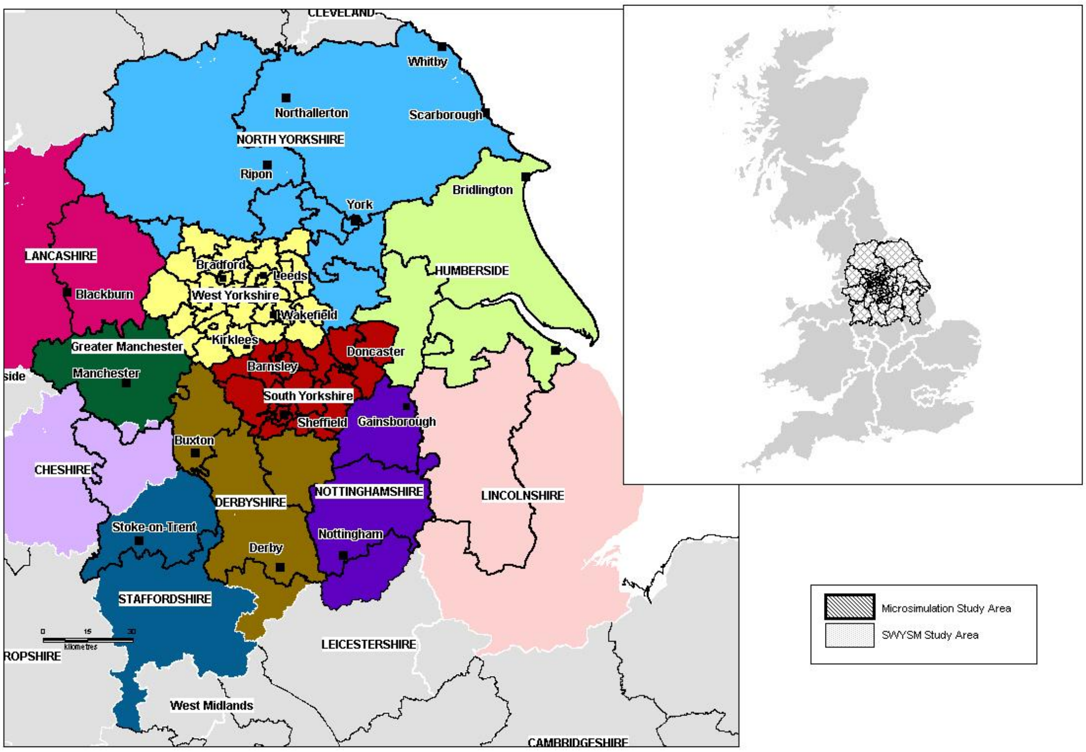

Figure 1. SWYSM Study Area

Transport-SWYSM is used for the rapid appraisal of transport strategies and policies. It is also used for all work involving transport economic efficiency (TEE) appraisal, as the standard TEE calculations are invalidated by land-use changes.

LUTI-SWYSM takes account of the interactions between transport and land-use over time. It is used to establish Reference Case land-use forecasts as inputs to Transport-SWYSM tests involving transport economic appraisal[1]. Its primary application is for the spatial analysis of the population, development and employment impacts of transport proposals. LUTI-SWYSM can also be used to provide forecasts of the impacts of land-use policies and specific plans.

Both modes of SWYSM were used in the work on WEBs. Transport–SWYSM (using a Reference Case set of land-use forecasts) was used for the calculation of transport economic efficiency benefits of the interventions tested; and LUTI-SWYSM was used for all other forecasting supporting the WEB calculations.

The SWYSM transport model has:

- a relatively coarse zoning system;
- simplified representations of the road and public transport networks, with capacity restraint effects on the road network being effected by area speed/flow relationships which were developed from a more detailed road traffic assignment model;
- trip matrices segmented by vehicle type and time of day, and for person trips, by trip purpose, car ownership, and mode;

[1] These land-use forecasts are then treated as fixed for all subsequent runs of Transport-SWYSM

- the main traveller responses of change of trip frequency, destination, mode, time of travel, route and parking location, with the hierarchy (ie the relative sensitivities) of responses varying by trip purpose;
- imported choice model parameters (mode and area-specific constants not required as the model operates incrementally on base matrices);
- a high degree of convergence between demand and supply, which is important for tests of policies which yield substantial changes in supply or demand;
- facilities for representing public transport operators' responses to changes in demand; and
- run times around 1 hour per run.

Whilst most highway supply (and consequently bus service supply) is treated within the model in a very aggregate way (ie directional area speed/flow.distance curves), the motorway and rail networks are represented in some detail.

In the LUTI form of SWYSM the transport model is run at five yearly intervals and the land-use/economic model in one-year steps. LUTI-SWYSM has the following key features:

- the travel demand choice models in SWYSM (frequency, mode, destination, time of day and route) are retained;
- the planning data inputs to SWYSM are provided by the land-use model;
- the land-use model represents recognisable processes of change, interacting over time, such as demographic change and the physical development of housing and commercial floorspace; and
- transport changes affect accessibility and environmental quality, which influence some of the processes of land-use change.

Many aspects of land-use change are only **indirectly** influenced by transport. The impact of a land-use change depends on the interaction between processes that are influenced by accessibility (e.g. the location of new households) and those that are not (e.g. the natural change in the population).

3.2 WEB calculations

Turning the suggested methodologies into a fully fledged implementation of an appraisal process capable of working with real outputs and able to produce results for multiple tests in a tractable timescale was a considerable task. In certain cases it required the implementation of certain procedures which were not anticipated in the original theoretical work. Given this, great care was taken to accurately reflect the concepts underlying the wider benefits and there was considerable liaison between David Simmonds Consultancy and the DfT throughout the project.

The SWYSM model provides much of the input required for the WEB calculations, but some further inputs are required. In addition to the suggested parameter values (taken from DfT, 2005, and related research by Graham, 2004, 2005) additional, spatially specific data is required on

- Worker GDP's,
- Worker wages, and
- Productivity differentials.

Where possible observed values of these were obtained from DfT, the Office for National Statistics or other publications (eg NERA, 2002). Many of these values also have to be forecast for the duration of the modelled period, and even beyond, if the appraisal timeframe exceeds the modelling horizon. This required consideration of a number of underlying assumptions regarding issues such as growth in per-worker GDP and wages, the influence of agglomeration effects in the reference case and regional trends in productivity.

The basic scope of the appraisal procedures is as follows:

- modelled period: 2000-2020;
- spatial coverage: South and West Yorkshire Multi-Modal Study Area (SWYSM);
- intervention year: 2005;
- appraisal period: 2005-2064;
- denomination of costs and benefits: £m in 2002 in 2002 pounds.

The components of the wider benefits could be calculated for each year of the forecast period, 2005-2020, or at least for the years in which the transport model is run (2005, 2010 etc). In practice, given the large amount of data manipulation required, the calculations have only been carried out for the final year of the forecast period (2020). The appropriate values for the intermediate and future years have been estimated for each of the four components. The assumptions underlying these estimates are detailed below for each case.

WB1, **agglomeration benefits**, were calculated using the equations previously outlined in section 2.2, the impact of changes in employment density between the tests and the reference case were assessed for the year 2020. To avoid double counting, the reference case GDP per worker values for the model zones were forecast for 2020 on the basis of the base year values and on the assumption of an annual growth of per worker GDP of 2%, **inclusive** of any agglomeration impacts which might be present in the Reference Case. This involves decomposing the 2% growth assumption into a study area component (approx 1.95% per year) and the effects of agglomeration which vary on a zonal basis dependent on the Reference Case trends in costs and employment re-location.

Intermediate year benefits are interpolated assuming linear growth of effects from 2005 up to 2020. After 2020 transport cost and location impacts were forecast to remain constant, while the 2020 GDP per worker figures are assumed to continue growth at 1.95% per year. Future year benefits are discounted at standard Cost Benefit Analysis (COBA) rates.

The employment and employment density measures are taken or derived from the SWYSM outputs. Values of GDP per worker were supplied by DfT, derived for the purpose of assessing wider economic benefits based on published GDP and earnings data from ONS' Regional Trends and Annual Survey of Hours and Earnings. Input values for use in this calculation were forecast taking account of an assumed rate of economic growth (1.95% per year) **exclusive** of growth arising from agglomeration effects in the Reference Case (to avoid double counting). The elasticity values were also provided by DfT.

Disaggregation by agglomeration impacts by sector, although clearly desirable and technically feasible, was not adopted for the standard WEB analysis due to issues of data availability and the time required for more detailed analysis. To assess the benefits of disaggregate analysis when disaggregate data became available a single test, test IF, was chosen for full disaggregate analysis. Disaggregation affects both the agglomeration and the move-to-more-productive-jobs effects.

As discussed above, WB3, **Increased output in imperfectly competitive markets**, is calculated from the savings to business travel and the suggested uprate factor of 10%.

The calculation of GP1, the increase in GDP due to **more people working** is fairly straight forward, the annual change in the zone to zone commuting costs and the commuting matrices are directly available from the LUTI model. One note is the slight change in formulation between the above approach and that reported by the Department (DfT, 2005) which was made in consultation with DfT, the cost changes are assessed with regard to average wages but the GDP impact is based on the contribution of a marginal worker, entering or leaving the labour market, with a GDP of 0.69 of the relevant average GDP per worker.

This benefit is again calculated for 2020 and extrapolated to future years taking into account government advice on changing values of time. Benefits in the period 2006-2020 are linearly interpolated from 80% of the 2020 impact in 2006. This differs from the profile for the move to more productive jobs and agglomeration effects and was chosen to more closely match the observed profile of commuter response.

Data on wages (by sector), earnings in proportion to GVA (area specific), and the data on GVA to GDP relations (sector specific) were supplied by DfT. GDP of marginal worker was specified as 0.69 of the GDP of an average worker. The labour supply elasticity was set as a single value of 0.1 (with no disaggregation by sector or area).

The generalized costs used in this calculation were the zone to zone commuting costs from SWYSM, averaged over modes. These generalised costs were calculated separately for manual and for non-manual workers within SWYSM. The changes in generalised costs were calculated from the separate results for these two socio-economic groups and then averaged.

GP3, the GDP effect of **moving jobs to more productive locations,** is calculated for the final modelled year (2020). Values for other years have been interpolated assuming linear growth of effects from the introduction of the intervention (in 2005) up to 2020. After 2020 the transport costs and location impacts were assumed to remain constant, while 2020 GDP per worker figures are assumed to continue growing at 2% per year.

No disaggregation by industry sector was done due to the unavailability of data on industry specific productivity per worker indices and GDPs.

4 TESTS: RESULTS AND TRENDS

A wide range of transport interventions were tested, examining:

- infrastructure based interventions;
- public transport fares and frequency changes;
- behavioural change measures;
- price based highway demand management;
- tests of packages (excluding and then including price-based demand management).

The design for the tests concentrated on improving conditions for the key economic drivers. Some of the later tests were combinations of earlier tests, to investigate any synergy effects. In addition supplementary analyses were carried out to:

- investigate the impacts of applying alternative functional forms of the Wider Economic Benefits calculation; and
- provide a detailed analysis of the drivers of Wider Economic Benefits, in terms of the importance of the impacts of different inputs (e.g. changing land-use patterns and changes to the time and money cost of transport).

We believe that this wide range of tests and the substantial exploratory investigations undertaken, regarding the influence of various inputs and assumptions, enables this work to promote a wider appreciation of some of the potential impacts, which different sorts of transport intervention might have. It shows how differential outcomes relate to both the differing transport impacts of the various interventions but also to the important contribution of underlying area characteristics.

4.1 The Testing Programme

The focus of the testing programme was on the effectiveness of various transport interventions for generating the previously outlined Wider Economic Benefits. Although the tests were purely illustrative it was considered important that the tests were realistic in nature and capable of being implemented in the real world. In particular, cost estimation needed to be feasible and outturn costs not prohibitively high. It was considered desirable that, at the outset, the tests should appear to have a good prospect of achieving good value for money and contribute to economic growth.

It was considered important that road user charging was the testing programme, although the costs of implementing intervention are subject to considerable uncertainty. Two different forms of road user charging were explored, namely, cordon and distance based. The latter was subject to a range of tests targeted at maximising TEE (Transport Economic Efficiency) benefits, culminating in application of a comprehensive procedure that imposed road user charges at the level of marginal social cost imposed. In the later stages of the testing programme considerable emphasis was placed upon combinations of existing tests. The main purpose of this was to investigate the extent to which combining policies produced a result that was more than the sum of the parts. A short description of each test is provided in TABLE 1**.**

TABLE 1 Testing Program

	Test code	Test description	Comments
Infrastructure Based Interventions	*HP*	Leeds to Sheffield Highway Improvements	Widening of selected sections of the M1, M621 and local road connections from Sheffield to the M1
	HQ	Leeds Urban Area Highway Improvements	Widening of the M621 and increase in highway capacity in the Leeds Urban Area
	HV	Leeds to Bradford Improved Highway Connections	Widening of selected sections of the M621, M62 and M606 and local road connections in Leeds and Bradford
	HR	Leeds Urban Area Major Public Transport Investment	Quality Bus Corridors, improved reliability, enhanced vehicles and stops, 30% bus fare reduction, 20% bus frequency increase
	HW	Leeds to Bradford Public Transport Improvements	Reduction of rail fares and increase in train speed and bus fare and frequency improvements between Leeds and Bradford
Public transport fares and frequency changes	*HU*	Intra Leeds Bus Improvements	Intra Leeds Bus Fare Reduction (30%) and Frequency Increase (20%)
	IF	West Yorkshire Bus Improvements	West Yorkshire County Bus Fares Reduction (30%) and Frequency Increase (20%)
	IH	South Yorkshire Bus Improvements	South Yorkshire County Bus Fares Reduction (30%) and Frequency Increase (20%)
	IJ	South and West Yorkshire Bus Improvements	South and West Yorkshire County Bus Fares Reduction (60%) and Frequency Increase (20%)
Behavioral change measures	*IL*	Smarter Choices in Urban Areas	Soft measures such as travel planning and better information provision for public transport, (represented in the model as a reduction of 30% in the weighting attached to time spent waiting for buses, a reduction in perceived bus journey times of 7 minutes and a reduction in perceived walk times of 6 minutes)
Price based highway demand management	*HX*	Cordon Charges, Towns and Cities in the FMA	Implementing the cordon charges derived in the course of the Road Pricing Feasibility Study (RPFS) work carried out using SWYSM
	IT	Distance Based Charging, 1st Iteration, FMA	Marginal External Cost (MEC) pricing, banded charging, max charge capped at 80p/km
	IY	Distance Based Charging, 2nd Iteration, FMA	Marginal External Cost pricing, banded charging, max charge capped at 80p/km
	IZ	Distance Based Charging, 3rd Iteration	Marginal External Cost pricing, banded charging, max charge capped at 80p/km
None pricing packages	*IB*	HP+HU	Leeds to Sheffield Highway Improvements + Leeds Urban Area Bus Fares and Frequency Enhancements
	IG	HV + IF	Leeds to Bradford Highway Improvements + West Yorkshire County Bus Fare and Frequency Enhancements
	II	IH+IF+HP+HV	South and West Yorkshire County Bus Fares Reduction (30%) and Frequency Increase (20%),

			Leeds to Sheffield and Leeds to Bradford Highway Improvements
Price based packages	*IW*	IJ + IT	South and West Yorkshire County Bus Fares Reduction (60%) and Frequency Increase (20%) + MEC Road User Charging, banded and capped, in the FMA
	IX	HV + IT	Leeds to Bradford Highway Improvements + MEC Road User Charging, banded and capped, in the FMA

4.2 Test Results

4.01 The summary of results is presented in

TABLE 2 in terms of the GDP impacts and in TABLE 3 in terms the Welfare impacts for the nineteen tests. Figure 2 illustrates the GDP/£ spent and benefit to cost ratios (BCR) for all schemes apart from those with highly uncertain costs. Full analysis is beyond the scope of this paper (it can be found in ETSR, 2006) but some summary findings are outlined below.

- Transport interventions in conurbations and major cities are able to make significant contributions to welfare and the economy, returning benefit to cost ratios generally in excess of 2.5.
- Schemes involving investment in transport provision that reduce the generalised cost for travellers, generally experience an increase of around 30% in welfare benefits as a result of the inclusion of Wider Economic Benefits.
- Because they are based substantially upon changes in the generalised cost of travel, wider economic benefits can be felt across an extensive geographical area.

TABLE 2 Wider Economic Benefits summary table: GDP impacts (mln 2002 UK £)

			of which				
		Total GDP (sum GP1-GP6)	Business user benefits (GP6)	Agglomeration (WB1, GP4)	Imperfect competition (WB3, GP5)	Labour market (GP1+GP3)	**Road pricing revenues total**
Infrastructure Based Interventions	*HP*	**1028**	762	287	76	-97	
	HQ	**3187**	1660	1030	166	331	
	HV	**1375**	724	369	72	210	
	HR	**4478**	2858	884	286	451	
	HW	**306**	158	104	16	29	
Public transport fares and frequency changes	*HU*	**678**	344	198	34	102	
	IF	**2219**	1231	518	123	347	
	IH	**993**	859	93	86	-45	

	IJ	**5327**	3407	1063	341	516	
Behavioral change measures	*IL*	**5902**	3577	1222	358	746	
Price based highway demand management	*HX*	**-1207**	519	-4589	52	-126	**12925**
	IT	**5888**	-1465	-14467	-146	-155	**75558**
	IY	**6852**	-4306	-18258	-431	56	**100192**
	IZ	**7691**	-5893	-19337	-589	357	**111042**
None pricing packages	*IB*	**1697**	1099	482	110	6	
	IG	**3686**	1985	912	199	590	
	II	**5572**	3585	1213	359	415	
Price based packages	*IW*	**10475**	1979	-14162	198	233	**74573**
	IX	**6597**	-1053	-14461	-105	-159	**76515**

TABLE 3 Wider Economic Benefits summary table: Welfare impacts (mln 2002 UK £)

			of which				
		Total welfare	Total conventional	Total additional	Agglomeration (WB1, GP4)	Imperfect competition (WB3, GP5)	Labour market (WB4)
Infrastructure Based Interventions	*HP*	**1548**	1213	335	287	76	-28
	HQ	**4626**	3319	1307	1030	166	112
	HV	**1750**	1243	507	369	72	65
	HR	**9734**	8396	1338	884	286	168
	HW	**707**	577	130	104	16	10
Public transport fares and frequency changes	*HU*	**1765**	1495	270	198	34	38
	IF	**5864**	5093	771	518	123	130
	IH	**3546**	3370	176	93	86	-3
	IJ	**15011**	13389	1622	1063	341	218
Behavioral change measures	*IL*	**15387**	13503	1884	1222	358	305

Price based highway demand management	*HX*	**-7924**	-3338	-4586	-4589	52	-49
	IT	**-39677**	-24973	-14703	-14467	-146	-90
	IY	**-56319**	-37579	-18740	-18258	-431	-52
	IZ	**-63722**	-43823	-19899	-19337	-589	27
None pricing packages	*IB*	**3181**	2578	603	482	110	11
	IG	**7587**	6268	1319	912	199	208
	II	**12500**	10763	1737	1213	359	164
Price based packages	*IW*	**-24678**	-10787	-13891	-14162	198	73
	IX	**-39090**	-24431	-14660	-14461	-105	-93

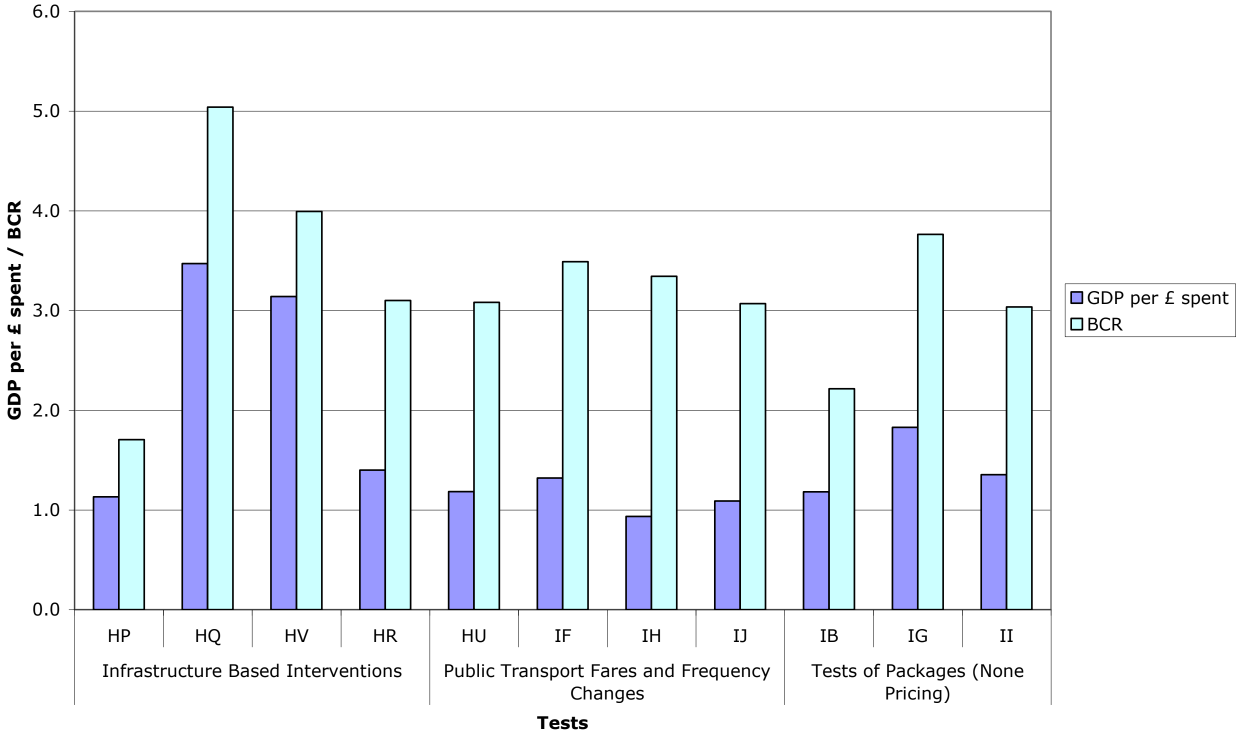

Figure 2. GDP per £ spent and benefit to cost ratios (BCR)

- The wider economic benefits of similar transport interventions can be significantly different between areas. For example, the study found considerable differences in the impacts of bus fares and frequency enhancements between West Yorkshire and South Yorkshire. This is partly due to their different levels of agglomeration, but partly to the GP3 (move to more productive jobs) calculation, which assumes fixed spatial productivity differentials.

- Of the wider economic benefits introduced above, benefit WB1, agglomeration economies, was the single largest benefit (or disbenefit) in all but one of the tests considered. In many cases the agglomeration effect is much larger than any of the other wider economic effects. This predominance may well be an inherent characteristic of the wider economic benefits defined.
- In the tests we have carried out, the effect of more people working tends to be the second largest absolute benefit (or disbenefit), and either the move to more productive jobs or increased output effects tend to be the least significant in absolute terms. These patterns are however more likely to be a reflection of the transport interventions we have tested; there is no evidence of any systematic ranking of the non-agglomeration effects.
- Tests of Road Pricing have indicated that it can provide significant benefits to the economy, but that design is crucial:
    - a badly designed road pricing scheme can damage the economy through negative Wider Economic Benefits;
    - road user charges must be targeted on congestion and be appropriate for the roads being priced (noting that it may not always be practical to implement schemes with a wide variety of charges).
    - analysis of WEBs must be included in any appraisal of road pricing, as it is possible with sub-optimal schemes to achieve positive Net Present Values using conventional welfare appraisal in isolation, where in many instances these would be largely or wholly negated once WEBs (particularly agglomeration) are allowed for.
- In general the modelling system indicated that the impacts of adding packages of measures together produces results that are the sum of the benefits of the same measures tested in isolation. Synergy is defined as occurring where the individual tests impact in the same direction (eg reduced car traffic); and the effect in the package is greater than that for the additive tests effects.
- The cost estimates used in calculating the net benefits or benefit: cost ratios of the interventions considered are subject to substantial uncertainty, though we have drawn on available evidence to estimate costs where possible. This is an inherent problem for any project which attempts to assess infrastructure and new technology proposals without undertaking detailed design (and, indeed, for many projects that do involve detailed design).

In considering the implications of our results, it must be kept in mind that we have not carried out a full appraisal of the interventions tested. No conclusions can be drawn from this report about the overall appropriateness or value of any particular intervention for implementation. Some of the interventions could, through the physical works necessary to implement them, have major adverse impacts on the environment. Particular examples of this are the urban highway capacity increases in tests HQ and HW, and the introduction of bus lanes as an addition to existing highway capacity in test HR. In all of these, townscape impacts would be a particular issue.

The road user charging schemes IT, IY and IZ could have adverse environmental impacts through increased use of roads that are environmentally sensitive and currently lightly trafficked, which could offset the more general environmental benefits of such proposals resulting from reduced traffic volumes.

Similarly, some interventions could have major benefits which have not been quantified in this exercise. For example, the enhanced access to work, health, educational and social opportunities, and hence social inclusion benefits, could be particularly strong for the tests involving bus fare decreases and frequency increases.

The present project has first of all confirmed that it is feasible to calculate wider economic impacts, using the methodology proposed by the Department, for a considerable variety of transport interventions singly and in combination. It has also in passing demonstrated the value of having major land-use/transport models available for application at short notice.

The analysis has not been carried out at as great level of detail as might have been desired. This was partly because of difficulties in obtaining some of the input values (eg GDP/worker) at the ideal levels of disaggregation, but partly because of practical limitations on the calculations that could be implemented in the time available. The latter meant, for example, that we have interpolated economic impacts for intermediate years even though we have land-use and transport model outputs from which we could in principle have calculated them directly.

The results have highlighted the importance of a number of modelling issues, notably the treatment of adjoining regions around the one being studied, in terms of displacement effects and of generalised cost changes (resulting from the displacement of congestion), and the treatment of the expenditure of the revenues from road user charging schemes (and from other transport tolls or taxes).

The major practical problem in the implementation of the enhanced appraisal process has been in the estimation of capital and operating costs. This is a general problem in transport policy formulation as well as in scheme appraisal; it is unaffected by the extension of appraisal methodology to include and quantify wider benefits. The emphasis placed by the Department on the use of costs that are robust has made it impossible for us to test strategies based on investment in inter-urban railways.

The scale of the wider economic impacts relative to the conventional benefit measures seems to be broadly as expected by the Department. The agglomeration benefits are generally the largest contribution to the new measures, followed by the benefits from more people working and from moves to more productive jobs. For the distance based charging schemes, the impact of the move to more productive jobs benefits are higher than the impacts of the more people working benefits.

5 CONCLUSIONS

The present project has first of all confirmed that it is feasible to calculate wider economic impacts, using the methodology proposed by the UK Department for Transport, for a considerable variety of transport interventions singly and in combination.

We also strongly agree with the underlying view in the new guidance that transport has wider economic effects than have hitherto been considered; the results we have obtained indicate that analysis of these effects can have a major impact on the appraisal of transport strategies.

The ubiquity and magnitude of the impact in the tests we assessed shows there is a very real need to understand better the mechanisms through which the wider impacts actually come about, (especially agglomeration impacts) and to review the assumptions underlying some of the present assessment (such as in moves to more productive jobs, where the present guidance ignores the potential impact of regional economic policies).

It has been argued that these effects could and should be brought fully within the scope of the land-use/transport models themselves such that their consequences feedback into the modelling of future year results. This would not affect the treatment of wider economic benefits in appraisal, but would mean that any other consequences (eg through more-people-in-work leading to more commuting, or higher GDP to increased housing demand and higher car ownership) would then be considered within the modelling process. The impact on forecasts and appraisal results would probably be slight, but such an approach would have the advantage of showing that the recognized problems of economic growth were being fully taken into account.

We have made extensive use of the DfT methodology as published. In doing so we have identified a number of areas of concern which we believe should be considered further in any assessment of agglomeration effects. Our key points are that

- much of the underlying research is based on single-establishment firms whose performance relates to a single location – whilst this is convenient for the purposes of analysis, it seems risky, at least, to assume that the same relationships between locational characteristics and productivity apply for multi-location firms (which represent a large part of the total economy);
- the DfT methodology is based upon a single measure of employment density – an approach which had separate elements relating to agglomeration effects in the labour market (using for example a density of labour supply) would be more convincing;
- the DfT methodology tends to generate agglomeration effects at a wide, regional scale, whereas our reading of the literature suggests that some of the effects are likely to operate at finer scales reflecting (in particular) average travel-to-work distances;
- there is a need for further consideration of the distributional aspect of some of these benefits - particularly the degree to which the wider benefits would flow from concentrating jobs in more prosperous areas at the expense of areas which already have substantial economic problems.

With all that in mind we believe the results and methodologies reported here are a major contribution to improved understanding and forecasting of the welfare and economic effects of transport intervention.

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REFERENCES

Gabaix X. Zipf's Law and the Growth of Cities. *American Economic Review: Papers and Proceedings*, Vol 89(2), 129–132, 1999a.

Gabaix X. Zipf's Law for Cities: An Explanation. *Quarterly Journal of Economics*, Vol. 114(3), 739–767, 1999b.

Glaeser E.L. Are Cities Dying. *Journal of Economic Perspectives* **12**(2), 139–160, 1998.

Glaeser E., Kallal, H.D., Schinkmann, J.A., Shleifer, A. Growth in Cities. *Journal of Political Economy* Vol. 100, 1126–1152, 1992.

DfT. *Transport, Wider Economic Benefits and Impacts on GDP*. Department for Transport. http://www.dft.gov.uk/stellent/groups/dft_econappr/documents/divisionhomepage/038896.hcsp, 2005.

Doring, T. and Schnellenbach, J. What Do We Know about Geographical Knowledge Spillovers and Regional Growth?: A Survey of the Literature. *Regional Studies*, Vol 40, 2006, pp. 375-395.

Ellison G. and Glaeser E.L. Geographic Concentration in US Manufacturing Industries: A Dartboard Approach. *Journal of Political Economy* 105: 889–927, 1997.

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

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

Graham D.J. Industrial Specialisation and Agglomeration in Britain. Working Paper, Centre for Transport Studies, Imperial College London. UK, 2004.

Graham D.J. *Wider Economic Benefits of Transport Improvements: Link between Agglomeration and Productivity*: Stage 1 report, UK Department for Transport, 2005.

Marshall A. *Principles of Economics*. Macmillan, London, 1920.

McCann, P. *Urban and Regional Economics*. Oxford University Press, Oxford, 2001.

McCann P. and Shefer, D. Location, Agglomeration and Infrastructure. *Papers in Regional Science: Golden Anniversary Issue,* Vol 83(1), 177–196, 2004.

McCann P. and Shefer, D. Agglomeration, Economic Geography and Regional Growth, *Papers in Regional Science,* **84**(3), 301-309, 2005.

Nera. *Estimated regional wage relativities for England*. A Report for the South East Area Cost Adjustment Group&Association of London Government, 2002. http://www.southeast-ra.gov.uk/our_work/advocacy/lobbying/nera_report.pdf

Simmonds, D.C. and Skinner, A. The South and West Yorkshire Strategic Land-Use/Transportation Model. In Applied GIS and Spatial Analysis, Clarke G. and Stillwell J. (eds), Wiley, Chichester, 2003, pp. 195-214.

Weber, A. *Über den Standort der Industrien.* Trans. by C.J. Friedrich (1929), *Alfred Weber's Theory of the Location of Industries*. University of Chicago Press, Chicago, 1909.