DISTILLATE

Improved Indicators for Sustainable Transport and Planning

Deliverable C2

Measuring wider economic benefits of transport

A case study in good practice for indicator selection

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Executive Summary

Previous research within DISTILLATE identified difficulties in monitoring the impacts of transport on important areas including the economy, health and the street environment. These are policy areas where the impact of transport interventions on changes in the outcomes are less easy to establish than, say, traffic flow levels and congestion. In addition, central government is being requested to specify fewer indicators to local authorities and to allow greater local autonomy in deciding what to measure. A key question is therefore how should local authorities approach the task of identify indicators that are both meaningful and operationally feasible once a monitoring need is identified?

A methodology has been established to evaluate whether new indicators are suitable for adoption against six key areas:

i. Clearly defined?
ii. Controllable?
iii. Measurable?
iv. Responsive?
v. Easy to understand?
vi. Cost

This deliverable reports on the application of this methodology to new indicators that might be applied to capture the impacts of transport on productivity and competitiveness which, in recent years, have moved further up the policy agenda with the production of the Eddington Report (2006) and the notion that transport interventions have a major role in shaping the evolution of our cities and their productivity and competitiveness.

The evaluation shows the value of understanding the relationships between the intermediate transport outcomes that can be measured (e.g. generalised cost) and the end outcomes that these are expected to influence (e.g. productivity). In this instance the evidence base for the relationship between transport and productivity is still comparatively new and what is available suggests that most local transport initiatives will have very limited impact on productivity. Further understanding will

need to be developed, probably through major scheme development examples, before the added value of monitoring any related indicators could be assured.

Productivity and competitiveness are just two examples of areas in which new indicators might be developed. We see wider possibilities for the application of the methods described in this report and we would encourage their application in generating a cost-effective and credible monitoring programme.

Whilst there appears little value in a local authority leading in productivity measurement, more generally there will always be risks and costs involved in the adoption of new indicators. There appears to be a strong case for central government pilots of indicators which appear to have promise so that the circumstances for their effective adoption can be identified.

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1 Purpose of this report

The DISTILLATE project is seeking to develop, through a focused, inter-disciplinary research programme, ways of overcoming the barriers to the effective development and delivery of sustainable urban transport and land use strategies and, through them, enhanced quality of life. Two surveys of local authorities have identified indicators to be a problem area in developing and delivering effective strategies. The “specification of core, statutory multi-sector indicators/targets for transport that can be adopted in all sectors at the local level in their policy and operational decisions” was highlighted as a key need to permit the development of more integrated strategies.

Research within DISTILLATE is identifying approaches to support more transparent and robust means of selecting indicators for use in decision-support (Marsden et al., 2007). Other work is focusing on the application of indicators to support decision-making frameworks and on understanding barriers to cross-sectoral or multi-level working that interact with indicators. This report focuses on the identification and selection of indicators that have hitherto been problematic.

In 2004 DISTILLATE surveyed its 16 local and regional partners and asked them to rate the importance and satisfaction with a range of indicators and the results are shown in Figure 1. Most of the indicators in the top right of the diagram have a substantial history and knowledgebase surrounding their measurement. This is not to suggest that there are no problems with their measurement but that these problems appear comparatively small to local authorities engaged with their use.

By contrast, indicators such as economy, street environment and health seem more problematic. These are indicators which would appear most directly applicable to the facilitation of cross-sector working and, as such, may represent a barrier to more integrated planning.

Figure 1: Importance and satisfaction with indicators (2004)

The importance of transport to economic development and growth has long been recognised. Indeed, the SACTRA report of 1999 focused on Transport and the Economy (SACTRA, 1999). In recent years this has further moved up the policy agenda with the production of the Eddington Report (2006) and the notion that transport interventions have a major role in shaping the evolution of our cities and their productivity and competitiveness. This may go above and beyond the current understood time savings benefits from congestion reduction. This suggests that local authorities look to monitor the impacts of their policies on the economy. But what would they measure, how frequently and how?

The initial work on indicators within DISTILLATE summarised the guidance on the selection of effective indicators. This work is reviewed briefly below to confirm the framework against which any proposed new indicators might be evaluated (Section 2). There then follows a description of the current state of art of knowledge about the links between transport, productivity and competitiveness (Section 3). This is used to identify those measurable factors which seem most relevant to capturing productivity and/or competitiveness impacts. Section 4 of the report evaluates the proposed indicators using the framework for indicator evaluation before the report concludes with recommendations about the extent to which local authorities should monitor these links as part of their Local Transport Plans and broader city or regional visions (Section 5).

2 Criteria for a good indicator

The early indicator review work found that "Indicators can be used for a variety of purposes from communicating with stakeholders (reporting), through benchmarking (reporting and comparing) to performance management (reporting, comparing and taking action). The application to which the indicator is put has a strong influence on the properties that the indicator must have with, in general, those that are used to influence management actions and financial rewards requiring more rigorous data collection processes, standards and frequency of reporting." (Marsden et al., 2005).

Irrespective of their end application there are six criteria which should apply to all indicators (*Ibid*., p 29):

i. Clearly defined - Where an indicator is not clearly defined it is rejected.
ii. Controllable - Where the impacts of transport policy interventions are likely to be dwarfed by changes to an indicator that result from extraneous influences, it should be rejected
iii. Measurable – Where an indicator is not measurable, including by a suitable proxy measure, it should be rejected.
iv. Responsive – If an indicator is unlikely to respond in the short-term to policy changes then this should be noted although, by itself, this is not grounds to reject an indicator.
v. Easy to understand – The indicator should be examined to ensure that it is presenting simple information. High degrees of aggregation of information can reduce the comprehensibility of an indicator and increase the risk of double counting of 'hidden' elements of that indicator.
vi. Cost effective – The benefits of collecting the data are sufficiently high to justify the cost of collection relative to alternative solutions.

Where indicators are selected which do not fulfil these criteria then they risk being misinterpreted and lacking credibility. Given the constraints on monitoring resources it is not wise to promote the adoption of indicators which do not meet these key criteria.

In order to conduct an evaluation on what to measure to capture productivity and competitiveness gains this report reviews the state-of-art appraisal guidance for capturing such ‘wider economic benefits’ and this is reported in Section 3.

3 Productivity, Competitiveness and Transport

The following sections of the report review the latest evidence on the impacts of transport on competitiveness and productivity. The research focused on these notions of economic progress as an initial research scan was unable to identify a strong or coherent literature on the relationships between transport and other aspects of economic performance such as retail strength or tourism. Much of the work on competitiveness and productivity is based around recently published Department for Transport guidance of how to appraise the wider economic benefits of transport interventions. The section identifies those parameters that appear most suitable for potential use as indicators to monitor changes in competitiveness and productivity.

This review of productivity and competitiveness is structured as follows: In this section the terms competitiveness, productivity and agglomeration economies are defined and discussed. These terms are central to DfT (2006) guidelines and to Graham’s (2005 and 2006) reports. Furthermore, a brief overview of the literature takes place, on how transport infrastructure, population concentration and business location affect productivity. The next sub-section examines Graham’s (2005 and 2006) approach and the effective density measures that are used for the calculation of agglomeration effects on productivity by him and DfT (2006). A sub-section follows on the DfT (2006) guidelines for calculating the wider economic benefits of transport and its impacts on GDP. Moreover, some issues with the DfT guidelines are identified and discussed. The concluding section attempts to evaluate some of the indicators for the wider economic benefits of transport, against the five criteria set out in Section 2.

3.1 Introduction to Productivity and Competitiveness

The wider economic effect of transportation is an important policy issue, to which attention has been given, especially since the SACTRA Report (DETR, 1999) recommendations. These follow the spirit of the spatial considerations in the economy, introduced by Krugman and commonly termed as “The New Economic Geography” (e.g. Krugman, 1991).

The Department for Transport (DfT) attempted to operationalise the calculation of wider economic effects of transport, in order to be used in appraisal. This undertaking is based mainly on two sets of studies, commissioned by DfT; namely Venables et al (1999) and Graham (2005 and 2006). The results and methodology of these studies and others were incorporated into one document of guidelines, DfT (2006).

There may be some confusion arising from the term “wider economic impacts” of transport. In the “New Approach to Appraisal” (NATA) tables it is taken to mean regeneration (DfT, 2006). “The UK Government takes the view that the economic impacts in a regeneration area are more valuable than identical impacts occurring elsewhere. It is the purpose of the appraisal of the wider economic impacts, not to duplicate the transport economic efficiency appraisals, but to assess this additional value of impacts which accrue in regeneration areas” (TAG, 2003c, Unit 2.8). It is obvious that these are important distributional effects and TAG Unit 3.5.8 provides guidelines for their inclusion in transport appraisal. Thus, the subject of “regeneration” is mostly covered with the DfT recommendations and furthermore is not an issue that will affect productivity directly.

The wider economic effects that this report is concerned with are the “external” benefits from transport improvements. These externalities come about due to market imperfections and “agglomeration economies” that will be defined below. These effects are examined in DfT (2006) and will be discussed later in detail.

3.1.1 Definitions

Before we proceed to examine any effects of transport on productivity and competitiveness, these two economic concepts must be defined first. This is because their meaning and significance very often raise confusion, creating misunderstandings. The economic definitions of the terms are given by Black (2002) as:

Competitiveness: *The ability to compete in markets for goods or services.* This is based on a combination of price and quality. With equal quality and an established reputation, suppliers are competitive only if their prices are as low as those of rivals.

Productivity: *The amount of output per unit of input achieved by a firm, industry, or country*. This may be per unit of a particular factor of production, for example labour employed, or 'total factor productivity' may be measured, which involves aggregating the different types of production factors. Productivity per worker can be increased by longer hours, more effort, or improved skills on the part of the labour force, or by more capital equipment, improved technology, or better management. Productivity is also affected by the level of output, if returns to scale are not constant[*].

The confusion associated with these widely used terms is underlined by Porter and Van der Linde (1995). They state that even though at the industry level the meaning of competitiveness is relatively clear, at the level of a state or nation the notion of competitiveness is less clear, because no nation or state is or can be competitive in everything. They suggest that the proper definition of competitiveness at the aggregate level is the average productivity of industry or the value created per unit of labour and per dollar of capital invested. Productivity depends on both the quality and features of products (which determine their value) and the efficiency with which they are produced.

[*] Returns to Scale:" *The relation between a proportional change in inputs to a productive process and the resulting proportional change in output*. If an *n* per cent rise in all inputs produces an *n* per cent increase in output, there are constant returns to scale. If output rises by a larger percentage than inputs, there are increasing returns to scale. If output rises by a smaller percentage than inputs, there are decreasing returns to scale" (Black, 2002).

From the above it can be gathered that competitiveness is a “vague” term for our purpose and is closely related to, and defined by productivity. Therefore, this text will focus on productivity and will not be further concerned with competitiveness directly.

The concept of productivity is a widely discussed subject by politicians, economists, managers and media, but as demonstrated by Tangen (2002) the understanding of this concept is quite poor and often is confused with terms such as profitability, performance, efficiency and effectiveness. In this text, the purely economic definition above is adopted.

In quantifying productivity, the most common aggregate output measures used are Gross Value Added (GVA) and Gross Domestic Product (GDP). ONS (2006) provides the official definition for these terms. Namely, GDP is defined as the total value of all goods and services produced within a country (or area). GVA measures the contribution to the economy of each individual producer, industry or sector and can be calculated as the sum of the factor incomes generated by the production process. The link between GVA and GDP in current prices is:

GVA at basic prices + Taxes on products - Subsidies on products = GDP at market prices

3.1.2 Definitions for Agglomeration Economies

Looking at the productivity definition above, the reference to “returns to scale” is most important for the relation between agglomeration economies and productivity. Agglomeration is essentially an economy (or diseconomy) of “density” (scale), which means that there are no constant returns to scale. A general definition of agglomeration economies is given by Black (2002) as:

The external economies available to individuals or firms in large concentrations of population and economic activity.

These arise because larger markets allow wider choice and a greater range of specialist services. Agglomeration economies are believed to explain the tendency of conurbations to contain an increasing share of the population of many countries. Beyond some point further agglomeration gives rise to diseconomies due to congestion and pollution.

From this definition of agglomeration economies, we can distinguish the importance of transport in large concentrations of population, with congestion being a reason for "agglomeration diseconomies" arising. It seems that "agglomeration economies" is one of the links in the "transport-productivity" relationship. Thus, Graham (2005) and DfT (2006) examine this relationship into two parts:

- The effect of agglomeration on productivity, for different areas and sectors
- The link between changes in transport services and agglomeration.

The definition of agglomeration economies above is not enough for the purposes of this report. Graham (2005) elaborates further and categorises under three headings the externalities generated through agglomeration:

i. *Internal scale economies* describe efficiency gains that occur as the overall scale of production is increased. They are related to the size of the individual firm and emanate from sources such as specialisation in the division of labour, cost reduction of inputs through bulk acquisition, and the more efficient use of specialised machinery. Increasing returns can also arise due to the existence of indivisibilities in factor inputs which require a minimum efficient scale of operation. With respect to agglomeration, the crucial assumption regarding internal scale economies is that they are internal at the plant level and therefore imply production at a single location rather than being spread across a number of locations. This is an explicitly spatial form of internal economies of scale which leads to the concentration of investment and factor inputs in space.

ii. *Localisation economies* describe efficiency gains generated through the increased scale of a particular industry operating in close spatial proximity. Benefits are thought to be generated in three ways; first, geographical proximity increases ease of communication facilitating 'technological spillovers' between firms within the same industry. Second, the formation of industrial agglomerations can induce efficient provision of intermediate inputs to firms in greater variety and at lower cost due to the growth of subsidiary trades. Third, firms can share larger markets for inputs and outputs and in particular they can share a local skilled labour pool. Localisation economies are intra-industry; they are external to firms but internal to the industry.

iii. *Urbanisation economies* describe the productive advantages that accrue to firms through location in large population centres such as cities. Firms derive benefits from the scale of markets, from the proximity of market areas for inputs and outputs, and from good infrastructure and public service provision. These spatial external economies are cross-industry; they are external to the firm and the industry but internal to cities. The sources of urbanisation economies have tended to be less well defined.

3.1.3 A Brief Literature Review of Agglomeration Effects on Productivity

There is an extensive literature on the effects of urbanisation and localisation economies on productivity. Baird (2005) for example draws on more than 40 mainly US studies, with a particular focus in transport infrastructure (highways). The methodology is also discussed, with the "production function[†]" approach being the earlier and most commonly used method (Cobb Douglas form and translog transformation). Aggregate cost functions were also employed in some studies, examining firms in a specific geographic area or industry. General equilibrium models that take in to account spill-over effects have been used in recent years, offering according to Baird (2005), the most promise in studying the impacts of transport infrastructure on the economy.

Baird (2005) concludes that highways and other public infrastructure types have a small marginal productivity, if any. It is also suggested that early studies that revealed high productivities had econometric problems, and more recent studies using more sophisticated methods offer ambiguous results. It is also pointed out that general equilibrium and other spatial models provide growing evidence that negative

[†] A function showing the maximum output possible with any given set of inputs, assuming these are used efficiently.

spill-over effects of highway investment create a “zero-sum” productivity picture. In other words, if highway investment is locally productive, the economic gains come at the expense of other localities in the region.

Graham’s (2005) review of 17 estimates for agglomeration economies does not completely agree with Baird’s (2005) conclusions. The estimates of elasticities for urbanisation economies range from 0.01 to 0.20, but the majority of values are under 0.10. This indicates that a doubling of city size is typically associated with an increase in productivity of somewhere between 1% and 10%. The findings of Rice et al (2006) agree with the above, with an estimate of urbanisation economies of 0.053, which means the doubling of a city size (or the economic mass of the area) increases productivity by 3.5% (=$2^{0.053}-1$). They use the term “economic mass”, which is measured on the basis of population of working age with in a series of driving time bands (30, 60, 90 and 120 min) around each area. One assumption is that the population of each area (NUTS3[‡]) is massed at the economic centre of the area, which lies entirely within a single proximity band. The alternative approach assumes that the population is evenly distributed across the area, so may be divided between several proximity bands. They estimate that bringing population from 60min driving-time away to 30 min away (from the economic mass centre) increases its impact on productivity by a factor of four. In a hypothetical case, where all driving times in GB were cut by 10%, productivity would be raised by 1.2% (Rice et al, 2006).

Laird (2007) in a study on the economic effects of commuting, suggested that a transport policy which reduced journey times (e.g. by 10%) would significantly increase commuting distance (by just over 5%), slightly increase total commuting costs (by 0.2%) and give rise to only a slight increase in wages (by 0.01%). A 0.01% increase in wages is equivalent to an extra £4 a year on a £34,000 annual salary (net of deductions), suggesting that wages are to all intents and purposes inelastic to transport policy. The effect of changes in transport costs on productivity through

[‡] [‡] The nomenclature of territorial units for statistics (NUTS) was drawn up by EUROSTAT to be a single, cohesive system of territorial groupings for the compilation of EU regional statistics. NUTS3 classification has the following thresholds of population: minimum of 150,000 and maximum of 800,000. In England there are 93 NUT3 regions.
http://ec.europa.eu/comm/eurostat/ramon/nuts/basicnuts_regions_en.html

agglomeration economies may be over 100 times greater than the impact on wages through labour supply effects.

Baranesa and Tropeanob (2003) constructed a theoretical general equilibrium paradigm for two areas, in order to examine whether technological spillovers are spatially bounded. They agree with the research above, in that a *slight* decrease in transport costs triggers spatial agglomeration and spurs innovation. However, they argue that a *dramatic* decrease in transport costs leads to tough competition including competition between regions. Such a decrease could induce knowledge sharing even though firms remain spatially dispersed. Therefore, in contrast with standard economy geography literature, a dramatic decrease in transport cost leads to both higher technical progress and firms' spatial dispersion.

In an interesting approach, Targa et al (2006) empirically tested a firm-level model that captures the relationship between the propensity to relocate from the current business location as a function of local and regional accessibility, agglomeration economies, firm-specific characteristics, business-specific activity attributes, perceptions or attitudes towards regional considerations, and factors that influenced the initial business location decision. Significant association was found between transportation supply and firm-level relocation decisions in a given area. This underscores the role of other firm and area-of-influence attributes in this process. In particular, the empirical results suggest that an increase of one mile of primary highways (within a circular buffer area of 4-mile radius) is associated with an increase of 66.2 percent in the likelihood of not relocating at all (0.32 elasticity evaluated at the mean), controlling for other firm and area-of-influence attributes. Likewise, this increase is also associated with a decrease of 18.0 percent in the likelihood of almost certainly relocating (-0.09 elasticity evaluated at the mean), ceteris paribus. However, neither of the two indices intended to proxy for two forms of agglomeration economies was statistically significant in the model specification.

The more complicated approach of partial (one industry) and general (all economic agents) equilibrium models (using simulations to test the effects) was followed by Venables et al (1999) and Venables (2004). Their analysis provides a paradigm for identifying the positive externalities of transport cost reductions. It captures the interaction between market access, supply of primary factors and supply of intermediate goods, together with the possibility that there are forward and backward linkages between firms, these encouraging the formation of clusters of economic activity. The essence of the new approach is to look at the implications of markets being less than perfectly competitive. It follows that the tools (indicators) of cost benefit analysis (CBA) that are commonly used for project appraisal may not be totally accurate, since they do not directly address such effects (e.g. in NATA). Changes in transport systems may change trade flows, and change both the scale and location of production. If production is undertaken by imperfectly competitive firms, then the real income gains from these changes may exceed those that would be calculated by typical appraisal methods.

3.2 Graham's Approach

In the literature, production functions are a common starting point for the analysis of economic productivity of public infrastructure (Baird, 2004). The most basic model postulates that national output (Y) is a function of:

$$Y = A^{*}f(K,L,G) \qquad (1)$$

where f is an unspecified function of private capital (K), labour (L), and exogenously supplied public infrastructure (G). The constant A describes total factor productivity. The measurements of output and inputs vary in each model, depending on the context. Graham's (2005) approach is based on this model form.

Graham (2005) used "Financial Analysis Made Easy" (FAME) data from 1995 to 2005, which are aggregate, averaged over time and do not contain peak and off-peak effects. FAME comprises data on the output (Y) of each firm, the total cost (C) of production, the number of employees (L), an estimate of capital assets (K), and the average wage per employee (W). The financial data are converted to constant prices by applying an annual price deflator. An annual time trend is included in the model as a sort of 'catch all' variable that captures unobserved temporal effects.

In order to calculate the agglomeration elasticities, measures of labour and population density had to be employed. The first measure that describes the concentration of labour in a given area is called effective density of employment.

Since this work is done for DfT in the UK the generic area of reference is a ward. The total effective density of employment (UD) that is accessible to any firm in industry o located in ward i is given by (Graham 2005):

$$UD_{io} = \frac{E_i}{r^{\alpha_o}} + \sum_{j}^{i \neq j} \left(\left[E_j \right] \cdot d_{ij}^{-\alpha_o} \right) \tag{2}$$

where E_i is total employment in ward i, r_i is an approximation of the radius of ward i, E_j is total employment in ward j, and d_{ij} is the distance between i and j. The value of α_o determines the effect of distance on the strength of density externalities for each industry o. If $\alpha_o > 1$ then density effects will tend to diminish rapidly with distance, if $\alpha_o < 1$ then they will be spread over a wider area. Note that the density effect that arises within the ward in which the firm is actually located (i.e. the first term on the right hand side of equation2) is measured by total ward employment divided by a proxy for average ward radius that is calculated assuming that the wards are roughly circular.

With the use of effective density measures and providing the production function with a “translog” specification, Graham (2005) calculated elasticities of productivity with respect to effective employment density. The models were estimated for 28 industry sectors; in manufacturing and service sectors there appears to be a strong link between higher productivity and the effective density of activity available to firms. For manufacturing as a whole the average elasticity of productivity with respect to effective density is 0.04 and for services it is 0.12. Particularly high estimates are found in transport services and public services. For transport providing firms (PT and freight), the higher elasticities may be indicative of the increasing returns to density which tend to affect transport operators (unit costs fall as the density of traffic increases). The coexistence of slightly decreasing returns to scale with increasing returns to density would be consistent with the cost structure of transport operators.

As mentioned above, Graham’s work was commissioned by DfT, in order to create operational guidelines, formulas and indicators to include in appraisal. For this purpose the 28 industry sectors categories were condensed to 9; elasticities of productivity with respect to agglomeration were calculated for 366 UK local authorities for each of the 9 categories (found in DfT, 2006). This is the basis for the DfT (2006) guidelines that will be examined below. It has to be stressed here that these elasticities were calculated with distance “effective density” measures, given in equation 2 (and not by the generalised cost “effective density” measures shown below).

Graham (2006) attempted to distinguish between localisation and urbanisation economies (as defined in section 3.1) and constructed two density measures at the ward level. The first measures the effective density of “own industry” employment (S) and the other measures the effective density of all other employment (R).

$$S_{io} = \frac{E_{io}}{r^{\alpha_o}} + \sum_{j}^{i \neq j} \left(\left[E_{jo} \right] \cdot d_{ij}^{-\alpha_o} \right) \tag{3}$$

$$R_{io} = \frac{E_i - E_{io}}{r^{\alpha_o}} + \sum_{j}^{i \neq j} \left(\left[E_j - E_{jo} \right] \cdot d_{ij}^{-\alpha_o} \right) \tag{4}$$

where E_i is total employment in ward i, r_i is an approximation of the radius of ward i, E_j is total employment in ward j, d_{ij} is the distance between i and j., with E_{io} being the employment of industry o in ward i and E_{jo} being the employment of industry o in ward j. Localisation externalities are captured by the effect of S on productivity while urbanisation economies are captured by the joint effect of (S + R) on productivity. The latter is similar to equation 2. Graham (2006) found that all of the positive localisation effects were identified within a 10 kilometre radius of the firm. The estimates also show that urbanisation externalities tend to be more prevalent and are also typically higher in magnitude than the localisation effects.

In order to relate further the labour density to transport, Graham (2006) used a database of ward to ward generalised costs. These costs comprise fuel and non-fuel vehicle operating costs and the value of time multiplied by the travel time. He constructed an aggregate density measure at the ward level based on generalised cost as follows:

$$UG_{io} = E_i + \sum_{j}^{i \neq j} \left(\left[E_j \right] \cdot g_{ij}^{-\alpha_o} \right) \tag{5}$$

where g_{ij} is the average generalised cost of travelling by road from ward i to ward j.

The overall pattern of results by industry is very similar, based on either distance or generalised cost "effective density elasticities". However, it is clear that generalised cost based estimates tend, pretty much consistently, to be of higher magnitude than the distance based measures. Calculating a weighted average "urbanisation elasticity" for manufacturing as a whole, where the weights are based on the proportion of manufacturing jobs in each sector, gives a value of 0.08 using the distance and 0.11 using the generalised cost density measures. Similarly, the weighted average "urbanisation elasticities" for services are 0.20 and 0.27 using distance and generalised cost estimates respectively (the weights are based on the proportion of "service" jobs in each sector).

Comparing estimates of urbanisation economies based on generalised cost to those based on distance gives some compelling evidence that urban road traffic congestion plays a significant role in 'constraining' the benefits of agglomeration, and consequently, that it may serve to reduce achievable levels of urban productivity. If, as Graham's (2006) empirical analysis suggests, congestion can give rise to diminishing returns, then the implication is that the productivity benefits of agglomeration could be increased by making appropriate transport interventions.

The question remains as to which measure – distance based or generalised cost based - provides the more useful estimates. On the one hand, since movement is not made according to Euclidean distance, and because we know that congestion diseconomies do exist, the UG (equation 5) variable probably provides a more accurate measure of the real effective density experienced by firms. However, it could also be argued that since standard transport appraisals already evaluate travel time savings, then if we wish to calculate additional agglomeration benefits that arise purely through increasing accessibility, estimates based on UD (equation 2) would be the more appropriate (Graham, 2006).

After this overview of Graham's approach we move on to see what DfT (2006) has proposed, drawing on all the above.

3.3 DfT Guidelines

The DfT (2006) report attempts to operationalise the estimation of wider economic benefits of transport. The studies of Graham (2005) and Venables et al (1999) are the cornerstones of this effort. It has to be stressed that the DfT (2006) analysis is based on aggregate economic measures; consequently it is an achievement to be able to examine transport effects on productivity down to the level of a local authority (agglomeration elasticities were calculated by Graham for 366 UK local authorities). At this level, benefits can be calculated from local transport infrastructures that change the local transport costs. However, further disaggregation (e.g. by transport mode and time of day) is very difficult and meaningless for such effects (agglomeration economies).

DfT (2006) published guidelines on estimating the following wider economic benefit (WB) instances:

- WB1: Agglomeration economies
- WB2: Increased competition as a result of better transport
- WB3: Increased output in imperfectly-competitive markets
- WB4: Economic welfare benefits arising from improved labour supply

The recommendations of DfT are briefly presented below for each of the above instances.

3.3.1 WB1: Agglomeration economies

The direct relationship between transport investment and productivity should be considered in a two-stage process. The concept of effective density is used to link transport and productivity. This includes both localisation and urbanisation economies. The effective density UG is similar to equation 5 above, namely:

$$UG_j = \sum_{k}^{k \neq j} \left([E_k] \cdot g_{jk}^{-\alpha} \right) \qquad (6)$$

where E_k is the work based employment in area k and g_{jk} is the average generalised cost of travelling by road from area k to area j. The value of parameter α determines the effect of distance on the strength of density externalities.

The wider economic benefits from agglomeration would be (equation 7): WB1 = (Elasticity of total productivity with respect to the density of employment in an area) x (Change in the effective density of employment in the area due to the project) x (GDP in the area)

Equation 7 is a linear approximation of equation 8, appropriate when agglomeration effects are calculated for each year:

$$WB1 = \sum_{o,j} \left[\left(ElP_{o.j} \cdot \frac{\Delta UG_j}{UG_j} \right) \cdot GDP_{o.j} \cdot E_{o,j} \right] \tag{7}$$

Whereas equation 8 can be used if there is a need to calculate the agglomeration effects for specific future years with a larger gap between them:

$$WB1_t = \sum_{o,j} \left[\left(\left(\frac{\Delta UG_{jt}}{UG_{js}} \right)^{ElP_{o.j}} - 1 \right) \cdot GDP_{o.j} \cdot E_{o,j} \right] \tag{8}$$

Where year s is the base year and year t is (each) future modelled year
o represents industries, j represents locations, and ElP_{oj} = Elasticity of productivity with respect to effective density on industry *o* in area j.
UG_j = Effective density of employment in area j (ΔUG_j = change due to transport project)
GDP_{oj} = GDP per worker in industry *o* and area j.
E_{oj} = Work-place based employment in industry *o* and area j.

As mentioned above, Graham (2005) has produced UK-specific evidence of the relationship between effective density and productivity by sector. These estimates provide elasticities of productivity (given in DfT, 2005a) that vary across industry sectors and Local Authorities (from 0 in many industries up to 0.3 in some sectors). DfT recommends using these elasticities to predict the impacts of increased effective densities on the productivity of separate sectors. Change in generalised cost between zones should be available for transport models used in the main scheme appraisal. Other data needed, such as GDP per worker for each zone and sub-regional GDP per worker by sector can be derived from data available from the ONS.

One major problem with the DfT guidelines here is the use of Graham's elasticities that are calculated from a "distance effective density" measure (equation 2). DfT (2006) effective density measure is based on generalised cost. Therefore in equation 8 one has to mix "generalised cost effective density" with an elasticity based on "distance effective density". As discussed above, there is a substantial difference between results produced from the two effective density measures (Graham, 2006). Hence, either the elasticities must be recalculated using "generalised cost effective density" or the DfT guidelines should use a "distance effective density" measure, as they should have done from the beginning (since they had the "distance" elasticities). It is understandable that from a policy perspective generalised cost is preferable, since it is more elastic (you cannot reduce distance in the same way as travel time) and seems to agree with policy initiatives to reduce congestion.

Clearly productivity responses are not instantaneous so the timescale over which to assess changes to productivity (dis)economies is uncertain. Both DfT (2006) and Graham (2006) imply that these effects should be taken into account in the appraisal of a new project that will affect the effective density of an area by changing the generalised costs of transport. We review in Section 4 whether there is scope to monitor the changes which arise as a result of deterioration of network conditions over time or as a result of non-major scheme LTP interventions (i.e. integrated transport block spending across a range of measures rather than individual schemes costing >£5m).

3.3.2 WB2: Increased competition as a result of better transport

On the issue of competition and transport, DfT (2006) adopts the assumption that: Even if there are barriers to entry and firms do possess market power, there are competition authorities that will limit the possibility of serious abuse of such a position.

DfT (2006) do not normally expect to find significant wider benefits owing to increased competition. However, they would consider that such effects may exist where one of the following applies:

- A scheme represents a very significant improvement to accessibility for an area;
- There is evidence of lack of competition in certain markets in the area;
- The scheme has a measurable impact on the level of competition in the area;
- The resulting wider benefit can be quantified.

3.3.3 WB3: Increased output in imperfectly-competitive markets

Transport appraisal captures benefits to firms by estimating the time savings for travel undertaken in the course of work. Firms will respond to such cost savings by reducing prices and increasing output. Where there is imperfect competition in a market, the value placed on additional unit of production (price) is normally higher than its (marginal) production cost. 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 placed on the additional production is higher than the cost of producing it. Since these second round benefits would not fall to the firms that receive the transport benefits, the value attached to time savings would underestimate the true benefits (DfT, 2006).

Conventional transport appraisal understates the transport benefits, by an “up-rate factor” (V) to the direct cost savings to firms, ie business time savings (BTS) and reliability gains (RG). This up-rate factor is (as shown in equation 10) the gap between price and marginal cost of production divided by price ((P - MC) / P), multiplied by the elasticity of demand for the imperfect market (ED). So:

$$WB3_t = (BTS_t + RG_t)^* \ V \qquad (9)$$

$$V = \frac{P - MC}{P} \times ED \qquad (10)$$

Where:

WB3 = Wider economic benefits from increased output in imperfectly-competitive transport-using industries

BTS = Business time savings

RG = Reliability gains to businesses

V = imperfect competition “up-rate factor”

ED = elasticity of demand for the imperfect market

t signifies the year

P = price

MC = marginal cost

Ideally this analysis would be done by individual sectors. However, DfT (2006) has not found robust evidence on demand elasticities at this level of disaggregation and an aggregate analysis is recommended.

If the price-marginal cost margin is large and demand is elastic, then this multiplier could be significant. If the price-marginal cost margin is small, and demand is inelastic, then the welfare benefits could be less significant. After adjusting for the inclusion of service sectors and for cost of capital, the variation in results between the 6 studies that were examined in DfT (2006) is quite low, with the margin varying from 0.2 to 0.27. DfT (2006) proposes that a best estimate of the aggregate (P-MC)/P for UK industries should be about 0.2.

The other variable needed is the Elasticity of Demand (ED) for the industry under analysis, in order to assess the size of these welfare benefits under this approach. In the DfT (2006) document we find that Newbery suggested using an ED of 0.5. Harris suggested a similar figure (Venables et al, 1999). Venables used a rather higher estimate (Venables et al, 1999). Using a “*(P-C) / P”* of 0.2 and ED of 0.5, equation 10 yields a multiplier V of 0.1. However, Davies argued that it is very hard to estimate ED robustly and there is little consensus even on aggregate demand elasticities. He therefore questioned the confidence that could be placed on an ED of 0.5 (Venables et al, 1999). However, there's a close theoretical relationship between (P-C)/P, ED and a third variable; industry concentration. Davies finds that, under certain assumptions, any two of these variables would determine the third. He therefore uses estimates of (P-MC)/P and the Herfindahl index of concentration to produce estimates of the “up-rate V”, of 0.1. He finds this estimate to be consistent with an ED of about 0.5 (Venables et al, 1999). DTI has also updated Davies' work with more recent evidence and their findings support Davies' estimates (DfT, 2006).

DfT recommends that the correct welfare gain might be one-tenth, or 10%, of the business time savings and reliability. So WB3 is 10% of (BTS+RG), and V = 0.1. There is an issue here, since the reliability is not included in NATA and DfT (2006) offers no guidelines on this issue. There is TAG Unit 3.5.7 (2003a) that offers some guidelines on calculating reliability values, but these are initial estimates and not to be used in appraisal officially.

Another issue is that the effects on imperfect markets may be more complex than the above analysis describes, particularly if one considers that per unit transport costs may vary across firms and levels of production. The analysis does not take into account dynamic effects that could be of importance in imperfectly competitive sectors. DfT (2006) however, considers this approach a reasonable approximation (basing it on Venables et al 1999), since the wide use of general equilibrium models is improbable due to their data needs.

3.3.4 WB4: Economic welfare benefits arising from improved labour supply

Decisions are based on alternative potential incomes after tax. If improved commuting generally gives people access to higher paid jobs, this would be recognised in appraisal by commuters' willingness to pay for time savings. However, as the benefits to the worker are based on post-tax income, there is an additional impact that is not captured by the individual's willingness to pay: the extra tax revenues that accrue to the exchequer from that choice. Increased taxation can be used to reduce the overall tax burden or to fund other beneficial projects that would otherwise not go ahead. The same impacts on the exchequer are associated with choices of whether to work or not and how much to work (DfT, 2006).

Commuting costs (including the cost of time and the inconvenience of overcrowding etc) are one of the effects that may limit how much, and how many, people work. Reducing costs of commuting can therefore bring wider economic benefits and these benefits can be split into three categories according to DfT (2006):

- More people choosing to work due to changes in effective wages (GP1)
- Working longer hours in current job (GP2)
- Working in more productive jobs (GP3)

DfT (2006) suggests the tax rate should be treated as 30% for effects GP2 and GP3 and 40% for GP1. The rate for GP2 and GP3 correspond to increased taxation from marginal income effects (ie existing workers being more productive and hence attracting a marginal tax) as well as increased operating surplus. The rate for GP1 relate to tax on average income effects (more people working, who attract the average tax), operating surplus and reductions in benefits. These tax rates reflect income tax, national insurance contributions and corporation tax. Below follow the recommendations on calculating GP1, GP2 and GP3.

GP1

The proposed formula for calculating the labour supply changes from a transport policy intervention in a particular year t is:

$$GP1_t = -\sum \left[\frac{\sum_j dT_{ij,t} \times C_{ij,t}}{\sum_j W_{j,t} \times C_{ij,t}} \times \sum_j GDP_{j,t} \times C_{ij,t} \right] \times El \qquad (11)$$

Where

C_{ij} = Commuters that live in area i and work in area j.

dT_{ij} = Change in generalised cost of commuting from i to j.

GDP_j = GDP per worker entering the labour market in area j.

W_j = Average wage from working in j.

El = The elasticity of labour supply to wages

The change in the labour force is given by the weighted average percentage change in effective wages due to the intervention (given by the sum of $dT_{ij,t} \times C_{ij,t}$ divided by the sum of $W_{j,t} \times C_{ij,t}$) multiplied by the elasticity of labour supply to wages (El). To estimate the GDP effect, this is then multiplied by the weighted average GDP per worker entering the labour force.

DfT (2006) have calculated an overall labour supply elasticity of 0.1 for men and 0.4 for women. Weighting these according to the national claimant count leads to an overall estimate of 0.15. It may be appropriate to vary this estimate if any of the above splits are significantly different from the national average in the study area. Data on wages are available from the Nomis database. This includes breakdowns by region, occupations etc.

DfT's transport modelling guidance recommends that the zoning system for transport models should be based on the 2001 census boundaries, with wards as the smallest building blocks. Where relevant, the data for calculating the effects therefore needs to be gathered on a ward level and aggregated to match the zoning system for the transport model. It is recognised that the analysis cannot be more detailed than that allowed by the transport modelling. In cases where the available transport data is a limitation and labour supply effects are thought to be of importance, it should be considered whether additional modelling work should be undertaken.

GP2

Time savings on commuting journeys are largely offset by longer commutes. The residual is split between labour and leisure. Labour's share in this split would be larger if the response in labour supply to a change in income was small. Furthermore, evidence typically shows that workers are not very responsive to changes in wages when choosing how much to work. This would indicate that changes in the costs of supplying labour, such as commuting costs, would have a very limited aggregate impact of how much people work and that such labour market effects will be small. In the absence of better evidence, DfT recommend assuming GP2 = 0.

GP3

The GDP effects of people working in more productive jobs can be estimated by assessing how a project can encourage relocation of jobs to where they are more productive. This will mainly apply to improved access to city centres, where productivity often is higher than for identical jobs outside. The GDP effect in year t is therefore:

$$GP3 = \sum_{A}\sum_{I} \Delta E_{AI,t} \times PI_{AI,t} \times GDP_{I,t} \qquad (12)$$

Where: ΔE_{AI} = Change in employment in area A and industry i.

PI_{AI} = Index of productivity per worker in area A and industry I, where the base is average national productivity per worker.

GDP = National average industry GDP per worker. (To avoid double counting of GDP already captured in WB1/ GP1, GDP here needs to be valued pre any agglomeration effects - ie GDP in the "do nothing" scenario.)

It is essential here that the productivity index PI_{AI} is adjusted for variables such as education, skills, age and other characteristics in order to isolate the productivity differentials caused by location. Although GDP per worker and earnings can be used to inform these differentials, it is not sufficient simply to compare average GDP per worker or wages in two areas.

This effect is related to agglomeration effects (WB1), although DfT (2006) suggest that it is an additional effect. They suggest that "WB1 will capture the growth in employment in an agglomerated area that increases the productivity of existing workers. GP3 will capture the effect that the jobs relocated to an agglomerated (and therefore high-productivity) area will be more productive than if located *elsewhere*" (DfT, 2006). However, this may not always stand. For example, in calculating WB1, if effective density increases spatially (e.g. less distance due to new road), it means that people who previously were located further away (hence in an "*elsewhere*" labour market) will be able to commute in more productive jobs, which should be captured by GP3 (DfT, 2006).

4 Evaluation

The work above suggests that competitiveness is too vague a concept at the city or regional level to operationalise in a transport monitoring strategy. Productivity impacts can be estimated using a variety of parameters that are relevant to transport. It has to be noted though, as DfT (2006) states, that "this is a developing research field, and the data requirements for perfect estimates seem to be well beyond what is available and often what is likely to be available. That points to producing the best estimates recognising that efforts on appraisal need to be proportionate". Consequently, not all indicators (WB1, WB2, WB3, and WB4) proposed by DfT (2006) are yet appropriate for appraisal use. This section begins by providing a brief summary of the indicators identified through the review, in order to select the appropriate ones that will be subjected to an evaluation against the five criteria set out in Section 2.

There is potential for the practical use of WB1 in appraisal, as will be discussed in the evaluation below. The use of WB2 is not recommended in appraisal by DfT, thus it will not be subjected to the evaluation. WB3 is essentially an up-rate factor (of 10%) on business time savings (BTS) and/or reliability gains (RG). WB3 cannot be disaggregated at a local level (or by specific industry). If either of BTS or RG are used in an appraisal the 10% up-rate factor can be used, but it is just an approximation. We therefore caution against the measurement of these indicators even if they were to be fully defined (which is not the case with reliability). WB4 (labour effects) is split into three parts: GP1, GP2 and GP3. The use GP2 is not recommended by DfT (2006). We conclude also that GP3 coincides in certain cases with WB1 and there is a danger of double counting. Only GP1 remains a potentially usable indicator in appraisal. Therefore, the following two indicators will be evaluated by the framework set out in Section 2:

- Generalised costs as an input to agglomeration economies from transport improvements (WB1)
- Generalised costs and commuting flows as an input to new entrants in the labour market (GP1, part of WB4)

4.1 Generalised cost as an input to WB1

Clearly defined?

One issue here is the error made by DfT (2006) in taking Graham's elasticities from the distance based "effective density" measure, but using generalised cost in calculating the WB1. We assume that this will be corrected before any practical use of the WB1 in appraisal.

Generalised cost is the major component for calculating WB1. This is a well defined concept combining out of pocket costs with the monetised value of travel time costs. The current advice on wider economic benefits is to use ward to ward generalised cost estimates although the time periods are not clearly specified. Wards are well defined units so this also seems feasible. Graham (2005) used daily averaged generalised costs, provided by DfT. Guidance on the calculation of generalised costs is given in DfT(2005b) and TAG (2007). The other elements (GDP, employment) are sufficiently defined. ***The indicator is clearly defined***

Controllable

External effects in GDP can be controlled for; external effects in the employment of the area may be an issue if they are significant (but then they can be identified as an error source). However, it is expected that generalised cost will produce the most significant changes in WB1. Transport policies are one of the dominant influences on zone to zone generalised costs. ***The indicator is controllable***

Measurable

All the elements of WB1 should be available from DfT and ONS, except generalised cost. Ward centroid to ward centroid generalised costs are typically estimated through transport models rather than measured. Measuring centroid to centroid journey times requires a series of journeys to follow that type of journey which is difficult to establish. There is currently no measured baseline data that is fit for purpose. The growth in satellite tracking devices may make this data easier to collect and process should it be seen as critical. ***The indicator is measurable but not currently collected***

Responsive

Very substantial changes in zone-zone generalised costs (such as those generated by major transport investment) are likely to be required to see significant productivity impacts. Annual monitoring would therefore be of little use although a less frequent approach (e.g. five yearly) might be appropriate. ***The indicator is not responsive to many smaller transport initiatives***.

Easy to understand

The element of the generalised cost in WB1 is relatively easy to work with from a technocratic perspective. It has disadvantages in being some way removed from the actual productivity impacts which could be calculated. It is also a very aggregate measure which may hide benefits to, for example, public transport improvements.

The impact of changes in generalised cost will be on a monetary measure (change in GDP) that is fairly easy to understand, to present to politicians and may be useful for communication with the public. However, understanding the whole procedure of calculating the agglomeration effects is much more difficult, especially for those without a strong background in economics. A degree of aggregation of information may also reduce comprehensibility, but the risk of double counting is very small (if GP3 is not used).

The proxy indicator is easily understandable but its relationship with changes in GDP is complex.

Cost-effective

A bespoke survey of zone-centroid to zone-centroid journey times would be prohibitively expensive given the uncertainty over the responsiveness of the indicator to most LTP interventions. The Department for Transport is making available increasing amounts of data from vehicles equipped with satellite tracking systems to local authorities. The data could be reinterpreted to approximate zone-centroid to zone-centroid journey times at relatively low cost. The use of such data should be piloted however before it can be concluded to be robust enough for tracking change over a five year period across a large area.

The data collection costs are currently prohibitive although new satellite tracking measurements may remove this barrier.

4.2 Generalised costs and commuting flows as an input to GP1

Clearly defined?

Generalised cost is discussed above and generally found to not be problematic subject to certain caveats. Commuting flows from zone to zone are available through the census and are clearly defined. ***The indicators are clearly defined***

Controllable

There are some elements in GP1 that may not be the result of transport changes. For example the change in the number of commuters for a given area is supposed to be as a result of a transport project and there are other external factors outside of LTP interventions which will influence commute destination choice (for example fuel costs). ***The indicator is not controllable.***

Measurable

DfT (2006) provides information on where the elements needed to calculate GP1 are available. Guidelines for calculating the generalised cost of commuting are given in DfT (2005b) and TAG (2007). ***The indicator is measurable.***

Responsive

Very substantial changes in commuting generalised costs are likely to be required to see significant impacts on labour supply as discussed above. More needs to be understood about the general underlying churn in the labour market. ***The indicator is not responsive to many smaller transport initiatives***.

Easy to understand

GP1 is essentially the extra tax from more people choosing to work due to changes in effective wages by reduction of transport costs. Whilst generalised costs and commuting flows are easy to understand the translation of these benefits into a tax figure is more difficult and, as the tax revenues do not flow to the local authorities, of limited value in LTP2 monitoring. ***The indicator value is not easy to understand in a local transport context.***

Cost-effective

The same difficulties exist for generalised cost as described above. The tracking of commuting flows on a more frequent basis than the census would be expensive relative to the likely benefits. ***The data collection costs are likely to be prohibitive but may be reduced with the advent of new technology.***

4.3 Conclusions

Table 1 below summarises the evaluations of each of the indicators. Whilst zone to zone generalised cost appears to have some promise as an indicator, further evidence would be required on the scale of change in generalised costs that needs to occur for there to be substantial productivity gains to be established. If these are only likely to emerge as the result of major schemes then it would not make sense to monitor this as part of local transport planning processes – although this does not diminish its importance in appraisal. At a local level it may be sufficient, for example, to consider trends in travel costs and commuting flows on a 10 year timescale alongside the census.

Table 1: Indicator evaluation matrix

	Generalised cost as an input to WB1	Generalised costs and commuting flows as an input to GP1
Clearly defined	✓	✓
Controllable	✓	×
Measurable	✓	✓
Responsive	×	×
Easy to understand	~	×
Cost Effective	~	~
Conclusion	Fail	Fail

This work shows the value of understanding the relationships between the intermediate transport outcomes that can be measured (e.g. generalised cost) and the end outcomes that these are expected to influence (e.g. productivity). In this instance the evidence is still comparatively new and what is available suggests that most local transport initiatives will have very limited impact on productivity and that further understanding will need to be developed, probably through major scheme development examples, before the added value of monitoring any related indicators could be assured.

Productivity and competitiveness are just two examples of areas in which new indicators might be developed. We see wider possibilities for the application of the audit method described in this report and we would encourage their application in generating a cost-effective and credible monitoring programme. Further advice on how to integrate the audit process described here with a strategic approach to assembling a monitoring strategy can be found in a companion guide (Designing and Monitoring Strategy to Support Sustainable Transport Goals, available from www.distillate.ac.uk).

Whilst there appears little value in a local authority leading in productivity measurement there will always be risks in the adoption of new indicators. There appears to be a strong case for central government pilots of indicators which appear to have promise so that the circumstances for their effective adoption can be identified.

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