Department for Transport

TAG Unit A2.4

Appraisal of Productivity Impacts

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Department for Transport
Transport Analysis Guidance (TAG)
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This TAG Unit is guidance for the **Appraisal Practitioner**

This TAG Unit is part of the family **A2 - Economic Impacts**

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1. Introduction

1.1.1 This unit provides guidance on how to quantify and value productivity impacts of transport investments for their inclusion within transport appraisal as part of the value for money assessment; and as non-welfare metrics such as GDP and jobs. Productivity is commonly defined as a ratio between the output volume and the volume of inputs. In other words, it measures how efficiently production inputs, such as labour and capital, are used in an economy to produce a given level of output.

1.1.2 In the absence of distortions and market failures, business user benefits will capture all of the productivity impacts associated with a transport investment – see TAG Unit A1.3 for guidance on the estimation of business user benefits. This unit provides guidance to capture the productivity impacts associated with a particular type of market failure, agglomeration economies.

1.1.3 There may also be productivity impacts associated with foreign direct investment and international trade due to market failures in non-transport markets. However, at present there is no agreed methodology with which to estimate these impacts in transport appraisal. If such or other impacts are considered material to the productivity impacts of a transport investment, see TAG Unit M5.3 for potential modelling approaches and analytical principles that should be applied.

1.1.4 Transport investments can have a broad spectrum of impacts and it is by no means certain that productivity will increase at either the local or national level; any productivity impacts will be context specific. For this reason prior to analysing productivity impacts, scheme promoters should develop an Economic Narrative, which articulates and justifies why a transport investment is needed to achieve the economic objectives set out in the Strategic Case as well as the scope of the analysis; this will inform the Appraisal Specification Report (ASR) (see TAG Unit A2.1).

1.1.5 The Economic Narrative should include information on the following: (1) identification of the expected positive and negative economic impacts and a description of the extent to which these are expected to achieve any economic objectives in the Strategic Case, as well as any significant unintended economic impacts of the scheme; (2) justification of why these impacts are expected to occur on the basis of economic theory and context specific evidence; (3) identification of the welfare change associated with these impacts, arising, for example from market failures; and, (4) identification and justification of the proportionate level of analysis to quantify and value the impacts.

1.1.6 In line with the principles of HMT Green Book guidance, the Department's appraisal process uses welfare analysis to determine value for money.[1] Under a well-defined set of circumstances user benefits will capture the entire welfare effects of a transport investment, including investment impacts. However, if there are (a) significant feedback effects into the transport market as a result of land use change or (b) 'distortions' or market failures that mean the economy is not functioning efficiently, additional benefits (or disbenefits) will arise as the impact of transport investment is transmitted into the wider economy.

1.1.7 The value for money assessment is based on national welfare impacts. Key to any assessment of induced investment is **displacement** – the extent to which induced investment impacts at the local level represent a relocation of investment from other locations. Changes in investment at a local level may not represent benefits at a national level.

1.1.8 In certain circumstances productivity impacts may also be valued in terms of changes in non-welfare metrics, for example Gross Domestic Product (GDP). Non-welfare measures of productivity impacts should be reported in the Economic Case alongside welfare measures. Non-welfare measures may be referenced in the Strategic Case, if they help inform the extent to which a transport scheme will achieve an economic objective, such as to rebalance the economy or regenerate a specific area.

1.1.9 The analysis which informs the non-welfare estimates referenced in the Strategic Case should use the same: scenarios in terms of the magnitude, nature and location of economic impacts, core assumptions such as population, employment and workforce skills, discount year, modelling of shocks, appraisal period and price base as welfare estimates.

1.1.10 This unit is structured as follows:

- Section 2 explains how productivity impacts and agglomeration economies from transport occur and how they are treated;
- Section 3 provides guidance on the quantification of agglomeration impacts;
- Section 4 describes how productivity impacts should be valued;
- Section 5 sets out some of the different sensitivity tests which could be conducted;
- Section 6 provides a checklist to aid the appraisal of agglomeration impacts; and
- Section 7 provides guidance on reporting productivity impacts.

[1] https://www.gov.uk/government/publications/dft-value-for-money-framework

2. Understanding Productivity impacts

2.1 Introduction

2.1.1 This section outlines the transmission mechanisms through which transport investment can affect productivity and how the impacts can be included in a Transport Business Case. The section is structured as follows:

- Section 2.2 explains the transmission mechanisms through which transport investments can affect agglomeration economies;
- Section 2.3 explains how agglomeration impacts can be measured in terms of GDP and welfare analysis and where these should be reported in the Transport Business Case; and
- Section 2.4 describes the process to assess productivity impacts resulting from transport investments.
- Section 2.5 sets out the process for assessing static clustering impacts.
- Section 2.6 describes the process for assessing dynamic clustering impacts.
- Section 2.7 explains how expected productivity impacts should be justified in the Economic Narrative.

2.2 Transmission Mechanisms and Displacement

2.2.1 An agglomeration economy is a particular type of placed based effect, in which individuals and firms derive productivity benefits from locating in close proximity to other individuals and firms. These benefits arise as a result of individuals and firms interacting with one another and are an important factor in the formation of clusters. Agglomeration economies arise from the external benefits from improved labour market interactions, knowledge spill-overs and linkages between intermediate and final goods suppliers - these can occur within an industry (localisation economies) and/or across industries (urbanisation economies). They arise due to sharing, matching and learning micro-foundations. Note, this guidance uses a single agglomeration elasticity capturing urbanisation but also some localisation effects; it does not provide separate estimates for localisation and urbanisation.

2.2.2 **Urbanisation economies:** These are economies of scale external to the firm and industry. They arise from a firm's proximity to the overall economic mass of an urban area, regardless of its industrial structure. Firms gain productive advantages from locating in large population and employment centres such as cities. These benefits are derived from the scale and diversity of markets, proximity of input and output markets, and from general infrastructure and public service provision. For example, if a financial institution relocates from a low-density area (e.g. a town) or expands its operations to a high-density area (e.g. major city), the economic mass of the urban area is increased and firms across industries may derive productivity benefits as an externality from the increased scale of economic activity.

2.2.3 **Localisation economies:** These are economies of scale external to the firm but internal to the industry. They result from the proximity of a firm to other firms within the same industry. This allows for productivity gains through enhanced specialisation. Localisation impacts occur when firms benefit from links to suppliers and the labour market, and knowledge spill-overs. For example, if a bank were to relocate to or expand operations in a city where financial institutions cluster, productivity impacts through localisation economies can arise due to improvements in the labour market and better matching of jobs to workers as the density and specialisation of a particular industry within the economic cluster increases.

2.2.4 Urbanisation and localisation economies are often experienced simultaneously. Diversity and scale of markets are crucial to urbanisation economies whereas specialisation and density of a particular industrial sector within an economic cluster are key to localisation economies.

2.2.5 Transport investment can affect agglomeration economies through two distinct mechanisms:

- **Static Clustering:** Transport investment can change the 'effective' density of the cluster by allowing individuals and firms to more easily traverse the cluster, thereby facilitating interactions. This clustering impact occurs with no change to land-use.
- **Dynamic Clustering:** Transport investment can lead to changes in the physical density of a cluster by inducing a change in the level or location of economic activity (land use change), thereby facilitating new or different interactions. Changes in the level and location of economic activity are related to labour supply and demand interactions – see TAG Unit A2.3 for guidance on labour supply impacts and the move to more/less productive jobs. Dynamic clustering also captures static clustering impacts.

2.2.6 Table 1 summarises the interaction of static and dynamic clustering with localisation and urbanisation economies. Annex E provides further information on the theoretical approach to productivity impacts.

Table 1: The Interaction of Static and Dynamic Clustering with Localisation and Urbanisation Economies

	Static Clustering	Dynamic Clustering
Localisation Economies	Transport investment increases the effective size of the cluster for firms in a particular industry. Knowledge spillovers within the cluster, and supply chain connections within the cluster are important. Individuals and firms traverse the cluster more easily, facilitating interactions.	Transport induces a change in the location or intensity of an industry's activity; productivity benefits from improved connectivity of single industry cluster. An industrial cluster expands/contracts.

	Productivity benefits from improved connectivity of single-industry cluster.	
Urbanisation Economies	Transport investment brings all industries effectively closer together, encouraging cross-industry labour market interactions, knowledge spill-overs and linkages. Productivity benefits are derived from the scale and diversity of accessible factor (e.g. labour) markets and product markets.	Transport induces a change in the location and intensity of overall economic activity; productivity benefits from improved connectivity of multi-industry cluster as the urban cluster expands/contracts.

Displacement

2.2.7 Key to any assessment of agglomeration is **displacement**; in other words the extent to which changes in local productivity are additional at the national level. Displacement reflects the extent to which an increase in economic activity in one location is partially or fully offset by reductions elsewhere. The default assumption in transport appraisal is the full displacement of employment impacts resulting from transport investment (see TAG Unit A2.3). That is, unless there is evidence of a net national impact of a transport scheme on employment in the UK, it should be assumed that the net job impact is zero.

2.2.8 **Static Clustering:** The impact of the transport project on employment is taken to be zero; the local and national productivity impacts are equivalent if the local geographical area modelled covers generalised transport costs (GTCs) for all affected trips. This is because static clustering involves no change in the location of economic activity, the productivity impact is solely the result of a change in generalised travel costs, which bring people effectively closer together. Thus displacement is not of concern in the assessment of static clustering.

2.2.9 **Dynamic Clustering:** This can result from the move to more/less productive jobs or from labour supply impacts. In the case of labour supply impacts (see A2.3), there is no displacement, such that the relationship with dynamic clustering is unambiguous: employment increases lead to higher productivity as the physical density of the cluster increases and vice versa.

2.2.10 In the case of moves to more/less productive jobs, where economic activity and employment can be displaced, the net dynamic clustering impact may be positive or negative. Areas gaining employment and experiencing a positive productivity impact do so at the expense of those losing jobs. However, the net productivity impact need not sum to zero. Assessments of dynamic clustering, in which there is employment relocation, should capture the productivity impacts upon areas of increasing and decreasing density. Transport external costs should also be taken into account and estimated for the change in land use.

2.3 Measuring Agglomeration Impacts

2.3.1 The Department's appraisal process is based on the principles of the HM Treasury Green Book guidance, which advocates the use of cost-benefit (welfare) analysis to determine the value for money of investment spend. Welfare analysis captures a broad range of impacts, such as economic, environmental and social. The results of welfare analysis are reported in the Economic Case as a national impact and inform the value for money assessment.

2.3.2 GDP and other non-welfare metrics may be used to inform the extent to which economic objectives, which are included in the Strategic Case, are expected to be achieved. These non-welfare metrics must be reported in the Economic Case but not included in the Value for Money assessment - see TAG Unit A2.1 for information on the links between GDP and welfare analysis.

2.3.3 Agglomeration impacts should be interpolated between modelled years in the same way as other benefits. After the final modelled year, agglomeration impacts should be grown by the weighted average of the work and non-work value of time based on the average share of traffic in the modelled years.

Welfare Analysis

2.3.4 The welfare analysis is reported in the Economic Case, which is exclusively focussed on net national impacts. As a result only those productivity impacts, which have been assessed at the national level, will be measured and reported. This is particularly important for dynamic clustering, where economic activity and employment may be displaced. The relationship with productivity will be context-specific; it could be positive or negative.

2.3.5 In most cases all of the welfare impacts will be captured by the estimation of user benefits – see User and Provider Impacts (A1.3). However, if there are (1) significant feedback effects into the transport market as a result of land use change or (2) distortions and market failures that means the economy is not functioning efficiently, additional benefits may arise when the impact of transport improvements is transmitted into the wider economy, as shown in Table 1.

2.3.6 The **agglomeration impact** captured by both static and dynamic clustering, in terms of changes to the effective and absolute proximity of households and firms is an externality; the individual household or firm does not consider these effects on third parties when making decisions about location choice, investment and employment. However, by firms co-locating they will transfer knowledge, have better labour matching and specialise, thereby increasing productivity. Thus, the entire productivity impact and hence GDP of the agglomeration economy is equivalent to welfare and additional to user benefits.

2.3.7 Section 3 of this unit provides guidance to capture the welfare change associated with a particular type of market failure – agglomeration economies. This provides a standardised national approach to estimating agglomeration impacts. In some cases context-specific approaches may be appropriate, for example, where the relative size of the productivity impact may depend upon the absolute size of the agglomeration. The use of context-specific estimates should be justified in the Economic Narrative (see section 2.7) and should be tested according to TAG Unit M5.3 on Supplementary Economic Modelling.

2.3.8 In certain circumstances GDP analysis may be used to supplement the cost benefit analysis, such as scheme prioritisation or understanding market failures not captured in the wider economic impacts guidance. For full details on assessing the costs and benefits of economic impacts and the circumstances in which GDP analysis may be warranted see TAG Unit A2.1.

2.3.9 Gross Domestic Product measures the value of marketable output produced by the factors of production and not the change in welfare. For this reason it should not be included in the Value for Money assessment. GDP estimates should be reported in the Economic Case. If they inform specific economic objectives, such as to rebalance the economy or regenerate a local area the Strategic Case may make reference to these.

2.3.10 In many instances the economic objectives of the Strategic Case will be locally focussed, such as to increase employment and GDP in a regeneration area (see also TAG Unit A4.3 Place Based Analysis). In such circumstances displacement may not be a primary concern of the scheme objectives. However, the net national estimates should be presented alongside these local impacts. This sets the local impacts in the broader national context.

2.4 Process to Assess Productivity Impacts

2.4.1 There is no absolute measure of agglomeration, instead academic literature relies on proxies, such as effective density or access to economic mass (ATEM). The proxy used in this guidance is referred to as ATEM, and it seeks to measure the impact of changes in generalised travel costs and employment location on the strength of an agglomeration.[2]

2.4.2 The methodology for estimating agglomeration impacts captures total productivity impacts of transport schemes which arise through either static or dynamic clustering, depending on whether land-use is assumed to be fixed or variable. TAG does not provide separate elasticities for urbanisation and localisation – see Appendix E for more details.

2.4.3 The impacts of dynamic clustering should only be estimated where changes to the location of economic activity have been appropriately forecast. The methods used to do this should be informed by the Economic Narrative. In cases where significant impacts are likely to be localised and have limited second-round (i.e. feedback) effects on the transport market (e.g. through congestion and crowding), it may be reasonable to apply evidence-based scenarios about how firms and households are likely to respond within that area. The treatment of

[2] Previous versions of A2.4 used the term “effective density”. ATEM is an equivalent term and is more commonly used term in the literature including research commissioned by the DfT. This change does not impact the methodology or equations, and the guidance for the wider impacts in transport appraisal (WITA) software will also reflect the change in terminology.

displacement should be made clear and consistent with the appraisal of employment impacts.

2.4.4 Where the relocation of economic activity is likely to take place across a wide area or have material second-round effects, the expectation would be that the analysis would be supported by a form of spatial modelling. To ensure consistency between the forecast generalised travel costs and the location of employment, there should be an interaction between the methodology to forecast land use change and the transport model – see section 2.6. Section 5 describes the sensitivity tests (such as those for inter-city schemes static clustering, intra-city dynamic clustering and freight impacts) which could be carried out alongside the core scenario estimates and the situations in which it is appropriate to apply them.

2.4.5 In addition, Laird and Tveter (2023) find that externalities from agglomeration may take a long time to accumulate. This ramp up is incorporated into the appraisal of static and dynamic clustering (see Section 4.2 and Appendix E for details).

2.4.6 The approach set out in this guidance is not applicable to pedestrian and public realm improvement schemes. There is some evidence that these types of schemes can also lead to agglomeration economies by attracting workers and firms, developing clusters in the process. Due to lack of robust evidence, no guidance is provided on how best to estimate these impacts.

2.4.7 As described in Appendix C, it is likely that the transport model zones do not match the Local Authority Districts used in the economic data set. It is important to ensure that all data are displayed at the same geographical level prior to calculation of productivity impacts. Appendix C offers guidance on collation, processing and aggregation of data.

2.5 Static clustering

2.5.1 Static clustering is calculated for schemes when that land-use change is assumed to be implicit. Employment or residential relocations are not modelled.

2.5.2 To calculate the impact of static clustering, the following steps should be followed:

1. Transport model data should be used to calculate average generalised travel costs (Equation 1) between each origin and destination zone. Each zone-to-zone journey should have one value of generalised travel costs (GTC), weighted by journey purpose.

2. Average generalised travel costs are then fed into the calculation of ATEM (Equation 2). One value of ATEM is used for all travel modes and journey purposes and this represents the level of agglomeration between two zones for each industrial sector.

3. The ATEM estimates feed into the calculation of the monetary impact of productivity. Equation 3 calculates the productivity change between the base and alternative case for two zones within a specific industrial sector. Equation 4 sums all industry specific productivity impacts to estimate the overall static clustering impact of the transport scheme.

2.6 Dynamic clustering

2.6.1 Dynamic clustering occurs when there is a change to the level or location of economic activity as a result of a transport investment. Dynamic clustering is calculated for schemes expected to result in change to the level or locations of jobs, and where the associated land-use changes have been modelled appropriately. When dynamic clustering impacts are estimated, static clustering benefits should not be included in the agglomeration benefits to avoid double counting.

2.6.2 Dynamic clustering impacts can be estimated either (a) using evidence-based scenarios about how firms and households are likely to respond to the transport improvement or (b) using a land-use model to forecast how the transport scheme would impact firms and households. Both the forecast of employment location and GTCs are required for the estimation of ATEM. In any scenario-testing, the treatment of displacement should be consistent with the appraisal of employment impacts and clearly described.

2.6.3 To ensure consistency between the forecast generalised travel costs and the location of employment, there should be an interaction between the methodology to forecast land use change and the transport model. In other words, the outputs from the transport model should be used to forecast the land use change, and the subsequent land use forecast should serve as further inputs to the transport model. In this manner employment locations are informed by generalised travel costs and the generalised travel costs by employment locations.

2.6.4 If the move to more/less productive jobs has also been identified as a potential impact of the transport investment in the Economic Narrative, this should be estimated using the same forecast of employment relocation as for dynamic clustering (see Employment Unit A2.3).

These steps should be followed to calculate the impacts of agglomeration:

1. Steps 1 and 2 from section 2.5 should be followed to calculate the base case ATEM, before the level or location changes are modelled.

2. Generalised cost and trip data from the land-use and transport models should be used to calculate the average GTCs of trips between the origin and all destination zones, once the change in the level or location of economic activity has been estimated i.e. in the alternative case.

3. The new average generalised travel costs are then fed into the ATEM calculation (Equation 2). In this case they are applied to the level or

location employment change; whether this is done using a land-use model or another method to generate this alternative scenario. This estimates the ATEM of each zone and industrial sector in the alternate case.

4. The base and alternative case ATEM (from steps 1 and 3) are applied to Equations 3 and 4 to calculate the agglomeration productivity impact. Note that the employment data for each zone and industrial sector must be the post-relocation value, as estimated by a land-use model.

Separation of impacts

2.6.5 Static clustering impacts will be captured by estimation of dynamic clustering effects. Dynamic clustering is the combined effect of a) the improvement in GTC from the scheme (static clustering), (b) the employment effects (land use change), and (c) any subsequent changes to GTC as a result of the employment effects. Because of the methodological form, the total productivity impact is not the sum of static clustering and land use change. When only static clustering is estimated changes in productivity are wholly due to changes in the GTCs between origin and destination zones.

2.6.6 To aid analytical transparency, scheme promoters should distinguish between the two types of clustering a) to indicate which of the two is driving the results and b) to compare the impact of the GTC change within the dynamic clustering analysis to the static clustering. The disaggregation of dynamic clustering into the distinct effects can be undertaken as follows:

1. Calculate the productivity impact using values of GTC estimated after changes to land-use have fed back into the transport model in Equation 1 but with base case employment levels in Equation 2. By holding employment constant this estimates the proportion of the dynamic clustering impact caused by changes to GTC.

2. Calculate the productivity impact using original do-minimum (i.e. with fixed land use) values of GTC in Equation 1 with post-relocation employment levels which result from land-use change in Equation 2. By holding GTC constant but varying the employment level this estimates the productivity impact of the shift in employment only.

3. The two individual impacts estimated above will not necessarily sum to give the total dynamic clustering impact calculated. Therefore, the proportion of employment effect relative to the total impact should be calculated using the sum of the individual impacts. This proportion should then be applied to the total dynamic clustering impact to give the overall estimate of the employment effect.

2.6.7 The disaggregation of dynamic clustering impacts into its component parts, GTC and employment impacts, allows for the identification of the key driver of the productivity impact. The importance of each component can therefore be checked to ensure it provides a reasonable estimate of the relocation impacts of the transport scheme. The relative importance of each component should be reported and justified alongside the overall productivity impact in the Economic Impacts Report (see TAG Unit A2.1).

2.7 Economic Narrative

2.7.1 Any analysis of productivity impacts should be justified in an Economic Narrative, as set out in section 5 of TAG Unit A2.1. Within the Economic Narrative, the scheme promoter should describe what, if any, productivity impacts are expected to occur and justify these. Furthermore, the scheme promoter should identify the welfare effects associated with any productivity impacts, whether these impacts are captured fully by user benefits or whether there are market failures, which provide additional sources of benefits and disbenefits. Finally, the Economic Narrative should outline the methodologies which will be utilised to quantify and value the productivity impacts. Box 1 provides a checklist of the types of information, which should be provided in the Economic Narrative, when assessing productivity impacts.

2.7.2 A transport scheme is most likely to have an impact on productivity, if it increases accessibility in an area in close proximity to an economic centre or large employment centre. In such cases, an appraisal of the productivity impacts should be considered.

2.7.3 To help scheme promoters identify if productivity impacts are relevant to their scheme, DfT has identified areas across England where, if a scheme falls within the area, productivity impacts could be expected to be significant. This guidance refers to those areas as ‘Functional Urban Regions’ or ‘FURs’. A map of these FURs is provided in Appendix A. Note that FURs should only be used as a guide. In some cases, productivity impacts may be relevant to transport schemes which fall outside of the FURs. This would be the case if the transport scheme improves accessibility to a local employment centre.

Box 1: Example Information required in Economic Narrative for Productivity Impacts

Below is a checklist of the types of information that should be presented in the Economic Narrative, if productivity impacts are to be analysed. **This list is not exhaustive** and additional information may be required to set the context of the transport investment, justify the impacts and explain the appraisal approach.

1. Expected Productivity Impacts

- Is the transport investment expected to have productivity impacts?
- If so, what effects are expected to occur?
  - Are these expected to be additional at the national level?

2. Justify Expected Productivity Impacts

- What is the transmission mechanism through which transport investment is expected to have productivity impacts?
  - Static or dynamic clustering?
  - Dynamic clustering: Why is economic activity expected to expand/relocate? What evidence is there that the transport investment will induce a relocation of economic activity?

- What evidence is there that locations neighbouring the transport investment are likely to experience agglomeration economies?
  - For example, does it fall within a Functional Urban Region? – see Appendix A for more information on Functional Urban Regions

3. Welfare Value of Productivity Impacts

- Are the expected productivity impacts fully captured by user benefits?
- Are there any market failures present, such that there may be sources of welfare additional to user benefits?
  - If so, what market failures are present?
  - What evidence can be brought to bear to demonstrate presence of market failures?

4. Quantifying and Valuing Productivity Impacts

- How are the productivity impacts to be quantified and valued?

2.7.4 Alongside the FURs map a worksheet (“Functional urban regions lookup workbook”)[3] has been released to accompany this Unit. These should be used to identify if the scheme is in an area that is classified as a FUR. The worksheet

[3] https://www.gov.uk/government/publications/webtag-economic-impacts-worksheets

can be used to check whether the Middle Layer Super Output Area (MSOA) in which a scheme is located lie within a FUR(s).

2.7.5 If a scheme falls across a number of FURs some distance apart, as would be expected for an inter-city scheme, productivity impacts can be assessed as set out in this guidance. The geographic reach of an agglomeration is reflected through the use of a 'distance decay' factor in the calculation and the reduced impact of longer journeys.

2.7.6 By default, it is assumed that the productivity impacts of static and dynamic clustering arise from the combined effects of urbanisation and localisation. If in the Economic Narrative localisation or urbanisation economies were identified as particularly relevant to a scheme and it is considered desirable to understand the extent to which these drive the overall productivity impact, scheme promoters can do one or both of the following

1. Utilise localisation/urbanisation elasticities and decay parameters drawn from the literature.
2. Estimate own localisation/urbanisation elasticities and decay parameters

These steps may be undertaken using Supplementary Economic Modelling (TAG Unit M5.3).

2.7.7 The estimated localisation/urbanisation impacts should be reported as a sensitivity test, not in the core scenario (see section 5 for more information).

2.7.8 As discussed in TAG Unit A2.1, the starting point for all transport appraisal is user benefits with fixed land-use, where the relevant mechanism through which transport investment affects productivity is static clustering. However, if the Economic Narrative identifies land-use change as a potential impact and this is explicitly modelled, then dynamic clustering may be undertaken and reported as an indicative monetised impact. If certain criteria are met, indicative monetised impacts can be included in the indicative benefit cost ratio (BCR) metric – see value for money framework for more information.

2.7.9 Additionally, if alternative transmission mechanisms or market failures have been identified, or it is decided to utilise context-specific or non-linear parameters, this should be justified in the Economic Narrative and tested in accordance with TAG Unit M5.3 for guidance. Note the results can only be reported as sensitivity tests to the TAG methodologies.

3. Quantifying Productivity Impacts

3.1 Introduction

3.1.1 We can't directly observe agglomeration and therefore use a proxy – ATEM. Changes in ATEM give rise to changes in productivity and can occur because of changes in GTCs or the location of employment. For the consideration of static and dynamic clustering the following considerations are relevant:

- Static: GTCs
- Dynamic: GTCs and location of employment.

3.2 Average generalised costs

3.2.1 The first step in estimating the productivity impacts is to calculate the average generalised cost; the average generalised cost is required for estimation of the ATEM, the average generalised cost should be calculated for all travel modes and journey purposes for each:

- origin / destination pair;
- scenario;
- modelled year;
- purpose[4]; and
- mode[5].

3.2.2 This is done by weighting transport model GTCs by the number of trips for each journey purpose (Equation 1). This produces mode specific GTCs for all purposes.

3.2.3 It is of key importance that GTCs are estimated for all relevant modes and trips to ensure an accurate estimation of Base case ATEM. For more details on this issue, see Appendix C.

3.2.4 Averaged generalised costs and trip quantities are outputs from the transport model and will therefore be displayed for each transport model zone. These should be aggregated to give values for each Local Authority District (LAD) prior to the calculation of the average generalised travel cost. For further details on the data requirements for estimating productivity impacts, including descriptions and sources, see Appendix B.

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[4] Generalised costs should be provided for business and commuting trips only; leisure trips are not included as it is assumed they do not impact on productivity.

[5] It is recommended that generalised costs are estimated for two modes; private and public transport. Appendix C provides advice on how to apply models with insufficient modal segmentation. Conversely, there may be transport schemes for which more detailed segmentation of modes is appropriate, for example where active modes are expected to have a significant contribution to ATEM. In such scenarios, further segmentation can be applied and it is important to ensure the mode share is weighted correctly in Equation 2.1. The justification for non-standard modal splits should be made in the Economic Narrative.

3.2.5 Where transport improvements lead to counter-intuitive changes in average generalised costs and therefore agglomeration, the reasons for this should be investigated. Provided this is not the result of an error, scrutiny of the use of Base scenario trip weights and Alternative scenario trip weights in Equation 1 combined with 2 may help to resolve the problem.

3.3 Access To Economic Mass

3.3.1 Following the calculation of mode specific average generalised costs, the next step is to calculate the ATEM of each area. The ATEM measures accessibility of area i to jobs in all the destination areas j.

Note: If estimating dynamic clustering you will need to forecast the location of economic activity either by using scenarios about how firms and households are likely to respond to the transport improvement or a land-use model which fully interacts with the transport model to forecast employment by zone for calculating the alternative case ATEM. The impacts on generalised travel costs after changes in location will need to be estimated.

3.3.2 Mode specific ATEM is calculated for each zone (Equation 2) by dividing total employment by a distance-decayed value of GTC (output from Equation 1) and then summing for all destination areas accessible from that zone.

3.3.3 Mode specific ATEM are calculated for each industrial sector in turn. Industries are aggregated into five sector groups; manufacturing, construction, consumer services, producer services, and public sector. This aggregation is based on the UK Standard Industrial Classification (SIC) index. For further details, refer to Appendix D.

3.3.4 Although ATEM is calculated for each sector in turn it is calculated using total employment within each destination area. This is because the elasticities and distance decay parameters reflect the impact of the density of the overall urban area, including a specific industrial sector, on productivity. Note: Total employment in each destination area is split across five sectors but ATEM is calculated for only four of them; we currently don't have an elasticity for the public sector - see section 5 for further guidance on estimating the productivity impact associated with this fifth sector.

3.3.5 The calculation of ATEM requires a distance decay parameter for each sector to be applied to average generalised costs. This represents the fact that the strength of an agglomeration diminishes with distance. The rate of this decay varies between industrial sectors. This decay parameter can be found in the Wider Impacts Dataset.

4. Valuing Productivity Impacts

4.1 Introduction

4.1.1 Calculating the productivity impacts of a transport scheme is done by comparing ATEM before and after the intervention to calculate a percentage change in ATEM. An elasticity of productivity with respect to ATEM (taken from the Wider Impacts Dataset) is applied to this change.

4.1.2 This is multiplied by the average GDP per worker in industry i to calculate the productivity impact which accrues to that industry from the denser urban economy. This is then multiplied by employment to estimate the total zonal value of the productivity impact (Equation 3).

4.1.3 The productivity impacts for each industry and zone are summed to give the overall productivity impact (Equation 4). The final productivity impact could be positive or negative. This depends on the impact of the scheme on generalised costs and employment distribution in the area.

4.2 Ramp up of dynamic agglomeration benefits

4.2.1 Laird and Tveter (2023) suggest dynamic agglomeration mechanisms may be around 50% of the total agglomeration impact and take up to ten years to fully appear following a worker's relocation.

4.2.2 A ramp up should be applied to 50% of all agglomeration benefits over 10 years, with the other 50% accruing in full at scheme opening, in line with Laird and Tveter (2023). The ramp up factors increment linearly from 0.5 in year 1 to 1.0 in year 11, where year 1 is on scheme opening (although there may be cases where before scheme opening is appropriate). The same method can be applied proportionality when static and dynamic clustering is appraised, and is contained within the WITA software.

4.2.3 However, the proportionate approach risks overestimating the dynamic clustering component of the benefits. Therefore, where possible, these land-use change lags should be represented in the SEM being used, and then fed into the appraisal of wider impacts directly. This can include any land use change impacts that may occur pre-opening.

4.2.4 In the absence of specific modelled lags, we recommend an additional default 5 year ramp each time there is a change ATEM from land use change (i.e. any productivity impact attributable to employment relocation) to represent this lag. This would mean there could be multiple ramps if there is land use change in multiple years. This lag is additional to, and needs to be applied in conjunction with, the 10 year ramp up discussed above. However, this would need to be implemented outside of WITA (i.e. off model).

4.2.5 Please see Appendix E for further justification of the above.

4.3 Profiling over the appraisal period

4.3.1 As with other appraised impacts, productivity uses the standard discount rate and price base as used across the appraisal - see TAG Unit A1.1 - Cost Benefit Analysis for further details.

4.3.2 Productivity should be interpolated between modelled years in the same way as other benefits. The inputs to the calculations below will therefore vary by forecast year unless specified otherwise. After the final modelled year, the productivity impact is expected to grow by the annual growth rate of real GDP per capita as presented in the TAG Data Book.

4.4 Equations used to calculate productivity impacts

4.4.1 This section presents the equations which are used in the calculation of productivity impacts. These equations are also contained in the WITA software which can be used to calculate Wider Impacts.

Equation 1 Average Generalised Cost

$$g_{i,j}^{S,m,f} = \frac{\sum_p g_{i,j}^{S,m,p,f} \; T_{i,j}^{S,m,p,f}}{\sum_p T_{i,j}^{S,m,p,f}}$$

$g_{i,j}^{S,m,f}$	is the average generalised costs of travel (weighted average by journey purpose), between area i and area j, for each mode m in the scenario S. This will vary depending on the forecast year f, to the extent that costs vary in the modelling of transport (TEE) user impacts.
$g_{i,j}^{S,m,p,f}$	is the generalised cost of trips from transport zone i to transport zone j, scenario S, mode m and purpose p. It needs to be aggregated to LAD level. This will vary depending on the forecast year f, to the extent that costs vary in the modelling of transport (TEE) user impacts.
m	is the transport mode: private and public transport. This will not vary by forecast year.
p	is the purpose of travel. This includes business and commuting trips but does **not** include leisure, which is unlikely to impact productivity. This will not vary by forecast year.
$T_{i,j}^{S,m,p,f}$	is the number of trips from transport zone i to transport zone j in the scenario S by mode m and purpose p. It needs to be aggregated to LAD level. This will vary depending on the forecast year, f, to the extent that the variable varies in the modelling of transport (TEE) user impacts.
s	is the scenario; either the base B or alternative A case.

Equation 2 Access to Economic Mass

$$d_i^{S,k,f} = \sum_j \sum_m \frac{E_j^{S,f}}{(g_{i,j}^{S,m,f})^{\alpha^k}}$$

$d_i^{S,k,f}$	is the ATEM d of origin area i sector k in each scenario S for forecast year f.
$E_j^{S,f}$	is the total employment for all sectors in area j for each scenario S for forecast year f. Note that employment will be the same in both scenarios in the calculation of static clustering with fixed land-use.
$g_{i,j}^{S,m,f}$	is the average generalised cost of travel from area i to area j in the scenario S for mode m as calculated in equation 1.
α^k	is the distance decay parameter for each aggregate industrial sector k. The decay parameter does not vary by scenario or forecast year.
k	is the aggregated industrial sector based on the UK SIC(07).

Equation 3 Sectoral Productivity Impact

$$\boldsymbol{WI1_i^{k,f} = \left[\left(\frac{d_i^{A,k,f}}{d_i^{B,k,f}}\right)^{\rho^k} - 1\right] GDPW_i^{B,k,f} E_i^{S,k,f}}$$

Equation 4 Total Productivity Impact

$$WI1^f = \sum_i \sum_k WI1_i^{k,f}$$

$WI1^f$	is the overall productivity impact, in pounds.
$WI1_i^{k,f}$	are the sectoral agglomeration impacts for each area i and sector k. They will vary depending on the forecast year f.
$\mathrm{d_i^{A,k,f}}$	is the ATEM of sector k in area i in the alternative case A (from equation 2). This will vary depending on the forecast year f.
$\mathrm{d_i^{B,k,f}}$	is the ATEM of sector k in area i in the base case B (from equation 2). This will vary depending on the forecast year f.
$\mathrm{\rho^k}$	is the elasticity of productivity with respect to ATEM for each sector k. These are taken from Graham et al (2009)[6] and will not vary by forecast year.
$\boldsymbol{GDPW_i^{B,k,f}}$	is the GDP per worker of Local Authority District area i sector k in scenario B for the forecast year f. Note that GDP per worker will be the same in both scenarios in the calculation of static clustering with fixed land-use.

[6] Graham D.J., Gibbons S. and Martin R. (January 2009), Transport Investment and the Distance Decay of Agglomeration Benefits

$E_i^{S,k,f}$	is total employment in sector k, origin area i in scenario S. This will vary depending on the forecast year f. Note that employment will be the same in both scenarios in the calculation of static clustering with fixed land-use.

5. Sensitivity Tests and Additional Assessments

5.1.1 Some transport schemes may have impacts on productivity which are not fully captured by the method described above, or scheme promoters may wish to adjust the recommended methodology e.g. by calculating context-specific agglomeration elasticities. In these cases, the variations to the methodology may be estimated and presented as sensitivity tests to the adjusted or indicative BCR, depending on whether static or dynamic clustering has been estimated. The choice of sensitivity tests should be considered as part of the Economic Narrative.

Sensitivity test for static clustering for inter-city schemes

5.1.2 For inter-city schemes, if agglomeration impacts are estimated, a sensitivity test should be carried out varying the value of the decay parameter. This should include a test that uses the highest value of the distance decay parameters (as provided in the Wider Impacts Dataset). This is to reflect the evidence that the strength of agglomeration impacts diminishes with distance.

5.1.3 Business travel may be particularly prominent on inter-city travel and the robustness of the agglomeration estimate should be assessed by applying a decay rate to this travel purpose that is the average of the decay rates across consumer and producer services.

Sensitivity test for freight trips

5.1.4 In the majority of applications, freight transport demand is assumed to be a ‘fixed matrix’ i.e. only subject to choice of route. For productivity impact appraisal, freight should not be regarded as a part of business travel or as an alternative mode. However, when data are available on freight flows and costs, freight movements should be included only as a sensitivity test. A change in the cost of freight will affect the average generalised cost of travel and therefore the resulting ATEM will be different. This in turn affects the productivity impact.

5.1.5 If a land use model which interacts with the transport model is available and it represents freight, it would be possible to assess if there are any employment relocation impacts resulting from the scheme’s impact on freight. These could be used to calculate the effect of freight on dynamic clustering and movements to more productive jobs.

Sensitivity test for localisation economies

5.1.6 Agglomeration economies can occur at an urban or an industrial level, urbanisation and localisation economies respectively. Currently the guidance captures both of these effects under a single elasticity and does not provide separate estimates for urbanisation and localisation. For further details see Appendix E - E1.6 to E.10. However, if in the Economic Narrative localisation economies were identified as a potentially significant impact, scheme promoters can do one or both of the following and report the estimated localisation impacts as a sensitivity test rather than as part of the core scenario:

1. Utilise localisation/urbanisation elasticities and decay parameters drawn from the literature.

2. Estimate own localisation/urbanisation elasticities and decay parameters.

To estimate localisation/urbanisation effects these parameters could be applied to the agglomeration methodology in Section 4. Alternatively, scheme promoters could employ or develop a different methodology. Ideally urbanisation and localisation elasticities should be calculated simultaneously; if this has been done, then the localisation and urbanisation elasticities should be considered additional. Otherwise the resulting economies are not additional as they potentially double-count impacts.

5.1.7 When estimating localisation economies, scheme promoters should follow the principles of the Supplementary Economy Modelling guidance (see TAG M5.3).

Additional assessment of public sector static agglomeration

5.1.8 The agglomeration parameters used in TAG were calculated using firm-level data. This means they lack data on certain industrial sectors, notably the public sector. This means that an elasticity of zero is effectively assumed and there is no productivity impact.

5.1.9 How much the public sector will benefit from agglomeration is difficult to identify. Conceptually there is no reason to believe that the matching, sharing and learning micro foundations to agglomeration would not also hold for the public sector. However, it is argued that a lack of competition may blunt or even block some of them, but counter-arguments exist that different institutions within a sub-sector of the public sector compete on quality. This is particularly the case in education and health where pupils and patients can choose where to get educated or treated.

5.1.10 In support of these counter-arguments there is some, albeit limited, evidence of agglomeration impacts in education and health. These empirical studies set out channels through which agglomeration associated with learning, matching and sharing in the public sector may take place. Analysis at an aggregate level of job switchers in the UK also identifies similar levels of flows of workers between different parts of the public sector and between the private and public sectors as within the private sector. The movement of workers is a key channel for learning.

5.1.11 Agglomeration economies in the public sector are likely to manifest themselves as improvements in quality. These will unambiguously increase welfare, however, their linkage to changes in GDP are not clear. Given that the welfare value of the public sector likely exceeds its GDP value, a lower bound estimate can be obtained of the change in welfare by applying the formulas set out in section 4 of this guidance using GDP per worker data for the public sector (this is now included in the wider impacts dataset as of May 2024). Such estimates should be treated as welfare enhancing only, and not as GDP enhancing.

5.1.12 In terms of the appropriate elasticity to use for a sensitivity test the empirical evidence is less clear. Therefore, it is recommended to use the economy wide average detailed in Table 2 below. A review undertaken for the Department indicated that, if anything, evidence supports the hypothesis that the effect in the public sector is closer to the economy weighted average, than it is to zero.[7]

5.1.13 Due to this greater uncertainty associated with the scale of public sector agglomeration effects, these impacts when considered in appraisal should only be included in the indicative BCR.

Table 2 Weighted Average Parameter Values for all Industrial Sectors

	Agglomeration elasticity (ρ)	Decay parameter (α)
Economy (weighted average)	0.043	1.655

Sensitivity test for ‘other’ industrial sectors

5.1.14 If a scheme is likely to affect areas with a significant proportion of ‘other’ employment (i.e. that which is not included in the 5 sectors for which data is explicitly collected), a sensitivity test can be carried out to determine the productivity impact for ‘other’ industrial sectors in the economy. The sensitivity test should apply the all-industry average values for the distance decay parameter and agglomeration elasticity (Table 2) to estimate the agglomeration impact for ‘other’ employment.

[7] Laird and Tveter (2024) Agglomeration and the Public Sector. Report to the Department for Transport. May 2024.

6. Checklist for Appraising Agglomeration Impacts

6.1.1 The tables below provide a checklist of key points in this Unit to use in setting up the analysis framework for assessing productivity and for checking back and identifying any potential issues that may affect the robustness of the analysis. Appendix C describes in detail issues around the data requirements for estimating productivity impacts.

Transport data checklist

6.1.2 The following aspects of the transport data should be checked and documented.

Table 3 Data Checklist

Issues	Check
Look and confirm that the generalised costs are comparable (same units) across the modes and purposes (including passenger/goods vehicles) that need to be considered.	
Determine that all necessary journey purposes are included (business and commuting).	
Determine that all necessary modes are included.	
Check the definitions of any segmentation of modelled data by car-ownership or car-availability levels, or by any other dimensions like time of day or socio-economic group, since it will be necessary to average over these segments to provide the generalised costs for use in the calculations.	
Find out how intra-zonal values have been obtained (e.g. using values that were used in the transport modelling, or estimated/assumed values). The documentation needs to make it clear how intra-zonal trips have been estimated.	
Confirm if generalised costs are for one-way travel or for round trips. The values should be estimated in a consistent way.	

6.1.3 The following questions of completeness presented in the following table (4) also need to be considered, and any gaps addressed.

Table 4 Completeness of Data

Issues	Check
Are Walking and Cycling modes modelled? (Walk mode is often not modelled, but walk times can usually be calculated from network distances, which are nearly always available. In some areas, cycling is also significant and needs to be considered).	
Is the transport model adequately detailed outside the main area of interest? (Problems that can arise include some modes being omitted outside the core area of the transport model, congestion not being considered outside the core area, and only modelling the corridor of interest: in this case the narrowness of the transport modelling will be insufficient for productivity analysis). See Appendix C for more detail.	

6.1.4 Questions of consistency listed in the following table (5) also need to be considered.

Table 5 Consistency of Data

Issues	Check
Do the differences in generalised costs show reasonable patterns, in particular: • Do generalised costs generally increase for longer journeys? • Do the differences in generalised costs across modes look reasonable? • What, if any, generalised costs are supplied where the mode data is not immediately available from the model? How were these estimated and tested for robustness? • Do the generalised costs change in the expected directions if transport supply improvements are introduced?	

6.1.5 The following checklist table should be considered and the conclusions summarised in the Economic Impacts Report (EIR). In such a review, it must be kept in mind that some or all of the economic impacts or benefits may be either positive or negative (i.e. benefits or disbenefits).

Table 6 Agglomeration Impacts Checklist

Topic	Issues	References/notes
Geographical extent: is the geographical coverage sufficient? i.e. is the model system large enough to take account of the majority of interactions to/from the area of interest?	Is there a risk of overstating the impacts case by not considering ATEM over a wide enough base due to not considering interactions with places beyond the modelled area?	The agglomeration calculations depend on modelling a large enough region to set the journeys affected by the scheme in context with all other significant journeys that are not affected by the scheme. Considering too small an area will tend to exaggerate the impact of proposals.

Transport modelling issues – is modelling consistent with this Unit and with other TAG guidance?	Completeness of data (modes, journey purpose, zone pairs).	Note that the transport data requirements (e.g. demand and generalised costs by mode and journey purpose) for agglomeration analysis are greater than the requirements for analysing conventional transport user impacts.
	Treatment of problem issues (e.g. missing intra-zonals).	A number of likely problems arising from the greater transport data requirements of WIs analysis are discussed, along with potential solutions, in Appendix C.
Employment data issues	Is the base case employment data taken directly from NTEM, or from another forecast?[8] A land use model which fully interacts with the transport model can be used to estimate scheme impacts on employment location.	
Scale of the productivity impacts	Compared to the other economy impacts.	Experience to date is that agglomeration is usually the largest of the wider economic impacts.
	Compared with the TEE benefits.	Previous experience is that where productivity impacts are relevant they are generally in the range of 10% to 30% of total TEE user benefits; see Feldman et al (2008).
Dynamic clustering	Have both dynamic clustering and MTMPJ effects been estimated?	See TAG Unit A2.4 – Employment for further information on estimation of the move to more/less productive jobs.
	Have transport external costs been estimated for the change in land use?	See TAG Unit A5.4 for further information for applying Marginal External Costs.
	Do calculations of dynamic clustering take into account both productivity gains and losses from relocation of households and businesses?	Dynamic clustering and the move to more/less productive jobs can comprise of both productivity gains and losses from relocation of employment and agglomeration/disagglomeration.
	Have the GDP and welfare impacts been separately estimated?	

8 If taken from another forecast, is that forecast consistent with NTEM data? If the forecast employment is altogether higher than the NTEM data, it should be considered as a sensitivity test for WIs purposes and a ‘core scenario’ compatible with NTEM forecast employment (at some level) should be used.

Analysis issues	To what extent are the benefits/disbenefits the result of the present spatial patterns of productivity?	Where benefits stem from the fact that present productivity levels are higher in one area than another, some comment should be added on whether these differentials can be expected to persist. If the area with lower productivity is the subject of interventions to increase its productivity, it may not be reasonable to assume that the differential is fixed.
	Sensitivity tests - what has been done and what does it indicate?	
	Factoring impacts over the appraisal period and discounting over time	What time profiles and assumptions have been used to extrapolate from modelled years across the appraisal period? Are discount and profile rates consistent with TAG?
	Comparison of spatial distribution of agglomeration benefits with conventional transport user benefits.	Whilst agglomeration impacts are likely to be greatest in urban areas, this is not necessarily true of user benefits. Understanding how the two compare geographically and articulating the differences are highly beneficial to the interpretation of the analysis.

7. Reporting Productivity Impacts

7.1.1 The purpose of the Transport Business Case is to aid the decision making process by presenting evidence of the potential impacts of a transport scheme in a transparent and consistent manner. Thus where the expectation of employment impacts can be justified and credible analysis brought, these should be reported.

7.1.2 Welfare and non-welfare measures of productivity impacts are reported in the Economic Case. Welfare measures inform a scheme's Value for Money assessment. Whilst in certain circumstances, non-welfare measures may also be referenced in the Strategic Case if they can usefully inform the extent to which an economic objective will be met. For example, an economic objective to boost local productivity may be best informed by expectations of the increase in local productivity that will be created by a scheme. See TAG Unit A2.1, Section 2 for details on the relationship between welfare and non-welfare measures; and TAG Unit A2.1, Section 7 for details on the reporting of welfare and non-welfare measures of economic impacts.

7.1.3 An Economic Impacts Report (EIR) should be included as an annex to the Economic Case that details all of the technical analysis underlying the measures reported in the Economic Case - see TAG Unit A2.1, Section 6 for details on producing an EIR.

8. References

Department for Transport, "Value for money framework" (2024), https://www.gov.uk/government/publications/dft-value-for-money-framework

Graham D.J, Gibbons S. and Martin R. (January 2009), **Transport Investment and the Distance Decay of Agglomeration Benefits**, Centre for Transport Studies, Imperial College, mimeo

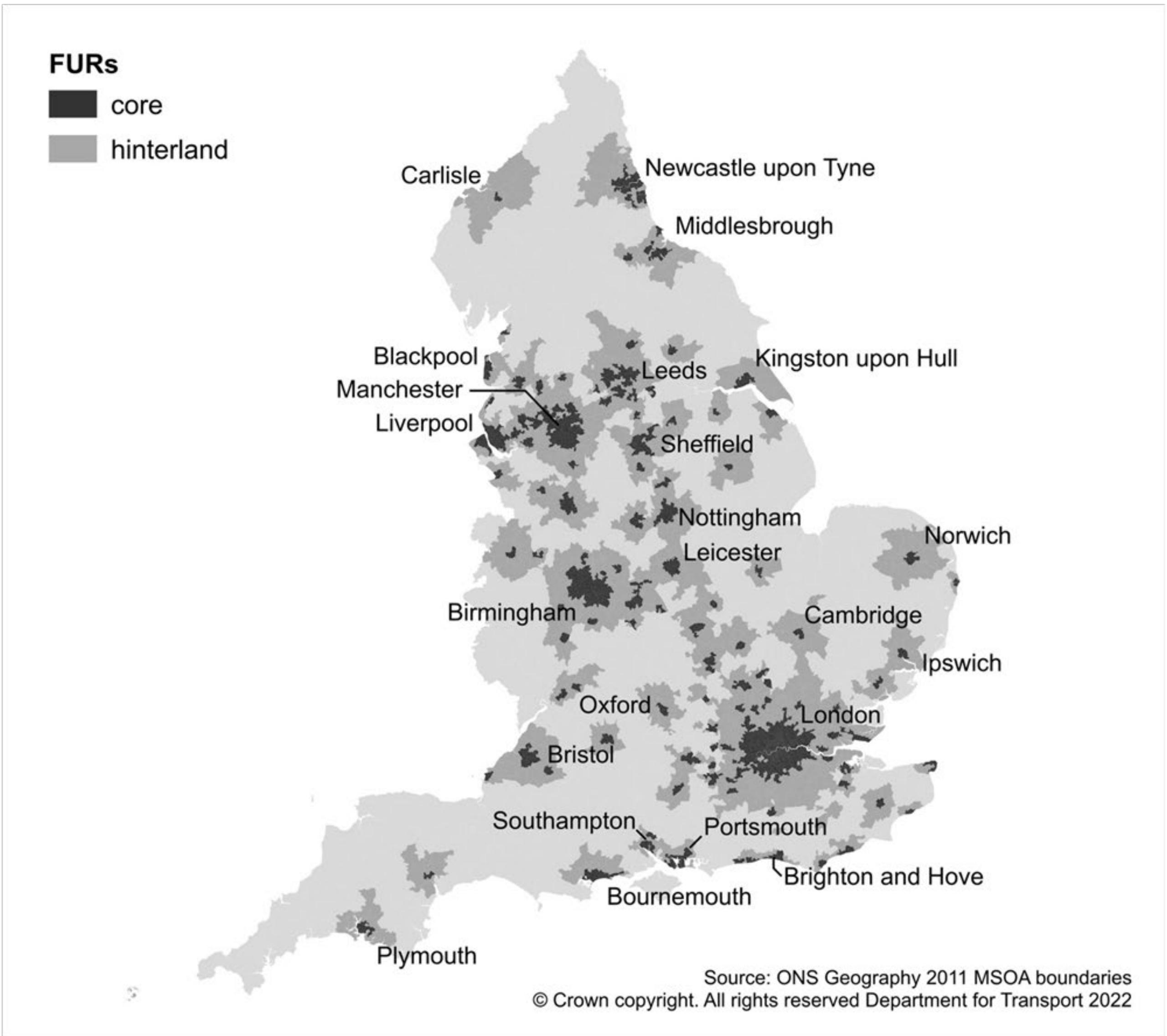
Laird and Tveter (2023) Agglomeration and transport appraisal: new developments and research directions. Report to the Department for Transport.

Laird, J.J. and E. Tveter (2024) **Agglomeration and the Public Sector.** Report to the Department for Transport. May 2024.

HM Treasury, "The Green Book", (2022), https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

Appendix A: Functional Urban Regions (FURs)

Figure 1 Map of England's Functional Urban Regions (FURs)



Background information on designation of functional urban regions

A.1.1 Figure 1 above identifies the Functional Urban Regions in England. This unit is also accompanied by a worksheet to use for checking whether the area designated as a Middle Layer Super Output Area (MSOA) in which a scheme is located lies within a FUR, is part of the hinterland or in neither.

A.1.2 Each FUR is constructed by firstly defining a core and then identifying a corresponding commuting field (or hinterland) for that core. Middle Layer Super

Output Areas (MSOAs) are used as building blocks for both the core and commuting field.

A.1.3 The core is defined by a minimum population (of 50,000) together with a minimum population density (of 15 people per hectare) for a MSOA. This is to reflect the fact that agglomeration impacts are most significant for transport schemes located within, or near, large and dense areas. A core can be made up of one or more MSOAs. The methodology largely follows that of the Definitions of Function Urban Areas (FUA) for the OECD metropolitan database.

A.1.4 For the commuting field, the MSOAs surrounding a core are examined. If more workers in the MSOA commute to that core than to any other core and a minimum 15% of the working population commutes to that core, then the MSOA is added to that core's commuting field. The use of a commuting field reflects the fact that agglomeration is influenced by the level of economic interaction between different areas, with stronger interaction delivering greater potential for agglomeration impacts. MSOAs are examined in a contiguous fashion building outward from each core, with MSOAs being added to a core's commuting field until a MSOA does not meet the two commuting thresholds set. Again, the methodology largely follows that of the OECD approach.

[9] . All cores across England are identified and commuting fields then constructed around these cores.

[9] Measures of commuting and workplace population at MSOA level are ONS figures from the 2011 census.

Appendix B: Data Summary

Table B1: Productivity parameter data

Variable Name	Data Description	Source	Details
$T_{i,j}^{S,m,p,f}$	Number of trips from zone *i* to zone *j* for mode *m* and purpose *p* and varying by forecast year f. It needs to be aggregated to the LAD level.	Transport Model Outputs	*i* is origin zone *j* is destination zone *S* is scenario: alternative (A) or base (B) case *m* is mode: private and public transport *p* is purpose of travel including business, commuting and freight in the sensitivity case. f is forecast year
$g_{i,j}^{S,m,p,f}$	Average generalised cost of travel from zone *i* to zone *j* in the scenario *S* for mode *m* and purpose *p* and varying by forecast year f. It needs to be aggregated to the LAD level.	Transport Model Outputs	*i* is origin zone *j* is destination zone *S* is scenario: alternative (A) or base (B) case *m* is mode: private and public transport *p* is purpose of travel including business, commuting and freight in the sensitivity case. f is forecast year Average generalised cost is in TAG price base year.
$E_j^{S,f}$	Total employment for all *k* sectors for scenario *S* area *j* varying by forecast year f.	Economic Data Set[10] LUTI and/or local forecasts for the sensitivity WIs estimate	*j* is destination area *S* is scenario: alternative (A) or base (B) case f is forecast year
α^k	Distance decay parameter.	Economic Data Set	α (alpha) is the distance decay parameter *k* is industrial sector
ρ^k	Elasticity of productivity with respect to ATEM.[11]	Economic Data Set	ρ (rho) is the agglomeration elasticity *k* is industrial sector

10 In the standard analysis where land-uses are held fixed, employment will be the same in the alternative case (A) and the base case (B).

11 The sector-weighted agglomeration elasticities should be taken as constant over the appraisal period. The exception is where robust forecast sectoral employment data is available and in these cases agglomeration elasticities may be re-weighted by sectoral mix for every forecast year.

$GDPW_i^{B,k,f}$	GDP per worker in Local Authority District *i* sector *k* in the base case (B) varying by forecast year f.	Economic Data Set	*i* is origin area B is base case *k* is industrial sector f is forecast year GDP per worker is in the default TAG price base year.
$E_i^{B,k,f}$	Total employment in the base case in sector *k*, area *i* varying by forecast year f.	Economic Data Set	*i* is origin area B is base case *k* is industrial sector f is forecast year
$GDPW^{N,f}$	Average national GDP per worker varying by forecast year f.	Economic Data Set	*N* is national f is forecast year GDP per worker is in the default TAG price base year.
$E_i^{A,f}, E_i^{B,f}$	Total employment in Local Authority District (LAD) *i* varying by forecast year f.	Economic Data Set	E is total employment in LAD *i* is origin area (A) is alternative case (B) is base case f is forecast year
PI_i	Index of productivity per worker in LAD area *i.*	Economic Data Set	PI is productivity index *I* is origin area
$T_{i,j}^{S,m,p,f}$	Number of trips from zone *i* to zone *j* for mode *m* and purpose *p* and varying by forecast year f. It needs to be aggregated to the LAD level.	Transport Model Outputs	*i* is origin zone *j* is destination zone *S* is scenario: alternative (A) or base (B) case *m* is mode: private and public transport *p* is purpose of travel including business, commuting and freight in the sensitivity case. f is forecast year

Appendix C: Data Used in Productivity Assessments

C.1 Collation of data

C.1.1 The data required for estimating productivity impacts fall into two groups:

- **Economic data:** this includes data on the productivity of labour, on employment numbers in an area, and agglomeration elasticities that show the productivity impacts that result from changes in the level of ATEM.
- **Transport model data:** this includes data on the user impacts of a scheme - generalised cost and travel demand information for the different users and modes for a Base (without scheme) and Alternative (with scheme) case.

C.1.2 These data come from these main sources:

- the Wider Impacts Dataset which contains relevant economic data and parameters;
- the transport model which provides journey times and demand data; and
- any land-use modelling carried out to estimate employment relocation impacts.

Economic data: overview

C.1.3 The Wider Impacts Dataset is a core economic data set which should be used for all estimates of Wider Impacts to ensure consistency of estimates across schemes. In summary, this data set contains the following data for calculation of productivity impacts.

Table C1 Productivity Data

Data	Value
Local GDP per Worker	by Local Authority District
Sectoral Employment Forecasts	by Local Authority District
Total Employment Forecasts	by Local Authority District
Agglomeration elasticities of productivity with respect to ATEM by industrial sector (ρ)[12]. This is a single elasticity capturing both urbanisation and localisation effects	manufacturing = 0.021 construction = 0.034 consumer services = 0.024 producer services = 0.083 economy (weighted average) = 0.043
Parameter for exponential decay of ATEM with generalised costs for different sectors (α).	manufacturing = 1.097 construction = 1.562

[12] Graham, D.J., Gibbons, S., and Martin, R. (January 2009); Transport Investment and the Distance Decay of Agglomeration Benefits.

Calculated for the above Agglomeration elasticities[13].	consumer services = 1.818 producer services = 1.746 economy (weighted average) = 1.655
Average national GDP per worker	by forecast year

Transport model data: overview

C.1.4 The estimation of productivity impacts builds on the modelled user benefits. It requires appropriate representation of relevant modes[14] and trips; as well as a high enough level of data granularity to minimise missing intra-zonal journeys, complete demand/generalised cost matrices, sufficient segmentation of modes or purposes; and full geographic modelling coverage. This enables the accurate estimation of Base case average GTCs and levels of ATEM.

C.1.5 An accurate estimation of the base case GTCs is crucial for the estimation of productivity impacts. This is because the scale of productivity impacts is dependent on the relative change in GTC; if the base case GTC is inaccurate, the relative change to GTC and hence the estimated productivity impacts will be incorrect.

C.1.6 To ensure an accurate estimation of productivity impacts the study area should be limited to the area in which the modelling provides a good estimate of Base generalised costs.

C.1.7 The need for a good estimate of Base generalised costs may be a particular issue for rail where multi-modal models are not usually available in scheme appraisals. Scheme promoters are encouraged to seek the advice of the Department when producing such estimates for uni-modal appraisals.

Transport model data: demand

C.1.8 Demand data should be extracted from the transport model for the full set of Origin and Destination (OD) pairs and segmented by mode, journey purpose and across time periods. The OD matrices extracted then need to be aggregated to match the level of aggregation for the economic data, normally to Local Authority District (LAD) level.

Transport model data: generalised cost

C.1.9 Generalised cost data should also be extracted from the transport model for the full set of OD pairs, and include all users and modes.

[13] Graham, D.J., Gibbons, S., and Martin, R. (January 2009); Transport Investment and the Distance Decay of Agglomeration Benefits.

[14] For the purpose of productivity analysis, 'relevant modes' refers to all modes that are utilised in the modelled area in the base case as well as all modes that are affected by the intervention itself.

C.1.10 The productivity assessment analyses the change in accessibility for different transport users and the benefits derived as a result of this change in accessibility beyond direct user benefits. To allow for this, the measure of the generalised cost change (resulting from the scheme) needs to be as full a measure as possible; it needs to capture time, travel cost, reliability and crowding disutility, where relevant.

C.1.11 The costs used should be calculated in the default price base, as per TAG Unit A1.1 - Cost-Benefit Analysis and as a weighted average across user groups, aggregated according to shares of different user groups (e.g. Commuting and Business/In-Work).

Geographical detail of data

C.1.12 The economic and transport data are often sourced at different levels of geographic detail. The productivity methodology largely uses data generated from transport and land-use modelling, building on modelled inputs to the TUBA cost benefit analysis. Specific inputs to the assessment of accessibility change include estimates of user demand for the different journey purposes and modes in the Base case and Alternative case scenarios. The main source for such data is model OD matrices of travel flows used in TUBA.

C.1.13 The inputs also include estimates of changes in generalised travel cost for each of the user groups and modes, for the different modelled years. Again, the main source for such data is the modelled input generalised cost information for TUBA.

C.1.14 The economic data set is put together at Local Authority District (LAD) level. The modelled transport demand and generalised cost data are likely to be at the level of geography selected for the transport zones of the transport model. This will vary in different cases, and will often be at a more detailed geographical level than the economic data. In such circumstances the transport data will need to be aggregated to LAD level to put the transport and economic data on the same level of geographic detail for analysis.

C.2 Identifying and resolving problems with data

Overview

C.2.1 The calculation of productivity impacts involves greater data demands than are required for estimation of user benefits. In a standard analysis of user benefits, only demand levels and changes in generalised costs are required. Journeys for which generalised costs and demand do not change are irrelevant to the calculations. In contrast, agglomeration estimates require accessibility calculations in which every possible commuting or business journey to, from or within the study area is to some extent relevant. Even if no direct or indirect change is envisaged, all modes, and zone pairs have to be considered for both business and commuting journeys.

C.2.2 The greater data demands can generate some problems with collating and preparing the required data. This section provides advice on dealing with some of the potential data deficiencies which will need to be addressed to accurately estimate productivity impacts. Inappropriate data can result in the incorrect estimation of the scale of productivity impacts as described in paragraphs C.1.4 to C.1.6.

C.2.3 The robustness of the productivity assessment depends crucially on the appropriateness of the transport model data on which it is based. The guidance below focuses on four particular problems:

- intra-zonal journeys not modelled;
- incomplete demand/generalised cost matrices;
- insufficient segmentation of modes or purposes; and
- insufficient geographic modelling coverage.

C.2.4 The appropriate degree of effort expended on correcting the missing demand and/or generalised cost cells depends on their importance for, or impact on, the productivity results. In general the importance of an OD pair is greater:

- the greater the size of the zones, in employment terms;
- the greater the proximity of both zones to the scheme and study area; and
- the greater the demand between the two zones.

Intra-zonal journeys not modelled

C.2.5 Transport models do not usually model intra-zonal trips, that is, journeys starting and ending within the same zone. However, these data are relevant to estimating productivity because they provide a full picture of how transport impacts on journey accessibility across the full affected area. Transport model zones should be disaggregated enough to minimise the number of intra-zonal trips and Intra-zonal journeys should be modelled where possible, although productivity may still be estimated if it is not possible to model intra-zonal trips.

Incomplete demand / generalised cost matrices

C.2.6 Another common instance where journey cost data are not available is where there is no recorded demand or generalised cost in the transport model. There are two common reasons for this: either there is negligible demand in reality, for instance where the distance between zones is large, or there is significant demand, but the flows are external to the study area so would not be directly affected by the interventions being modelled.

C.2.7 In either case, disregarding the flows can be acceptable for conventional user benefit calculations. In the latter case, ignoring the costs of movements between these zones can introduce a bias in the productivity assessment because the journey costs are important for correctly estimating agglomeration levels and the scale of changes in agglomeration that result from the intervention compared to the pre-intervention situation.

C.2.8 Depending on the accuracy needed and the mode and journey purposes represented by the missing data, there are three potential options for approximating generalised costs for missing inter-zonal journeys:

- in many circumstances the transport model can produce a full set of generalised costs, even if there is no demand. This is the preferred option; or
- extract data from other models that have better representation of the average journey costs between the relevant zones, if this is available; or
- use other non-modelled data sources and/or extrapolate from known costs for similar zone pairs in the model.

Insufficient segmentation of modes or purposes

C.2.9 Recommended inputs to the productivity assessment include transport model data, for two modes (private and public transport), segmented by two purposes; business and commuting (with freight in the sensitivity case). Considerable effort should therefore be put in to ensuring these segments are covered.

C.2.10 Where modes are not covered by the transport model, it may still be possible to estimate productivity, provided that the modes that are not modelled do not have a significant mode share within the study area.

C.2.11 For example, if public transport is missing, then the model will be a purely car based model. In this case, it may be necessary to estimate non car costs. However, at the Local Authority District level, public transport mode share would not always be significant outside major urban cores, so sometimes a pure car based approach might be sufficient. The appraisal would, however, need to justify the case for having a pure car approach; this should be explained in the Economic Narrative.

C.2.12 Where parts of the modal data are missing from the model (e.g. bus or coach), an adjustment can be made, by obtaining and using evidence on the share of the missing modes in the calculation of average generalised costs. This evidence might be obtained from alternative transport models and to achieve consistent GTCs non-modelled data sources might be utilised and extrapolated from.

C.2.13 Where user groups are not segmented into the required purposes (commuter and business as a minimum), productivity can be estimated using evidence of the proportion of journeys by purpose for each mode. Two steps are involved:

- Using evidence of purpose shares for each mode to disaggregate the demand matrices. It is essential here that the evidence of purpose shares takes account of differences by mode (e.g. lower proportion of business trips by bus than car) and differences by OD pair (e.g. lower proportion of commuting trips for longer distance journeys).
- Estimating the generalised cost by journey purpose based on the existing generalised cost data.

C.2.14 The best evidence on mode and purpose splits will need to be chosen on a case-by-case basis. The best source of such evidence would be another transport model where that is available. Other potential sources include Census Travel to Work data and the National Travel Survey.

Insufficient geographic modelling coverage and detail of geographic/spatial units used

C.2.15 As noted earlier in this section, the study area for estimation of agglomeration impacts should be limited to the area in which the modelling provides a good estimate of Base generalised costs and ATEM. Data on demand and generalised cost are required for all flows, whether they are affected by the modelled intervention or not.

C.2.16 Estimates of productivity impacts are likely to be misleading if they are estimated for areas for which the transport model does not provide a good representation of all the geographic areas. The transport model should be examined to provide assurance that the area for which productivity impacts are estimated is adequately represented by the transport model, and estimates from outside this area should be excluded from the overall estimate. Again, the reasoning behind these decisions should be included in the Economic Narrative.

C.2.17 For schemes modelling employment relocation, there should be an assumption of no additional employment from outside the modelled area.

C.2.18 In addition, as set out in Laird and Tveter (2023) the current TAG methodology for estimating agglomeration is susceptible to the Modifiable Area Unit Problem (MAUP), a phenomenon which occurs when aggregating spatial data which can be minimised but not eliminated. As a result, this may lead to upward biases in the estimated agglomeration benefits. Where this is possible, agglomeration calculations should be undertaken at a smaller level of spatial aggregation (i.e. below LAD level).[15]

[15] Please see Tveter et al (2022) Spatial aggregation error and agglomeration benefits from transport improvements for a deep dive into the MAUP issue.

Appendix D: Sectoral Aggregation Information from UK SIC(03)

D.1.1 The table below provides the necessary sectoral aggregation information from UK SIC(03) 2 digit classification to the five sectors used in the Wider Impacts estimates.

D.1.2 The most recent data for industrial classification can be found in SIC(07).[16] The changes made between the two indices would not lead to a significant impact in the agglomeration parameters calculated by Graham (2009), therefore the current sectoral aggregation is appropriate to use in the calculation of productivity impacts.

Table D1 Sectoral aggregation

SIC(03) 2 digits	SIC(07) sectors included 2 digits*	Description	Sector Group
15	10, 11	Food and Beverages	Manufacturing
16	12	Tobacco	Manufacturing
17	13, 14, 17, 33	Textiles	Manufacturing
18	14, 15, 32	Apparel	Manufacturing
19	15, 22, 32	Leather	Manufacturing
20	16, 32, 33, 41, 43	Wood	Manufacturing
21	17, 18	Paper	Manufacturing
22	17, 18, 58, 59	Publishing	Manufacturing
23	19, 20, 24, 38	Fuel	Manufacturing
24	20, 21, 26, 32	Chemical	Manufacturing
25	22, 27, 32, 33, 43	Plastic and rubber	Manufacturing
26	23, 33	Mineral	Manufacturing
27	24	Basic Metals	Manufacturing
28	1, 24, 25, 28, 32, 33, 41, 43	Fabricated Metals	Manufacturing
29	25, 27, 28, 30, 32, 33, 43, 95	Other Machinery	Manufacturing
30	26, 28, 33, 62, 95	Office machinery	Manufacturing
31	23, 25, 26, 27, 28, 29, 30, 33	Electrical machinery	Manufacturing

[16] http://www.ons.gov.uk/ons/guide-method/classifications/current-standard-classifications/standard-industrial-classification/index.html

32	26, 27, 28, 33, 95	Communications equipment	Manufacturing
33	26, 27, 28, 32, 33, 35	Medical instruments	Manufacturing
34	28, 29, 33	Transport equipment	Manufacturing
35	28, 30, 33	Other transport equipment	Manufacturing
36	13, 16, 17, 20, 22, 25, 26, 28, 29, 30, 31, 32, 33, 95	Furniture	Manufacturing
37	38	Recycling	Manufacturing
40	35	Electricity, gas and steam	Manufacturing
45	39, 41, 42, 43, 80	Construction	Construction
50	45, 47, 52	Motor trade	Consumer Services
51	10, 11, 46	Wholesale	Consumer Services
52	47, 95, 96	Retail	Consumer Services
55	55, 56	Hotels and restaurants	Consumer Services
60	49	Land transport	Consumer Services
61	50, 52	Water transport	Consumer Services
62	51	Air transport	Consumer Services
63	52, 74, 79, 85	Travel support	Consumer Services
64	53, 60, 61	Post and courier	Consumer Services
65	64	Finance	Producer Services
66	65	Insurance	Producer Services
67	66	Auxiliary financial	Producer Services
71	77	Machinery rental	Producer Services
72	33, 58, 59, 62, 63, 95	Computer related activities	Producer Services
73	72	Research and Development	Producer Services
74	2, 59, 63, 64, 69, 70, 71, 73, 74, 77, 78, 80, 81, 82, 85	Other business activities	Producer Services
75	81, 84, 91	Public Administration	Public Sector
80	85	Education	Public Sector
85	75, 86, 87, 88	Health and Social work	Public Sector

*Note: some SIC07 sectors are part of more than one SIC03 sectors. The correspondence table can be found here (“Correlation between UK SIC 2003 and UK SIC 2007”).

Appendix E: The Theoretical Approach to Productivity Impacts

Cities and agglomeration

E.1.1 There is a significant literature on the topic of why people cluster together in cities and towns. The world contains plenty of undeveloped, open space, but people and firms are willing to pay large premiums to locate within dense urban clusters. This is a result of the increasing returns which are derived from agglomeration economies.

E.1.2 The theory of agglomeration economies and why cities are formed is based on the notion that individuals benefit from being 'near' to other individuals, and firms benefit from being 'near' other firms and their input markets.

E.1.3 Literature on this subject generally describes three sources of agglomeration economies based on the work of Marshall (1890): labour market interactions, knowledge spillovers and linkages between intermediate and final goods suppliers. These sources can also be described as "sharing, matching and learning"[17] .

E.1.4 Agglomerations contain a large proportion of the population; the highest proportions of the population in urban areas are seen in developed countries (80%[18]) with the least in poorer countries (29%).

E.1.5 Agglomeration economies lead to productivity increases for the firms and workers involved. A firm which locates in an agglomeration will not only increase its own productivity, but lead to productivity increases for those around it. The productivity impact is thus an externality and during the appraisal process will be additional to any transport user benefits created by the transport investment.

Localisation and urbanisation

E.1.6 Literature generally distinguishes two ways in which productivity impacts are generated by an increase in agglomeration; localisation and urbanisation economies.

E.1.7 Localisation economies are those resulting from firms' proximity to other firms within the same industry. This allows for increased specialisation within industries where firms benefit from links to similar suppliers and the labour market, and knowledge spillovers.

E.1.8 Urbanisation economies, in contrast, are those resulting from an industry's proximity to other industries. Firms gain productive advantages from locating

[17] Duranton, G. and Puga, D. (September 2003); Micro-foundations of urban agglomeration economies
[18] World Bank databank, 2013

close to workers and firms in other industries. These benefits are derived from the scale of markets, proximity of inputs and outputs, and from general infrastructure and public service provision.

E.1.9 The elasticities and decay parameters calculated by Graham (2009) are based on firm accessibility to overall economic mass, meaning they capture the combined effects of localisation and urbanisation. This explains why Equation 2 applies industry-specific GTC values to the total level of employment. This estimates the ATEM experienced by each industrial sector, to which we then apply the agglomeration elasticities.

E.1.10 Graham (2007)[19] finds problems in "estimating distinct urbanisation and localisation impacts for highly urbanised sectors". Therefore we do not attempt to distinguish between urbanisation and localisation in the core scenario as this risks conflating impacts and double counting the productivity impact.

Transport and clustering

E.1.11 Transport investments can lead to changes in agglomeration and therefore influence productivity as they can reduce travel costs and affect how 'near' firms are to each other and their input and labour markets. These changes come about through two distinct mechanisms; static and dynamic clustering.

E.1.12 **Static clustering** is the mechanism which the productivity impact measures in the core scenario, assuming there is no change in land-use. Static clustering occurs when a transport investment reduces the effective distance between two firms by reducing transport costs, although the firms' locations remain unchanged. This leads to improved communication, trade and links between firms, which contribute to the agglomeration economies described above.

E.1.13 **Dynamic clustering** occurs when a transport improvement reduces costs, enabling economic activity to locate in a spatially concentrated way. This can come about by improving links to an area, enabling economic activity within the area to expand or by enabling the formation of concentrated 'clusters' of specialised firms such as the financial centre of the City of London or Silicon Valley.

Methodology justification: average generalised costs

E.1.14 The estimation of average generalised travel costs (GTCs) is a key component of the calculation of agglomeration impacts. There is not one clearly correct method for all cases. The TAG recommended approach (see section 3.2) is to calculate mode specific GTCs (for all purposes). However, in certain contexts this method can produce distorted results and an alternative approach may be considered that uses trip weights to calculate one GTC for all modes and purposes.

[19] Graham, D.J. (February 2007); Identifying urbanisation and localisation externalities in manufacturing and service industries

Example 1 - A policy to encourage mode shift

E.1.15 A policy may be introduced that intends to shift people from using private modes to more costly public modes; in turn relieving congestion on the private road network and encouraging more people to travel to a particular locality. If more people are now using the higher cost mode then the single trip-weighted GTC will increase. If, as intended, more people are now travelling to a particular locality, we would expect there to be positive agglomeration effects. However, the single trip-weighted GTC method will calculate disagglomeration effects. The TAG recommended approach of mode-specific GTCs will calculate the expected positive agglomeration effects.

Example 2 - A policy when mode shares are unequal

E.1.16 A policy may be introduced that changes the GTCs associated with a mode used for only 10% of trips to a particular locality. Using mode specific GTCs where each mode is weighted equally, regardless of mode share, will calculate inflated agglomeration effects. A change in ATEM for a mode with a 10% share of trips would have the same impact as a similar change in ATEM as a mode with a 90% share of trips, despite the policy influencing a much smaller number of trips. Using a single trip-weighted GTC may mitigate against producing distorted results. However, caution should be exercised when using the single trip-weighted GTC given its tendency to produce counter-intuitive results. In such instances, scrutiny of the use of fixed or variable base and scenario trip weights may help resolve the problem.

E.1.17 In the case of schemes that add new modes, please speak to the Department for Transport to agree a sensible approach.

Methodology justification: ATEM

E.1.18 As mentioned in E.1.9, the work done by Graham et al to calculate the elasticities and decay parameters for TAG used measures of economic mass to find the impact of agglomeration on productivity. This resulted in parameters which capture the impact of changes in the overall economic mass of productivity.

E.1.19 Equation 2, which calculates the ATEM of each industrial sector, uses employment data for the total area, for all industries. By applying industry-specific decay parameters to total employment the equation captures the total ATEM for each industry.

Methodology justification: specification of agglomeration parameters

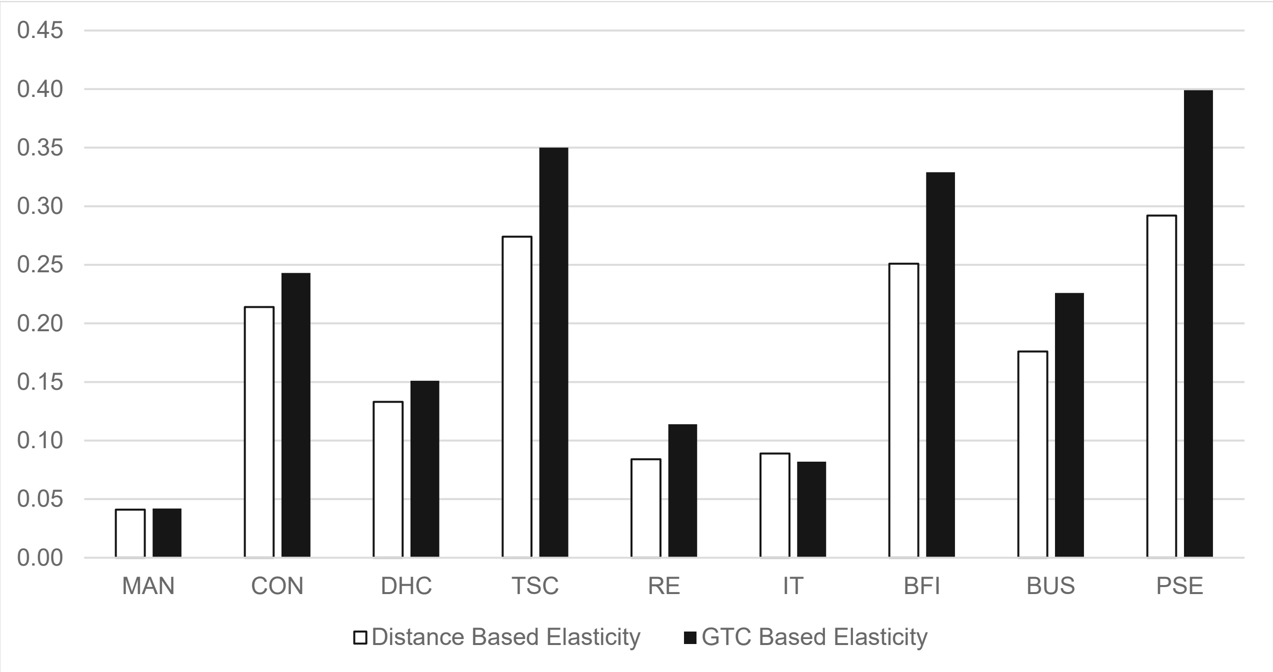
E.1.20 The estimation of agglomeration elasticities on the basis of straight line distance as opposed to generalised travel costs (GTCs) is considered an acceptable approach. This is because there is little significant difference between the results of these two alternatives approaches. Figure 2 compares the two approaches to calculating elasticities calculated by Graham[20] for the UK. The results were broadly similar with the distance based elasticities generally slightly smaller. The most significant difference was in public services, for which TAG assumes nil elasticity.

- There are reasons to believe the GTC based elasticities could be upwardly biased, but the level of bias is unknown:
- There is a risk of double counting congestion impacts when using a GTC-based elasticity. GTC measures of ATEM capture the diseconomies of congestion, therefore reducing congestion would increase the ATEM. However, reductions in congestion are already captured through user benefits.

E.1.21 There is also an issue of endogeneity arising from the relationship between transport infrastructure and productivity. The existing level of transport is partly dependent on demand, which is in turn dependent on productivity. It is possible that the level of productivity in an area leads to an increase in infrastructure and thus ATEM, and not the other way around. Therefore a GTC-based measures may potentially overestimate the elasticities.

E.1.22 The agglomeration parameters used in TAG were calculated using a distance-based measure of ATEM. This was done due to the broad similarity with distance based elasticities and to avoid double counting and endogeneity issues which could potentially arise when using a GTC-based measure of ATEM.

Figure 2 Comparison of elasticity measures[21] for the UK, as calculated in Graham (2006)



[20] Graham, D.J. (December 2006); Variable returns to agglomeration and the effect of road traffic congestion
[21] Sectors: manufacturing; construction; distribution, hotels and catering; transport, storage and communication; real estate; IT; banking, finance and insurance; business services; public services.

Methodological justification: Agglomeration ramp-up

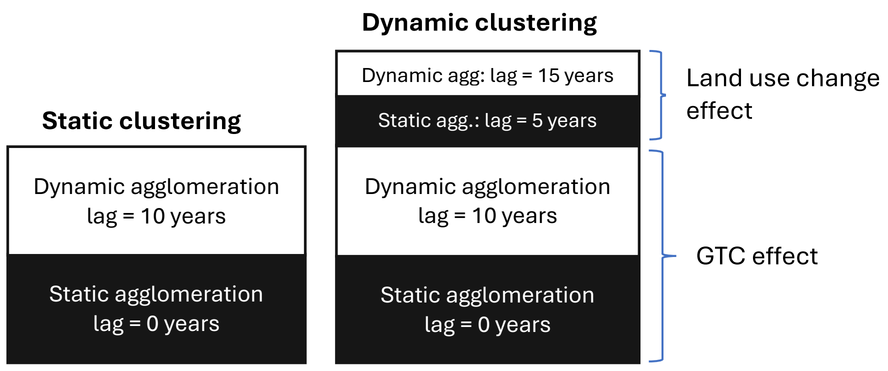
E.1.23 Laird and Tveter (2023) explains that there is likely to be a long ramp up before agglomeration economies appear. This is due to a time lag for the dynamic effects to fully feed through (e.g. learning), whereas static agglomeration mechanisms (e.g. matching or sharing) occur instantaneously. Evidence suggests dynamic agglomeration mechanisms may be around 50% of the total agglomeration impact and take up to ten years to fully appear following a worker's relocation.

E.1.24 It is important to distinguish between static and dynamic agglomeration mechanisms, and static and dynamic clustering. Static clustering is where ATEM changes due to changes in generalised travel costs (GTCs). Dynamic clustering is where there are additionally changes in land-use and employment location, which cause further changes in ATEM.

E.1.25 In contrast, the terms static and dynamic agglomeration refer to different underlying agglomeration mechanisms (e.g. sharing, matching and learning). Static clustering leads to agglomeration impacts via both static and dynamic mechanisms.

E.1.26 Dynamic clustering, where estimated, will subsume and include static clustering impacts, and also operates via static and dynamic mechanisms. Paragraphs 2.6.6 recommends dynamic clustering impacts are broken down into two components: (i) the change in productivity due to GTC driven changes in ATEM; and (ii) the change due to land-use and employment location effects. Figure 3 below sets out the different ramp ups for each element as described in Laird and Tveter (2023), noting that a simpler approach is adopted in TAG.

Figure 3 Ramp up of agglomeration benefits as set out in Laird and Tveter (2023)



E.1.27 Because a simpler approach is deployed (as set out in section 4.2), there is a risk of overestimating the dynamic clustering component of the benefits. This is because there are frictions between the land-use effect (e.g. the worker moving from one city to another) and agglomeration economies forming as set out in Laird and Tveter. In addition, at least some of the effect occurs on scheme opening. This is because there may be pre- scheme opening effects (mostly relevant to the largest schemes), and because dynamic clustering includes static clustering. This is why TAG recommends the additional use of land use change lags as set out in paragraph 4.2.4.

Methodological Assumptions

E.1.28 There are a number of assumptions made in the methodology described in this unit. Some of these which haven't yet been mentioned are described below. Their aim is to simplify the process of calculating productivity impacts so that it is a manageable task. From a theoretical perspective reducing the number of assumptions can be desirable but this guidance is designed with practical applications in mind.

E.1.29 By not taking into account the time at which trips occur, the methodology described in this unit assumes all time periods are equal with regards to productivity. In reality, the different time periods are likely to contain different breakdowns of journey purposes. For example, the morning and afternoon peak are more likely to contain commuter trips, and the inter-peak period business trips. By not differentiating between periods, the assumption is made that these trips are equally important to productivity.

E.1.30 The methodology also doesn't represent the impacts of various trip purposes on productivity; the same elasticity is applied for trips of all purposes. This assumes that each business or commuting trip is as important for productivity as the next.

E.1.31 The elasticities in this unit lack context-specificity with regards to geographical scope as they were calculated on an overall basis for the UK. Research has demonstrated that agglomeration elasticities vary by urban area and city size. Therefore in the context of schemes in individual cities the broad elasticities may not accurately capture the full productivity impact.