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Transport Appraisal and Economic Density – Conceptual Economic Framework

Final Report

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1. Introduction

This document sets out the Conceptual Economic Framework (CEF) for the scoping study aimed at large-scale re-estimation of the agglomeration parameters applied in the Department for Transport (DfT) Transport Analysis Guidance (TAG).

The core aim of this report is to provide a critical assessment of the current economic model used to calculate Wider Economic Impacts (WEIs) of agglomeration in transport appraisal, with particular focus on potential sources of overlap with other elements of appraisal.

Alongside, the report presents a brief review of the literature on consumption externalities to explore the possibility of including these effects within the current TAG framework.

1.1 Context

The re-estimation of the agglomeration parameters applied in TAG is needed because:

1. The currently used parameters were estimated in the late 2000s while better data sources, such as highly disaggregate data on origin-destination travel flows, have become available since then.

2. There is an opportunity to rely on state-of-the-art econometric tools, especially when it comes to treating endogeneity concerns, which are widely recognised in the agglomeration literature. In relation to this objective, it will be beneficial to inscribe the entire empirical exercise in a potential outcomes causal inference framework for a start.

3. Several concerns have been expressed in the literature with regards to some technical features of the studies underpinning the current TAG. These issues need to be addressed, also in light of technical improvements that have been proposed so far. Key concerns include: the structure and components of the Access To Economic Mass (ATEM) measure; potential differentiations of the agglomeration elasticity (e.g., sectoral, geographical and distance-dependent); the distinction between urbanisation and localisation economies; the type of outcome measure (whether total factor productivity or wages); the type of impedance measures (e.g., generalised costs, travel times and distance); and the nonlinearity of the agglomeration-productivity relationship.

4. Concerns need to be addressed in relation to the potential exclusion of the stock of transport infrastructure in calculations.

5. The recent spatial economics literature has generated evidence on the importance of consumption externalities as foundations of agglomeration. The re-estimation project should explore whether and how these additional benefits could be represented as WEIs in appraisal.

1.2 Scope

This CEF assume the core appraisal model of TAG does not change. That is, while the empirical methodology behind the estimates should be improved in the re-estimation study, the partial equilibrium nature of the appraisal model and the fundamental assumptions behind additive wider economic impacts will not change.

This is particularly important in the context of double counting. It is acknowledged that TAG's extended partial equilibrium model where the wider economic impacts of transport interventions (that is, TAG Level 2 & 3 impacts) are derived as additive elements to the direct welfare effects (TAG Level 1 impacts) might not be effective to rule out double counting. However, this is taken as a constraint to the re-estimation research, which will aim to find the ideal empirical method accordingly.

1.3 Objectives

The objectives of the report are to:

1. Explain the economic framework underlying the current TAG practice on the economic appraisal of agglomeration economies.

2. Describe the potential channels of overlap between the three categories of WEI that are assessed in UK appraisal.

3. Comment on the inclusion of consumption externalities in appraisal.

The report is structured as follows. The first section describes the three key elements of the economic model of TAG that are relevant to the calculation of agglomeration related WEIs. The second sets out the challenges that arise due to integration of these elements in an additively separable manner. The last section summarises the recent literature on consumption externalities, and provides a preliminary assessment on whether these effects can be included within the current TAG framework as an additive effect.

2. Three mechanisms of the TAG appraisal model

The current economic framework underpinning TAG derives the welfare impacts of transport interventions as *additive* elements. These elements are the outcomes of partly or fully separated economic models. This section focuses on three models which are particularly relevant to the calculation of agglomeration-related WEIs:

- The transport model which establishes the direct user benefits and transport-related externalities of the intervention (TAG Level 1 impacts)
- The agglomeration model through which we expect that the wider agglomeration benefits can be quantified, and (TAG Level 2 and 3 impacts)
- A spatial model from which we derive any further externalities related to the spatial reorganisation of economic activity, that is, the relocation of firms and households (TAG Level 3 impacts).

These mechanisms are first described here, whereas Section 3 describes potential interferences between the models and the empirical challenges these create in the empirical estimation of agglomeration related WEIs.

Figure 1 depicts a schematic representation of the most common methodology behind the calculation of direct transport user benefits and externalities. At the heart of this mechanism there is a transport model which derives the equilibrium travel cost and demand after the transport intervention in a three-step iterative process.

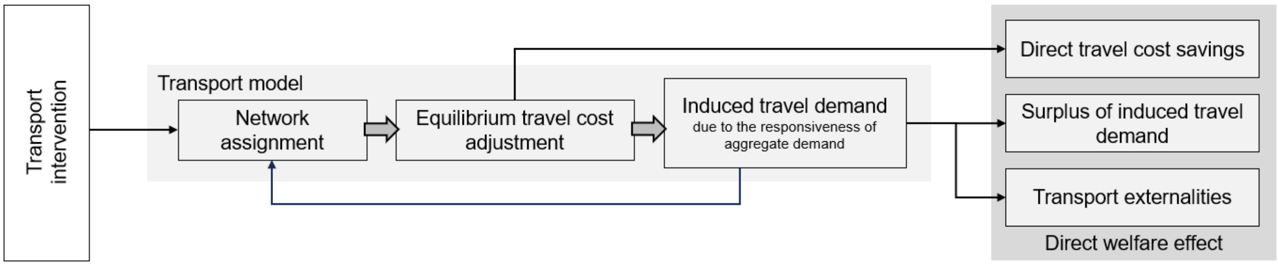
First, using the estimated impact of the policy on the travel cost experienced on a limited number of links within the transport network, a mode and route assignment algorithm models the redistribution of demand in the entire network.

Second, based on the reassigned travel volumes, a new travel cost can be calculated for each link in the network. This step implies that travel impedance changes theoretically everywhere in the network, not just where the intervention happened.

Third, in response to the network-wide readjustment of impedance, the transport model derives induced demand, i.e. the volume of additional travel that the new transport costs on the network imply. More specifically, we get a new travel demand matrix.

The change in the demand matrix will affect mode and route choice shares again, and thus the three steps above are repeated until the iterative process converges to a new equilibrium *in the transport market*.

Figure 1. Quantifying direct welfare effects through the transport model



After convergence, the transport model yields three measures used in economic appraisal. The direct travel cost savings of those who travel before as well as after the intervention are an outcome of the equilibrium travel cost matrix. In principle, this includes travel time savings in road use and a potential reduction in crowding inconvenience in public transport.

From the combination of change in travel cost and demand levels, the additional benefit of induced demand is derived assuming a linear demand curve and using the well-known rule of half in most of the cases. From the volume of induced demand, the transport externalities (for example pollution, accidents, etc.) and the indirect tax- and fare-revenue effects associated with the newly generated vehicle miles are calculated.

The second mechanism considered is the agglomeration model depicted in Figure 2. Transport improvements reduce the impedance between various actors in the spatial economy and thus they increase the effective economic density of the locations affected.

The first aim of the agglomeration model is to derive the change in access to economic mass for each location using information on the travel cost reduction delivered by the policy. In the second step the analyst predicts the change in firm productivity in response to the increase/reduction in access to economic mass, for each location. This calculation is supported by the agglomeration elasticity; that is, the elasticity of firm productivity with respect to economic mass, the core empirical relationship at the focus of the current project.

From the predicted change in productivity the economic model of TAG derives the wider economic impact of agglomeration. At this stage, no distinction is made yet between static and dynamic effects in the agglomeration model, assuming that in an ideal appraisal model they could be handled jointly.

Figure 2. The agglomeration model

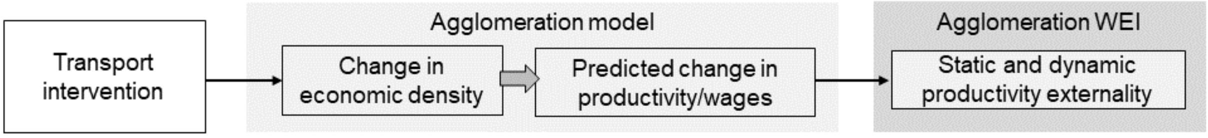
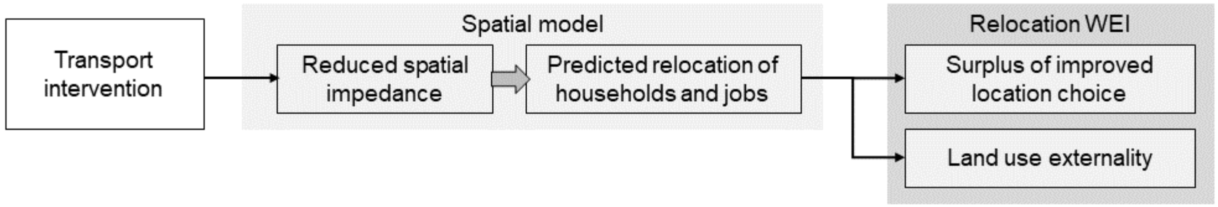


Figure 3 which outlines the flowchart of a spatial model of firm and household relocation. Once again, the key hypothesis is that transport improvements reduce the cost of travel between distinct geographical locations, and the reduction in impedance is known to the analyst. The purpose of the spatial model then is to predict the transformation of urban form in response to the policy, that is, the pattern of firm and household relocation in space.

Figure 3. The spatial model of firm and household relocation



In this dynamic representation of the spatial economy the transport improvement enables households to perform activities in locations that they prefer to their previous locations. In practice, this normally means a more ideal separation of residential and workplace locations as local amenities and economic conditions (e.g. wages, housing prices) rarely offer perfect conditions for leisure and work-related activities at the same place. The surplus households gain from improved location choice is the first wider economic impact included in Figure 3.

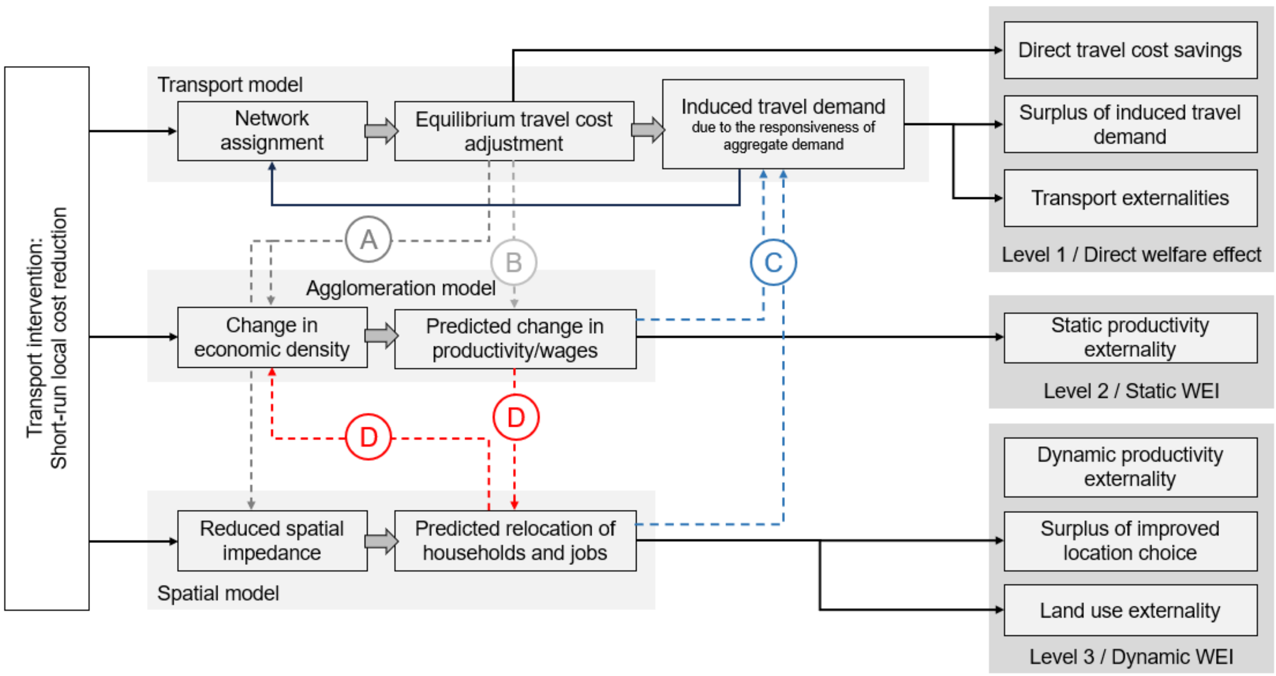
At the same time, relocation affects land use as well, and the spatial reorganisation of economic activity may generate additional externalities as well. Ignoring spillovers in the transport sector at this stage, such externalities may include negative (loss of green space, more energy consumption in more spacious homes) as well as positive ones (agglomeration economies through greater variety in consumption). More generally, relocation affects the spatial pattern and thus the cost of the provision of public services and the supporting infrastructure, as discussed in more detail in Section 3.3. of the Scoping Study.

3. Methodological challenges of measuring agglomeration impacts

The transport, urban and environmental economics literatures provide an abundance of tools to model the three mechanisms above *separately*. However, combining these channels of policy impact assessment into one integrated framework in which the three groups of welfare effects remain additively separable is a challenging task. (Note that additive separability is an implicit consequence of the decision that DUBs are modelled in partial equilibrium.) The main challenge is the presence of interdependence between the inputs and outputs that the three models rely on or produce. In the presence of spillovers, it becomes increasingly difficult to preserve the additive separability of welfare effects.

Figure 4 combines Figure 1 to Figure 3 such that the transport, agglomeration and spatial models remain identifiable as they were introduced above via the horizontal linkages indicated by solid arrows. In this graphical representation, spillovers between the three impact channels can be visualised as vertical linkages between some of the values flowing across three models. These are indicated by dashed lines in Figure 4. Furthermore, the main outcomes of the economic appraisal enlisted on the right side of the figure are now regrouped according to the levels they belong to in the TAG framework.

Figure 4. Combination of the transport, agglomeration and spatial models in an integrated framework



It is possible to identify four potential sources of overlap that create potential theoretical and/or empirical challenges; these are marked by upper case letters from A to D. The rest of this section explains these vertical linkages and the related methodological challenges in separate subsections.

3.1 Defining the change in access to economic mass

Link A connects the 'equilibrium travel cost adjustment' in the transport model with the 'change in economic density' in the agglomeration model and 'reduced spatial impedance' in the spatial model. The key source of confusion here is that the network-wide transport cost matrix changes between various stages of the transport modelling process and it is unclear which transport cost matrix should be used when the agglomeration gains are appraised.

ATEM can be calculated assuming a travel cost reduction only on the links directly affected by the policy, ignoring the subsequent reorganisation of traffic in the network. This may be considered as the change in ATEM in the very short run. Allowing for more adjustment in mode and route choice, another travel cost matrix and a new vector of ATEM values would result for each location. When the trip generation and trip distribution stages of the classic 4-stage model are also active during demand modelling, there are further margins of adjustment leading to induced demand. The stage-of-the-practice is that trip generation is mostly muted, but the trip distribution stage is aften enabled in TAG-based appraisal exercises. Given that induced demand builds up gradually, and short to medium to long run aggregate demand elasticities are different, the transport model may generate a range of different predictions for the change in ATEM.

The economic interpretation of the short-run change in ATEM is rather different from a long-run adjustment. When a long-run demand prediction is applied (as it is often the case in practice), the presence of induced demand implies that the economic potential unlocked by accessibility is already exploited by those who decide to travel. In this case it is more likely that a fraction of the agglomeration benefit is part of the newly induced consumer surplus as well (see Section 3.2 below for more detail). Note that this overlap in benefits is never complete. As long as higher productivity (higher wages) affects workers who do not use transport at all, a part of this benefit remains an externality.

This double counting threat is more limited when the very-short-run change in ATEM is applied. However, it remains questionable whether that state can be considered as an equilibrium, even within the transport market. This question is relevant because appraisal is a comparative static exercise; thus, it assumes equilibria by definition.

The issue of short-run versus long-run change in ATEM is relevant from an empirical point of view as well. When the agglomeration elasticity is estimated from first-differenced or longitudinal data, the gap between time lags may affect the magnitude of the estimate. Intuition suggests that the assumptions applied in the empirical model and the appraisal application should be consistent in this respect.

Link A has a branch pointing to 'reduced spatial impedance' in the spatial model. Our concerns are very similar to the previous discussion: It is tempting to rely on a spatial model that predicts land-use effects from a long-run traffic equilibrium. However, this creates confusion in the appraisal model because this equilibrium travel cost may be contaminated by new traffic volumes induced via channels unrelated to location choice.

3.2 Internal and external benefits of improved accessibility

Recall that that the agglomeration model creates a link between the change in ATEM and its impact on firm productivity or labour productivity reflected in competitive wages. Firm productivity (e.g. total factor productivity), in turn, is estimated from the relationship between the quantity of inputs and the firm's output.

Note that firms in an urban area are also transport users, so that transport/infrastructure services themselves are also a production factor. Thus, a reduction in transport costs may impact output through two channels: (i) by lowering the price of one of the inputs and thus increasing the profit-maximising output, and (ii) by increasing ATEM and making firms more productive through agglomeration externalities.

Because transport costs and ATEM are systematically linked to each other, the external and non-external impacts of transport improvements on firm productivity are hard to disentangle in an empirical model, causing confounding bias in the estimation of the agglomeration elasticity. This creates an endogeneity concern from an empirical point of view and a threat of double counting in the appraisal exercise. This link between the equilibrium travel cost and firm productivity is indicated by Link B in Figure 4.

3.3 Multiple channels of induced demand

Link C denotes potential ambiguity around the way induced travel demand is taken into account in appraisal. The main threat is that beside the reorganisation of traffic after the intervention, further demand may be induced as a result of firm productivity gains (agglomeration model) and household and firm relocation (spatial model).

The threat of double counting is most obvious in case of the additional demand induced by relocation: In principle, the economic impact of relocation should appear as a Level 3 benefit in the appraisal exercise where the 'surplus of improved location choice' (in other words, the value of an improved choice set in location-related household and firm decisions) should include the benefit of longer commutes. However, if induced travel demand in the transport model also includes the extra miles of longer commutes, then part of the 'surplus of induced travel demand' on Level 1 is double counted.

A similar concern emerges in case of agglomeration: after the transport improvement, firms that become more productive generate more travel demand, turning their productivity gain into higher levels of activity. This induced demand should not be counted twice, both as a direct user benefit (Level 1) and an agglomeration externality (Level 2). In the transport model, the volume of induced demand is governed by (i) trip generation, trip distribution, mode and route choice decisions in a 4-stage model, or (ii) aggregate demand elasticities. The analyst needs to consider whether the demand model is a short-run or long-run representation of reality, i.e. what dataset was used in the underlying empirical models.

3.4 Static and dynamic agglomeration externalities

Finally, Link D signifies the obvious challenge that static and dynamic agglomeration economies are very difficult to disentangle empirically. In other words, when we observe an increase in productivity in parallel with an increase in ATEM, it should be known to what extent this is due to an improvement in individual firms' productivity or the replacement of less productive firms with more productive one as part of their relocation in space.

This threat is primarily econometric but it also has an impact on appraisal outcomes as the Level 2 static agglomeration benefits are likely overestimated if the empirical model ignores firm relocation and spatial sorting.

Furthermore, the predicted change in productivity may have a feedback effect on the location of firms and households, causing yet another source of double counting between Level 2 and 3 benefits – see the vertical link labelled "D" in Figure 4. Note, however, that TAG assumes that Level 3 dynamic agglomeration benefits encompass static agglomeration, so there is no need in practice to additively separate these quantities.

4. Consumption and amenity benefits

4.1 Definitions

Sections 2 and 3 above covered agglomeration economies related to firm productivity. Intuition and a growing body of empirical evidence suggests that not only firms are affected by improved accessibility: effective economic density may also translate into amenities (or disamenities) that make urban areas more (or less) attractive for workers and residents.

Based on these premises, it is a natural question whether at least a part of the change in amenity levels are separate from the net benefit directly perceived by transport users and thus the associated economic spillovers should be accounted for in transport appraisal. The spatial economic literature distinguishes two broad groups of consumer-side agglomeration economies that are relevant to be defined separately in this report.

The first group includes positive *consumption externalities* which reflect that urban density enables residents to consume a greater variety of non-tradable goods and services at lower prices. When non-tradable services must be consumed where they are produced but transport is costly within a city, households have an incentive to locate close to service providers. By improving access to a location where consumption takes place, the range of locally available services increases and prices may also fall due to spatial competition.

Glaeser et al. (2001) attribute the rise of consumption-centric urban cores to this mechanism. From a partial equilibrium perspective, greater product variety and lower monopoly mark-ups can be considered as an externality as residents who do not use transport services may also perceive some of the associated benefits. At the same time, a double counting concern is present in this channel of agglomeration because at least a fraction of transport users may enjoy these benefits. Thus, their willingness to pay for transport services captures the fact that their utility from consumption increases with their ability to travel to high-density destinations. Note the parallels of this concern with the matching benefits of productivity externalities.

The second group can be labelled as *amenity spillovers*. This agglomeration mechanism reflects the fact that the attractiveness of urban locations for residential and other activities may depend on the surrounding economic density irrespective of the local price and diversity of consumption possibilities. For example, public spaces in dense urban areas may be equipped with more advanced facilities such as street lighting, paved roads and pedestrian infrastructure, and other amenities.

Moreover, proximity to others increases the possibility and quality of human interactions which may affect wellbeing. This phenomenon is similar to knowledge spillovers, one of the well-known micro-foundations of the productivity literature, but it relates to non-work activities. The perceived amenity stemming from urban density is likely heterogeneous among urban residents. Some individuals may experience discomfort as a result of a dense built environment and frictions with others. Therefore, the net value of amenity spillovers is not necessarily positive.

Based on these definitions, Section 4.2 covers the existing empirical evidence while Section 4.3 reviews existing models that can serve as a basis for incorporating amenity effects in the economic framework of transport appraisal.

4.2 Empirical evidence

The review of the literature estimating the consumption value of agglomeration suggests that direct empirical evidence on this theme remains scarce. One of the first attempts come from Couture (2016) who provide an estimate of the gains from variety in the US restaurant industry. Using travel data and detailed online microgeographic data on local businesses available via Google Places, Couture (2016) developed a framework to identify an individual's willingness to pay for access to a preferred location from the extra travel costs that they incur to reach it.

Based on their estimates, Couture (2016) calculated the aggregate welfare gains from product variety in the US to be approximately 2% of consumer expenditures on travel. A major limitation of Couture (2016)'s approach is that they take as given both the location of the origin of trips and the set of destinations, whereas density matters partly because it changes the set of potential venues and, as a result, possibly alters the choice of residential location.

More recent attempts to valuating the consumption benefits of agglomeration such as Ahlfeldt and Pietrostefani (2019) and Miyauchi et al. (2021) are based on spatial general equilibrium models that are discussed in the next sub-section.

In another study, AitBihiOuali (2022) proposed an empirical strategy to calculate the amenity benefits of cities in the Midlands and the North of England. Building upon the theoretical framework of Glaeser et al. (2001), AitBihiOuali (2022) suggested that at spatial equilibrium, the valuation for urban amenity can be expressed as the difference between urban rent and urban wages. However, such valuations comprise other impacts of agglomeration including innovation, decreased travel speeds due to congestion, and reduced pollution and energy use, that are already partly captured in TAG and, therefore, creates the threat of double counting impacts. For a detailed list of impacts of agglomeration, see Ahlfeldt and Pietrostefani (2019).

4.3 Economic models of amenity/consumption benefits and their compatibility with appraisal

The review of the literature suggests that combining traditional productivity externalities with consumption externalities has been an open challenge in recent years and Moon (2022) is likely the first attempt which achieved that.

Moon (2022) develops a spatial general equilibrium model based on Anas and Kim (1996) and Lucas and Rossi-Hansberg (2002) with the following features. (i) Households consume a variety of both tradable and non-tradable goods. (ii) The production of urban goods involves agglomeration (urbanisation) economies, so firms have an incentive to cluster in close locations within the city. (iii) Households must travel in a congestible transport network to access non-tradable services. They have an incentive to form dense residential areas close to the producers of non-tradables because this allows them to access a greater variety.

Moon (2022) explores the impact of the strength of the two agglomeration forces on urban spatial structure. This model would be suitable to compute the welfare effect of transport improvements in the presence of consumer externalities but the paper's focus remains on urban form.

Would it be possible to turn Moon's model into a structure similar to Venables (2007), which provided the primary justification for the calculation of productivity benefits in TAG? There is no trivial solution in this respect. The key simplifying assumption of Venables (2007) is that urban production takes place in one location (the 'CBD') and, due to perfect competition and the production and labour markets, any improvement in productivity is capitalised in wages.

This assumption turned out to be acceptable in light of the monocentric city tradition in urban economics. By contrast, consumption externalities assume love of variety in the location of consumption and the main channel through which agglomeration benefits households is an increase in variety. Thus, the monocentric city model is not suitable to capture this externality.

An appraisal-oriented economic model which is more tractable than Moon (2022) requires significant research efforts, and even if that investment is made, compatibility with TAG's partial equilibrium framework cannot be guaranteed.

Amenity spillovers can be measured as well as predicted for counterfactual policy scenarios in quantitative urban models hallmarked by Ahlfeldt et al. (2015) and a series of follow-up papers. Quantitative urban models are spatial general equilibrium models in which households' decisions on residential and workplace locations are endogenous.

Ahlfeldt et al. define the attractiveness (amenity) of discrete locations as a numerical variable that can be quantified using observed economic outcomes such as commuting patterns and the spatial distribution of wages and floorspace prices. Then they decompose the location-specific amenity levels into a part that can be explained by access to economic mass and a location fundamental determined by geographical characteristics. This approach offers a suitable structural method to estimate the elasticity and distance decay of amenity externalities and then apply the model in the appraisal of counterfactual policy scenarios.

However, as mentioned above, quantitative urban models feature general equilibrium as opposed to the partial equilibrium framework of TAG. The contribution of amenity spillovers to welfare is not additively separable because household utility is a nonlinear (multiplicative) function of the amenity value. This means that, using this model, one cannot prove that a partial equilibrium application of the estimated elasticity is free from the double counting concern.

5. Conclusions

This report reviewed the economic framework underlying the current TAG practice on the economic appraisal of agglomeration economies.

The economic model of TAG derives the welfare impacts of transport interventions as *additive* elements that are the outcomes of three partly or fully separated models: (1) a transport model measuring the direct user benefits (DUBs) and transport-related externalities of the intervention, (2) an agglomeration model quantifying the wider agglomeration benefits, and (3) a spatial model measuring other externalities related the relocation of firms and households.

It is necessary that agglomeration effects reflect, as far as possible, a pure externality scale effect, net of the effects of other transport cost attributes (for instance, time and money costs) that potentially scale with economic density, proxied by ATEM.

However, there are potential spillovers between the above models that pose significant challenges to the empirical estimation of agglomeration related WEIs. These challenges and the related questions that the Scoping Study will seek to address are summarised below:

1. Changes to economic density (ATEM) for the estimation of agglomeration benefits are quantified from the predicted equilibrium travel cost after the intervention, which contains induced demand from various sources. This may introduce a bias because induced demand is governed by a feedback effect of cost reduction, and even agglomeration benefits themselves. The question that arises is: How should ATEM be measured such that the influence of time-based productivity effects generated via cost reduction can be avoided?

2. Firm output might be affected through channels other than changes in density. For instance, firms use transport as a production factor and thus a reduction in the equilibrium transport cost implies higher output even without agglomeration. This may lead to possible double counting between direct travel cost savings and productivity externality. If both the externality and non-externality attributes are changing systematically with density (ATEM) in the same direction (e.g. increasing), and they have the same general effect on productivity (e.g. creating gains), it is possible to distinguish them empirically? What econometric adjustments can be applied to deal with this issue? Are they foolproof? Is there a need to redesign the fundamental approach used to calculate WEIs of agglomeration?

3. Transport interventions may induce new travel demand via three channels: direct cost reduction, agglomeration benefits, and relocation. It may be incorrect to account for all these benefits as Level 1 DUBs as this may lead to double counting of impacts. It is therefore critical for the analyst to understand the data underlying the estimated demand curve for Level 1 DUBs.

4. Relocation affects economic density. Appraised Level 2 WEIs need not to capture relocation effects (sorting by productivity). How are relocation and sorting adjusted for in empirical calculations?

This report also reviewed the growing literature on the consumption and amenity benefits of agglomeration. Spatial general equilibrium models can deliver elasticities of amenity value with respect to access to economic mass. However, the contribution of amenity spillovers to welfare is not additively separable. Therefore, application of these elasticities in partial equilibrium framework of TAG may lead to double counting of impacts. The scoping study will seek to identify the estimation approaches that minimise this effect or provide better clarity on the range that double counting might cover.