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Supplementary Guidance
Appraisal Of New Modes

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Transport Analysis Guidance (TAG)

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This TAG Unit is part of the family **Supplementary Guidance**

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1. Introduction to the appraisal of new modes

1.1 Defining new modes

1.1.1 As set out in TAG Unit A1.3 - User and provider impacts, user benefits in the general case are appraised using the so-called 'Rule of a Half' (RoH), which provides an estimate of the change in consumer surplus in the market for travel following a change in generalised cost (GC). A pre-requisite for applying the RoH is that the number of trips and associated generalised cost are known in both the Do-Something (DS) and Do-Minimum (DM) scenarios.

1.1.2 The fundamental issue in the case of new (or removed) modes is that either the DM or DS GC is not readily available. In theory, for adding a new mode, the relevant DM GC which needs to be fed into the RoH is the smallest GC which would lead to zero demand if the mode were available in the DM (this is sometimes called the 'reserve price', and is the price where the demand curve meets the cost axis). Usually, this GC will be substantially greater than the DS GC, necessitating the use of numerical integration.

1.1.3 At its simplest, a new mode (or sub-mode) is one that is introduced into the DS but does not exist in the DM. Taking rail as the most common example, in the simplest case, without the scheme, rail does not exist as an option; there are no viable lines or stations via which to travel. Therefore, in the DS, rail must be treated as a genuinely new mode.

1.1.4 However, other, slightly more complex cases may also require a 'new mode' methodology:

- The mode exists in the DM but only for certain origin-destination (OD) pairs; in the DS the mode is then extended to serve other ODs in a different area. As travel by this mode has become a viable option for these ODs (whereas there was no demand in the DM by definition), it should be treated as a new mode in the DS.
- The mode exists in the DM but the cost for some ODs is so high that it is not used (or very rarely). An example might be two nearby towns, rail travel between which in the DM involves a significant detour via a major interchange, but which have a direct rail link built in the DS. Again, the existence of new mode trips in the DS requires specific attention in the appraisal; the methods contained in this guidance are valid approaches to consider in these cases.

1.1.5 Note that in some models, it may be possible to avoid having to treat (for example) rail as a 'new mode' even if new stations and lines are opened. This usually requires demand to be modelled on a zonal (rather than station to station) basis, with a deterministic representation of station choice. In this case all zone pairs strictly have rail 'available' as a mode, even if the access/egress requirements are onerous. In addition, rail could be treated as a public transport (PT) sub-mode, with demand allocated to it deterministically as part of the assignment process[1].

1.1.6 Where the choice of public transport submodes (bus, guided bus, light rail transit (LRT), rail) is handled as part of the assignment process, there may be an explicit mode choice mode that predicts the car/PT split but the choice between, say, bus and LRT is handled in essentially the same way as the choice between two alternative bus routes.[2] Typically a matrix of PT trips is input to the assignment and a matrix of PT costs output. Because inter-modal trips (i.e. the use of more than one PT mode) can be modelled, it may not be possible to obtain separate trip or cost matrices by PT submode. In terms of inputs to Transport User Benefits Appraisal (TUBA), such a model can therefore only provide matrices for a generic PT mode.

1.1.7 Dealing with new PT submodes in such an arrangement is mostly straightforward. For the DS the new submode and its route(s) are coded into the PT network and then the model is run as usual. PT costs can be obtained for the DM and the DS and the new mode problem identified above does not occur.

1.1.8 The lack of matrices by submode places limitations on a TUBA appraisal, for it means that user benefits and operator revenues cannot be calculated for each submode separately. In particular the costs and benefits for the new submode cannot be separated from the costs and benefits associated with any changes for existing submodes.

1.1.9 Economic parameters for a generic PT mode should be calculated from the TAG Data Book (e.g. Table A1.3.1 for working values of time) using local values for the mix of demand (e.g. bus/rail split) in the modal areas.

1.1.10 When applying such an approach in TUBA, the new submode should not be identified as a new submode in the economics file. A further challenge occurs if the existing submode has charges associated with it, as may be the case when LRT users all switch from bus. In this case the change in operator revenue by submode will not be correct, although the net change across all modes and the user charge benefit will be correct. This can be partially overcome by making sure that the DM charge and the DS charge are specified as separate types (e.g. bus fare in the DM and LRT fare in the DS). The TUBA output tables will then produce the change in revenue by charge type, from which the correct change in charge type by submode can be calculated. The Transport Economic Efficiency (TEE) table can then be modified manually if required. However this solution is only technically valid in the extreme case where there one new

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[1] Note, handling PT submode choice in assignment only avoids the 'new modes' problem if there is an alternative PT option in the DM for a given OD pair. If the new mode introduces a PT offer whereas previously there was none, the problem still arises.

[2] Where stochastic PT assignment is undertaken, please contact tasm@dft.gov.uk for advice on skimming costs for input to TUBA.

submodes takes all its demand from one other pre-existing submode (e.g. all LRT users switch from bus).

1.1.11 Such modelling approaches are potentially appealing methods to circumvent some of the challenges of appraising new modes. However care should be taken to demonstrate that deterministic station and/or sub-mode choice is a reasonable assumption and consistent with observed behaviour. An agent-based method may also assist in representing the choices and user decision-making when a mode is introduced. For more details, see TAG Unit M5.4 – Agent-based methods and activity-based demand modelling.

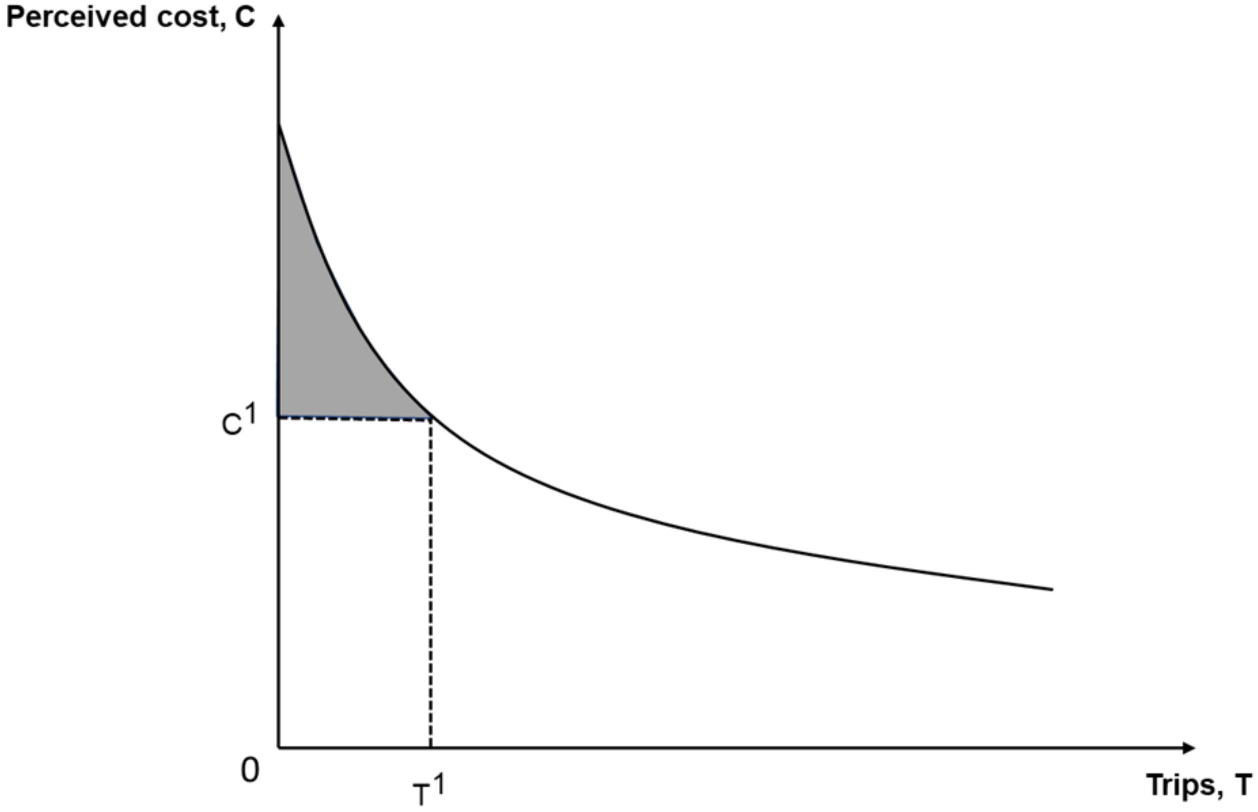
1.1.12 Note, while this guidance is explained in terms of new modes, the methods presented can also be used 'in reverse' to appraise taking away a mode. The most common anticipated application of this guidance is for appraising new rail lines and stations, but there may be other cases of new modes where it is relevant. For example, introducing a new technology which creates a radically new transport option, or introducing tram/light rail in a city which currently has none. If an intervention generates a qualitatively different travel choice that cannot be modelled deterministically within a combined mode assignment[3], then the guidance contained in this document should be considered relevant.

1.2 The 'new mode problem'

1.2.1 Theoretically, estimation of the consumer surplus for a new mode is based upon estimating the shaded area shown in Figure 1. However, where a mode is new in the DS, there is no observable cost for this mode in the DM (the demand is zero by definition). Estimating this consumer surplus requires the analyst to extrapolate the demand curve until it meets the cost axis, which comes with significant challenges, particularly when using a non-linear demand function, such as a constant elasticity function. The Rule of a Half (RoH) cannot therefore be easily applied in cases of new modes.

[3] As opposed to a scenario in which there is perfect correlation between alternatives in the choice nest, the mode choice sensitivity parameter (lambda) tend to infinity and the choice is purely deterministic (i.e. based upon the lowest cost option). In this situation a combined mode assignment can be justified

Figure 1 Consumer surplus of a new mode



1.3 When the issue arises

1.3.1 Problems arise for the conventional RoH whenever elements entering the calculation are unavailable. For new modes, this normally occurs in the DM, but can also occur in the DS (e.g. closure of a station).

1.3.2 For the highway mode, new links will generally be part of an overall route (except in the very unlikely case of a zone without existing road access), and since route choice is almost always deterministic, no problems arise. Likewise, improving service levels for existing PT modes will not lead the new modes issue, but rather can be handled within existing guidance. Issues are most likely to occur for rail, and particularly with new stations. However, there may be other examples such as adding new and innovative travel options, such as micro-mobility and autonomous vehicles as alluded to above.

1.3.3 Where multiple new stations are opening, which may be to some extent complements or substitutes for one another, this inter-dependence should be accounted for within the analysis. The simplest approach is to calculate the benefits of each new station incrementally, by successively removing them from the DS network. For example, you could first calculate the benefits associated station A, and then work out the benefits associated with station B *conditional* on station A already having been removed.

Standard modes with zonal structure

1.3.4 Where models have a zonal structure, with a stochastic station choice model (SCM), adding a new station can be handled in broadly one of two ways:

1. Link the new station to the DM network in a way which delivers near zero demand for the station, for example (a) using a walk (i.e. access) link to the nearest existing station or (b) linking the station to the DM rail network with a link cost high enough to deliver around 2% of DS demand from that station. This provides the 'pseudo-DM' cost on a link basis, which then feeds into the costs for choices in the demand model.

2. For each OD pair (ij), and for each combination of origin station (R), destination station (S), access (x) and egress (y) mode, which involves the new station, increase the overall GC to deliver around 2% of DS demand for that *ixRSyj* combination.

1.3.5 The key difference between the two is that approach (1) defines a single 'pseudo-DM' cost for accessing the new station, which then feeds into the cost for all *ixRSyj* combinations involving the station in the DM, whereas approach (2) estimates a different pseudo-DM cost for each *ixRSyj* combination. The first approach is likely to be easier and quicker to implement, but either approach is acceptable; see Section 3.4 for more detail on defining relevant costs for the pseudo-DM. The 'alternative mode' approach to appraisal, detailed later in this document, is unlikely to be a viable basis for calculations when a stochastic SCM is used, given the need for diversion factors across multiple dimensions (*xRSy* combinations).

1.3.6 When using approach (1), it will usually be more appropriate to link the new station directly to the rail network with a sufficiently high cost (approach 1(b)) rather than linking to an existing station with an access cost (approach 1(a)). This is because the difference between the pseudo-DM cost and DS cost will then be defined in terms of rail Generalised Journey Time (GJT) and fare, rather than access or egress (A/E) costs, which is intuitive since A/E costs are usually unchanged by the scheme.

1.3.7 If the cost of a station pair is deterministic, the problems above can be avoided, since travellers will choose the least cost pair in both DM and DS cases and the new station is simply treated as unavailable in the DM case. This is akin to the highway treatment of new links above.

1.3.8 Where the model has no SCM, access to rail for certain OD movements may be very inconvenient, so that there is zero (or immaterial) demand in the DM. Similar to the SCM case above, the choices here are to:

1. Link the new station to the DM network with a link cost high enough to deliver around 2% of DS demand from that station.

2. Increasing GC to deliver around 2% of DS demand, on an OD basis.

1.3.9 Either approach is acceptable so long as it delivers negligible DM demand (i.e. around 2% of DS demand).

1.3.10 Adding a 'realistic' link to the existing network, such as a walk link to an existing station, does not guarantee that the DM demand for the new station will be negligible. Therefore, this approach is not recommended. In particular, it has been found that when the new station is close to an existing station it may be allocated too much use in the DM. In general, the analyst’s focus should be on finding the smallest pseudo-DM cost needed to yield around 2% of DS demand, however this is done.

1.3.11 It is recognised that defining different pseudo-DM costs for potentially thousands (or more) OD pairs will not always be practical. Therefore, it may be preferable to seek the 2% of DS demand on a link rather than OD basis, or to use a common pseudo-DM cost (or cost increment) for all choice combinations involving the new station(s) (whether that is OD pairs or *ixRSyj* combinations).

1.3.12 The approach (whether OD, choice or link-based) should be verified to check that it delivers around 2% of DS demand across each OD pair with non-trivial daily DS demand. If this is the case, and appropriate numerical integration has been undertaken, the results should be sufficiently robust. Care should be taken to ensure that there are enough intermediate points to capture benefits accurately on all affected ODs/choice combinations.

Station-station models

1.3.13 In some cases, it will be decided that the effort of constructing a standard zonal model is disproportionate, or data requirements insurmountable. Many existing rail models, developed using tools such as MOIRA, are primarily based on station-station demand.

1.3.14 In these cases, it is still in principle possible to construct a pseudo-DM in the same manner, but the only available means by which to do so is incrementing the DS station-station cost to achieve negligible demand. It is not possible to ‘connect’ stations to the network. However, it may still be proportionate to define a common pseudo-DM cost (or cost increment) for all relevant station-station pairs, as discussed above.

1.3.15 The 'alternative mode' approach, detailed later in Section 4, is most likely to be appropriate where uni-modal, station-station demand modelling has been undertaken.

2. Methods for appraising new modes

2.1 Available methods

2.1.1 Where a mode can be considered 'credible' in the DM (i.e. if there is non-trivial demand on a daily basis and the generalised cost is not excessive), there is no need to use the new mode appraisal guidance and the standard RoH methodology applies. If DM demand is of a negligible (or zero) volume, the mode cannot be considered credible in the DM and alternative methods are required.

2.1.2 Given the challenges of appraising new modes accurately, there is no one approach in the existing literature that offers a proportionate and credible method in all cases. Instead, two broad approaches are recommended, depending upon the DM availability of alternative modes. These approaches may need to be amended to the specifics of the case in question, depending on factors such as a data availability, and the context of locally available modes. The two methods are:

1. Calculating a 'pseudo-DM' level of cost which would suppress trips on the new mode to near-zero, and then applying RoH calculations in the usual way (with numerical integration). This is termed the **own-cost (OC) approach**, and is currently implemented within TUBA.

2. Appraising changes in generalised cost for specified groups of switchers, based on the difference in generalised cost that each group using the new mode experiences, compared to their DM travel choice. This is termed the **alternative mode (AM) approach**.

2.1.3 Each of the two approaches outlined above can be used to provide validation or a sense-check of the other, although noting the need for analysis to remain proportionate. The AM approach relies on (i) the availability of relevant modal diversion factors; and (ii) being able to specify a large proportion of modal utility within generalised cost, leaving as little as possible in the 'error' term. By comparison, the OC approach relies closely on the assumptions implicit in the demand model. For example, where a multinomial logit model for mode choice is used, the OC approach assumes individuals' unobserved modal utilities follow a Type 1 Extreme Value (Gumbel) distribution.

2.1.4 Table 1 below provides a summary of the benefits and challenges of both methods. Section 5.1 contains more information on factors to consider when choosing a methodology for appraisal.

Table 1 Summary of methods for appraising new modes

	Alternative Mode approach	Own-Cost approach
Benefits of approach	Does not require an explicit demand model	Approach more consistent with underlying demand modelling, especially where mode choice is represented in the model
	Analysis based directly on estimates of pre-scheme and post-scheme travel choices.	Where demand forecasts are well-calibrated and validated, approach is most consistent with underpinning demand model
	Able to reflect relative journey quality between modes more explicitly, without modifying a demand model	Requires inputs from a single-mode only for appraisal, although generally the costs of competing modes are required in estimating the pseudo-DM cost, in the underlying modelling
	Intuitive approach with a more direct link to likely strategic objectives for mode-shift interventions	Always produces a positive benefit, implicitly reflecting individual variation in modal preferences
Challenges of approach	Wider range of inputs required, from parameters (e.g. diversion factors) to demand (across multiple modes)	Requires specific assumptions to approximate full demand curve, which can be subject to error and lead to overly high benefits
	Required to extrapolate demand curve for pure generated trips	Reflecting relative preferences for journey time spent on each mode robustly generally requires reflecting them in the demand model, which may be challenging
	Assumes ability to capture all elements of modal utility (including Alternative Specific Constants) within generalised cost, otherwise wrong-sign benefits can occur	Typically will not predict a material proportion of pure generated trips, contrary to diversion factor evidence for shift from/to 'no travel'

3. The Own-Cost (OC) Approach

3.1 Summary of approach

3.1.1 The own-cost approach follows the work of Nellthorp and Hyman (2001)[4], who proposed an extension to the RoH framework to account for those situations where the RoH loses accuracy. One of these scenarios is the introduction of

[4] Nellthorp, J., & Hyman, G. (2001). Alternatives to the rule of a half in matrix-based appraisal. Proceedings of European Transport Conference.

new modes in the DS, and to provide a viable alternative to the standard RoH in these cases, Nellthorp and Hyman propose an OC approach, focused on the market for the new mode in question[5].

3.1.2 Taking rail as an example again, the approach can be summarised as:

1. Considering the rail market only, generate a forecast of DS trips (at OD or station-to-station level), given expected GCs.

2. Given this, generate an estimate of what GC would need to be for the number of rail trips (in the DM) to be near-zero[6]. This produces a so-called 'pseudo-DM', with an estimated level of trips and costs (T^0 and C^0 in Figure 2; see below for more details).

3. Treating this pseudo-DM as a 'regular DM', estimate the user benefits following standard appraisal guidance using the RoH (see [TAG Unit A5.3 - Rail Appraisal]() for more details). Given the size of cost change from DM to DS, this will likely require the use of numerical integration.

4. Using linear interpolation, calculate the **remaining** 'triangle' of user benefits between the pseudo-DM and the cost axis. This uses the following formula:

$$Benefit = \frac{1}{2}T_0(GC_{int} - GC_0) = -\frac{1}{2}T_0^2\left(\frac{GC_0 - GC_A}{T_0 - T_A}\right)$$

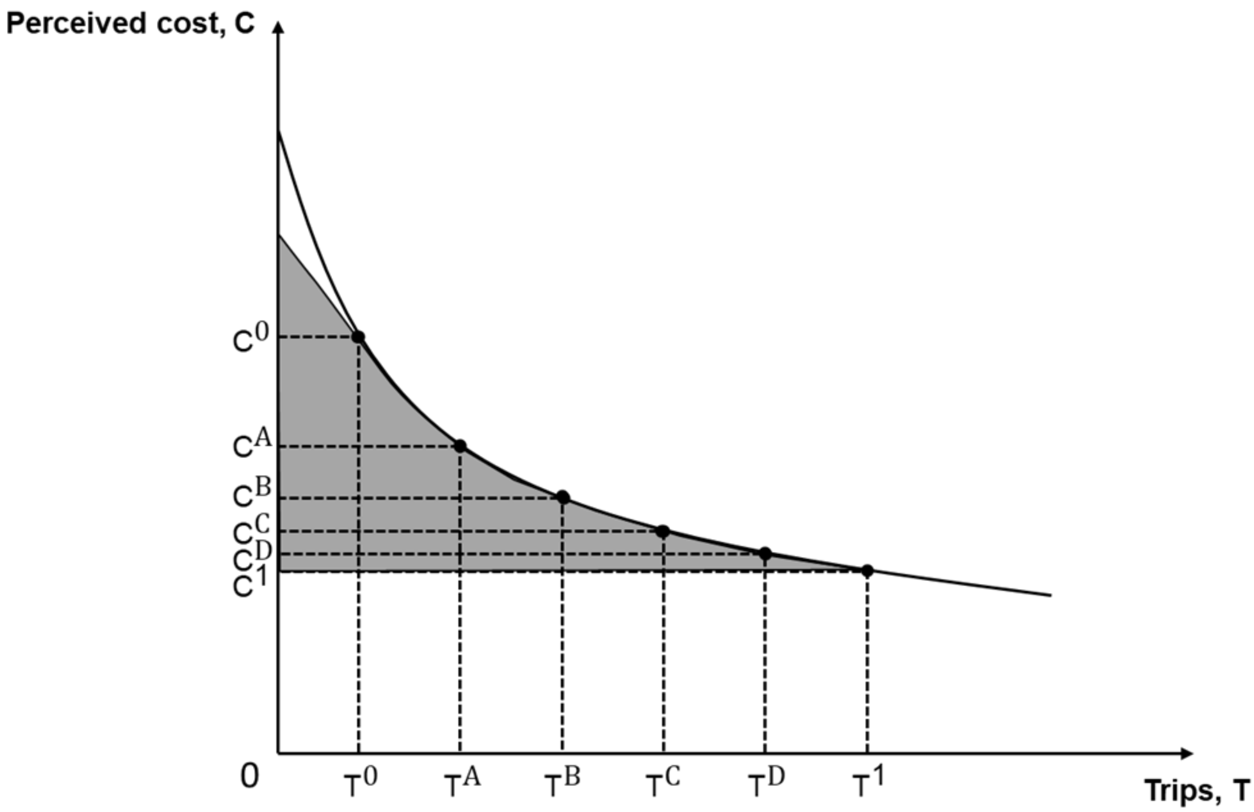
5. The GC intercept is given by $GC_{int} = GC_0 - gradient \cdot T_0$. The gradient is estimated from the change in cost and demand between the pseudo-DM and the next modelled point down the demand curve (denoted point A) as $gradient = \frac{GC_0 - GC_A}{T_0 - T_A}$.[7]. This can also be broken down into sub-components of GC if desired, as with the regular application of RoH.

[5] Nellthorp and Hyman (2001) consider a number of solutions, including those presented in the Common Appraisal Framework. See: MVA, Oscar Faber TPA, University of Leeds (1994). Common appraisal framework for urban transport projects. Department for Transport and Birmingham City Council.

[6] This estimate should be grounded in the transport modelling approach, and the Values of Travel Time (VTT) associated with this. By contrast, the monetised user benefits estimation (steps 3-5 of the above) should use appraisal VTTs.

[7] Usually point A will be an intermediate point, given use of numerical integration. Where NI is not used, point A will simply be the DS.

Figure 2 Own-Cost appraisal with numerical integration



3.1.3 The OC appraisal approach therefore only requires inputs relating to a single mode. However, in general the costs of competing modes are needed to estimate the pseudo-DM cost, within the transport modelling. Please refer to Table 1 for a summary of the benefits and challenges of each approach.

3.1.4 Because of consistency with the underlying demand modelling, where multimodal modelling is carried out, the OC appraisal approach should be used.

3.1.5 In principle, when applying the OC approach with multimodal models it is possible to capture purely generated trips using the new mode in the DS, provided that the demand model has a trip frequency component. Often, frequency response is omitted from multimodal models as it is far less material and relevant than other demand responses, for most policy decisions being appraised. However, evidence from diversion factors (e.g. RAND, 2018; Clark & Parkin, 2022) tends to suggest a role for trip frequency responses, even where all modes are considered (including active travel). The guidance presented here is applicable regardless of whether frequency has been modelled, but consideration should be given to including a trip frequency component in the demand model. This is likely to improve the realism of results.

3.2 Defining the 'pseudo-DM'

3.2.1 Generating the pseudo-DM data is a question of finding a set of costs which, when passed through the demand model, give very low (but non-zero) OD flows using the new mode, the aim being to find a point on the demand curve that is close to (but not on) the cost axis. In principle, this approach can be used with either uni-modal or multi-modal demand models.

3.2.2 Finding the pseudo-DM cost that will produce the correct number of trips for a credible user benefit estimation is ultimately a task of defining a potentially arbitrarily high cost level, and hence can prove challenging to estimate and verify. Following Nellthorp and Mackie (2001)[8] we recommend that the pseudo-DM demand has around 2% of the DS number of trips. Finding the corresponding cost that gives rise to this demand is partly a matter of trial and error. However, an initial estimate can be found from the DS GC using the following approximation, undertaken at OD level:

$$GC_0 \approx GC_1 (\frac{E - 0.98}{E})$$

3.2.3 where E is the elasticity of the demand function at the DS[9] and GC is the generalised cost in the relevant scenario (see below for further detail on defining costs). While many appraisals will consider multiple DS scenarios, analysts should adopt a proportionate approach when defining the pseudo-DM, choosing one DS scenario as the basis for defining the pseudo-DM GC (rather than having multiple pseudo-DM GCs for each DS tested). Once the pseudo-DM cost has been defined, it can then be retained across all scenario appraisals, for convenience and consistency.[10]

3.2.4 With E expected to typically fall in the range –0.1 to –0.5, this would give DM costs of between approximately 3 and 10 times the DS costs. As discussed in the following section, it generally considered better that there are too many trips in the DM rather than too few, and therefore 3 times the DS cost is recommended as the starting point. If the pseudo-DM cost is estimated to be in excess of this, please contact TASM@dft.gov.uk before using the results for appraisal.

3.2.5 If the pseudo-DM cost is significantly higher than for DM modes with very little demand, or significantly less than for DM modes with significant demand, the analyst should be able to clearly explain this in terms of (un-modelled) perceived quality differences between modes (note, this can also include travellers' inherent preferences for different modes). A higher pseudo-DM cost could in principle be justified if alternative travel options are of poor quality, while a lower pseudo-DM cost could be justified if the new mode is of relatively poor quality. Similarly, these cases could be justified if there is significant unobserved variability in individual preferences.

[8] Nellthorp J. and Mackie P. (2001). Alternatives to the rule of a half in matrix-based appraisal. Institute for Transport Studies, University of Leeds, Final report to DETR.
[9] This approximation is based on the DS point elasticity of demand. An exact equation involving the arc elasticity of demand can also be derived. However, the arc elasticity of demand increases substantially when the DM number of trips is close to zero and it is not possible to state beforehand what value it will take between the DS and the correct pseudo-DM.
[10] This is merely a practical convenience. In theory it should not affect the results significantly whichever DS is chosen to pivot off, as there is a single underlying demand curve as shown in Figure 1.

3.3 Considerations for uni-modal models

3.3.1 When using a uni-modal model, the OC method is reliant on a more simplistic representation of demand, which does not directly account for the availability and cost of competing modes. Although this is generally acceptable for incremental changes in supply, to find a pseudo-DM cost the uni-model typically needs to be stretched far outside of the range of costs over which it was estimated. This introduces additional uncertainty. If there is sufficient evidence to implement it, the AM approach may be more suitable where uni-modelling has been undertaken.

3.3.2 Particular care should be taken when defining the pseudo-DM for constant elasticity demand functions, which tend to generate extremely high cost levels as the demand curve approaches the cost axis. The extrapolation of constant elasticity functions in this way is **not** recommended. A semi-elasticity function should be used instead, as this will produce a much more realistic pseudo-DM cost, more in line with the logit demand function used in multi-modal modelling.

3.3.3 The semi-elasticity function can be calibrated to produce the required constant elasticity at the DS level of demand and cost as follows. The appropriate constant elasticities can be taken from the rail forecasting guidance in [TAG Unit M4 - Forecasting and Uncertainty] and/or the Passenger Demand Forecasting Handbook (PDFH).

$$D = \alpha e^{bGC}$$

3.3.4 Where α is some constant, b is set equal to E/GC_{DS} where E is the required constant elasticity in the DS.[11] This can then be used to 'pivot' from a given DS point to a pseudo-DM. For example, to retrieve the cost giving 2% of DS demand:

$$D_0 = 0.02D_1$$

$$\begin{aligned}
&\Leftrightarrow \alpha e^{bGC_0} = 0.02\alpha e^{bGC_1} \\
&\Leftrightarrow bGC_0 = \ln 0.02 + bGC_1 \\
&\Leftrightarrow GC_0 = \frac{\ln 0.02}{b} + GC_1 \\
&\Leftrightarrow GC_0 = GC_1\left(1 + \frac{\ln 0.02}{E}\right)
\end{aligned}$$

3.3.5 As above, the analyst could contact TASM@dft.gov.uk before using a pseudo-DM cost greater than 3 times the DS value, even though in principle this could be justified in certain circumstances.

[11] Simple algebra shows that this yields the required elasticity *E* from the semi-elasticity function where $GC=GC_1$, as required:

$$\eta_{D,GC} = \frac{\partial D}{\partial GC}\frac{GC}{D} = b\alpha e^{bGC}\frac{GC}{\alpha e^{bGC}} = bGC = E\frac{GC}{GC_1} = E$$

3.3.6 Compared to the AM approach, this could potentially give noticeably larger benefits. Where uni-modal models are used, it is therefore recommended that sensitivity testing is undertaken and the results from both the OC and AM methods are presented.

3.3.7 This approach may also lead to overly large benefits for very long distance trips. In such cases,to try and mitigate this, it may be more prudent to calculate the pseudo-DM on a link basis as discussed earlier, and/or consider the potential for longer distance GC elasticities to be greater in magnitude than for short distance flows.To some extent larger benefits are expected for longer disance trips, as they are likely to be of greater value.

3.4 Defining relevant costs for the pseudo-DM

3.4.1 It is recommended that the above process of estimating the appropriate costs for the pseudo-DM is undertaken using **total GC, covering all components of cost, including fare**. In rail modelling in particular, this could entail conversion of costs to GC to run the above process, or equal proportionate increments of GJT and fare could be used.[12] One exception is access and egress costs. As discussed earlier, these are unlikely to be affected by a new station, so should not be increased to obtain the pseudo-DM cost. Rather, equal proportionate increments of the cost elements associated with the rail leg (e.g. GJT and fare) should be used instead.

3.4.2 The appropriate pseudo-DM cost may vary between OD pairs and purposes, depending on the modelling structure. When running the demand model, the costs used for the other modes should be the DS costs.

3.4.3 The individual components of the DS cost should be increased by the same factor in the pseudo-DM, i.e. the relative size of the individual components remains the same. The total new mode benefit should not be literally interpreted as broken down into different components (e.g. time, cost, fare). Only the total result (change in consumer surplus) is unambiguous.

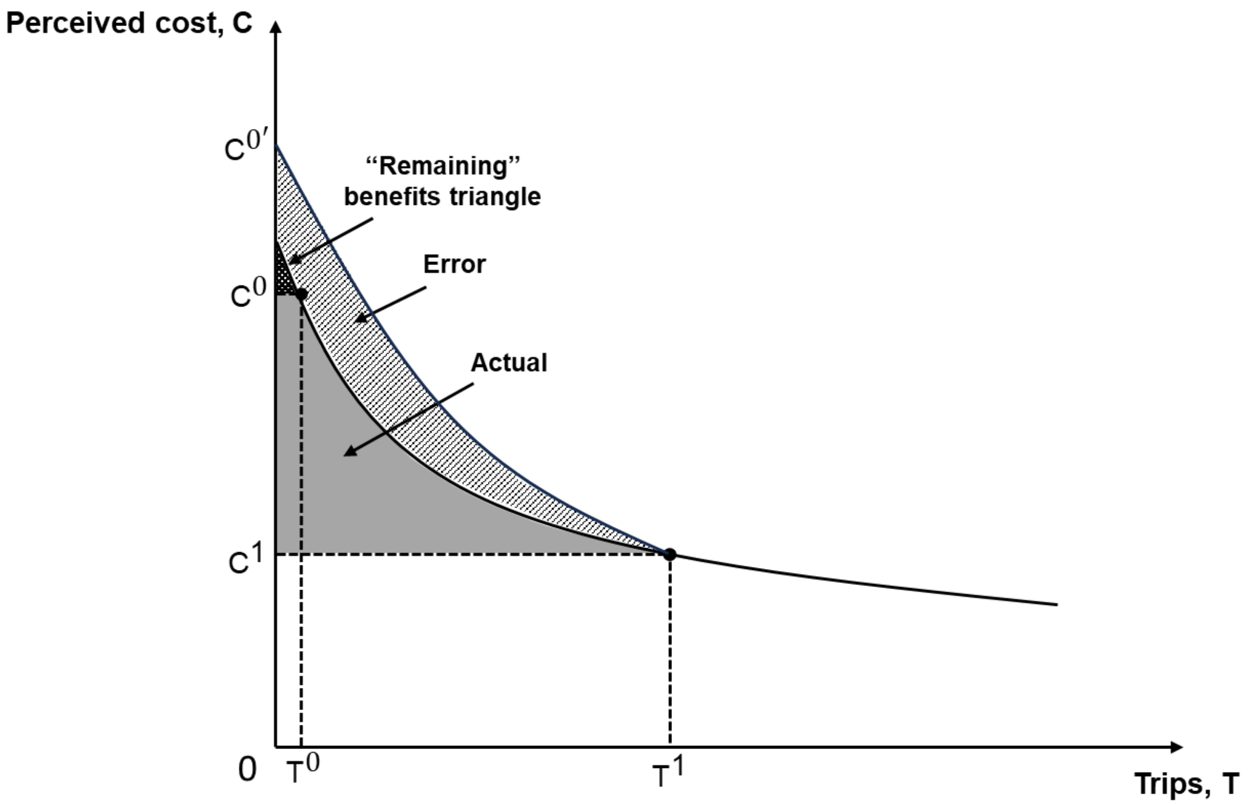
3.5 Minimising sources of error

3.5.1 When setting the pseudo-DM costs, steps should be taken to ensure that all ODs have a non-zero level of trips. This is to avoid the risk that costs are set too high, resulting in an overestimation of benefits - this is shown in Figure 3, where a pseudo-DM cost level of C^0 is used to avoid the overestimation of benefits that would result from setting the pseudo-DM cost level as $C^{0'}$. Given the difficulty in verifying whether a cost that gives a zero demand is the lowest cost that will achieve this objective, it is recommended at all ODs have some non-

[12] It should be noted that, unlike with the use of GC, using separate components (such as GJT and Fare) can lead to slightly different benefit calculations depending on the order in which these components are incremented and how much each is incremented by in total. This does introduce some arbitrariness into the results, and hence the recommendation of equal proportionate increments should always be followed to ensure consistency across appraisals.

zero level of trips (for example T^0 in the below figure); in general it is better to have too many trips in the pseudo-DM than too few.

Figure 3 Overestimation of new mode benefits resulting from inappropriate pseudo-DM



3.5.2 There is also a risk where demand curves are asymptotic to the cost axis, where very high costs will give a very low (but non-zero) number of trips and benefits will again be overestimated.

3.5.3 Note that demand curves are usually convex near the cost axis, meaning the triangle method will tend to slightly underestimate this part of the consumer surplus, provided the pseudo-DM is not too close to the axis. Making sure that the pseudo-DM is not too close to the cost axis will therefore tend to provide a conservative estimate of benefits.

3.6 The OC approach and numerical integration

3.6.1 Using the methodology described above will likely lead to very large cost changes between the pseudo-DM and the DS, requiring the use of intermediate points (see Section 3.1). This is particularly the case given the focus of the OC approach is on the part of the demand curve that is likely to be highly non-linear (the section nearest the Y axis). Where proportionate to calculate, at least 3-5 intermediate points are recommended[13] for new modes (in addition to the pseudo-DM), in order to provide a better approximation of the demand curve.

[13] Nellthorp J. and Mackie P. (2001). Alternatives to the rule of a half in matrix-based appraisal. Institute for Transport Studies, University of Leeds, Final report to DETR.

3.7 Considerations and uncertainty

3.7.1 The OC approach requires a trial-and-error approach to estimating the pseudo-DM, as well as challenges in validating the assumptions used. As a result, where possible, analysts should assess and communicate the sensitivity of the user benefit estimation to the specific approach taken. Additionally, where multi-modal modelling has not been carried out, triangulation using the AM approach may offer a sense-check on outputs.

4. The Alternative Mode (AM) Approach

4.1 Summary of approach

4.1.1 Ojeda-Cabral, Batley and Johnson (2021, 2023)[14] propose a method for examining new modes that is based upon observing the change in time and costs experienced by identified groups of travellers, relative to their previous (DM) choice. Hence the AM approach considers the GC of a different mode in the DM, and compares this with the GC of the new mode in the DS. The benefit is the difference between the two GCs.

4.1.2 As noted earlier, the AM approach is only likely to be justified where uni-modal demand modelling, with no representation of station choice, has been undertaken. In these cases, it may be a helpful and pragmatic alternative to the OC approach, although it is based on quite different underpinning assumptions.

4.1.3 An important assumption of the AM approach is that all elements of utility of travel by each mode are captured within the GCs used. In principle this should include any alternative-specific constants or mode-specific values of time associated with each mode, as well as any other relevant quality factors or time multipliers. If it is not possible to quantify all (or most) of these within the GCs used for the benefit calculations, then the results from the AM approach are likely to be unreliable. Note, it is also possible to include quality factors and time multipliers when using the OC approach, but ideally they would be integrated into the demand model as well.

4.1.4 Purely generated trips, that is those made by users who did not make any trip in the DM, are assumed to get half of this benefit on average as a simplifying assumption. Under the AM approach, their benefit cannot exceed the difference between the two GCs (or they would have already travelled in the DM) and it cannot be less than zero (otherwise they would not travel in the DS). Therefore, on average, half the benefit is a reasonable assumption.

[14] Ojeda-Cabral, M., Batley, R., and Johnson, D., Rail Openings Appraisal, Review and development of appraisal practice for new railway lines, stations and services, Final Report; RSSB, November 2021

4.1.5 The method presented here is termed the 'reduced' AM method, as it treats travel by rail and bus as a composite good called 'travel by public transport'. This is based on the approach of Sugden (1972),[15] as described in Ojeda-Cabral and Batley (2023).[16]

4.1.6 Taking rail as an example, the AM method can be summarised as follows:

1. Undertake rail demand forecasts for the DS (see TAG Unit M3.2 - Public Transport Modelling and PDFH for relevant guidance).

2. In the DM, rail is not considered a credible option for travel. Instead, assume bus is considered to be a credible option between the relevant OD pairs. Apply appropriate diversion factors (see below for more detail) to the DS rail forecast to estimate DM bus demand diverted to rail, with the remaining portion of DS rail demand being either 'pure generated' (i.e. did not travel in the DM) or switching from another mode such as car. Define each component of GC (e.g. fares, user charges, in-vehicle time (IVT), access/egress and any multipliers for crowding etc) for both modes.

3. Consequently, GC estimates for both modes can be generated. It is recommended that, where possible, the same components of GC are used for both modes, to maximise comparability.

4. Calculate transport user benefits via the RoH, where travellers that switch from bus to rail (from DM to DS) receive the full benefit (as existing users of public transport), while newly-generated rail trips and trips switching from car get half the benefit of bus 'switchers'[17] via the usual RoH mechanism. Transport user benefits consist of several components, such as time and cost, that must be derived separately, and then combined. For each segment, the time component of RoH is given by the following expression, where the subscript *bus* denotes the mode being switched from for that segment, in this case bus.[18]

$$Time\ benefit = 0.5 \times (T_0 + T_1) \times \left(Time_{bus} - Time_{rail} \times \frac{Mult_{rail}}{Mult_{bus}}\right) \times \frac{VTT_{bus} + VTT_{rail}}{2}$$

$$Money\ benefit = 0.5 \times (T_0 + T_1) \times (Charge_{bus} - Charge_{rail})$$

5. Where T0 and T1 represent trips in the DM and DS (note that T0 is the number of trips diverted from bus to rail, and T1 is the total number of trips by rail in the DS), Time_mode represents the travel time relating to a given

[15] Sugden, R. (1972). Cost-Benefit Analysis and the withdrawal of railway services. Bulletin of Economic Research, 24(1), 23-32.
[16] Ojeda-Cabral, M. and Batley, R. (2023) The 'multi-modal approach' to user benefits in new mode contexts: a rejoinder
[17] If changes in GJC are estimated to be >33%, Numerical Integration is recommended if possible to mitigate for ROH overestimation of benefits. This may require an assumption to be made about the shape of the demand curve.
[18] Strictly speaking, the VTT outside the brackets should represent the average VTT of switchers, before any multipliers are applied. This is likely to fall between the observed average VTTs for the two modes, so a simple average is taken in the absence of further evidence.

mode, VTT is the relevant Value of Travel Time recommended in TAG Unit A1.3 - User and Provider Impacts and Mult_mode are the mode-specific time (or equivalently VTT) multipliers for a given group (e.g. the group of bus-rail switchers); see below for further details on these multipliers. Note, for non-business travel, $VTT_{alt} = VTT_{rail}$ for all alternatives, as we use the all-mode average equity VTT for these trips.

5.1 This gives perceived time savings benefits (i.e. those adjusted for modal quality differences) for each segment.

5.2 Note these calculations only cover transport user benefits. Other appraisal impacts can be calculated using standard TAG methods, except for wider economic impacts which are discussed later in this guidance.

6. Combine these perceived time savings benefits with those from operating costs, fares and user charges (estimated using RoH in the same manner to derive overall transport user benefits).

7. Calculate other appraisal impacts such as operator revenues and indirect tax in the usual manner.

4.1.7 The AM approach is hence rooted in credible DM and DS choices (including 'no travel'), generating user benefits without the need to extrapolate the full demand curve to the cost axis. This reduces reliance on assumptions about the 'pseudo-DM' cost, which can potentially be arbitrary and lack validation.

4.1.8 In cases where rail is the new mode in question, RSSB (2021) provides a methodology for 'full' AM approach, that incorporates switchers from both public transport (bus) and car (and potentially other modes). The 'reduced' method shown above provides an alternative measure of the user benefits from former car users by merging them with new trips, thus implicitly assuming they receive half the benefits of former bus users.

4.1.9 For details of the 'full AM approach', please refer to Ojeda-Cabral, Batley and Johnson (Appendix A. RSSB, 2023)[19]. Note where applied, the 'full' AM approach should consider the impact of car ownership on mode shift. For example, those DS rail users without cars should not be allocated to the car-rail sub-market.

4.2 VTT Multipliers

4.2.1 Where it is expected that the perceived (dis)-utility of travel time is different across modes, in order to proxy quality benefits for those that move from one mode to another, it is recommended that multipliers are applied to the VTTS recommended in the TAG Data Book (Table A1.3.1 Values of Time per person).

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[19] Ojeda-Cabral, M., Batley, R., and Johnson, D., Rail Openings Appraisal 2, Testing to support improvements in the appraisal of new rail lines, stations and large service enhancements, Final Report; RSSB, February 2023

Table 2 below displays the recommended VTT multipliers between mode, relative to car, adapted from Mackie et al. (2003)[20].

Table 2 VTT Multipliers for rail and bus, as % of car VTT (from Mackie et al (2003), Table 20)

Trip purpose and distance*		**VTT rail, as % of VTT car ($Mult_{rail}$)**	**VTT bus, as % of VTT car ($Mult_{bus}$)**
Commute	2 miles	94	131
	10 miles	85	119
	25 miles	78	109
	All distance up to 25 miles**	**83**	**123**
Other non-work	2 miles	97	134
	10 miles	84	118
	50 miles	75	104
	200 miles	67	93
	All distance up to 200 miles**	**76**	**124**

* This should be based on distance by car; ** Distance weighted average; NB: Here, $Mult_{car}$ = 100 by construction.

4.2.2 This table displays how VTT varies for the same group of respondents, across mode. It hence implies that time spent travelling by rail is of a higher quality than by car, which in turn is higher than time spent travelling bus, and that this effect is exacerbated at longer distances.

4.2.3 The original research did not derive equivalent factors for business travel. As a result, it is recommended that analysts apply the commute multipliers for these trips in the absence of business evidence. While Mackie et al (2003) is viewed as the best UK evidence currently available, given the limited nature of evidence in the area of VTT multipliers, they should not be applied outside the scope of the AM approach.

4.3 Diversion factors for the AM approach

4.3.1 RAND (2018) provides recommended diversion factors for rail interventions. TAG already contains recommended diversions factors for bus and cycle interventions (see Tables A5.4.6 and A5.4.7 in the TAG Data Book). These represent the proportion of new travel on a mode that would otherwise have used another mode or that would not have travelled (called 'generated demand').

[20] Mackie, P.J., Wardman, M., Fowkes, A.S, Whelan, G., Nellthorp, J. and Bates J. (2003) Values of Travel Time Savings UK. Working Paper. Institute of Transport Studies, University of Leeds.

4.4 Considerations and uncertainty

4.4.1 It should be noted that the AM approach requires different appraisal data and approaches compared to the OC approach, in that GC has to be estimated for at least two separate modes (the new mode in the DS, and the DM mode). There is also a requirement to assess the credibility of the mode in the DM case in order to make an informed choice of method in the first case. Analysts should consider carefully the likely analytical requirements of the AM approach for their scheme as part of an appraisal specification process.

4.4.2 In some cases, it may be clear that the most credible DM travel option (involving PT) is a multimodal trip where car or another PT mode is used to access the nearest rail station, with rail then used for the onward journey. Indeed, in some cases there may be no end-to-end non-rail public transport option (e.g. bus) at all, which could necessitate a chained trip such as this. In such cases analysts may have to consider more flexible assumptions to achieve a suitable basis for the appraisal of their specific scheme.

4.4.3 One approach is to use the combined GC of a multimodal trip as the DM GC within the AM approach. Where this approach is used, it should be clearly justified, ideally with relevant local evidence on diversion factors. Care should also be taken to ensure that this does not lead to DM flows from the alternative origin station which are inconsistent with observed demand from that station. If there is no viable DM route using PT (e.g. bus), then no demand should be allocated to the relevant submarket (e.g. bus-rail) in the AM appraisal calculations. Hypothetical modelled data for a non-existent bus service, for example, should not be used, as the AM approach is founded on *actual* DM travel choices.

4.4.4 Adoption of these flexibilities should be accompanied by commensurate assurance and consideration of the implications for the resulting appraisal conclusions.

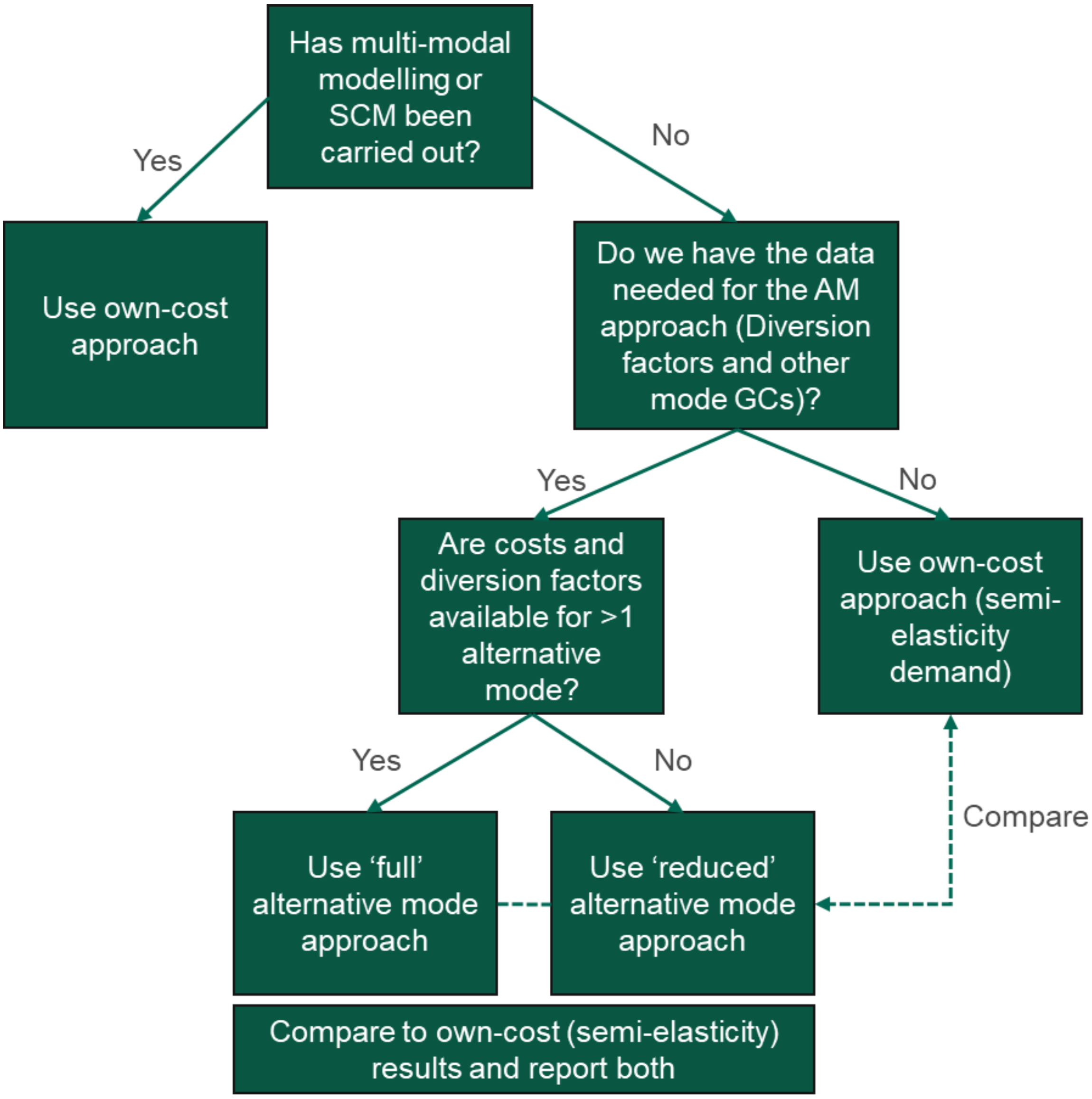
4.4.5 Where appraisal using the AM approach results in negative benefits for sub-markets, these should be subject to additional scrutiny, to ensure the underlying costs of trips are intuitive and justified with regards to the intervention in question. Where this is not the case, negative benefits should be set to zero. Any negative benefits would be inconsistent with the idea that those trip users have voluntarily switched from other modes.

5. Application in appraisal

5.1 Deciding on an appropriate methodology

5.1.1 Because of consistency with the underlying demand modelling, where multimodal modelling is carried out the OC appraisal approach should be used as noted in Section 3.1.4. The AM approach should **not** be used in these cases, where it may give inconsistent and/or misleading results. Figure 4 displays a decision tree to assist analysts in selecting the appropriate methodology.

Figure 4 Decision tree for appraisal approach



5.2 TUBA and new modes

5.2.1 TUBA follows the above outlined OC approach. The data inputs for a new mode in TUBA are the same as for other modes. Pseudo-DM matrix data should be treated like normal DM data and entered in the INPUT_MATRICES table as scenario '0'. New modes are identified via the 'New_mode?' (Y/N) column of the VEHICLE_TYPE/SUBMODE table of the economics file (see the TUBA manual for further details). This changes the standard TUBA calculations as follows:

- Calculation of additional 'triangle' for user benefits normally calculated with ROH
- Unlike normal DM, new mode pseudo-DM data does not affect the following calculations:
- Non-working vehicles non-fuel VOC user benefits
- Operator revenues
- Indirect tax revenues
- DM total user costs
- DM fuel consumption

5.2.2 Anyone using TUBA to deal with new modes is requested to contact the TUBA support team with their experience and any problems to help improve the evaluation of approaches to new mode appraisal.

5.2.3 Although usually referred to as the new mode problem, using TUBA nomenclature, the same problem arises with new submodes or vehicle types.

5.3 Wider Economic Impacts (WEIs)

5.3.1 Currently, there is no recommended guidance for appraising agglomeration or labour supply impacts in the case of new modes. Output change under imperfect competition impacts can be appraised in the usual way, as 10% of Business User Benefits, even in the case of new modes. Ojeda-Cabral, Batley and Johnson (2023) explore potential approaches for calculating agglomeration benefits with new modes, but none of these are currently deemed sufficiently well developed to be included in TAG. The Department is exploring the issues in this area and we hope to bring forward guidance in future.

5.3.2 In the meantime, analysts are free to explore the use of (i) pseudo-DM costs, in the case of the OC approach; and / or (ii) weighted average alternative mode costs,[21] in the case of the AM approach.[22] These can be used in place of the 'standard' DM costs, for the DS mode in question, within WEI calculations. Before including agglomeration or labour supply impacts within formal economic case reporting, in the case of new modes, please contact TASM@dft.gov.uk to discuss.

6. Worked examples

6.1.1 The below worked examples display simplified demonstrations of the AM and OC approaches. A spreadsheet containing the calculations for these worked examples is available alongside this guidance. It should be emphasised that

[21] It is recommended that the diversion factors, excluding pure generation, are used for the weighting. For example, in the case of new rail with 30% diverted from bus, 40% from car and 30% pure generation, the DM 'rail' GC for WEI calculations would be (0.3/0.7) x (DM bus GC) + (0.4/0.7) x (DM car GC).

[22] In case (ii), caution should be exercised because in some cases the DS GC could exceed the DM GC, which could (implausibly) lead to agglomeration dis-benefits.

these examples are simplifications of the approaches detailed in this guidance, and the accompanying spreadsheet should not be considered a tool for undertaking new appraisals.

6.2 Alternative Mode Approach

Scheme background

6.2.1 The DM scenario features car and bus as viable options for OD pairs in the model. Rail is then added as a viable option in the DS, via the addition of a new line and stations.

Step 1: Estimate DM and DS demand across mode and define GC components

6.2.2 This example implements the 'full' AM approach.

6.2.3 After undertaking rail demand forecasts for the DS scenario, diversion factors are applied to these DS rail forecasts to estimate DM bus demand (i.e. trips switching from bus), the DM car demand (i.e. trips switching from car) as well as the ‘pure generated’ share of rail demand. These diversion factors are assumed to be 35% bus, 45% car and 20% pure generation. Of these 20% pure generated trips, 50% are assigned to the car-rail submarket and 50% to the bus-rail submarket. Ideally, this allocation for pure generated trips would be informed by bespoke analysis of the relevant submarkets. In the absence of this, a simple 50:50 split between the two submarkets is considered appropriate.

6.2.4 In this simplified example, only commute trips have been estimated, with an assumed DS demand of 550 trips. The resulting demand for each submarket, in trips, is calculated as follows and shown in the table below.

- Bus-rail market: DM = 35% x 550 = 193; DS = 193 + 50% x 20% x 550 = 248.
- Car-rail market: DM = 45% x 550 = 248; DS = 248 + 50% x 20% x 550 = 303.

6.2.5 The appropriate components of GC should then be defined. Where possible, these components should be consistent across mode, to maximise comparability. In this simplified case, only cost (fare in £s) and in-vehicle time have been defined, as shown in the below table. These have been aggregated to give a total generalised cost.

Table 3 Modelled demand and generalised cost components

	Sub-market / mode	DM	DS
Trips (commute only)	Bus-rail	193	248
	Car-rail	248	303
Fare/VoC (£)	Bus	£10	£10
	Rail	N/A	£8
	Car	£6	£6
Time (mins)	Bus	70	70
	Rail	N/A	30
	Car	60	60

Step 2: Define values of time and quality multipliers

6.2.6 Total GC by mode can then be calculated by a) monetising the in-vehicle time component and b) combining appropriately with the cost component.

6.2.7 When applying values of time, the appropriate multiplier from Table 2 should be used to scale the value to account for journey quality differences across mode. Simple average 'base' (i.e. before the application of quality multipliers) VTTS for the bus-rail and car-rail submarkets are calculated via the following formula:

$$\frac{VTT_{alt} + VTT_{rail}}{2}$$

6.2.8 Where VTT_alt relates to the relevant mode (car or bus) - which in this case, following TAG for commute VTTS, is the same for all modes (£9.95 in 2010 prices and values). In this simplified example, the all-distance average quality multipliers have been applied.

Table 4 Values of Time and multipliers

Category	£/hr (2010 prices/values)	VTT Multiplier (Commute, all-distance)
TAG Commute 'base' VTTS	£9.95	N/A
Bus multiplier	N/A	1.23
Rail multiplier	N/A	0.83
Car multiplier	N/A	1

Step 3: Calculate user benefits using RoH for each component of GC

6.2.9 While bus-rail and car-rail switchers receive the full benefit, newly-generated rail trips get half the benefit of the sub-market they are allocated to, as detailed in the formulae below which are applied to each of the two sub-markets. For the bus-rail submarket, *alt* = bus whereas for the car-rail submarket, *alt* = rail.

$$Time\ benefit = 0.5 \times (T_0 + T_1) \times \left(Time_{bus} - Time_{rail} \times \frac{Mult_{rail}}{Mult_{bus}}\right) \times \frac{VTT_{bus} + VTT_{rail}}{2}$$

$$Money\ benefit = 0.5 \times (T_0 + T_1) \times (Charge_{bus} - Charge_{rail})$$

Table 5 Time benefits for different user groups (full AM approach)

Beneficiary groups	Time benefit	Money benefit	Total
Bus-rail	£1,820	£440	**£2,260**
Car-rail	£1,608	-£550	**£1,058**
Total	£3,428	-£110	**£3,318**

6.2.10 Benefits have also been calculated using 'reduced' AM approach. This entails setting the diversion factor for trip generation to 65% (the sum of the car and pure generation factors used above), and assigning all generated trips to the bus-rail submarket (which is now the only submarket).

Table 6 Time benefits for different user groups ('reduced' AM approach)

Beneficiary groups	Time benefit	Money benefit	Total
Bus-rail	£3,072	£743	**£3,814**
Total	£3,072	£743	**£3,814**

6.3 Own-Cost Approach

Scheme background

6.3.1 Under the OC approach, we consider only the rail demand curve for user benefit calculations. The DM scenario does not feature rail as a viable option for OD pairs in the model. Rail is then added as a viable option in the DS, via the addition of a new line and stations.

Step 1: Estimate DS demand for rail and define GC

6.3.2 The first step in the OC approach is to generate a forecast of DS rail trips, given the expected GC. In this simplified example, we have cost (fare in £s) and in-vehicle time defined for the DS; via Values of Time, a total GC can be calculated[23]. This can be used to forecast a DS demand. In the case of multi-modal modelling (MM), the costs of competing modes will also be needed as inputs to the demand model. The example has been setup to give DS demand of 550, in the AM approach example above. This is based on a total of 1000 trips in the DM, which when combined with the mode shift and frequency responses to adding a new mode (rail) leads to 550 DS rail trips.

6.3.3 Generalised cost sensitivities, or 'lambda' values of -0.15 and -0.01, respectively, for mode choice and frequency response have been used for this simple example (with no destination choice: this is for one OD). These are broadly in line with the expected scale of generalised time sensitivity parameters based on TAG M2.1 - Variable demand modelling. In practice, for a real appraisal, a multi-modal demand model (which will contain parameters of this form) will be used to forecast DS rail demand.

Table 7 Components of rail generalised cost, and derived DS demand

GC component	Value
Cost (£)	£8.00
In-vehicle time (mins)	30
Value of Time (TAG Commute) (£/hr)	£9.95
Total GC	**£12.94**
Trips (commute only)	**550**

Step 2: Generate a 'pseudo-DM' from estimated DM GC

6.3.4 The own-cost method relies upon estimating the level of GC that would be needed for the number of DM rail trips to be near-zero. In the example multi-modal model used here, a multiplier of 3 was used for a pseudo-DM GC of **£38.83**. This was found to give DM demand of 22 trips, which is 4% of the DS level. Increasing this to a multiplier of 3.5 gave 1.5% of DS trips in the pseudo-DM, which was deemed too low (as noted earlier, it is better to have too many trips in the pseudo-DM than too few).

6.3.5 To demonstrate the OC method with uni-modal (UM) modelling, we also calculate benefits using a semi-elasticity (negative exponential) demand curve. For this, the assumed GJT and fare elasticities were -1 and -0.7 respectively, which in this instance (for simplicity) are combined into an overall GC elasticity of -1.7.[24] This demand function has been applied incrementally from the given DS rail demand of 550 trips from the multimodal model, to a pseudo-DM demand of 4% of DS trips (i.e. 22 trips). The value of 4% was chosen to make the results more directly comparable to the multi-modal modelling results noted

[23] Note that in this worked example, for simplicity, modelling and appraisal VTTs are identical, but this will not necessarily be the case in reality.

[24] It follows from the properties of elasticities that the generalised cost elasticity is the sum of GJT and fare elasticities, so long as all components of GC (namely GJT and fare) change by the same proportion.

above. The associated pseudo-DM cost come out at **£37.45** from applying the formula from Section 3.3 above:

$$GC_0 = £12.94\left(1 + \frac{\ln 0.04}{-1.7}\right) = £37.45$$

Step 3: Estimate user benefits using the RoH with numerical integration

6.3.6 With GC and demand derived for both DM and DS scenarios, total user benefits can be estimated via the usual RoH approach and numerical integration (NI) with the results as shown in the table below. In this case three intermediate points were used as this gives sufficient accuracy relative to the 'true integral' result.[25] The AM appraisal results are also shown alongside for ease of comparison.

6.3.7 The small 'triangle' of user benefits between the pseudo-DM and the cost axis is also calculated, using the formula given earlier in the guidance.

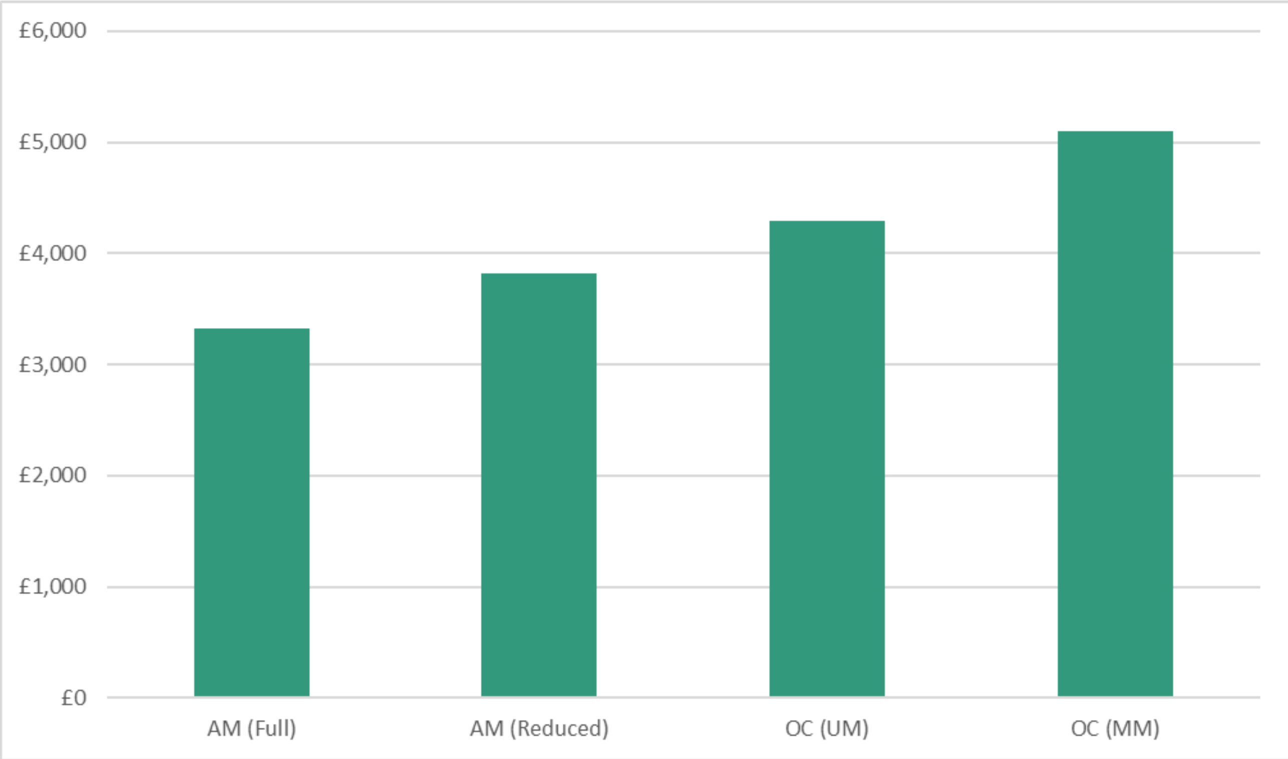
Table 8 Total user benefits under OC and AM approaches

Modelling approach	Time benefit	Money benefit	Triangle	Total
AM	£3,428	-£110	N/A	**£3,318**
AM (reduced)	£3,072	£743	N/A	**£3,814**
OC (UM)	£1,618	£2,619	£55	**£4,291**
OC (MM)	£1,928	£3,121	£46	**£5,096**

6.3.8 Figure 5 below compares benefits for each of the three methods. If MM modelling was actually used for the scheme in question, it would only be necessary to report the rightmost column. If UM modelling was used however, there would be greater uncertainty around the results so both the AM and OC(UM) columns should be reported and compared.

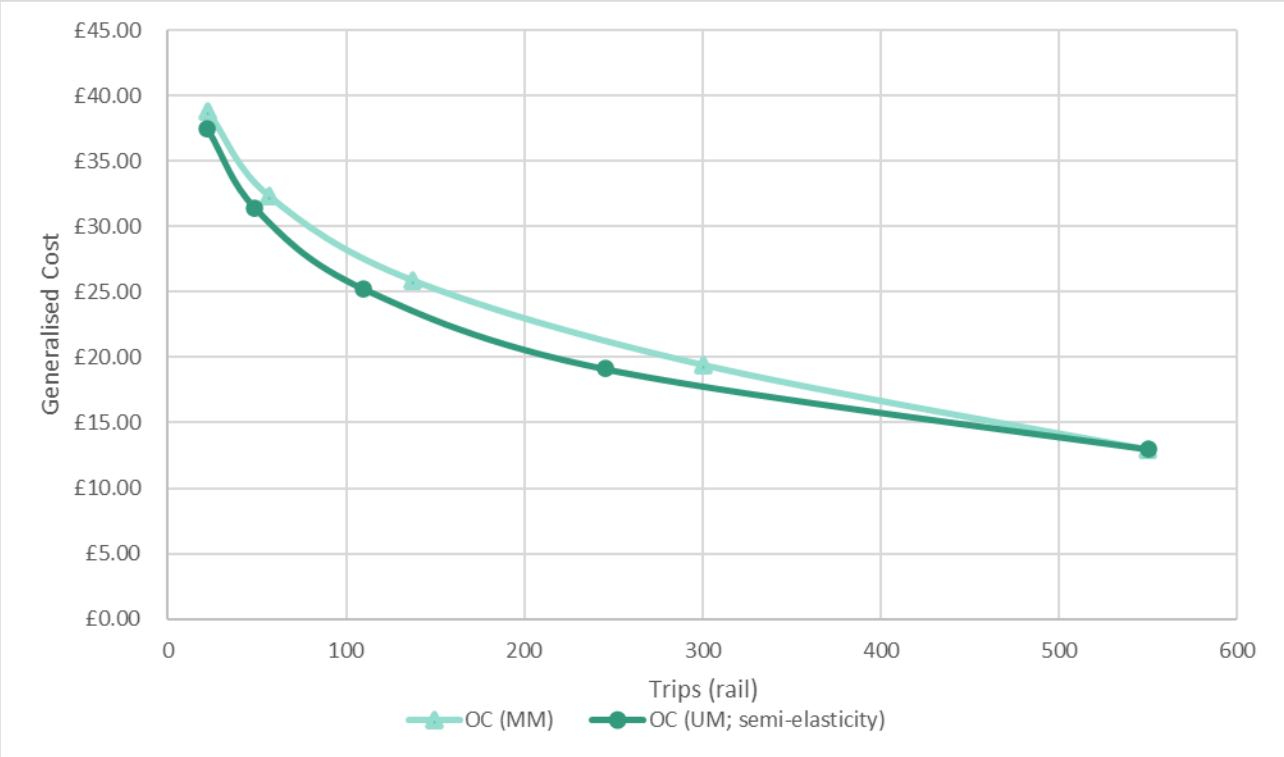
[25] While in most applied settings the true integral result will not always be possible to calculate, given the simplified model form used in this example it can be solved for analytically.

Figure 5 Total monetised benefits by appraisal methodology



6.3.9 Figure 6 shows the demand curves, with intermediate points used for numerical integration, for the two OC sets of calculations. Intermediate points have been evenly spaced along the cost axis for simplicity. In reality, greater accuracy will be achieved if the intermediate points are concentrated where the demand curve is least straight, which will tend to be closer to the cost axis. The higher benefits for the MM case are driven by a slightly steeper demand curve, corresponding to a lower elasticity.

Figure 6 Own-cost approach demand curves



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8. Document Provenance

This Unit was first published in May 2025, and expands upon guidance on the appraisal of new modes that was previously contained in the DfT's TUBA 'General Guidance and Advice' document (2020). It draws on evidence from the work of Ojeda-Cabral, Batley and Johnson (2021, 2023), as well as the peer review of this research by Bates (2023).