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TTWO0213: Audit of Distributional Weight Analysis

Task 3: Think Piece

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V1.0, 29th September 2023

ITS ARUP

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1 Introduction

To complete the study 'TTWO0213 Audit of Distributional Weight Analysis' being undertaken by Arup and ITS Leeds for the Department for Transport, 'Task 3' consists of a think-piece around the wider implications of adopting DWs – this encompasses not only the implications for appraisal, but also those for modelling, and for policy more generally.

The scope of this think-piece is as follows:

- First, to revisit the key issues, challenges and arguments for and against DWs in transport and the practice and policy positions potentially available to DfT in this regard.
- Second, to consider the implications of the DfT's proposed approach to implement DWs in transport in the context of Green Book principles, and the potential for alternative options.

2 The HMT Green Book's position on Distributional Weights

The Green Book (HMT, 2022) sets out the general principles of public sector appraisal. TAG can be viewed as an application of these principles to the transport sector. Annex 3 of the Green Book (p.96) outlines the principles for the application of distributional analysis in an appraisal. Distributional analysis is understood as "*assessment of the impact of interventions on different groups in society (…) according to their characteristics (e.g. income level or geographical location)*" (p.96).

2.1 Longlist stage

The question of distributional analysis is first set out in Chapter 4: "Generating Options and Long-list Appraisal" (p.28). It sets the principle that:

"Significant income distribution effects, should be considered at the longlist stage, whether or not they are an objective of a policy, or are collateral consequence of implementing an unrelated policy. Distributional effects may apply to defined income groups, household types or types of business. At the longlist stage they may be a constraint on the feasibility of some options".

Second, when it comes to appraisal, the principle of proportionality comes into play (p.28):

"Appraisal of distributional effects should be proportionate to the likely effects on those affected".

2.2 Shortlist stage

The requirement for distributional analysis becomes more prescriptive at the shortlist stage. For instance, we note the following statements (p. 54):

"*Where distributional effects (e.g. on income) are relevant, they should be appraised. Assessment of distributional impacts could range from a simple quantitative or descriptive approach where the scale of the effect is relatively low, to an in-depth appraisal and detailed calculation of distributional effects where the scale is relatively high*"

"Where effects are significant for a group concerned, a clearly presented analysis identifying gaining and losing groups and estimating the effects on their welfare should be carried out"

"Distributional weights can be used as part of the distributional analysis where there is understood to be a social value that differs from simple additionality due to who gains or loses"

"In practice the use of distributional weighting is challenging (…). If distributional weightings are used to adjust estimated costs or benefits depending on which groups in society they fall on, the analysis with weightings should be presented alongside the analysis without weightings".

"Distributional issues should also be considered when conducting research to calculate generic reference values for appraisal. For example, the income distribution of a sample population may be taken into account in order to adjust a generic value to represent the total population".

This guidance must be interpreted for its applicability to transport. If we agree that distributional effects are relevant for transport schemes, the Green Book requires an assessment of such effects, which may or may not include distributional weights. This will depend on what the *scale* of the distributional impacts is, which could be assessed empirically but may also be subject to judgement.

What has been the implementation in TAG so far? We argue that TAG has, to date, included two relevant aspects:

- the use of reference values (mainly the VTTS) that considers distributional issues through the treatment of income. The VTTS plays a central role in transport appraisals.
- a descriptive qualitative approach through the 'Social and Distributional Analysis' guidance, although arguably with limited development and use in practice (and a focus on road schemes).

A relevant conclusion so far is that the Green Book seems to leave open the question of using distributional weights vs. relying on other forms of distributional analysis.

2.3 Detailed distributional appraisal guidance

Annex 3 (p.96) presents more details on the prescribed principles and approaches for distributional analysis, building upon the above – and this is perhaps the most relevant part of the guidance. We highlight the following quotes:

"It is not proportional to calculate all distributional effects. The appraisal method employed for considering distributional effects should be proportionate to the likely consequences for those affected and may be judged based on:

1. *Where the impact on those affected is minor it may be sufficient to ensure that decision makers are made aware of the effect and its likely scale, and possible options for avoidance or mitigation.*
2. *Where it is a significant collateral effect of another policy a straightforward monetary analysis may be required.*
3. *Where redistribution is a policy objective such as payments under the welfare system or if it is highly significant in terms of the impact on incomes and welfare of those affected then a weighted and equivalised income distribution analysis may be justified".*

These words of the Green Book raise important questions and set out the downstream challenges for any sector required to implement Green Book guidance. The heterogeneity of transport schemes means that some cases (e.g. concessionary fares, accessibility or levelling up schemes) would include redistribution as a policy objective – thus clearly justifying a distributional analysis – and others would not. And among the latter (i.e. schemes which do not specify redistribution as a goal), some could still have significant distributional effects. Some projects may be thought to have significant collateral effects (e.g. HS2) and in such cases the interpretation of the phrase *"straightforward monetary analysis"* would need to be made explicit. Against this background, the implementation of Green Book principles may warrant the use of distributional analysis – which may or may not include distributional weights – in some transport schemes but not others. An initial step towards potential inclusion in TAG would seem to require the translation of this part of the Green Book guidance, which is open to interpretation, into the specific context of transport.

The first challenge is, therefore, to decide whether calculating distributive effects is proportional in some or all transport applications. If the main criterion is materiality, that would suggest that areas such as transport subsidy, concessionary fares, future tax policy or accessibility (to name a few) would be likely to qualify. By contrast, areas such as infrastructure investment are more concerned with efficiency and less with distribution. Nevertheless, should a pragmatic approach be devised, this may become more easily extendable to all transport applications, limiting controversies around which schemes/policies should be subject to distributional weighting.

Secondly, on the topic of distributional weighting, the Green Book states (p.96):

"*When assessing costs and benefits of different options it may be necessary or desirable to "weight" these costs and benefits, depending on which groups in society they fall on. This is in addition to estimating the "unweighted" costs and benefits, which is the minimum requirement of Social CBA. In weighted analysis, financial benefits for lower income households are given a higher social value than the equivalent benefits for higher income households. Weighted estimates should be presented alongside unweighted estimates to demonstrate the impact of the weighting process*".

Hence, the second challenge is the requirement for unweighted costs and benefits to be presented. Our interpretation of this is that HMT mandates the use of behavioural (WTP) values and the Kaldor-Hicks test as the 'minimum requirement'. It is worth noting that DfT practice in using standard values of non-working time conforms with this requirement *on average*, but clearly does not do so for particular projects which appeal to better off or worse off transport users, areas and modes[1]. This raises a question around what 'unweighted estimates' should be provided for comparison with the weighted estimates which are the main focus of discussion. Since current TAG (VTTS) reference values have embedded distributional considerations in various ways, a first implication of the application of this mandate would be a revision (possibly a re-estimation) of non-work VTTS values to produce behavioural values. These values would need to be consistent with the agreed – yet to be devised – approach for 'unweighted estimates', in a way that there is consistency with the selected approach for DWs. Our appreciation is that all other components of CBA including employers' business travel time are consistent with this aspect of guidance although there are debates to be had with HMT, DoH and DEFRA about the use of standard values for safety and local environmental impacts. Thus, the overall challenge would be to ensure there is clarity around what standard values represent, with these ideally representing 'unweighted' values and thus facilitating a neat application of DWs to effectively present the two sets (unweighted and weighted) of CBA results.

Still on this point, it can be argued that the debate around the introduction of DWs in transport should be framed in terms of a comparison with the current VTTS approach which, as mentioned, includes some distributional considerations (see section 3 of this report). Thus, when interpreting the Green Book, one should assess the proportionality of applying DWs in light of this 'pragmatic but imperfect' current TAG approach. The current VTTS approach has its pros and cons and could be the departing point to consider the move towards the use of

[1] TAG Unit A1.3 explains the current approach taken, which in the absence of DWs mitigates for the adverse impact of income effects (section 4.3.4): "*If values of time for appraisal are based on individuals' willingness to pay (behavioural values) which are related to income, then investment decisions will be biased towards those measures which benefit travellers with higher incomes. Investment would be concentrated into high-income areas or modes, and the interests of those on lower incomes, who may already suffer from relatively lower mobility and accessibility, will be given less weight. For this reason, the first source of variability is controlled for by the use of national average values in table A1.3.1, which should normally be adopted in transport appraisal*".

DWs. An initial question is thus whether the current VTTS approach is an acceptable application of Green Book principles for distributional effects in transport.

The third and main challenge is to create a practical and intelligible method of weighted analysis capable of application by the many users of TAG across the range of projects and policies. This raises questions about the balance between proportionality and standardisation in appraisal. Should the same approach be used for a £100 million project and a £1bn project? Should weighting be used for all types of transport schemes, or only for those with clearer/stronger distributional impacts? Should weighting be mandatory or should there be a possibility for a different type of distributional analysis that complements the presentation of unweighted costs and benefits?

2.4 The application of distributional weights

Details on the application of distributional weights, when considered necessary or desirable, are also provided in Annex 3 pf the Green Book. We reflect on some of these below.

"is the analysis targeted at individuals or a mixture of households of different size and composition? If the latter then equivalisation may be required, prior to applying weights"

"is the income of the group affected by the intervention known? If known and a welfare weighting approach is proportionate it should be used to calculate the welfare weight. If not, then the HBAI income groups can be used".

These set the fourth and fifth challenges for the application of DWs in transport. The principal beneficiaries of most infrastructure schemes are users (i.e. drivers and passengers), but it may not be straightforward to obtain data on the incomes of transport users. Furthermore, in transport it is possible that the benefits are passed on to groups that may differ from users (e.g. land-owners), which would require further assumptions or complexity in the estimation. This issue of benefits transfer is discussed in section 4.3

The Green Book cites DWP as an example of application of DWs. The proposed DWP approach requires the use of distributional weights for at least two groups: i) taxpayers, as the funders, assumed to have median income; and ii) beneficiaries of the policy/scheme, which may be from different income groups. The DWs for the beneficiaries will be based on their income relative to the income of the average taxpayer. The technical details of this particular application and other variants were the focus of the Task 2 report. Another example is provided in the DLUHC appraisal guide (Annex H)[2], including the illustration of a practical application to social housing tenure. In this case, the scheme is targeting households or individuals, making it easier to establish the income of the groups affected for DWs implementation. It is arguably the case that transport schemes are more complex in their

[2] https://www.gov.uk/government/publications/dluhc-appraisal-guide/dluhc-appraisal-guide#annex-h-distributional-impacts

distributional implications, which would further justify an upfront investment to translate the Green Book principles into a practical approach for TAG.

3 Distributional considerations in current reference values

Current TAG does not include explicit distributional weights, but it uses references values (VTTS) to measure benefits and disbenefits which have embedded distributional considerations[3]. Thus, we next discuss the distributional impact aspects of the most recent 2014/15 national VTTS study, which forms the basis of current TAG values.

Batley et al. (2019) presents an overview of the 2014/15 VTTS study for DfT, undertaken by Arup, ITS Leeds and Accent. The role of income effects on the VTTS was an important factor (as it had also been at the time of the previous 2003 study by Mackie et al., 2003). The main debate revolved around "*whether the VTTS used in appraisal should be a pure WTP value or should be adjusted to a standard value reflecting the income distribution of the travelling population*" (p.22). In order to generate nationally representative average values, an exercise in sample enumeration was conducted. In that context, four possible options were identified jointly with the DfT:

1. Averaging over income, but not segmenting by income – this leads to a single average VTTS (this was the approach followed in 2003)
2. Calculating values at 'average' income – similar to option 1, but where the weighting process assumes all trips have 'average' income.
3. Removing the income covariate from the choice model, allowing the income effect to be picked up by other covariates – this was deemed pragmatic but clearly a case of model misspecification.
4. Applying distributional weights from the Green Book – values would be calculated for each trip (as in options 1 and 2), but subsequently weighted according to income quintiles using Green Book weights.

Another inter-related issue further complicated the debate: 'transport' is not homogeneous and the different modes of transport have different qualities (and, thus, time savings can be valued differently by mode, e.g. due to comfort or time use opportunities), as well as trips of different lengths (e.g. longer journeys often associated with higher VTTS). Low-income users may gravitate to cheaper (but worse) transport modes; high income users may gravitate to better (but more costly) modes of transport. Ideally, values should separate income effects from 'mode effects'. However, the models estimated were not able to fully dissect the two effects, and the decision on 'what VTTS to use in appraisal' became more complex[4]: this was

[3] See detailed discussion in section 3 of the Task 2 report from the current study.

[4] We note that all this was relevant for non-work trips only (i.e. excluding business trips).

because, even after controlling for income, the VTTS differences by mode were counterintuitive (i.e. they did not reflect the expected comfort/time-use effects). For example, the quality of bus is expected to rank worst across mode, but in some segments bus values of time were found to be the lowest across modes. In addition, the distance effects increase the complexity of such analysis, as the ranking of VTTS across modes can also be affected by their respective journey length distributions. The key point is that even the best models – controlling for income and distance – suggested the presence of residual income effects.

Given this confounding between income and mode effects (or 'self-selection' problem), it was recommended that (for non-work), VTTS values should be 'mode-free', i.e. an average over the sample of trips for all relevant modes. Upon this decision, the treatment of income using option 1 or 2 as above was considered, both yielding very similar results. We note that this was an issue for commute and other non-work trips, but not for business trips – which are subject to different considerations as time savings accrue to a mix of employees and employers. For business, variations across modes were interpreted to represent admissible differences for use in appraisal.

4 Key issues in the literature

Just like the DfT's technical paper (which was the focus of Task 2), the relevant literature for the application of DWs in transport appraisal is mostly intertwined with the use of VTTS in national appraisal guidelines. This is because, as we have seen, the use of VTTS in appraisal is not free from distributional considerations and VTTS has indeed been the most common route to embed distributional concerns in transport CBA. Even if DWs have not been used in transport so far, policy choices around VTTS selection have had distributional implications.

In the transport literature, Börjesson and Eliasson (2019)'s paper entitled 'Should values of time be differentiated?' is the most recent and comprehensive discussion of the issues within the scope of the present think-piece. Börjesson and Eliasson summarise the decades-long debate in the transport literature around the differentiation of VTTS for CBA, including theories and practical applications. However, B&E do not address the question of applying DWs directly. While the literature in transport is limited around DWs, there have been important recent contributions in the broader economics literature (e.g. Adler, 2016, Hammit, 2021 and Brent, 2023).

4.1 Behavioural versus 'equity' valuation inputs

B&E (2019) outline two lines of argument in transport appraisal: i) on the one hand, the works by Galvez and Jara-Diaz (1998) and Mackie et al. (2001) who favour the use of 'social' values that take into consideration distributional concerns related to income; ii) on the other hand, the arguments by Sugden (1999) and Harberger (1978) who favour the use of 'behavioural' values – dealing with distributional issues separately. According to B&E the debates have led to the following practical positions to be considered:

- A single equity VTTS (no differentiation)
- A set of VTTSs that, controlling for income, are differentiated with respect to a range of workable dimensions (taking into account variations in the marginal utilities of time across groups)[5].
- A set of VTTSs differentiated across workable dimensions, and that do not control for income (i.e. fully 'behavioural' values)

We would argue that, in practice, most countries fall into the middle category, which in itself is broad and can include multiple combinations. For instance, although the UK has traditionally adopted an 'equity VTTS' approach, in reality UK guidance contains a set of VTTSs that vary across some dimensions (e.g. purpose and, within business trips, also distance and mode). The 'equity' approach in the UK refers primarily to having a single VTTS across the purposes of commute and leisure. What this really means is that some expected or observed variation in the marginal utility of time has been 'washed out'. In particular, the main 'sacrifice' of this approach is that the non-work VTTS does not vary by mode. By contrast, the official VTTSs in Sweden vary across modes for all purposes – we will discuss what this actually implies and how it compares to the UK in the following sub-section, as the 'mode effect' is a distinct issue to be addressed. B&E (2019) conclude that a "single" (equity) VTTS should not be used in any case and that the VTTS should be controlled for income only under some circumstances. In their view, there are two key factors which dictate whether VTTS should be controlled for income: i) whether prices are under public control (i.e. changeable by policy interventions) and, ii) whether benefits are 'transferred' to agents other than travellers (e.g. land owners). If either of these is likely to hold, then B&E would favour the use of behavioural values (not controlled for income).

While equity values have been justified on the grounds that a Kaldor-Hicks' basis of CBA would give more weight to richer people than to poorer people (e.g. Mackie et al., 2001), proponents of behavioural values have flagged the anomalies that may occur with equity values (e.g. Sugden, 1999). For example, expecting higher WTPs for low-income users (e.g. by bus) may mislead pricing policies; more generally, the use of equity values blurs the ability to compare projects which focus on time savings with policies targeting changes in fares. In essence, the debate revolves around the trade-off between the positives of observing and using preference variation in marginal utilities of time vs. the positives of avoiding a regressive CBA giving higher weight to richer people.

[5] As DfT pointed out to us, an issue with B&E's controlling for income approach, which they do not address, is that this implies that the relevant marginal utility of income elasticity is the same as (or more precisely, the negative of) the VTTS income elasticity (~0.3-0.5 or so); whereas the Green Book is much more progressive at 1.3.

The Green Book's approach to DWs could possibly assist in reconciling these two positions, since the CBA would include both a scenario with behavioural values (i.e. unweighted benefits) and a scenario with DWs which takes account of the distributional issues that motivate the interest in equity values. Adler (2016), in an overview of CBA and DWs, indeed notes that *"DWs might be brought to bear on environmental policy choice and, perhaps, solve dilemmas with respect to the choice between differentiated and population-average valuation of goods"*. This also shows that the issue is not specific to transport and VTTS only, and suggests that any application of DWs in transport should consider other value inputs in a consistent way.

4.2 The issue of mode effects

Unlike other sectors, transport has always been known for containing several sub-sectors (roads, rail, bus, etc.) that compete with each other, with different pricing and tax regimes (Foster, 2001) and with different qualities as public goods from a user perspective. There are policies and projects that trigger, purposely or not, changes in the use of each mode. It is important that CBA can handle those, but so far the inability to successfully differentiate values across modes has been a barrier. One of the problems has been the complex role of income effects, which was largely responsible for the lack of mode segmentation for non-work trips. It can be argued that the use of DWs opens up new opportunities for better reflecting mode differences, since equity issues would be dealt with separately.

The problem of disentangling 'mode effects' from income effects (more generally, 'user effects') has been explored in depth by Flügel (2014). One conclusion from this work is that such separation is possible but it requires additional SP surveys to those used in the UK 2014/15 VTTS study. In the 2014/15 study, the surveys intercepted users and asked them about their WTP to save time on their currently used mode only. However, in order to disentangle user from mode effects, SP experiments need to also ask *the same group of users for their preferences on alternatives modes*.

B&E's results for Sweden also reveal variations in VTTS across modes which do not reflect the expected comfort effects – with bus users having the lowest values, thus suggesting the presence of residual income effects. In contrast to the view taken in Batley et al. (2019), they do not seem concerned with this 'self-selection' issue feeding through into the appraisal – perhaps because they align with the view that distributional issues should be dealt separately from the valuation of impacts. However, it is likely that the Swedish mode-specific VTTSs also include income effects and not only comfort/time-use effects. B&E's position is that behavioural values should, at most, only control for income through the income variable. Once this is done, all remaining variation would form part of the behavioural values. Subject to addressing the mode effects issue, such an approach to behavioural values could be seen as one way of calculating the 'unweighted' benefits and costs prescribed by the Green Book, coupled with the application of DWs at a later stage to analyse distributional impacts. Last but not least, B&E make an important disclaimer to "not exaggerate" the decision problem of whether to control for income differences when deriving the VTTS. They argue that, while their paper focuses on income effects, "*even more important is to differentiate the valuations*

of different travel time components, such as in-vehicle time, waiting time and walking time, and other time-related quality factors such as travel time variability and crowding" (p.372). It can be argued that the evidence base on all these factors is thinner and more outdated than that for the VTTS itself, and this may suggest a balancing exercise going forward. It would seem important to update and strengthen these other key value inputs for transport appraisal alongside the development of distributive weights.

The bottom line is that the use of DWs can facilitate the important task of segmenting across modes by handling income/equity considerations separately.

4.3 Initial and final beneficiaries

In current appraisal practice, it is assumed that travel benefits on employers' business trips accrue to the firm (and ultimately more broadly to consumers through competitive processes). So behavioural values are mandated and distributive weights will not be required since the benefits are transmitted widely across the economy. However, if this assumption is challenged – i.e. part of the travel benefits accrue to the employees as individuals – then this may open the door to also consider the role of DWs on this consumer segment.

When it comes to non-working trips, both commuting and leisure, current practice is based around the proposition that the standard values of time represent the social value of (say) one unit of commuting time whoever is the ultimate beneficiary. Who really gets the final benefit of a transport improvement depends on the relevant elasticities; they might accrue to the traveller or be passed partially or wholly into the land market or via the labour market back to employers.

If distributive weighting is to be applied to user benefits, that does force an explicit assumption regarding the identity of the final beneficiaries. Most likely, the assumption will be that commuters and leisure travellers retain all the benefits they receive initially (i.e. the incidence of initial and final benefits is identical). In a full spatial economy model with changes in accessibility driving changes in economic activity, it would be possible to test this assumption. But in a partial equilibrium transport model setting, it is difficult to test this assumption. Literature review of relevant evidence might be a starting point. Our view is that that the assumption is likely to be valid for leisure time, but is more questionable for commuting time in view of well- established land rent/commuting cost trade-offs. Exploring the final incidence of transport benefits (theoretically and empirically) would seem an important avenue for future research, not only to inform the application of DWs, but also to inform understanding of transport and land value interactions and Level 3 appraisal.

It is perhaps worth noting that although the Wider Impacts sections of TAG are logically distinct from the user benefit sections – the agglomeration, imperfect competition and dependent development arguments all depend on there being a range of transmission mechanisms which operate between transport, accessibility and economic change. Some of these transmission mechanisms (e.g. via employers' business travel and logistics) would be

unaffected, but any related primarily to accessibility for commuting would be blocked off if benefits are taken to accrue 100% to the commuter.

The initial vis-à-vis final benefits problem is not unique to transport schemes, applying also to flood protection schemes for example. But the intimate relation between accessibility, activity and employment does make it particularly acute in the transport setting.

4.4 On the use of DWs in CBA

The literature in transport has not really dealt with the issue of applying DWs in CBA practice, and has focused on the treatment of distributional impacts through the VTTS. Under this sub-heading we reflect upon some of the most relevant and recent contributions in the literature mainly from outside the transport field.

There is a large body of work in this area since the 1950s, as noted in a recent overview of the topic by Adler (2016). Adler too starts by noting that the use of some form of constant or average values in CBAs (e.g. population averages) is a way of mitigating for the 'distributional insensitivity' of CBA. It terms of practice internationally, the author only mentions the UK as an example of CBA guidance currently recommending DWs – noting that DWs used to be adopted in World Bank guidance at some point in the 1980s (Little and Mirrlees, 1994). Hammit (2021) further notes that the European Union guidance (EC,2015) considers weighted CBA as a method that "can be possibly used".

A more recent example comes from Dutch appraisal guidance. This mentions weighting by income classes as an option in special cases (as an exception to the rule), but does not provide a prescriptive approach (Romijn and Renes, 2013). Dutch officials, through a working group on 'costs of taxation and SCBA', have recently discussed the application of DWs in CBA. Their conclusion was that if distributional effects are important, the project benefits/disbenefits should be mapped for different income groups. However, the explicit application of DWs is not recommended[6]. The discussion suggests that even the task of mapping the effects by income groups was expected to be challenging.

From a theoretical perspective, the debate around the use of DWs can be linked to the adherence or not to the Kaldor-Hicks efficiency criterion. Adler (2016) suggests that a Social Welfare Function (SWF) is an alternative basis for CBA which does not explicitly require the K-H criterion. In this sense, any chosen use of DWs would be approximating a particular form of SWF. There is agreement in the literature that the decision to use any specific SWF requires a normative judgement – however, Adler argues that the same goes for the decision to use an unweighted CBA. This view resonates with Galvez and Jara-Diaz (1998) and Mackie et al. (2001) in a transport context.

[6] See report: Should CBA's include a correction for the marginal excess burden of taxation? | CPB.nl .

Hammit (2021) discusses the use of standard values (as a *numeraire*) and the importance of recognising its implicit influence on CBA, further arguing that the acceptance of CBA may increase if distributional impacts were incorporated more explicitly. The paper includes a discussion of practical concerns for the use of DWs, such as dealing with the explicit consideration of different values across population income groups. Hammit cites the value of a statistical life (VSL) as a controversial example from past US experiences: "*attempts to use different values based on income or age have met with sharp public and political opposition*" (p.81).

More recently, Brent (2023) also revises the issue of DWs and presents a new justification for their use. Brent argues that a SWF for a truly social CBA must have a dual objective: efficiency and equity. If equal distribution weights are used, only efficiency is of social value according to Brent. Therefore, Brent justifies the use of DWs as a way of accounting for people's preferences for equity. The paper claims that 'inadequate attention' has been given to how DWs can and should be estimated, and discusses the available methods.

Based on this broader literature, it would seem advisable to undertake further theoretical work that underpins the application of DWs in transport, to establish a robust basis. Adler (2016) and Hammit (2021) provide various discussions of possible SWFs as conceptual bases for CBA. At the practical level, it seems that the estimation of DWs is also an under-researched area. Brent (2023) provides new thinking in this space which may be worth considering for the development of DWs for TAG.

5 Implications for modelling

In the following sections we focus on the main implications for modelling schemes to allow for distributional impacts appraisal from a practitioner's perspective. A key assumption made is that distributional weights are income based and therefore income segmentation would be required, however we acknowledge that DWs can be based on a range of other variables.

5.1 Modelling considerations of further income segmentation

Application of DWs in appraisal will require specific considerations and modelling capability to reflect the segmentation of demand and appropriately reflect the behaviours of different income groups. In an ideal world, transport models would be segmented to capture different behaviours by different income groups. These would facilitate appraisal segmented by income group and an easy implementation of DWs. However, an alternative approach may be used whereby elasticity models based on NTS/NRTS data are used, as suggested by DfT. DfT would need to provide clear guidance on how to do this as well as available parameters to enable practitioners to undertake such analysis.

Assuming that income segmentation is implemented in transport models to accurately capture changes in behaviour by income group, a key consideration is which DWs will be

provided, whether that will be one set of DWs by income group, or further DWs by region, journey purpose, ticket type etc., as well as how many groups. If there is just one set of DWs, then this will be easier to apply in practice but will have caveats described in section 6.

Increasing model segmentation typically results in more computations and longer run times, and although software and hardware configurations are providing more flexibility for practitioners to overcome, this can still be a challenge. Applying DWs in appraisal will require segmentation in modelling and inevitably increase the computation times which may make other modelling methods, such as Agent Based approaches, more relevant for testing the behavioural effects of DWs. Noting that these are less commonly used, we restrict the remaining commentary to more traditional approaches and how they can be reasonably adapted.

Current TAG modelling units do include advice around implementing income segmented models and this could provide a general basis for applying DWs in appraisal – some observations on their applicability and potential issues for practitioners are presented below.

Income segmented models are implemented by using more disaggregate generalised costs including time, distance and cost parameters derived from TAG units and the accompanying databook. Specifically, the TAG databook contains a hidden 'Income segmented VTTS' tab which presents the Arup, ITS and Accent 2014/15 VTTS split by income groups of <20k, 20-40k and >40k. This presents mode specific work values for car, public service vehicle and taxi – but not for other modes. Further guidance is available in TAG Unit M2.1 Appendix B on deriving income segmented VTTS. The available values can be used to generate income segmented values for the categories covered, although this becomes more complex if different income groups are required. A key consideration would therefore be whether the databook would be updated to provide new segmentations of VTTS for use by modellers.

In addition, in TAG Unit M3.1, para 2.8.7 reflects that, when income segmented models are developed, it is important to maintain the same distance coefficient in assignment models so that the income variation only impacts tolls or fares. This can involve scaling of distance parameters to achieve the same distance coefficient across income levels. This approach is typically used where tolling or charging is introduced in the future and enables developers of models to build an unsegmented base model and introduce segmentation after calibration and validation.

It is unclear whether there is behavioural basis for this scaling adjustment, and applying DWs into the appraisal process may need to challenge this approach and examine whether the modelled behaviours (e.g. route choice, destination choice, etc.) are plausible and can be validated. This would also extend to areas such as target elasticities used for realism testing and ranges associated with different groups where evidence supports this. This would add to the data and time requirements for building models.

It is unclear whether and to what extent DWs would impact upon the use of cost damping[7] approaches in demand models. Whilst the relationship between perceived travel costs and distance is considered non-linear, the inclusion of more income / group segmentation may influence how existing guidance is applied and in which context.

Implementation of a wider range of segmentation and behavioural values in modelling software tends to be more viable in demand modelling where the functions and configurations of algorithms are typically at the modellers' discretion. Such software tends to provide more flexibility for different segmentation and functions. By contrast, in assignment/supply modelling, the software tends to be more restrictive on the use of non-linear functions. It is unclear whether behavioural evidence would require different implementations for assignment algorithms and this should therefore be reviewed.

Data to support the segmentation of models will be a key issue. The aim of DWs in appraisal is to account for different income groups that make up a population; if there are a high proportion of low-income households then user benefits will be inflated. The amount of segmentation required is dependent on the distribution of income. The result should be a relatively equal split of demand between income bands. Distributional weighting can also be done by region, or ticket type if that is the focus of the policy. Whilst aggregate data may be available to adjust appraisal results, the embedding of DW into a modelling framework will be more data intensive. Through work for National Highways, Arup has explored the use of NTS data and ONS data to enable segmentation of demand matrices to reflect income variation. This has used synthetic models to help estimate potential spatial variations in income distribution as a workaround to the lack of data. Methods such as this and / or other datasets would need to be developed to provide a practical basis to reflect spatial variations in base year matrices coupled with appropriate forecasting methods / data to reflect any spatial variations in income over time. Moreover, to apply DWs and use the results in decision-making, Transport User Benefit Analysis (TUBA) would needs to be updated accordingly.

5.2 Would the considerations vary by scheme/policy type?

Modelling considerations will vary by scheme type, but they will also be dependent on the policy aims. There are theoretical considerations when modelling benefits using DWs. For example, what are the implications of comparing different modes (rail vs bus projects targeted at different groups)? Should all types of intervention be evaluated using DW? Current Green Book guidance suggests that DW approaches should be used for areas such as transport subsidy, concessionary fares, and future tax policy, whereas areas such as infrastructure investment are less important as the goal is primarily efficiency rather than distribution. We do not however think that this distinction is hard and fast, and it is evidently the case that the

[7] The process of dealing with the non-linearity of perceived changes in travel costs with distance.

benefits of transport infrastructure schemes could vary considerably across income groups – thus justifying the applications of DWs.

It will be important to demonstrate in the distributional impacts scoping phase why the application of distributional weights might be beneficial. DfT should make a decision on whether distributional weights should be applied to all interventions to enable comparisons of BCR on a like-for-like basis, or whether they should be applied only where interventions have explicit distributive impacts. If applying DWs to all interventions, there should be user customisable levels of segmentation according to data availability/proportionality.

5.3 What additional questions would DfT need to consider for modelling (and possibly commission work to address)?

Current modelling guidance provides a basis for the application of DWs where they are income based. How this is extended to cover the full range of potential groups that could be covered by DWs is something requiring further consideration particularly where better behavioural validation is required. This should include alternative or complementary models, such as those applying agent-based methods (ABM) that are emerging in practice and potentially forming part of further modelling guidance in TAG. These models can provide a more detailed picture of impacts on travel patterns across many different population groups – albeit dependent on available disaggregate data.

It is unclear whether better behavioural insight from more disaggregate models will offset the extra time and resource required to develop them and so drawing out a framework to advise practitioners on suitable examples or case studies should be considered by the DfT.

On the data side, the DfT could review the appropriate sources and methods supporting the segmentation travel demand by income group, including appropriate validation techniques. On a more practical note, case study analysis to review the extent of changes to model run times would provide some insight on the appropriate proportionality considerations for practitioners.

6 Implications for social and distributional analysis more generally

6.1 How would new guidance on DWs interact with TAG 4.2?

When writing new guidance on distributional weighting (DW), it is vital to keep in mind how it will interact with existing TAG 4.2 guidance. The interaction will depend on how DWs can be used.

Firstly, it is important to understand that the purpose of distributional weights (DWs) is to better capture the value of user benefits to those groups most impacted, accounting for their marginal utility of income. In practice, we would need to show the distribution of benefits and disbenefits by income group (in adapted DIA tables), which can feed into decision making on

route options and/or reduced ticket prices for low-income groups. DW analysis could be part of a wider set of considerations which aim to increase accessibility for transport by reflecting how benefits vary by income. Nevertheless, DWs can be used for groups other than low-income, for instance we can evaluate user benefits by gender as it is well established that travel preferences vary by gender.

When looking at DW benefits, the primary focus is user benefits as these are typically the largest benefits generated by the transport scheme. However, non-users of transport schemes can be disproportionately affected, so there is a question on whether the distributionally weighted impacts should also look at non-user benefits, for instance air quality impacts affecting deprived communities, and wider economic benefits such as regeneration benefits.

Secondly, it would be useful for practitioners to know how DWs are used when making investment decisions and evaluating business cases, as increased transparency will increase their usage. If a second BCR is produced with distributional weights, value for money guidance should be updated to reflect how the overall VfM of the project should be determined based on both a weighted and an unweighted BCR. The DW-based BCR might be considered to be the BCR that best reflects equity rather than efficiency – but there is likely to be some debate on this.

Thirdly, when using DWs in appraisal to compare transport schemes, clear guidance should be provided on proportionality and what size of scheme would require this type of analysis, as the analysis could require significant work. The criteria for applying DWs in the Green Book may not be appropriate, as it is based on whether redistribution is a policy aim but does not consider if it is a policy implication. Considering the diverse nature of projects, where some may have broader economic impacts while others focus on social benefits, we suggest that Activity and Agent-Based models (A^2BMs) have the potential to improve equity analysis due to their capacity to capture more disaggregated impacts. There is perhaps a case for extending TAG to include such approaches.

6.2 Would it complement or substitute?

We consider DW analysis to be complementary to the current TAG guidance, given that not all transport promoters will have the capacity to develop these models themselves and indeed it may not be proportional to do this. In addition, the existing guidance covers descriptive analysis of distributional impacts which should not be lost if distributional weights are implemented and a weighted BCR is added. TAG Unit 4.2 is currently used to structure the distributional analysis, define key indicators and identify groups of interest. Such analysis will remain useful irrespective of whether DW analysis is available.

6.3 Is there likely to be consistency between the policy implications stemming from DWs vs. 4.2?

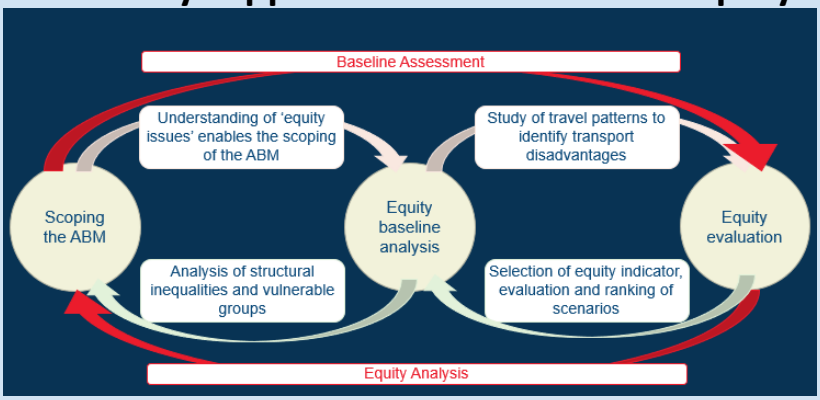
We are mindful that policy implications stemming from DWs and TAG Unit 4.2 could diverge depending on the specific objectives and priorities of a given transportation project or policy and how DWs and TAG are used.

DWs applied using the Green Book method may have the potential to contribute to a rebalancing of where transport investment is spent, if a higher weighting is allocated to schemes in lower income areas leading to higher BCRs in lower income areas when schemes are compared nationally. By contrast, TAG Unit 4.2 highlights which groups benefit from a given scheme, for example enabling consideration of which route option may advantage or disadvantage particular groups. It also helps the practitioner to better understand where supplementary measures may be required to support access by lower income groups (be it a new rail line, road or other scheme).

6.4 Additional considerations and approaches to DIA

We recognise that there is a need to accurately evaluate the potential social impacts of transportation policies and the consequences for different groups of the population. In this context, activity and agent-based models have been shown to produce robust analysis of distributional impacts, overcoming the lack of income segmentation in traditional travel demand models. However, practical applications of these models are limited, and the literature in this area is still in its early stages of development. Below, we summarise a case study from one of the few applications exploring how well an A2BM travel demand model performs an equity-based analysis of various transport planning scenarios.

Case Study: Applications of A²BMs for equity analyses



Source: Arup's elaboration.

We have used BERTIE[1], the Regional A²BM for Transport East (developed by Arup), to explore the potential applications of agent and activity-based models to evaluate equity effects of transport policies and interventions including road pricing, electric vehicle scenarios and active travel scenarios.

This research work has also developed a framework for using A²BMs to evaluate equity impacts and identifying both the beneficiaries and those negatively impacted by transportation-related policies.

Results confirmed the suitability of A²BMs for equity analyses as they provide better information (individual-level changes) on the extend that different planning scenarios affect disadvantaged groups (i.e., low-income people, women, and the elderly) and allow decision makers to rank policies based on the achievement of equity objectives. The analysis indicated that favouring inclusive modes or encouraging an electric vehicle transition do not immediately raise issues of equity. In contrast, low-income people were found to be more adversely affected by road charging schemes, which can lead to substantial social equity disbenefits. In the light of this conclusion, this study offers some key strategies allowing for the adoption of more equitable road pricing solutions.

[1] BEhaviouR & Transport: Impact & Equity Model.

Our work included:

1. **A review of the literature and practical applications of A²BMs for transportation equity analyses.**
2. **Establishing a framework for using A²BMs to evaluate equity impacts and understand the "winners" and "losers" resulting from transportation-related policies.**
3. **Applying the proposed approach to a real-world case study using BERTIE.**

7 Discussion

The previous sections have flagged some of the key issues and challenges for the implementation of DWs in transport, setting the context for this discussion. The discussion will build upon the three pillars explored so far: i) the Green Book mandate, ii) the state of affairs in TAG relative to distributional impacts and income effects (mainly through the VTTS), and iii) the key academic literature.

Before we start, we also note a number of related questions of special interest to DfT (as per the ITT) which will be addressed in this section:

1. *Is it robust to apply DW to TUBs when in reality benefits may be transferred downstream or upstream to other markets?*
2. *Moving to DW exposes anomalies in the treatment of TUBs where there is mode shift. Do the VTTS differences by mode (when DW are applied) reflect user effects (i.e., even when controlling for income) or mode effects? Where it is the former, this challenges the existing application of RoH. Do we need to address this?*
3. *In theory, only mode effects relating to comfort and convenience (i.e., MUT effects) on the value of time should be captured in choice utility functions, while user segments should be also reflected within the model. In principle we agree with this assertion, but in practice the two effects are often confounded.*
4. *Is discounting (which is a form of inter-temporal distributional weighting) consistent with the distributional weights proposed here?*

It seems to us that the application of DWs, given the complexities involved and the lack of precedents in the transport appraisal sector, needs to be a balancing exercise between theory, practicality and proportionality.

When considering a CBA as a whole, the following points seem relatively clear:

- There should be no DWs on capital, maintenance and renewal costs.
- DW would apply only to the impacts to individuals and/or households.
- In transport, DWs should apply to all impacts on users, and not only travel time saving impacts (thus, any approach should be generic and coherent to cover the VTTS and other reference values and benefits calculations). For instance, consider a scheme that combine time savings, monetary (e.g. fare) changes and reliability improvements. All user benefits should be treated in the same way.
- There may be a question around their application to externalities (safety, noise, accidents), which will be discussed later, but their application to all user benefits in a consistent way would seem necessary.
- DWs would not be relevant for modelling and forecasting, where behavioural values are used. The DWs would come at the stage of appraisal once all benefits have been calculated – first unweighted and then weighted. However, there would be a benefit in a move to a behavioural values approach with DWs for appraisal, since the unweighted CBA will be more transparently aligned with the modelling.

Secondly, and more importantly, in addressing the challenge of implementing DWs in TAG, there is a series of (less straightforward) issues which need to be worked through:

- **Theoretical basis**. What social welfare function (SWF) is being assumed?
- **At what level are the DWs going to be applied?** To what group of individuals? How is the segmentation going to take place in practice so that a set of guidance-based DWs can be readily applied to all schemes that require them? And at what component level (e.g. VTTS or at a more aggregate level (benefits to different groups of people)?

Potentially, if you have a clear population to which to apply DW, then are distance-based weights still needed?

- **Reference values for unweighted impacts**. There is a need to think about what reference values (VTTS and other relevant valuation parameters) would be used to generate the unweighted benefits and costs. This requires us to go back to the drawing board and possibly re-think and re-do the analysis of the VTTS models with the 2014/15 data. The role of that model changes. What should be the drivers of the model? What is now the meaning of the variation by distance, mode, etc.? Should the values be controlled for income? For example, are we happy with behavioural values as they are or do we think distance may be a proxy for something else related to income?[8]
- The **level of granularity** to be applied will require consideration. Do we replace a single value for commuting VTTS, which is itself a weighted average, by a large table of values varying with income, journey length, etc.? For the very largest schemes, would scheme specific data on user characteristics be required?
- **Mode effects**. Until a new VTTS study, with new experiments, is undertaken, the issue with mode effects will remain. The existing 2014/15 data will not enable the disentangling of mode effects and thus the estimation of VTTS by modes that differ according to comfort/time-use, etc. This has limitations for the appraisal of schemes that involve substantial mode switching. For example, the behavioural values would show bus to have the lowest VTTS, even after controlling for income. Consider, for instance, a Restoring Your Railway new line scheme (e.g. Dartmoor Line) where many bus users switch to rail. Applying behavioural values at face value would imply an increase in the VTTS of those users, which would be counterintuitive as rail is expected to offer a better quality service. The problem is that the VTTS SP data did not contain information relevant to switching behaviour or mode effects for the same individual. Therefore, this will remain a gap until new data is collected. If behavioural values are used with the current data, this will need to be thought through, perhaps making provision for a different use of VTTS in such mode switching contexts.
- Mindful of the above, a shift to using DWs would help address the issue of user vs. mode effects, in turn tackling the long-standing debate between proponents of **behavioural values vis-à-vis equity values**. DWs would enable the CBA to exploit all the advantages of behavioural values (unweighted results) while also addressing the distributional concerns explicitly (weighted results).
- **Dynamics.** Another question to consider is 'what happens when a project moves a user group from one category to another'? The application of behavioural values and DWs would seem easier in situations where behaviours remain relatively unchanged between Do Minimum and Do Something (i.e. marginal projects). Anomalies may arise

[8] See section 3.2 of the Task 2 report.

once we consider dynamic effects, which could happen in relation to mode switching or changes to the mix of trips by distance or purpose.

- **Final beneficiaries**. Any reference value of non-working time is essentially agnostic relative to the treatment of initial versus final benefits. So, one unit of time benefit is worth one unit regardless of whether it accrues to the traveller, or is passed back to the employer, or to the land owner. If distributive analysis is to be applied, this forces us to make an explicit assumption about who really gets the benefits of commuting and leisure time changes. We think this requires discussion.
- **Do we have the necessary input data from transport models?** For example, for Project A, do we know the journey length distribution from which to calculate the weighted average VTTS? How do we handle intrazonal trips, external to external trips etc? We suggest there is a need to consult the modelling community on the practicalities, depending upon exactly what is proposed. If we believe that behavioural VTTS varies with income and journey length, what are the implications for the number of user classes required in modelling? This was discussed in detail in the consultation on the 2014/15 VTTS study (DfT, 2016)[9]
- **What position is taken on safety and environmental impacts** which accrue to households? In principle do we need weighted values of statistical life, NOX, particulates, noise, etc.? Can an argument be sustained that extending weighting to such impacts is not proportionate? However, consider a scheme which links to wealthy cities/towns by means of a polluting and noise new transport link, where the negative externalities are mainly felt in the in-between poorer communities. There may be schemes that require DWs to be used also for externalities, so this will require some thinking.
- **Fares and prices**. The different treatment of VTTS and money in appraisal introduces some problems in appraisal which consistency could help to address. However, there will be practical issues to be worked through. In some appraisal contexts, the impact on fares can be relatively ill-defined and simple assumptions are made. The join between the Passenger Demand Forecasting Handbook (PDFH) and TAG, and between generalised journey time (GJT) versus generalised costs (GC) may need to be revisited. A decision will be needed on the treatment of VoC in roads appraisal. There may be resistance in some quarters to translating the face value of fares, tolls and VoC into a distributive weighted value.

[9] See the think piece by Whittaker and Hanson in Annex C.

8 Concluding remarks and recommendations

8.1 Concluding remarks

This think-piece has addressed the key issues around the implementation of distributional weights (DWs) in transport appraisal, with a focus on the UK context. To the best of our knowledge, DWs are not applied in any transport appraisal guidelines worldwide, with the only exception being the World Bank in the 1980s for a short period of time. Recently, the issue of DWs was seriously considered in the Netherlands but ultimately officials decided against the use of DWs, opting to recommend the mapping of distributional effects instead. The academic literature in this area is also thin.

The Green Book provides some guidance on when and how to appraise distributional effects, including the specific case of using DWs in CBA. The Green Book seems to leave open the question of using distributional weights vs. relying on other forms of distributional analysis, which mainly depends on the scheme/policy context and proportionality. However, the generic wording of the Green Book feels open to interpretation. This, coupled with the complexities specific to transport appraisal, leads us to conclude that an initial step towards potential inclusion in TAG would seem to require the translation of this part of the Green Book guidance into the transport context.

If DWs are applied, the Green Book sensibly prescribes that the CBA presents both unweighted and weighted results. In a transport context, this means there is a need to first rethink and establish what input values (VTTS, but also other value parameters) should be used to obtain the unweighted results. This is not trivial since the central parameters in transport (VTTS) have traditionally embedded some distributional considerations. In the absence of DWs, the debate has traditionally focused around the use of 'behavioural values' vs. 'equity values'. The use of DWs could possibly assist in reconciling these two positions, since the CBA would include both a scenario with behavioural values (i.e. unweighted benefits) and a scenario with DWs which takes account of the income distribution issues that motivates the interest in equity values.

Therefore, to apply DWs in transport, the definition of behavioural values must first be addressed. The selected set of behavioural values should be aligned with the proposed DWs, bearing in mind feasibility in terms of data and modelling. Also, there should be consistency across the different unit values for all benefits – including all forms of user benefits (e.g. different travel time components, monetary costs, etc.) and other benefits (e.g. health and environment related values). Even with a focus on VTTS alone, it is not immediately obvious how behavioural values should be formulated, as a number of segmentation options must be considered (including combinations across purpose, mode, distance and income). In an ideal scenario ('first best' approach), DWs should be applied by income segment, whilst other dimensions of segmentation are dealt with through the process of deriving behavioural values.

In practice, the above means that the debate around the introduction of DWs in transport should be framed in terms of a comparison with the current VTTS approach. While we believe

there is a sound theoretical appeal for using DWs – in terms of the advantages it can bring to enhance appraisal – the issues highlighted in this report are not trivial and warrant substantial effort. Thus, we would recommend that the DfT first reconsiders the various ways in which, jointly, behavioural values and DWs could be devised.

8.2 Recommendations

The current DfT proposal to change from mileage-weighted average values of travel time for commuting and other non-work purposes to a set of appraisal values varying also by distance is, we suspect, one of the most significant proposed changes to appraisal practice for many years. Before committing in principle, and to help prepare for the consultation phase, we recommend that the Department takes the following actions.

R1	The Department of Transport (DfT) should first undertake further analysis to better understand: • Whether time benefits for commuting and other non-work purposes can confidently be assumed to accrue to the traveller rather than passing substantially to other economic factors. • Whether distance banding rather than time banding is clearly justified and whether it risks producing systematic bias in favour of relatively fast modes and journeys. • Whether applying banding to appraisal values but not to demand modelling accentuates consistency issues. • Whether the modelling community is comfortable with the practicalities of income segmented demand modelling. • Whether intended practice relating to the treatment of time benefits is consistent with the way in which the lead Departments for health, safety and environmental values are intending to respond to the Green Book recommendations.
R2	Then, if DfT is minded to move forward, we recommend the development of some case studies to illustrate the size and pattern of the effects relative: a) to the status quo and; b) to the status quo modified by the recommended Green Book distributive weight but without distance banding. The use of case studies will also help to flush out some of the issues discussed above, including practicalities and the question of proportionality.

R3	We think that DfT might benefit from discussions with officials and experts in the Netherlands and Sweden where the issues of 'behavioural' versus 'standard' values, and the application of distributional weights, have been extensively debated.

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Title	TTWO0213: Audit of Distributional Weight Analysis Task 3: Think piece
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Editor	Richard Batley
Version Number	1.0
Date	29th September 2023
Distribution	
Availability	Restricted
Signature