

Think Piece: Appraisal using Activity and Agent Based Models

Research Report
for
Department for Transport



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List of Abbreviations

AABM	Activity and agent based models
AcBM	Activity based models
AgBM	Agent based models
CS	Consumers surplus
CSI	Consumers sentiment index reported monthly by S&P Global
DfT	Department for transport
DVLA	Driver and vehicle licensing agency
EV	Electric Vehicle
GIS	Geographic information systems
GPS	Global positioning system hand-held device
GV	Goods vehicle
HGV	Heavy goods vehicle
LUTI	Land use transport interaction models
LGV	Light goods vehicle
MaaS	Mobility as a service
MCC	Manual classified counts
MGV	Medium goods vehicle
NTS	National Travel Survey
ONS	Office for National Statistics
PDC	Peter Davidson Consultancy Ltd
RoH	The consumers surplus Rule of a Half
RP	Revealed preference
SEV	Shared EV
SP	Stated preference a technique to measure travellers VoT and WTP
SM	Standard transport Model as described in TAG

SMA	Appraisal with the SM as described in TAG
SWB	A person's stated measure of their wellbeing
TAG	Transport Analysis Guidance
TASM	Transport appraisal and strategic modelling part of DfT
ULEZ	Ultra-low emissions zone
VAAD	Valuing activities undertaken at the destination
VAWT	Valuing activities undertaken while travelling
VDM	Variable demand model
VoT	Value of time
VTTs	The value of travel time savings
Wellbeing report	DfT's publication "Transport, health and wellbeing – an evidence review for the DfT" (see references for details)
WTP	Willingness-to-pay
ZEZ	Zero emissions zone

1 Executive summary

The Transport Appraisal and Strategic Modelling (TASM) team at the Department for Transport (DfT) has been exploring activity based and agent based modelling (AABM) and in May 2024 published [Transport Analysis Guidance \(TAG\) unit M5.4](#) on agent based methods and activity based demand modelling. A few activity based demand models have been built in this country, with an increasing interest in using AABMs. There has been a question whether an AABM can be used for appraisal. TASM, wishing to explore this further, commissioned Peter Davidson Consultancy Ltd (PDC) on 3rd May 2025 to carry out this think-piece study involving some blue-sky thinking into AABMs and their potential use for appraisal.

The analyses, conclusions, and views expressed in this report are those of PDC, based on their professional judgement and informed by inputs from experts across academia, government, and industry, and should not be interpreted as the official positions or decisions of the Department for Transport.

This report does not provide definitive and final actions, instead it seeks to open up this subject area for discussion and debate and provides initial thinking for DfT and the industry as we start exploring the possibility of using AABMs for appraisal. It does not examine all the detail necessary to establish the scientific evidence-base for AABM appraisal and it does not solve all the problems of appraisal with AABMs. It does seek to discuss some of the issues and recommend ways which these could be addressed with further research and consideration by others. There may be issues which this report overlooks or does not give sufficient airing.

This project set some nomenclature for AABM which it contrasted with the standard model (SM). It discussed activities versus agents and introduced the conventional activity and agent based architecture with a population synthesiser, activity generator and activity scheduler replacing the trip generation part of the SM. Although both use the logit choice model, one of the key differences of AABM's is that they operate on individual people rather than (the SM's) trip ends. The logit models from both produce probabilities of choosing each of the choice alternatives. The AABM goes a step further and uses Monte-Carlo simulation to make the decision to select one of the alternatives. This introduces stochasticity into the model which complicates the appraisal process which require special treatment in AABM.

The project adapted the idea of the Consumers Surplus (CS) to develop several AABM appraisal methodologies which were put to a workshop of academics and practitioners, economists and modellers on 24 July 2025, to seek their views and their more general views on using AABMs for appraisal as follows:

1. Applying the current appraisal methodology in activity based and agent based models with three potential solutions as follows:
 - a. Build trip matrices from the synthetic population's decisions for input to TUBA

- b. Apply CS to the synthetic population's decisions and build benefit matrices.
 - c. Apply CS to the synthetic population's decisions, tabulate over individuals (eg to investigate equity), with the sum giving benefits.
- 2. Extending the current value of travel time savings (VTTS) methodology, to include the value of the time spent undertaking the activity itself as
 - a. The value of the activity while travelling (VAWT)
 - b. The value of the activity undertaken at the destination (VAAD)
- 3. Exploring other potential opportunities such as valuing wellbeing, life satisfaction and happiness improvements.

The workshop endorsed these methodologies with detailed comments including:

1. AABM modelling methodologies would need to be adapted to support appraisal in particular to address the stochasticity nature of AABMs
2. The current appraisal potential solutions would need testing in practice.
3. The value of activities could be included in appraisal where they change between without scheme (DN) and with scheme (DS). Research would be needed to devise a suitable set of definitions for each type of activity VAWT, VAAD. These would need reliable measurement avoiding overlap with VTTS while ensuring complete coverage.
4. Wellbeing, life satisfaction and happiness was considered to be important and should be included in appraisal, preferably with its own metric
5. The workshop suggested a complete top-down rethink of the appraisal objectives.

Not every scheme would require valuing activities and wellbeing but for those that do, DfT could share data and tools to ensure compatibility between schemes, unify strategic and economic appraisal cases, support early stage optioneering and help develop National policy. This report outlines a suggested toolset which essentially involves DfT preparing a synthetic population of the whole country together with its lifestyle AABM. This model would also be suitable for assessing UK policy and devising transport strategy.

Taking the workshop ideas and developing them, this project sought and found evidence of transport's effect on wellbeing, life satisfaction and happiness. It found that *"wellbeing is strongly linked to transport because a good transport system enables access to work, services, and social connections, while also promoting physical activity and reducing environmental harms. Conversely, transport barriers can cause stress and negatively impact physical and mental health, particularly in areas with poor accessibility. Investing in the transport system can improve wellbeing, life satisfaction and happiness"*.

The evidence of transport connections to various aspects of wellbeing are discussed including to air quality, biodiversity, greenspace and other place-based wellbeing. Social scientists often recommend that measures of subjective well-being (SWB) should augment the usual measures of economic prosperity. There is intense public and political interest in lifestyle, wellbeing and happiness as shown in the UK by the

S&P Global UK Consumer Sentiment Index (CSI) Monthly Monitoring Survey of about 1,500 households which has been reporting financial wellbeing with its own metrics continuously since 2009.

The project describes how life events can be modelled within the AABM with techniques such as lifestyle modelling by considering them as long-term choices which can be modelled using RUM choice models within a lifestyle context which start with the synthetic population. Households make long-term choices (such as choice of home/ job/ school location, car purchase) and they are increasingly being incorporated into AABMs as a better way of modelling these decisions (than for example land use transport interaction (LUTI) modelling) – again using RUM concepts. The lifestyle model sits on top of the activity generator sub-model and below the population synthesiser in the typical AABM model architecture.

The idea behind this is that decisions about where to live, which job to take, which school the children should go to, are often triggered by life events within the household such as when a household has children, when they reach nursery, primary or secondary school age, if or when they go to tertiary education, when they leave home, when they get a partner, when they have their own children, when the parents retire and so on. Life event changes can also be triggered by changes in job or other changes such as those of parents or grandparents. These lifestyle changes are not the only times when these decisions change. There are various different variants of the lifestyle model but in principle, they have two parts as follows:

- 1) Forecasting the type of life event and when it happens – the life event trigger.
- 2) Forecasting the decisions which ensue from the triggered life event.

Forecasting the life event trigger draws on the ideas from cohort survival modelling which is an established methodology for forecasting populations such as the UK's. During one year, a proportion of households will have a life event which can then be used to trigger changes in the household's decisions. RUM choice models can be used to forecast the decisions which ensue from a life event trigger. The location of the new house/ job/ school etc could be determined with a destination choice model with transport access a key determinant. These behavioural relationships are already well understood and modelled with RUM choice models. Lifestyle models like this could be quick to take into account trends in the population such as the drop in driving license ownership for young people as they get older.

Validation is as important for AABMs as it is for the SM although with different emphasis. AABM logit model coefficients are usually estimated using discrete choice maximum likelihood logit model estimation (as are some SM). This process estimates elasticities directly on local data with statistical evidence for their efficacy such as the coefficients' 't' statistic and various model fit statistics based on the proportion of the loglikelihood explained by the model (eg the rho bar squared, AIC or BIC statistics). This should bear more weight than overall elasticities such as quoted in TAG so the latter, while worthy of comparison, should not override the former.

AABMs have another validation opportunity offered by the reasonableness of the behavioural mechanisms of individuals. This would involve taking an individual in the

population and tracing their decisions together with the values of the variables used in their decision-making. The analyst would need to report on them clearly and in such a way as the reader can see that that person would indeed make those decisions for their activities under those levels of fare, travel time etc.

AABMs can be applied with final pivoting but they are best applied without ie as absolute whereby the sequence of trips and tours which come out of the model, get assigned directly. Absolute assignment allows the assigned flows to be directly traced back to the individual people who are on that link which allows the full set of segmentation variables to be used to tabulate and analyse link flows enriching AABM's capabilities to understand travel behaviour, facilitating equity analysis, air quality analysis (through knowing the vehicle type and its emissions profile) and a lot more.

Other aspects not currently addressed by AABM lifestyle modelling, but which are important for wellbeing, such as a person's health, could be incorporated into the lifestyle modelling framework. Each person's health would need to be incorporated into the base year synthetic population and this could be accomplished by knowing the proportion of the population with each type of ill-health for each cohort in the population (eg from census data) and putting this on the synthetic population using one of the methods described herein.

Having used the AABM lifestyle model to forecast the components of wellbeing for the DN and DS scenarios, the appraisal process needs to apply measures of wellbeing and devise a metric with which to value wellbeing improvements (or deterioration). There are various wellbeing metrics in current use including subjective wellbeing (SWB) but this topic needs further research if it is to be integrated into appraisal.

The project described how DfT might help the modelling and appraisal process by preparing a set of data and tools which would comprise developing a national activity, wellbeing and lifestyle model. This could potentially augment and eventually replace the National Trip End Model. It would forecast the future changes in activities, wellbeing and lifestyle to provide trip ends for the existing aggregate models and provide the future-year synthetic populations for AABMs which are consistent for appraisal. It could also model government policy priorities, forecast revenue (eg from EV taxation), help plot the path to transport net zero etc. DfT could use the National AABM to test national and regional policies by changing any of the model inputs including the following:

- New rail, bus etc corridors and services including high speed rail
- Fares, fare structures such as railcards, season tickets, mobility as a service (MaaS) etc (the AABM has almost infinite segmentation possibilities), eg free off-peak fares for the elderly or mobility impaired.
- Behavioural responses to changes in travel attitudes such as home-working, regional policy such as levelling-up, economic prosperity, jobs, homes, wellbeing, happiness etc.

- Policies which speed-up changing the vehicle fleet such as EV take-up, CAV. The model could forecast revenue raised from taxation eg from road use charging, fuel taxes or by charging EV's per vehicle mile, and many more.
- As well as all the conventional land use and transport supply changes commonly the province of the SM.

The demand part of an AABM generally runs much quicker than the assignment part and the National AABM could be configured to run even more quickly for example the whole UK population could be run through the National AABM in under 30 minutes.

This National AABM could be connected to the driving and vehicle licensing agency's database (DVLC) from which it could automatically generate a set of vehicle agents which could be appended to represent the vehicle of each person in the synthetic population. The vehicle agents would retain the details of each vehicle such as its drive train, fuel type, range, carbon and other emissions profile. This would be carried right through the assignment model so as to forecast the emissions on each highway link in the networks. This could be used to forecast emissions and air quality policies such a Zero Emission Zones (ZEM) or Ultra Low Emission Zones (ULEZ). This model architecture was used successfully recently in a major Middle East model to help devise urban emissions policies and measures to support their drive to net zero.

Scheme promoters would receive a synthetic population from which they could extract their area of interest rather like they do now with the National Trip End Model's trip ends. A set number of scenarios might be run by DfT and their corresponding synthetic populations created and provided to scheme promoters but with proper behavioural response modelling and forecasting. It could also be used in conjunction with a scheme to provide its wellbeing metric.

Following the workshop suggestion to re-think appraisal from the top-down by examining the ideal appraisal objectives, this project considered that the economy, wellbeing and national policy should be the three main appraisal objectives.

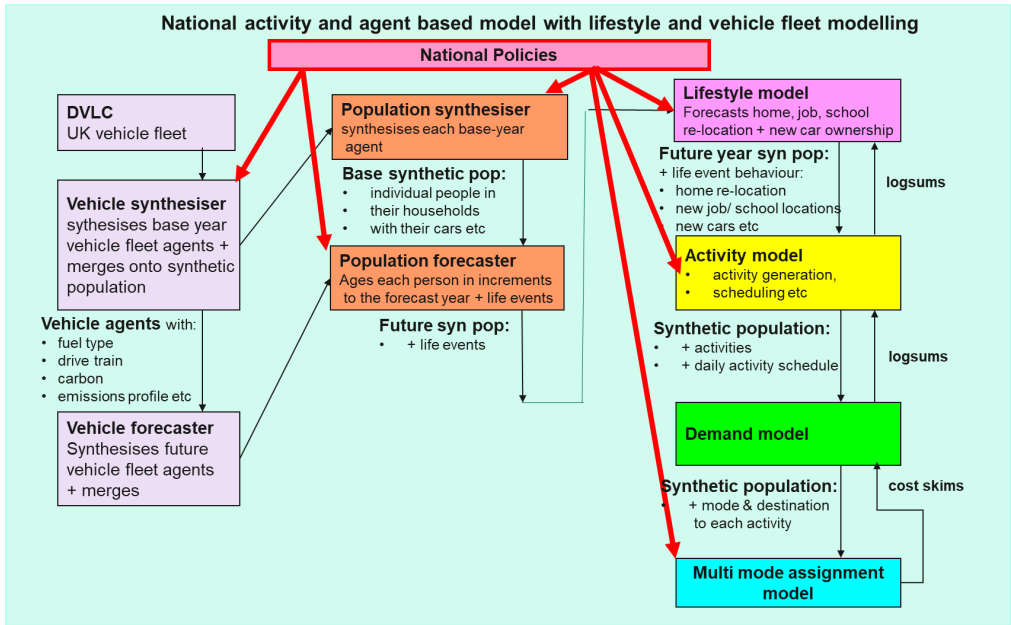


Figure 1.1 National lifestyle AABM model architecture with vehicle fleet modelling

2 Introduction

The Transport Appraisal and Strategic Modelling (TASM) team at the Department for Transport (DfT) has been exploring activity based and agent based modelling (AABM) and in May 2024 published [Transport Analysis Guidance \(TAG\) unit M5.4](#) on agent based methods and activity based demand modelling. A few activity based demand models have been built in this country, for example, those models developed by Transport for London (Teye 2024), Transport East (BERTIE 2025), Oxfordshire (Davidson 2024), Truro park and ride (Clarke 2008), and models for Glasgow, Barcelona and Lyon developed for the Esprit EU project (Porter 2017, Davidson 2018).

Interest in using AABMs is increasing and at some point, they or others may wish to use an AABM for appraisal. TASM, wishing to explore this further, commissioned Peter Davidson Consultancy Ltd (PDC) on 3rd May 2025 to carry out this think-piece study involving some blue-sky thinking into activity and agent based (AABM) models and their potential use for appraisal. The project generated some ideas which were put to a workshop of academics and practitioners, economists and modellers on 24 July 2025, to seek their views on these ideas in particular and more generally on AABMs and their use for appraisal. The workshop ideas were then developed into workable solutions and recommendations for DfT. This is the final report of this project which was completed in November 2025.

This report does not provide definitive and final actions, instead it seeks to open up this subject area for discussion and debate and provides initial thinking for DfT and the industry as we start exploring the possibility of using AABMs for appraisal. It does not examine all the detail necessary to establish the scientific evidence-base for AABM appraisal and it does not solve all the problems of appraisal with AABM. It does seek to discuss some of the issues and recommend ways which these could be addressed with further research and consideration by others. There may be issues which this report overlooks or does not give sufficient airing.

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2.1 Research objectives

When this project started, this think-piece study aimed to:

1. Understand whether activity based modelling (AcBM) and agent based methods (AgBM) can be used in a transport appraisal, and if so, how it might affect how appraisals are carried out.
2. Identify aspects of appraisal that may change as a result of insights that can be gathered from activity based modelling and agent based methods.
3. Identify evidence gaps and key research required for adapting transport appraisal methods when activity based modelling and agent based methods are used

This research was guided by a set of principles encapsulated by the following:

- A theory of the economics of time (eg DeSerpa 1971)

- Consumers surplus (eg Marshall 1890)
- Random Utility Maximisation theory (RUM) (eg McFadden 1974)

Where the benefits from a transport scheme are related to the surplus consumers make by using the scheme instead of their current method (route, mode of transport etc). This involves valuing time which currently means valuing the travel time but might also include time spent on other activities. RUM theory models a person's decision (eg to use the scheme) between a set of choice alternatives (eg the current method) based on maximising their utility where utility is composed of a measured part and a random part.

2.2 Structure of this report

After this brief introduction (chapter 2), this report describes the current standard model (SM) appraisal together with areas where it could be improved (chapter 3). Chapter 4 describes how AABMs could be used to provide SM – compatible appraisals together with some of the advantages and disadvantages of tying-in AABMs to the SM appraisal. Chapter 5 describes extending the appraisal to include the benefits associated with the activity itself as well as those associated with travelling to and from the activity. Chapter 6 describes the workshop held to discuss these results. Chapter 7 describes the evidence for transport's effect on wellbeing, life satisfaction and happiness. Chapter 8 describes the AABM architecture needed for appraisal with activities and life events. Chapter 9 describes the extension of AABM to support the inclusion of wellbeing, life satisfaction and happiness in appraisal. Chapter 10 describes recommendation for data and tools which DfT might want to develop to support scheme appraisal with AABMs. Chapter 11 provides a top-down view of what appraisal objectives could look like if approached afresh. Chapter 12 crystallises the research into a set of conclusions, suggestions, recommendations and offers a set of ways of taking this think-piece forward. Appendix A contains the notes from the workshop. The draft final report was sent to the workshop attendees and others. It has not been possible to incorporate all their comments, ideas and papers they reference, so their text, paper references etc are given in full in Appendix B.

This report concentrates on appraisal with AABMs bringing-in AABM features wherever appropriate. It is not a treatise on AABM's which are covered elsewhere (eg Davidson 2008 or Istaiwi 2025).

3 The Standard Model and appraisal

This chapter describes those aspects of TAG's Standard Model (SM) Appraisal (SMA) which are relevant to the ensuing discussion on Appraisal with Activity and Agent Based Models. The full SMA is covered in TAG itself.

3.1 The standard model

The SM comprises a set of sub-models which are run sequentially within a feedback loop as follows (see figure 3.1):

- The trip generation model prepares the set of trips generated by, and in some cases attracted to, a zone, for a particular market segment. For the full SM, the travelling 'market' is segmented by trip purpose, car availability, income and perhaps a limited number of other dimensions. These other dimensions could include for example season ticket availability. Model segmentation is limited by the need to produce trip matrices for each segment from the demand model.
- The demand model splits these trip ends to produce a set of zone-to-zone matrices of trips by mode (and perhaps by time period/ time interval) for each of the market segments. This model is usually cast as a hierarchy of RUM choice models with the costs propagating up the hierarchy to ensure the models are sensitive to supply changes. Gravity distribution models do not fit into the logit hierarchy, perform progressively poorly for sparse trip matrices, limit segmentation even more and are poor candidates for appraisal.
- The trip matrices are aggregated to combine market segments into matrices-for-assignment and then assigned to the networks for each transport mode (perhaps for each time period and time interval). The traffic and public transport flows produced by this model may not flow at the speeds assumed in the demand model so these new speeds are passed back in the form of cost skims to the demand model.

The demand and assignment models are rerun and iterated until the flows and speeds are unchanged, whereupon the model is deemed to have converged to a unique solution. The resulting converged flows and speeds in the form of the trip matrices and cost skims are input into the appraisal process.

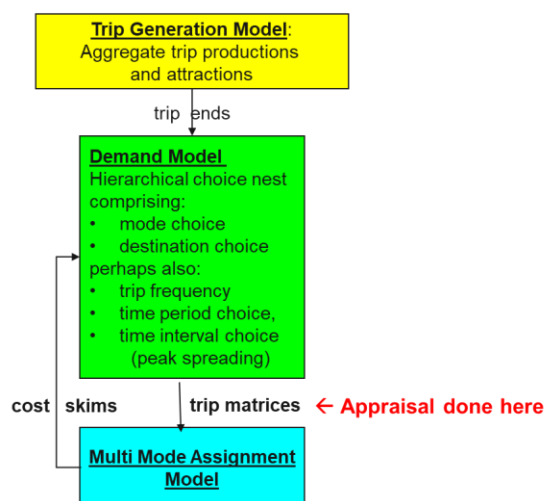


Figure 3.1 Architecture of the Standard Model

3.2 Appraisal with the standard model

Appraisal is undertaken for a particular transport intervention or scheme and the model is run for the two scenarios: without the scheme (the Do Nothing (DN) scenario) and with the scheme built (the do-something (DS) scenario). The volume changes in response to supply changes. The DN and DS converged trip matrices, cost skims and other modelled results are used in various parts of the appraisal process. The user benefits are calculated by considering the Consumers Surplus (CS) between the DN and DS scenarios in the demand graph (figure 3.2). The scheme's CS is measured by the travel volume changes in response to supply changes from the DN (ie P0, T0 in figure 3.2) To the DS scenario (T1, P1 in figure 3.2). The CS is calculated from half the product of the travel volume and cost changes which is known as the 'rule of a half' (RoH) (see figure 3.2).

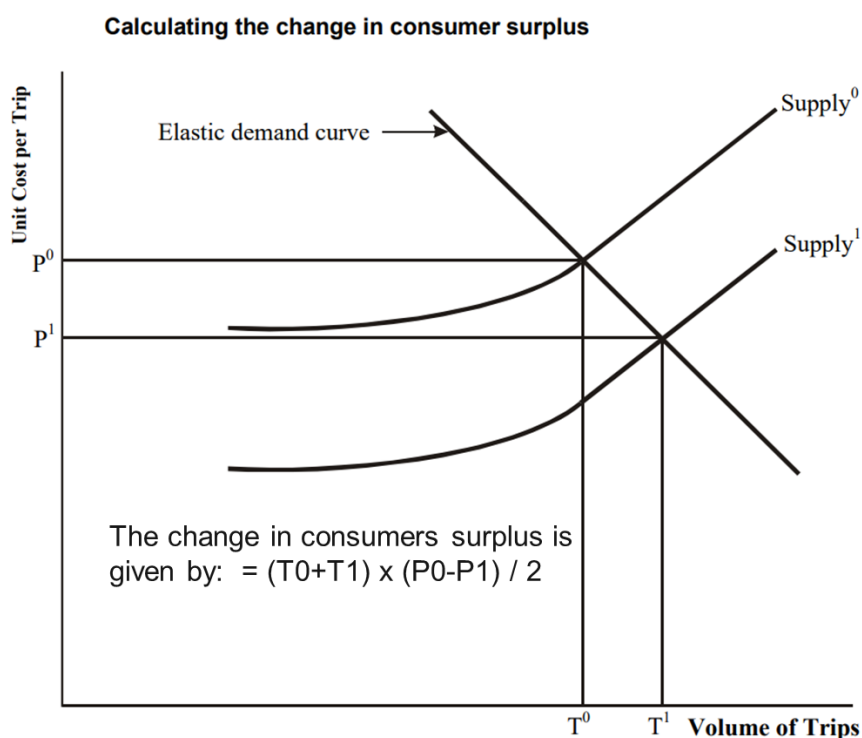


Figure 3.2 Measurement of a scheme's consumers surplus with the standard model.

4 Appraisal with activity and agent based models

This chapter describes what we mean by a TAG appraisal with activity and agent based models (AABM) in the context of this think-piece research.

4.1 Activities versus agents

Activity based models (AcBM) change the modelling paradigm by considering that travel is governed by the activity being undertaken at the destination, so that the travel to it and from it, is dependent on the nature of the activity. Activities can be such things as work, shopping, socialising, being educated, undertaking sport, leisure etc. They can be undertaken at home, at work or at other locations sometimes with more than one at the same time (such as working while listening to music). Activities are considered to be undertaken sometimes in sequence and possibly at different locations. The travel between activities is the SM's trips and the trips between a sequence of activities is the tour. The trips, as used in the SM, can be obtained from an AABM if necessary - so an AABM can do everything that the SM can do (and more).

People do activities, so in order to sensibly model activities the model has to consider individual people which are described as 'agents' so activity based models usually deal with agents although they don't have to – an activity based model could be devised to aggregate people into groups and hence not be agent based, but that is not normally done.

There can be agent based models (AgBM) without activities. AgBMs can also model other types of agents, which are not people. For example, the Esprit project model (Porter 2017) had different agents for shared electric vehicles (SEV) and for charging stations where each type of agent had its own properties and sub models. The SEV agent had its level of charge, rate of discharge, range, status (being driven, being charged, waiting to be used), location, destination (if being driven) etc. Charging stations had their capacity, maximum electrical charging capacity, list of SEV's being charged etc. This model also had people agents and the model simulated not only their activities but also the interaction between all the various agents.

The use of agents opens up a vast possible application panorama for transport models, helps explore appraisal in more depth and opens up a whole new field to be exploited.

4.2 Conventional activity and agent based model architecture

Activity based models are driven by a synthetic population which is a list of all the people in the study area with the households they are in, the location of the house they live in, their cars, bicycles etc owned (see figure 4.1). Each person is of a certain age so babies travel with their carers, children go to school. Adults are employed full time, part time, retired, unemployed, being educated or maintain the household. This helps the Activity Model determine the activities they undertake. These dynamics can be captured in an activity based model by the activity generator.

If one household member is using the only household car then it can't be used by another household member. If a household member doesn't have a driving license then car would not be an alternative for their trips. Families sometimes travel together for social, leisure, shopping etc. Someone needs to escort the children to school or escort an adult to the train station. These dynamics are modelled in the activity scheduler which schedules each person's activities throughout the day generating each persons' daily activity schedule.

The demand model finds the location where each activity is to be undertaken together with the mode of transport used to get there. It could also include other decisions such as whether to pay to go through a congestion charging area (or ultra-low emission zone (ULEZ)) or not. The activity's location may depend up the activity schedule and vice-versa, so there is normally feedback between sub-models often in the form of the logit model's logsum. Nesting the various choice models in a hierarchy connected by their logsums is the generally accepted only way to configure these decision dependencies.

The results from each choice model can be a set of probabilities (ie from a hierarchy of choice models) but more often one single alternative is selected as the decision (ie with a probability of unity) and all other alternatives are rejected (ie have a probability of zero). This most often uses a Monte-Carlo methodology where the probabilities are converted into a cumulative probability distribution across the alternatives and a random number used to select the chosen alternative. This stochastic (ie Monte-Carlo) process relies on random number draws which means that if the sub-model is rerun, it may not give the same answer. This introduces a level of complexity especially when it comes to comparing the results from two (or more) model runs in such things as appraisal. This complexity is not insurmountable and requires care in selecting the most appropriate methodology depending upon what the results are to be used for.

The assignment model can be much the same as for the SM although more detailed results can be achieved with finer temporal and spatial resolutions.

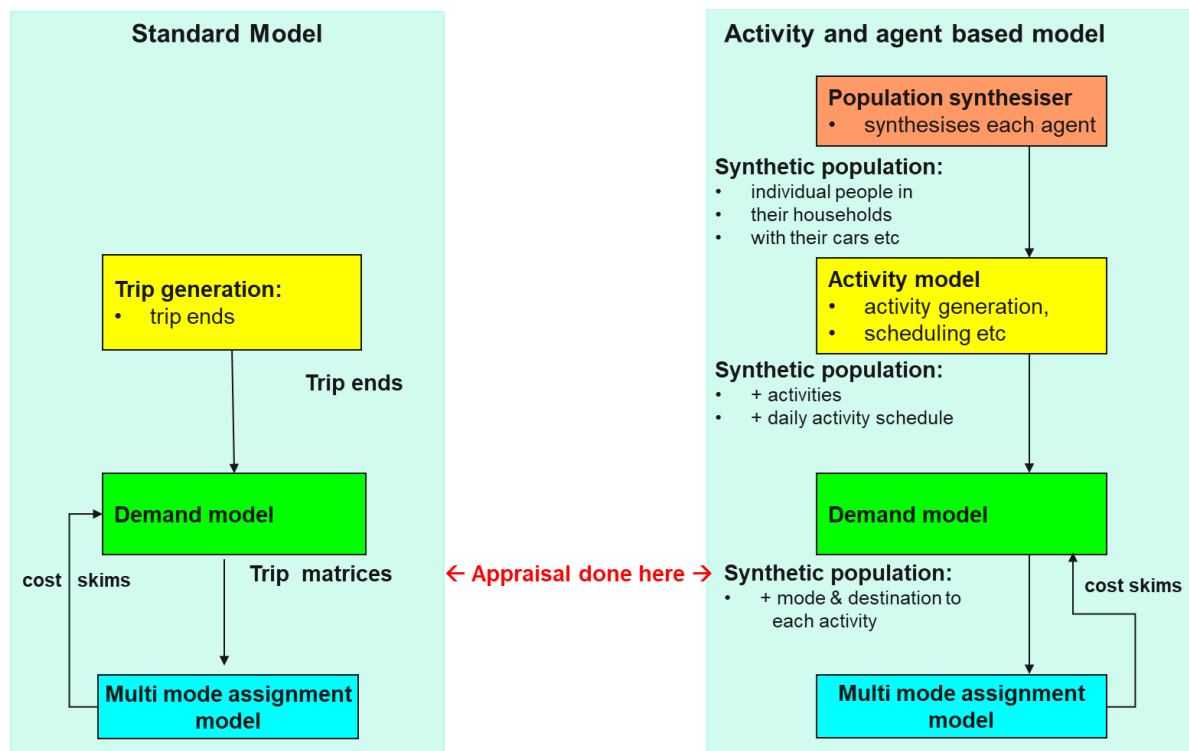


Figure 4.1 Activity and agent based model architecture compared to the standard model

4.3 What appraisal improvements do AABMs offer?

AABMs take modelling to a much finer level of detail than the SM, with not-necessarily more complexity, data requirements or computation. Their efficacy relies on a statistically better use of data by retaining detail right through the modelling process and aggregating at the end rather than (with the SM) aggregating first (at the trip end stage) whereupon the disaggregate detail is not available for modelling. The finer level of detail makes them a much finer tool for modelling and appraisal – the surgeon's equivalent of a scalpel to the SM's chainsaw.

As can be seen from the foregoing, the net outcome is that the results from all these AABM sub-models is put back onto the synthetic population so the synthetic population holds all the data about each person including details about them together with the decisions from all their choices. This is an important feature which facilitates a much richer analysis of the model results. Importantly it also means that the whole set of data for the individual is available for all models which facilitates a whole set of new modelling features.

AABMs support a much finer level of market segmentation – in fact with each individual modelled, it is the ultimate in market segmentation. It helps model the household's competition for the household car. It helps keep track of a person's ULEZ charge allowing time dependent or daily charges to be modelled properly. Public transport fares can be modelled properly with season tickets, family tickets, senior railcards, etc. Different people have different access to money, or the ability to pay and may make different choices when it comes to paying for transport. AABMs can use this personal detail effectively in modelling. They facilitate better modelling of parking where for example parking charges depend upon the duration parked which in turn depends upon the activity duration. Parking spaces could be considered as agents which: have a charge rate per hour, get used, freed up and available for the next car (this was very successful in the Truro parking model (Clarke 2008)). The modelling community are still exploring the potential of AABMs especially utilising its extraordinary segmentation abilities.

4.4 Consumers surplus appraisal with AABMs

AABMs produce all the results that the SM does such as traffic flows, public transport ridership and revenue, active mode flows, land use impacts. In addition it facilitates other outputs so the SM appraisal can be undertaken from AABM outputs by building trip matrices from the model outputs, (that can be linked back to the synthetic population) - and inputting them into the usual benefit calculation with for example TUBA together with the cost skims. This is:

- Appraisal Solution 1 and it essentially reproduces the SM appraisal process.

Applying the RoH to each individual person means that for one agent $T1 = T0$ (see figure 4.1) so their change in consumers surplus is given in figure 4.2 as $T0 \times (P0 - P1)$ which for one individual $T0 = 1$ so this reduces to simply $(P0 - P1)$. Using this for every individual person in the synthetic population and applying it back to each person would give the scheme benefit accruing to each individual person. From this the scheme benefits can be calculated in one of two ways as follows:

- Appraisal Solution 2. Build benefit matrices and compare this with the SM
- Appraisal Solution 3. Sum the benefits over individuals to give the scheme benefits.

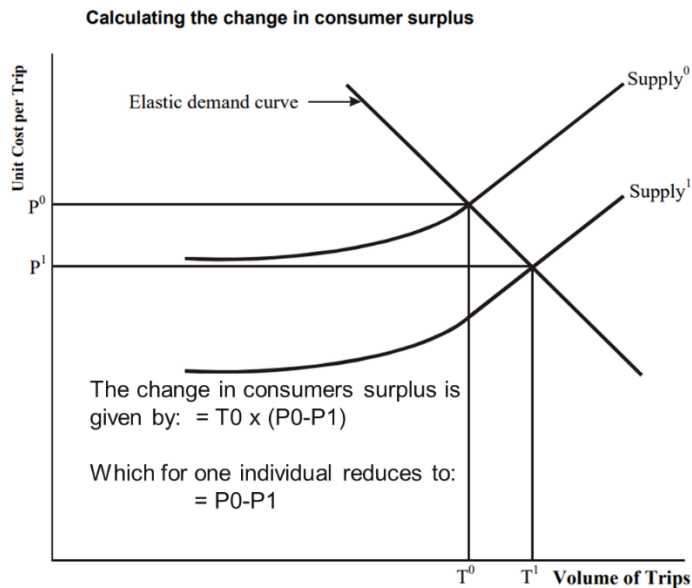


Figure 4.2 Measurement of a scheme's consumers surplus with an AABMs synthetic population.

Thus, subject to testing, in theory AABMs seem to be able to provide the same appraisals as the SM (see for example Vovsha 2009), and by capitalising on all the modelling advantages of AABMs over the SM, this methodology offers potentially much more as follows:

- They have the distinct advantage that the consumers surplus benefit is attached to each individual which can be tabulated against any of the household/person variables to see who wins and who loses and by how much. With equity analysis capability such as this, transport interventions can be targeted at certain groups eg those on low incomes, high polluting vehicles, levelling-up etc
- Some transport interventions are difficult to model properly with the SM eg congestion charging, parking, air quality measures ULEZ/ZEZ, EV's, CAV's, on-demand services, MaaS, fares, micromobility, shared services such as shared electric cars. Agent-based models could allow these to be appraised on the same basis as conventional transport interventions.
- They can be applied to variable activity patterns (with care), thereby bringing-in the possibility of including such activities as home-working, teleconferencing and valuing other types of activity in the appraisal process
- Analysis can 'see' each person using a particular link, together with their attributes which, if tabulated, offers insights such as equity. If the household vehicles' emissions profile data is in the synthetic population, then detailed emissions can be forecast for that link.
- AABMs can support more complex nesting structures so the model can model more detailed behavioural mechanisms.
- They could avoid some problems with SM appraisal such as how to derive the DN travel costs for a completely new mode of transport (such as a new light rail system)

which does not exist in the DN situation. In this case each person would have their activity schedule for both DN and DS from which costs could be skimmed.

One of the disadvantages of AABMs flows from their stochastic nature. CS is calculated as the, usually relatively small, difference between two big numbers (ie P1-P0). This small difference can be lost or rendered inaccurate, by the stochasticity. The AABMs demand model would normally comprise a choice hierarchy which, if it is a logit model choice hierarchy, would give choice probabilities. (These choice probabilities are then normally used by the AABM to form a distribution of the probability of each alternative being chosen to which a (Monte-carlo) random number draw is applied so that one alternative is selected. This alternative is then carried forward into the forecast as the decision or 'chosen' alternative.) These choice probabilities could be used in appraisal instead of the decisions which would avoid this stochasticity problem. The model can be restructured so as to minimise stochasticism such as using incrementation. Other potential solutions could adopt methods to control the random numbers to provide better comparison between DN and DS costs.

Some model structures are particularly prone to stochasticity especially when applied to appraisal such as MATSims algorithm for swapping activities in the daily schedule (ie their activity plan).

AABMs retain some of the appraisal problems of the SM. These include problems associated with poor assignment model convergence between DN and DS; different values of time between the model and appraisal.

While theoretically equivalent, these three appraisal solutions posed above need to be tested in real models to cement their equivalence in practice.

Some of the AABMs sub-models such as the activity scheduler, may not be able to avoid monte-carlo simulation which might preclude their inclusion in appraisal. These models are not part of SM, so keeping them fixed between DN and DS for appraisal would be no worse than for the SM. Investigating the benefit contribution of each model stage could provide additional insight. For example, it may be of interest to find the additional benefits accrued from allowing activity schedules to change when compared to keeping them fixed (between DN and DS). It is relatively straight-forward to extract the resulting probabilities from the AABMs demand model (ie that part below the activity schedule) so fixing the activity schedule for appraisal could be less prone to monte-carlo stochasticity. It may also be possible to use the logsums for appraisal and this should be considered and tested. This could facilitate more complex choice hierarchies, more levels in the hierarchy and more alternatives.

4.5 Some AABM modelling implications to facilitate appraisal

AABMs model all 24hrs of the day so agent based assignment models would maintain the agent detail throughout the modelling process (although AABMs can be driven from the SM's type of assignment models which cover just a few time periods). This facilitates modelling the full 24hr junction flow history with time-dependent queuing so in theory AABM assignment should use meso or microscopic assignment techniques which represent congestion in a much better way. For insightful analysis of individuals, such as equity analysis, it is best to retain the relationship between link flows and the agents they are made up of, right through the assignment model. This means avoiding pivoting and matrix estimation. This may mean that the TAG assignment validation criteria should take into account that not all traffic in the trip matrix may not both start

and end its trip during the validation period. This is especially the case for larger study areas.

The population synthesiser is commonly used to forecast the future-year population. One methodology for this, is to draw households from a household travel diary survey so as to meet overall zonal targets such as the forecast average household size, car ownership, employed residents etc. Variants of this methodology exist some of which could involve a stochastic process. However, the draws from one forecast year may be quite different from another and from the base year which could lead to inconsistencies in the forecast between forecast years. This difference could propagate into appraisal which is much more sensitive to small differences between DN and DS scenarios, as extra 'noise'. This could produce inconsistent CS benefits. Methods of avoiding this is covered in chapters 8 and 9.

5 Including the value of the activity in appraisal

5.1 Problems with only using the value of travel time savings

The value of travel time savings (VTTS) of rail commuters and of business travellers has been falling, according to recent evidence. This raises the conundrum of whether their consumers surplus has dropped and whether this reduced VTTS should be used to model their travel decisions and for rail scheme appraisal. The falling VTTS is ostensibly because rail travellers are spending the time more productively on emails etc. This situation could occur whenever travel time can be useful. For example, drivers of Connected and Autonomous Vehicles (CAV) will in theory be able to concentrate on activities other than driving and use the time more productively (eg emails). This implies that the activity they are undertaking while travelling (VAWT) has a value too which should also be taken into account if they change between scheme DN and DS.

Presumably given the choice, even with the ability to do their emails, people would still prefer a quicker rail journey to their destination, *ceteris paribus*, so VTTS would be expected to be greater than VAWT. VAWT may be non-linear in the sense that short trips may not be so attractive for undertaking activities. On the other hand, long trip activities may be valued more highly because they can be relatively more productive. The activity value may also depend on getting a table or be in a quiet area or have WiFi or an electricity charging point.

If activities undertaken while travelling have a CS value (VAWT) then it follows that other activity change due to a transport intervention could also have a CS value which brings into scope such behavioural change as home working or teleconferencing instead of commuting and business travel.

Certain schemes are considered beneficial but give disbenefits including place-based schemes such as pedestrianising a town centre facilitated by one-way traffic management systems. These typically take away road space causing disbenefits, yet are considered beneficial by providing a better town centre environment, more popular shops etc which improves the economic vibrancy of the town centre. Public transport improvements designed to promote more sustainable travel including Light Rapid Transport (LRT), bus priority measures, bus-only lanes, remove a lane of traffic, introducing car delay disbenefits which are seldom compensated for, by additional public transport user benefits. Other transport interventions including congestion charging areas, Zero Emission Zones (ZEEZ), Ultra Low Emission Zones (ULEZ), toll bridges, all restrict car use in favour of better urban 'place'. These measures are deemed to be generally beneficial to society, yet seldom, if ever, achieve positive CS benefit.

In these situations, adding the value of the activity undertaken at the destination (VAAD), in the better town centre environment, with better air quality, without reliance on the car, could help redress some of the short-fall in CS benefits.

5.2 Consider including the benefit from undertaking the activity itself

Consider adding the CS benefit due to the activities, both VAWT and VAAD, to those from VTTS. If the activities do not change between DN to DS, then there are no activity benefits only VTTS benefits so this defaults to the SM approach to appraisal. If the activity duration gets extended between DN and DS, this could have a value although some of this could be captured in the VTTS.

If the person's destination activity changes between DN and DS then this could well have a value because the person does actually change their activity so presumably, they find it more beneficial. Activities while travelling could be valued differently to the same activity undertaken at the destination. To summarise, the CS benefits would be the sum of the following:

- The Value of Travel Time Savings as now (VTTS)
- The Value of the Activities undertaken While Travelling (VAWT)
- The Value of the Activities undertaken At the Destination (VAAD)

Appraisal could just use VTTS even if the activities change which is SM appraisal and only consider activity changes if they are relevant.

5.3 Is there precedence for valuing the activity itself?

Academic literature on valuing activities and travel seems well established in the literature eg as follows:

- 1971 - De Serpa suggested putting a value on activities as well as travel time
- 1978 - Train and McFadden led to a VTTS equal to the wage rate
- 2008 - Jara-Diaz (also, 2020, 2024, 2025) valued travel time savings and activity time derived from travel diary and activity data from Chile, Switzerland and Germany to value various activities considering that people's activity pattern work-leisure balance was in equilibrium
- 2016 – Kickhofer and Nagel, Microeconomic interpretation of MATSim for benefit-cost analysis
- 2017 - Sivakumar et al prepared a framework for joint modelling of activity choice, duration and productivity while travelling
- 2024 – Bates productive use of travel time paper described his initial thoughts and future direction

5.4 Analysis of valuing the activity itself

Valuing the activity itself could have the following advantages:

- Working-from-home and other in-home versus out-of-home decisions are likely to change in future. Valuing the activity itself, rather than the travel to and from the activity could offer a more consistent approach to measuring benefits
- Certain schemes give VTTS disbenefits but are generally considered beneficial because they are implemented and AABM could facilitate their appraisal. Some could give VAWT & VAAD benefits eg pedestrianising a town centre encourages new leisure activities, better working environment etc. Bus lanes, LRT schemes etc provide extra mobility for non-car owners and more opportunity for activities. PnR frees up city-centre parking space for activities. Congestion charging and air quality measures produce a better environment thereby encouraging more activities.
- In-vehicle activities such as on-train, in autonomous vehicles would be valued.
- Even without valuing activities, AABM appraisal could be more accurate eg much finer segmentation by using individual's characteristics. They could use individual willingness-to-pay (WTP) drawing from a mixed logit WTP

distribution. This could provide more appropriate behavioural responses to eg fares, parking charges, season tickets.

- Could allow appraisal of complete strategies to support the strategic case or optioneering during early-stage scheme development, or land-use/ transport plans and policies.

It could open up new possibilities such as in the example of a new school bus service which takes the children to school thereby avoiding the school-run by parent 2 who is now free to get a full-time job. A few less cars for the school run versus a new school bus may not change the congestion and hence the conventional benefits but this household has made a big gain and there is one more worker in the UK economy.

There would be some issues which would need to be addressed including:

1. Defining different activity types. The various different activities would need to be unambiguously defined and these could start by considering the trip purposes commonly used in modelling.
2. While travelling, VAWT would need to be measured separately from its VTTS for different activity types. Methodologies exist for valuing travel time (eg SP, RP) and these could be applied to find a value for the different activities.
3. Measuring VAAD for different activity types. Time spent working has received much research and to lesser extent so has different types of leisure time. These could form a starting point for valuing activity time both while travelling and at the destination (or origin or home).
4. Finding the arithmetic of VAAD eg is 100 minutes one hundred times one minute.
5. AABMs are more likely to need stochastic processes which would need using specialised techniques for appraisal.
6. If in doubt consider activities unchanged so omit VAWT and/or VAAD which defaults to VTTS

5.5 AABM architecture to facilitate appraisal with activities

It would be easier to adopt consumers surplus theory if the AABM-specific models (population synthesiser, activity generator, activity scheduler) could be mathematically formulated within RUM theory then (see figure 5.10). One way this could be achieved is by formulating the activity generator as a RUM choice between for example:

1. Not doing the activity
2. Doing it at home
3. Doing it remotely
4. Doing it while travelling

The Activity scheduler can be formulated as a RUM choice between time intervals which could be 24 hourly intervals or could be coarser such as the SM-type time intervals eg:

1. Early morning before work
2. During work time

3. During lunchtime
4. While returning home after work
5. In the evening

This could allow the whole model to be one big choice nest with cost skims entering at the bottom of the nest, logsums passed up the nest and either probabilities or monte-carlo'ed decisions passed down the nest. This would give versatility to the consumers surplus benefit.

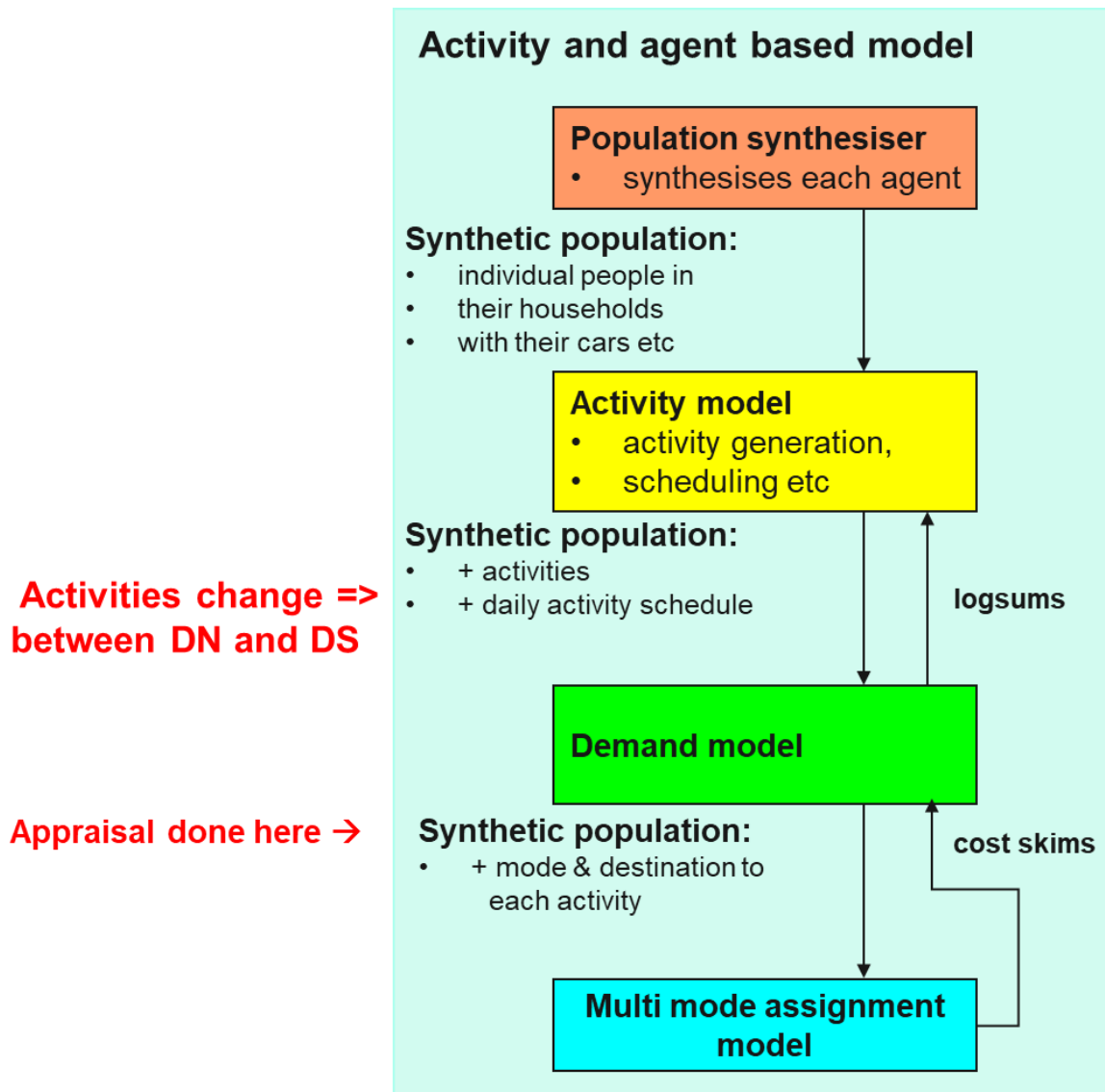


Figure 5.1 AABM model architecture hierarchy of Random Utility Maximisation choice models

6 Results from the workshop

The project formulated a set of think-piece ideas on how appraisal could be undertaken with AABMs. These ranged from extracting SM-type outputs from the AABM and putting them into a SM-type appraisal (eg with TUBA), through applying SC to AABMs agents, to valuing the activities themselves. Finally, the workshop invited other ideas from the delegates, sparked by our ideas of including wellbeing and happiness in appraisal. This chapter summarises the discussions which ensued.

Transport Appraisal and Strategic Modelling (TASM) within Department for Transport (DfT) has been working with Peter Davidson Consultancy Ltd (PDC) to explore the feasibility of undertaking an appraisal using activity and agent based models (AABM) including agent based methods (AgBM) and activity based demand modelling (AcBM).

An online workshop was held on 24 July 2025 to gather views from experts in the industry on how we might carry out an appraisal using these types of models, what would be required and what would be different from using the traditional transport models.

This note summarises the workshop discussion which was structured into 3 workshop topics as follows:

1. Applying the current appraisal methodology described in Transport Analysis Guidance (TAG) to AABMs which is summarised in chapter 4
2. Extending the current appraisal methodology to include activities which is described more fully in chapter 5.
3. Other opportunities which activity based models and agent based methods could open up which is built-up in subsequent chapters.

This is followed by our analysis of the main issues which emerged. Further details of the workshop are outlined in Appendix A. The workshop slides are given in Appendix B (in a separate file).

6.1 Workshop topic 1: Applying the current appraisal methodology to AABMs

The first topic of the workshop discussed whether the current appraisal methodology could be applied using activity based and agent based models (AABM). This essentially involved one of three methods as follows:

1. Building trip matrices from the synthetic population's agents which could then be applied with their associated skims to TUBA. The trip matrices could be single-mode or multi-mode as per the standard model (SM). This method would improve on the SM by supporting the detailed segmentation provided by the agents within the confines of TUBA's capability. It reflected the use of current methods in TUBA where trip matrices were required.
2. Applying the consumers surplus approach to each synthetic population agent's individual 'trips' or 'tours' to calculate their consumers' surplus benefits. For one agent the consumers surplus simplified to the cost difference because the 'trips' would not change between the do-nothing and the do something (ie in TAG notation $T_0=T_1$ which for one agent is $= 1$). Benefit 'matrices' could be built from the synthetic population which could be applied to cost-benefit as per a TAG appraisal benefit-to-cost ratio (BCR).

This had the advantage that the benefit matrices could be compared to those derived from the SM.

3. Applying the consumers surplus approach to each synthetic population agent's individual 'trips' or 'tours' to calculate their individual consumers' surplus benefits (as per method 2). However, in this case the scheme benefits could be calculated from summing the benefit from each individual agent in the synthetic population. As well as being able to compare the scheme benefits with the SM (ie as per method 2), this method could tabulate the agents' benefits against any of the variables in the synthetic population. This is a powerful facility which could be used to produce many interesting outputs for example equity analysis seeing who benefits most from the scheme and who benefits least. It could be used to target schemes at certain segments of the population. If the synthetic population had the emissions profile of each agent's vehicle, it could be used for air quality analysis and many others.

Subject to suitable testing, these methods built upon those in TAG and could potentially enhance current appraisal methodology for example by accommodating more complex nesting structures. They could also help to overcome problems with the current methodology eg 'new mode' problem of finding the scheme do-nothing costs associated with a 'new' mode.

Concerns were raised about whether this approach could adequately capture individual-level impacts, as well as the need to understand how stochasticity affected appraisal. The conversation also questioned the definition of "current methodology," distinguishing between theoretical foundations and practical reporting steps, such as those specified in TAG. The importance of benchmarking results against traditional models. A few cited a potential difficulty in isolating individual items (e.g. time savings) from the overall utility functions.

The potential of AABM for evaluating road pricing was noted, alongside the importance of representing how transport interventions influenced not just travel but also activity participation, which varied in perceived benefit across individuals. Ultimately, the focus shifted from whether methods yield consistent results to whether they truly reflected the full spectrum of factors influencing individual decision-making.

There was a general consensus that the first thing to do would be to apply the current appraisal methodology to AABMs to see whether it gave the same answers (compared to traditional models). This would give confidence in being able to extend or change the appraisal methodology, for example, by including activities. National Highways are already doing some research in this area, where an AABM is being used to calculate economic impacts using current appraisal methods and the results compared against results from traditional models.

6.2 Workshop topic 2: Extending current appraisal with activities

The second topic of the workshop discussed extending the current appraisal methodology to include the benefit of undertaking the activity itself. This benefit may include valuing the time spent undertaking the activity but might also include other factors such as the value of the activities' outputs. Extending the current appraisal methodology in this way can be considered in two parts as follows:

1. Valuing the activities undertaken while travelling (VAWT)
2. Valuing the activities undertaken while at the destination (VAAD)

There is potential to build on current methods to value the act of travelling itself, especially for walking and cycling. The value of time savings already reflects changes in activity, but it could go further by integrating a theory of valuing activities and linking this to existing economic models: *“If we can model something well and explain it clearly, we can include it in appraisals, not just time, but also health, productivity, and other outcomes”*. AABMs could help us capture the value of different activities including their comparison (e.g. leisure at different locations). Measuring the value of an activity could be challenging and would involve careful research. However, some tools are available including revealed (RP) and stated preference (SP) methods.

Valuing activities could help address some anomalies arising with current appraisal methodology for example certain schemes are considered beneficial but give disbenefits including pedestrianising a town centre which takes away road space causing disbenefits, yet is considered beneficial presumably by providing a better environment, more popular shops etc which improves the economic vibrancy of the town centre. Other examples might include bus lanes, park and rides, LRT schemes, air quality restrictions and perhaps congestion charging. The question arises: could valuing the activity help explain, quantify and rectify this?

On the other hand, if the activities do not change between scheme do-nothing and do-something, then with no additional activity benefits, this collapses to be the current methodology so consistency with current appraisal could be maintained.

Including the value of the activity means that appraisal could be applied to a whole set of schemes such as comprise a complete transport plan, strategy or policy. This would allow plans, strategies and policies to be compared so as to quantify their relative merits and select the ‘best’. It would also provide a better ‘synch’ between the strategic and economic cases. This would need to be based on sound economics and measurement of the value of different activities.

Generally, the meeting accepted the need to extend the current appraisal methodology to include valuing activities. Valuing travel time savings should avoid double counting, since the benefit often comes from gaining time for other activities. Understanding what people do with saved time (e.g. like getting more sleep versus working longer) can help refine valuations. For active modes like walking and cycling, the journey itself may be part of the benefit, even if it comes with time or comfort trade-offs. However, we need a solid theory to value time spent on different activities. Some argued that activity time is fixed and already accounted for in existing models, so additional valuation may not be necessary.

6.3 Workshop topic 3: Other opportunities which AABMs could open up

The final topic of the workshop discussed opportunities which activity based modelling and agent based methods could open up. There is interest in using AABMs to explore wider benefits beyond travel time savings, such as wellbeing, happiness, and lifestyle changes.

Jobs, homes and schools are very important to policy-makers so need to receive special attention by modellers. They lead to improving ‘wellbeing’ and ‘happiness’. Households make long-term choices (such as choice of home/ job/ school location, car purchase) and they increasingly need to be incorporated into AABMs as a better

way of modelling these decisions (than for example Land use LUTI modelling) – again using RUM. These choices can be geared around lifestyle changes such as leaving home, getting a partner, starting a family, children going to primary school, then secondary and tertiary, children leaving home, parents downsizing, retiring and so on. Including wellbeing happiness and lifestyle changes into appraisal in some way – even qualitatively - could enhance scheme/ plan/ strategy/ policy decision making.

Happiness, wellbeing and lifestyle are being considered by researchers for example, while Moshe Ben-Akiva's work focuses more on forecasting lifestyle shifts, there is broader literature valuing health and wellbeing. AABMs could support early-stage decision-making (like optioneering) by helping to understand utility and activity patterns, even if these benefits can't be precisely monetised.

However, concerns remain about double counting, proportionality, and whether wellbeing impacts are already captured through existing methods like willingness to pay. If wellbeing is included, it should be clearly defined and possibly treated as a separate metric. There's also a need to ensure all impacts, positive and negative, are considered, including those affecting non-travelers.

There was a general view that AABMs could open up opportunities to value wellbeing, lifestyle and happiness, however, it must be based on sound economics, not just as an extension to the current measures such as the BCR.

6.4 Discussion on each topic

General agreement

There was general agreement that using AABMs could enhance appraisal by opening up new possibilities for valuing travel and activities. The analysis presented during the workshop offered a useful framework for delegates to explore and discuss these possibilities. It was recognised that the value of travel time was evolving, particularly as people increasingly engage in productive or enjoyable activities while travelling (such as checking emails on the train). This highlights the need to consider activity valuation in specific circumstances.

Opportunity for a new framework

Delegates highlighted the need for clarity on whether AABMs should be adapted to fit current appraisal methods or used to develop entirely new frameworks. Many argued that the true value of AABMs lies in moving beyond traditional metrics like travel time savings, especially as modern transport priorities increasingly focus on resilience, carbon reduction, and equity. There was concern about being constrained by legacy appraisal methods, which were shaped by older modelling approaches: *"If economists had AABM outputs from the start, they might have developed different valuation frameworks, ie. ones that reflect activities and broader societal impacts more directly"*. AABMs offer the potential to model activities and evolving lifestyles, enabling the appraisal of indirect benefits (e.g. a new school bus enabling a parent to work). However, this shift would require industry-wide training and a change in mindset. While a paradigm shift seems inevitable, it will take time. Delegates also debated whether travel time savings should still be included and whether AABMs are a replacement for four-stage models or serve a different purpose altogether.

The consensus leaned toward using AABMs to support early-stage decision-making and strategic thinking, with a focus on activities and outcomes rather than just travel time. However, it is clear that this provides an opportunity to identify a new appraisal framework.

Consistency with existing framework

While it's useful to demonstrate that AABMs can replicate traditional appraisal outcomes, such as journey time savings, the real value lies in their ability to go beyond legacy methods. The meeting concluded that any new appraisal framework should remain consistent with traditional approaches where appropriate, but also embrace the broader capabilities of AABMs to support more innovative and comprehensive analysis.

Caution

Delegates expressed caution about extending existing appraisal methods too far into AABM territory without a clear and robust economic narrative for valuing activities. Concerns were raised about overestimating the capabilities of modelling and the difficulty of disentangling travel time savings from broader utility functions, which may not accurately reflect behavioural motivations. It was emphasised that modelling and appraisal should evolve together, with appraisal decisions grounded in what models can realistically deliver. While TAG provides flexibility, challenges remain in applying appraisal at the individual agent level, particularly in interpreting consumer surplus within disaggregate models where activity value is not directly represented.

The meeting concluded that any new appraisal framework should be guided by a clear economic rationale, carefully distinguishing between the value of activities and travel time savings to avoid misrepresentation or double counting.

Developing the objectives for a new appraisal framework

AABMs offer a transformative approach to transport appraisal by enabling both bottom-up (by replicating traditional appraisal outcomes) and top-down alignment with broader national policy goals like health, equity, and carbon reduction. Unlike conventional models that rely heavily on value of time savings (VTTS) and benefit-cost ratios (BCR), AABMs can simulate nuanced behavioural shifts, such as changes in activity patterns due to homeworking, and assess individual-level exposure to environmental harms and benefits. This makes them particularly suited for modern urban planning challenges.

To fully leverage AABMs in appraisal, there's a need to distinguish between resource-based metrics (e.g., carbon, accidents, time) and economic value metrics (e.g., consumer surplus), ensuring that valuation methods align with the metrics being appraised. A gradual integration starting with simpler agent based simulations alongside traditional methods can build familiarity and evidence. However, a more radical shift may eventually be required, especially if we move toward directly valuing time spent on activities rather than just time saved. This shift would necessitate foundational changes in economic theory and appraisal frameworks.

A new appraisal framework should look at separate metrics (not just the BCR) such as resource-based metrics and economic-based metrics will need to be developed which could capture behaviour-change. Whether it should be an evolutionary step or

a paradigm shift, foundational work for a new appraisal framework can begin now to support future transformation.

Engaging with the public

A future appraisal framework must be clear, communicable, and publicly engaging, helping communities understand and influence decisions, as seen in shifting attitudes toward pedestrianization. Validation should extend beyond behavioural accuracy to include public and political acceptability.

This means designing appraisal tools that not only model impacts effectively but also present outcomes in relatable ways. Building public understanding will be key to shaping policy support and ensuring the framework reflects real-world priorities.

Early-stage appraisal, optioneering and strategic case

Appraisals using traditional transport models often overlook wider societal benefits such as carbon reduction, improved air quality, and accident prevention. There is a growing shift toward evaluating transport's broader impacts on society and the economy, beyond just the direct effects on travelers. AABMs offer a way to capture these indirect benefits, such as enabling employment through improved access, and can help align appraisal frameworks more closely with policy goals like health, equity, and decarbonisation.

AABMs also have potential to strengthen the connection between the strategic and economic cases in transport appraisal. Even at early stages of project development, such as optioneering, AABMs can provide valuable insights through their utility-based outputs. While precise monetisation may be difficult, there is a clear rationale for using econometric values from AABM outputs to inform early-stage decision-making and support a more holistic appraisal approach.

The meeting agreed that a revised appraisal framework should make effective use of AABMs to support early-stage appraisal, optioneering, and the development of a compelling strategic case, especially where traditional methods fall short in capturing the full spectrum of societal impacts.

Maintaining proportionality

The work involved in developing the appraisal and modelling methodology should be appropriate for the scheme/ plan/ strategy/ policy etc it is being used to assess. This could be helped by DfT producing a common set of data, tools etc to effect and support new appraisal and modelling methodologies. These could be identified at an early stage and weaved into its development.

Some schemes don't need ABM

AABMs may not be the best tool to assess some transport schemes. If AABMs are not applicable, the appraisal framework should default to the existing method.

Logsums and random utility maximization models

While logsum-based nested models are commonly used, they are not universally adopted. Alternative AABM structures exist and their relative strengths and weaknesses should be acknowledged. It is important to align valuation methods with appraisal metrics, preferably (though not necessarily) within the framework of Random

Utility Maximisation models (RUM), to ensure consistency and interpretability. The logsum, or accessibility approach, is appealing due to its flexibility, as it can be readily converted into time or cost units. In conclusion, while various modelling approaches may be valid, aligning with RUM and incorporating the logsum where appropriate offers a robust foundation.

Data and measurement

Practical implementation of an appraisal framework using AABMs depends heavily on data availability and a clear understanding of what is feasible now versus what may be achievable in the future. A tiered approach was suggested to guide development: identifying what can be done with current data, what could be enabled with additional data, and what remains beyond reach. There was also discussion around whether existing knowledge is sufficient to model behaviour at a highly disaggregate level, given the resource intensity and cost of implementing and validating new methods.

There was an agreement that a new appraisal framework would require valuing activities, which is an area with limited existing research, therefore, necessitating further investigation. In the meantime, reliance on existing and emerging data sources will be essential.

Addressing practical challenges

Concerns were raised about addressing the many practical challenges not least of which is the role of stochastic variation in AABMs, particularly for infrequent decisions like residential relocation, where randomness can disproportionately influence outcomes. While uncertainty and stochasticity are not flaws, they are potential tools for capturing real-world variability although it was emphasized that stochastic variation was quite different from the day-to-day variation in travel behaviour. However, their impact across different stages of AABMs needs careful consideration to avoid unintended distortions in model results.

A key issue discussed was the importance of reproducibility. Setting a random number seed is a useful starting point, but not sufficient. Consistency across multiple model runs is crucial to ensure that observed differences stem from the intervention being tested, not from Monte Carlo randomness. The group emphasised the need for further research into alternatives to established modelling concepts like equilibrium, convergence and validation.

It was concluded that advancing a new appraisal framework will require deeper investigation into activity valuation and robust implementation by addressing practical challenges, such as managing stochastic variability.

6.5 Overall workshop conclusions

The workshop agreed that the current appraisal methodology should be applied to AABMs to assess whether it produces similar results. This would help build confidence in extending or modifying the approach to incorporate activities and other elements.

There was a general consensus on extending the current methodology to include the value of the activities. This enhancement would improve alignment between the strategic and economic cases. However, it must be underpinned by sound economic principles and robust methods for valuing different activities.

The workshop overall agreed with valuing the activity while travelling and the activity at the destination as part of the VTTS appraisal process and that AABMs were the most suitable modelling paradigm for this. All agreed that care needed to be taken in VTTS/ VAWT/ VAAD measurement to ensure that activity value was not double counted

The workshop agreed that wellbeing life satisfaction and happiness was an important component and should somehow be included in appraisal but opinions differed as to the best way of achieving this with some suggesting that it should be part of measuring VTTS in some way and others suggesting it be a separate metric.

An important idea which came out of the workshop was that AABMs provide an opportunity to identify a new appraisal framework with a clear economic narrative. Simply extending current appraisal methods into AABM may not be effective. For meaningful outcomes, modelling and appraisal need to be developed in close coordination, ensuring they evolve together and remain aligned as follows:

- Developing a new appraisal framework would require valuing activities, which is an area with limited existing research, so further investigation is essential. In the meantime, progress will depend on making the most of current data and incorporating new data as it becomes available. Care should be taken in separating the value of the activity from the value of the travel time savings. The appraisal framework should be transparent, ensuring it can be clearly communicated and easily understood by the public.
- Where possible, AABM methods should align with RUM, use of the logsum etc. Practical challenges, such as stochastic variability, must be addressed and further research is required to establish modelling concepts like equilibrium, convergence and validation.
- A new appraisal framework can be approached from AABM perspective (bottom-up) and top-down, ie. from what is needed to address government's broader national policy goals such as health, equity, carbon reduction, air quality, levelling-up, sustainability, resilience and active travel. AABMs should be useful for early-stage appraisal, optioneering and to provide evidence to support the strategic case.
- The foundational elements of a new appraisal framework and modelling methodology could be explored now to support future transformation. This provides an opportunity to develop other metrics beyond the traditional BCR, such as resource-based metrics and economic-based metrics which could capture behaviour-change. It's important to consider whether this should be an evolutionary step or a paradigm shift.
- The work involved in developing the new appraisal framework and modelling methodology should be appropriate for the scheme/ plan/ strategy/ policy etc it is being used to assess. This could be helped by DfT producing a common set of data, tools etc to effect and support new appraisal and modelling

methodologies. These could be identified at an early stage and weaved into its development.

It was acknowledged that there is value in exploring new opportunities enabled by AABMs, such as wellbeing, lifestyle and happiness, provided these approaches are based on sound economics. These considerations do not need to be direct extensions of the current measures such as BCR, could have their own metrics and could be useful for early-stage appraisal, optioneering and building a more evidence-based strategic case.

7 Evidence of transport's effect on wellbeing, life satisfaction & happiness

7.1 Wellbeing, happiness, life satisfaction and life events

This highlighted the desirability of including wellbeing, happiness, life satisfaction and life events within the appraisal process. So this chapter explores the contribution which transport makes to them and makes the case for including them more prominently in the appraisal process. Subsequent chapters show how this can be accommodated within the AABM framework by modelling life events with AABMs lifestyle chapter 9.

7.2 Evidence of transport and wellbeing

This chapter describes some of the evidence on the effect of transport on people's wellbeing, life satisfaction and happiness. Some of this evidence is currently used in appraisal (eg physical health wellbeing effects), some of it is partly used (eg income wellbeing effects), and some isn't (eg the wellbeing effect of an unemployed household member getting a job).

This evidence will be used in chapter 9 to support the report's thesis that AABMs provide a better, more suitable framework for modelling and forecasting wellbeing, life satisfaction and happiness so as to support a more refined treatment of wellbeing in appraisal. It will also describe the AABM architecture required to do it.

The DfT commissioned a report on the connection between transport and wellbeing (DfT Transport, health and wellbeing 2019) which described the ways in which these could be causally connected which is summarised in section 7.2 below. This led to a "Review of TAG impacts through a wellbeing lens" report by DfT (2024) (**wellbeing report**) which showed how wellbeing could be included in the current way appraisal is done as described in TAG. It uses the concept of Stated Wellbeing (SWB) which is a person's subjective scaling of their wellbeing at the time that the survey question was asked. The focus of my report is to think how appraisal can be done with AABMs. As is shown herein, AABMs offer new ways of doing appraisal and these ways can provide a much better framework for including wellbeing in appraisal. But first a summary of DfT's wellbeing reports in sections 7.1 and 7.2. This is followed by other evidence of transport's effect on wellbeing and of the importance of wellbeing itself in sections 7.3 through to 7.7.

7.3 Overview of DfT's report on transport and wellbeing

The section under this heading is an overview of DfT's publication "Transport, health and wellbeing (DfT 2019). The overview is as follows:

Wellbeing is strongly linked to transport because a good transport system enables access to work, services, and social connections, while also promoting physical activity and reducing environmental harms. Conversely, transport barriers can cause stress and negatively impact physical and mental health, particularly in areas with poor accessibility. Investing in the transport system can improve wellbeing, life satisfaction and happiness.

Positive impacts of transport on wellbeing

- **Enhances economic opportunities:** Good transport systems help promote economic growth.

- **Jobs and income:** Improves access to job opportunities, job quality and helps increase household income.
- **Housing:** Improves access to housing opportunities.
- **Improves health and mental health:** Reduced reliance on cars can lower air and noise pollution, both of which negatively impact mental and physical health.
- **Promotes social connections:** It facilitates social interaction and community engagement, improving social wellbeing.
- **Enhances access to green space and leisure activities:** Which itself leads to improves health, mental health, wellbeing, life satisfaction and happiness.

Positive impacts of sustainable transport on wellbeing

- **Improves emissions and air quality:** Reduced reliance on cars can lower air and noise pollution, both of which negatively impact mental and physical health.
- **Encourages physical activity:** Active travel, such as walking or cycling to a bus or train station, improves physical fitness and health.
- **Encourages physical activity:** Active travel, such as walking or cycling to a bus or train station, improves physical fitness and health.

Negative impacts of poorly designed transport or the lack of effective transportation on wellbeing

- **Can create barriers:** Lack of affordable, reliable, or accessible transport can lead to missed appointments, delayed care, and a reduced ability to connect with the community. Poorly designed schemes can cause severance which reduces access to those living nearby.
- **Can contribute to health problems:** To those living nearby, transport schemes can cause stress and injury, and vehicle emissions can lead to cardiovascular and respiratory diseases.
- **Can cause environmental harm:** The transport system can contribute to pollution, noise, and climate change, which can negatively affect both individual and community health.
- **Can create inequalities:** "Transport deprivation" can significantly reduce life satisfaction and mental wellbeing for individuals and communities, especially those in rural areas.

7.4 Discussion of DfT's report on wellbeing and appraisal

The DfT's wellbeing report investigated wellbeing from the point of view of appraisal and modelling although it did describe the causal connections which transport influences. The wellbeing report detailed the places and methods where wellbeing, life satisfaction and happiness including those described below were already in, or could be added-in, to TAG appraisal with SM modelling. For the purpose of this report, the extracts provided below are from the point of view of establishing their relationship with wellbeing so that wellbeing can be modelled with AABM and used more effectively in appraisal. (references are to the wellbeing report page numbers):

There is a common theme running through all these possible determinants of wellbeing which relates to the need for increasing the segmentation available from modelling so that wellbeing can be more effectively modelled and used for appraisal. AABMs can provide that more detailed segmentation.

Income wellbeing.

The relationship between income and wellbeing is now well understood with econometric evidence of robust relationships between income and Subjective Wellbeing (SWB). For example, the elasticity of the marginal utility of income with respect to income has been estimated ranging from 1.19 to 1.34 by at least 6 independent international studies and is used in the Treasury Green Book to determine the distributional weights and the income term in the Ramsey formula for discounting. Potentially the wellbeing value of income represented by the distributional weights is relevant to the income impacts of transport interventions and possibly to other money impacts on households - e.g. to changes in transport fares (p 35).

Employment wellbeing.

This has emerged from three decades of empirical research showing that employment has a significant and large effects on wellbeing - particularly the effect of being employed compared with unemployed. Effects have been found in longitudinal studies as well as cross-sectional ones, and in general recessions versus localised employment shocks (closures) which help to demonstrate causality. The empirical evidence includes a confidence interval: Employment versus unemployment: wellbeing impact is 0.46 (95%CI: 0.38 to 0.53).

Better quality employment could have a value, where quality is defined in terms of factors such as job security, skills, autonomy, clarity of responsibilities, supportive workplaces and social connections. Although there is current evidence that these effects exist, the numerical values are reported with only low confidence, and causality is unclear.

Changes towards part time working have also been investigated, and the sign of the wellbeing effect was found to depend on whether the respondent wanted more or fewer hours, which tended to go by gender, however there are concerns about causality.

The move to more productive jobs is already included in the welfare appraisal in the form of a Tax Wedge impact (TAG Unit A2.3, Section 3.3), however the welfare implications of the increase in household income is not currently subject to the relationship between income and wellbeing (above). This could be explored. (p 34)

Travel time wellbeing.

One research study found highly significant negative relationships between commute time and two 'domain satisfactions': (i) job satisfaction; and (ii) satisfaction with the amount of leisure time. It seems likely that individuals may be balancing commute time against other factors (such as earnings, job roles and housing).

The field of commuting and life satisfaction is such a central one to transport analysis that it seems to warrant further research effort, in particular whether a significant causal relationship between commute time and life satisfaction can be established, and whether the counterbalancing effects of housing costs and quality can be controlled-for and quantified (since those are also of policy interest in a transport-housing-land use context). Further conceptual research is needed establishing the extent to which SP and RP based values are expected to overlap with wellbeing-based values, and thereby how the wellbeing concept of value of travel time is distinct from VTTS. Happiness-based analysis offers an opportunity for further validation. There is scope for segmentation to better represent heterogenous behaviour (and welfare impact) across population groups.

There is the potential to explore some additional attributes using wellbeing, such as the interaction with weather and instantaneous travel conditions, and variables such as whether accompanied or not (and by whom). Some of this could be also achieved using other forms of data (e.g. in SP choice experiments, in some cases with the aid of simulation). On a note of caution, not all additional attributes will produce large wellbeing effects - the main drivers of VTTS are likely to remain the access to opportunity/ activities provided by the transport system, and some of the journey attributes already identified as key to the disutility of travel (including unreliability, wait time and crowding). (p 37)

Health wellbeing.

Some health wellbeing is already included in appraisal for example active travel although AABMs potentially offer the prospect of a better modelling framework for their quantification. An area where wellbeing research brings potentially useful additional evidence (to TAG) is around mental health such as symptoms of psychological distress which might affect life satisfaction. Poor health causes quantified spillovers from the person who is unwell to their spouse/ partner and potentially to other household members. One study found that only 6-7% of the total impact on life satisfaction is transmitted by health – and that is primarily by mental health. (p 41)

Noise wellbeing.

Transport noise impacts on wellbeing are a promising area for wellbeing-based valuation and two independent research studies produced significant empirical relationships between transport noise and wellbeing although these studied aircraft noise, so further research would be needed. Night-time noise was found to have a stronger effect on wellbeing than daytime noise and noise outside the house may be perceived differently from inside it and may depend upon the level of noise insulation. The wellbeing report identified the need for increased segmentation. (p 41)

Air quality wellbeing.

Several international studies have identified a causal link between air quality and wellbeing although not all are within a transport context and they differ in a number of aspects. However

international literature contains wellbeing-based values (or effect sizes) for SO₂ and PM₁₀ concentrations, these values may not be readily applicable in UK transport appraisal for the reasons given in the report. The wellbeing value of NO₂ has been measured in different studies with wide variation. (p 44)

Accessibility wellbeing.

In one key recent study, the perception of public transport services “in your local area” was measured to have a significant positive influence on life satisfaction including its causal relationship as did access to services, mental health and strain. Access to a car was found to have a minor positive role in positive mental health outcomes and to reduce loneliness in those aged over 50 particularly for those in rural areas and those with mobility impairments. The report notes that it will be important to recognise the different accessibility requirements of people with different impairments and the intersection with people’s wider circumstances and their travel context eg travelling with luggage. (p 45)

Biodiversity and greenspace wellbeing.

Biodiversity impacts are not currently valued in TAG, although a non-monetised assessment of biodiversity impact is included. A research programme is underway, focusing on modelling and economic valuation of biodiversity, funded by NERC (Natural Environment Research Council) within which, there are different strands. Notably there is a set of projects focusing on the mental health and wellbeing benefits of nature engagement through measures of soundscape complexity. These studies are due to report in 2025-6. When this research reports, it may have implications for urban design and for townscape impacts. e.g. from improved 'green infrastructure' such as street trees and parks/parklets, as well as from any loss of biodiversity due to construction impacts. There is also a link to the noise component of appraisal, since one recognised opportunity to improve noise valuation in public spaces is to recognise that noise is part of - and its impact varies with - soundscape as a whole, which may contain a mix of positively-perceived and negatively-perceived sounds.

One (unrelated) study found that increasing amounts of greenspace within a local area had significant positive impacts on life satisfaction which was consistent with extensive health literature on the same topic. Another study showed that this effect is non-linear and that 75% of Berlin residents had less green space than they would like. Another showed that green spaces with greater biodiversity are more positive for wellbeing indicating some complementarity between wellbeing effects of biodiversity and of green space. Increasing green space is not a direct policy aim of transport although in an integrated land-use transport context it may well be. Avoiding reducing green space may be a concern for (the location of) new infrastructure construction. (p 48)

Place-based and other wellbeing.

A scoping review has found a large body of evidence linking heritage sites with wellbeing. Another study examined the wellbeing impacts of a place-based regeneration project. The social costs of crime and antisocial behaviour are already measured in research for the Home Office and are used from time to time in transport appraisals where reductions in crime/antisocial behaviour are expected to be a

significant benefit. There is now wellbeing-based research on the welfare costs of crime, including the fear of crime and the experience of being a victim of violent crime. One study measured the wellbeing impact of roadworks of £31,375 per incident which is much higher than the (then) TAG VTTS value of £9,973 which indicates a possible additional wellbeing component. (p 51)

7.5 Other determinants of wellbeing, life satisfaction and happiness

Esteban Ortiz-Ospina and Max Roser (2017) - "Happiness and Life Satisfaction" Published online at OurWorldinData.org. Retrieved from: 'https://ourworldindata.org/happiness-and-life-satisfaction' [Online Resource] as follows:

How happy are people today?

Were people happier in the past? How satisfied with their lives are people in different societies? And how do our living conditions affect all of this? These are difficult questions to answer, but they are questions that undoubtedly matter for each of us personally. Indeed, today, life satisfaction and happiness are central research areas in the social sciences, including in 'mainstream' economics.

Social scientists often recommend that measures of subjective well-being (SWB) should augment the usual measures of economic prosperity, such as [GDP per capita](#).¹ But how can happiness be measured? Are there reliable comparisons of happiness across time and space that can give us clues regarding what makes people declare themselves 'happy'? We discuss the data and empirical evidence that might answer these questions. Our focus here will be on survey-based measures of self-reported happiness and life satisfaction. Here is a preview of what the data reveals.

1. Surveys asking people about life satisfaction and happiness do measure subjective well-being with reasonable accuracy.
2. Life satisfaction and happiness vary widely both within and among countries. It only takes a glimpse at the data to see that people are distributed along a wide spectrum of happiness levels.
3. Richer people tend to say they are happier than poorer people; richer countries tend to have higher average happiness levels; and across time, most countries that have experienced sustained economic growth have seen increasing happiness levels. So, the evidence suggests that income and life satisfaction tend to go together (which still doesn't mean they are one and the same).
4. Important life events such as marriage or divorce do affect our happiness but have surprisingly little long-term impact. The evidence suggests that people tend to adapt to changes.

...

Do people tend to adapt to common life events by converging back to a baseline level of happiness?

Clark et al. (2008) use data from the German Socio-Economic Panel to identify groups of people experiencing significant life and labour market events and trace how these events affect the evolution of their life satisfaction. The visualization here shows an overview of their main findings. In each individual chart, the red lines mark the estimated effect of a different event at a given point in time (with 'whiskers' marking the range of confidence of each estimate). In all cases, the results are split by gender, and time is labelled so that 0 marks the point when the corresponding event took place

(with negative and positive values denoting years before and after the event). All estimates control for individual characteristics, so the figures show the effect of the event after controlling for other factors (e.g., income, etc.).

The first point to note is that most events denote the evolution of a latent situation: People grow unhappy in the period leading up to a divorce, while they grow happy in the period leading up to a marriage.

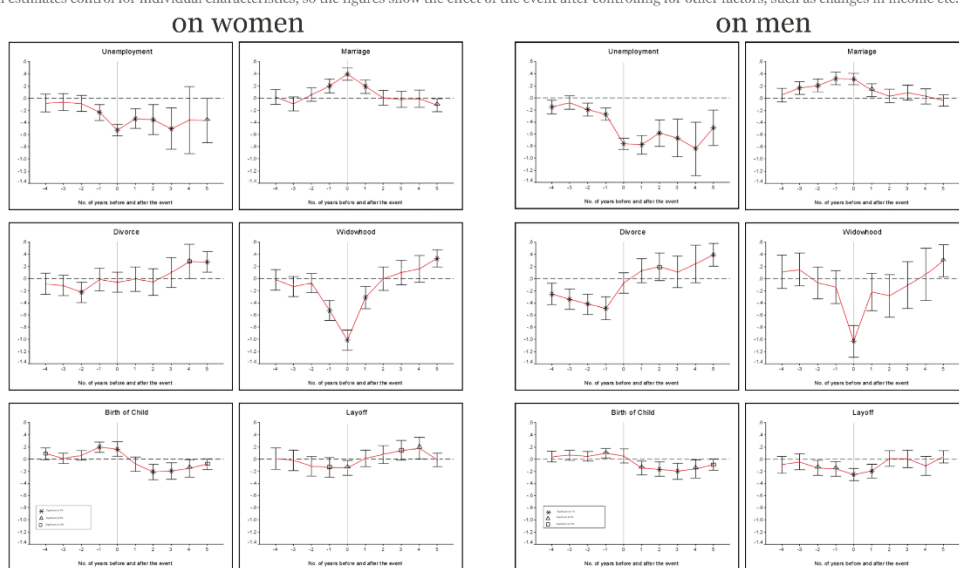
The second point is that single life events do tend to affect happiness in the short run, but people often adapt to changes. Of course, there are clear differences in the extent to which people adapt. In the case of divorce, life satisfaction first drops, then goes up and stays high. For unemployment, there is a negative shock both in the short and long run, notably among men. And for marriage, life satisfaction builds up before the wedding and fades out after it.

In general, the evidence suggests that adaptation is an important feature of well-being. Many common but important life events have a modest, long-term impact on self-reported happiness. Yet adaptation to some events, such as long-term unemployment, is neither perfect nor immediate.

The effect of life events on life satisfaction



In each individual plot, the red line marks the estimated effect of the corresponding event at a given point in time. 'Whiskers' denote the range of confidence around estimates. Time is labeled so that 0 marks the point when the event took place. Negative and positive values denote years before and after the event. All estimates control for individual characteristics, so the figures show the effect of the event after controlling for other factors, such as changes in income etc.



Visualisation from Clark, Diener, Georgellis, & Lucas (2008) – Lags and leads in life satisfaction: A test of the baseline hypothesis. The Economic Journal, 118(529). The visualization is adapted by OurWorldinData.org. There you find more research and data visualizations on happiness and development.

Higher national incomes go together with higher average life satisfaction

If we compare life satisfaction reports from around the world at any given point in time, we immediately see that countries with higher average national incomes tend to have higher average life satisfaction scores. In other words, people in richer countries tend to report higher life satisfaction than people in poorer countries. The scatter plot here shows this.

Each dot in the visualization represents one country. The vertical position of the dots shows the national average self-reported life satisfaction in the Cantril Ladder (a scale ranging from 0-10 where 10 is the highest possible life satisfaction), while the horizontal position shows GDP per capita based on purchasing power parity (i.e., GDP per head after adjusting for inflation and cross-country price differences).

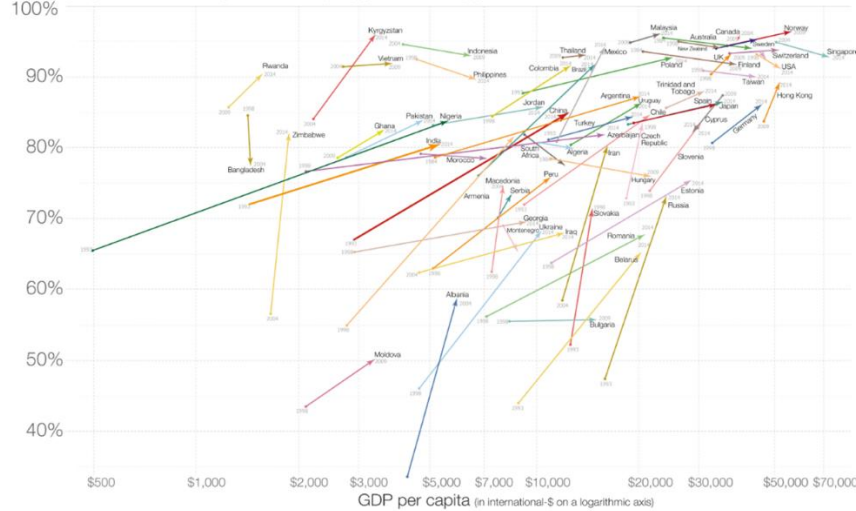
This correlation holds even if we control for other factors: Richer countries tend to have higher average self-reported life satisfaction than poorer countries that are comparable in terms of demographics and other measurable characteristics. You can read more about this in the [World Happiness Report 2017](#), specifically the discussion in its chapter 2. As we show below, income and happiness also tend to go together [within countries](#) and [across time](#).

Self-reported happiness vs income over time

Each arrow shows the change between the first and last available data points.



Share of people that answers they are either 'very happy' or 'rather happy'
100%



Data sources: self-reported happiness from the World Value Survey; GDP at chained PPPs in 2011 International dollars, from the Penn World Tables. The visualization is available at OurWorldinData.org. There you find the research and more visualizations on happiness and related topics. Licensed under CC-BY by the author Max Roser

Are we happier when we spend more time with others?

In 1938, a group of Harvard researchers called the Harvard Study of Adult Development, decided to start a research program to track the lives of a group of young men in what eventually became one of the longest and most famous longitudinal studies of its kind. The idea was to track the development of 724 teenage boys through periodic interviews and medical checkups, with the aim of understanding how their health and well-being evolved as they grew up, and researchers continue to monitor today the health and well-being of those initial participants who are still alive, most in their late 90s (Easterlin et al 2011)

Robert Waldinger, the current director of the study, summarized – in what is now one of the most viewed TED Talks to date – the findings from decades of research. The main result, he concluded, is that social connections are one of the most important factors for people’s happiness and health. He said: “Those who kept warm relationships got to live longer and happier, and the loners often died earlier.” Here, we will take a closer look at the evidence and show more research that finds a consistent link between social connections and happiness.

But before we get to the details, let me explain why this link is important. As most people can attest from personal experience, striving for happiness is not easy. In fact, the search for happiness can become a source of *unhappiness* – there are studies that show actively pursuing happiness can end up decreasing it. The data shows that [income and happiness are clearly related](#), but we also know from surveys that people often [overestimate the impact of income on happiness](#). Social relations might be the missing link: In rich countries, where minimum material living conditions are [often satisfied](#), people may struggle to become happier because they target material rather than social goals.

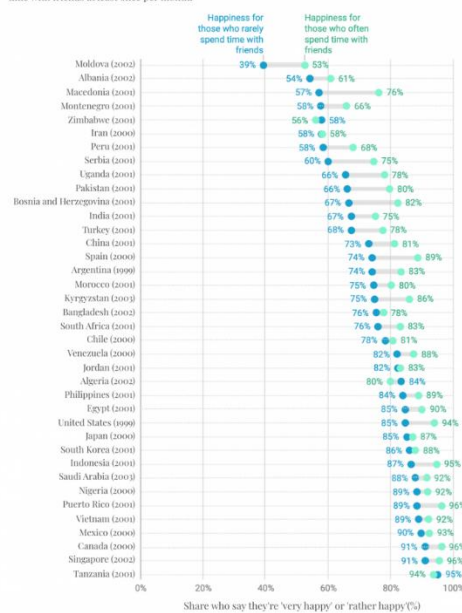
The cross-sectional correlation between happiness and friends. The [World Values Survey](#) is a large cross-country research project that collects data from a series of representative national surveys. In the fourth wave (1999-2004), the survey asked respondents hundreds of questions about their lives, including whether they were part of social or religious groups, how often they spent time with friends, and whether they felt happy with their lives.

By comparing self-reported happiness among those with and without frequent social interactions, we can get an idea of whether there is indeed a raw correlation between happiness and social relations across different societies. The next chart shows the comparison: The green points correspond to happiness among those who interact with friends at least once per month, while the blue dots correspond to happiness among those who interact with friends less often (Clark et al 2008). This chart shows that in almost all countries, people who often spend time with their friends report being happier than those who spend less time with friends. (Brinkman et al 1978)

Happiness and friends



Share of people who say they are 'very happy' or 'rather happy', among those with and without regular interaction with friends. People with regular interaction with friends are those who report spending time with friends at least once per month.



The data comes from the World Values Surveys (1999-2003). The question on frequency of interaction with friends was asked in the context of time spent at work, clubs, or places of worship.
Source: World Values Survey (Wave 4, 1999-2004) Licensed under CC-BY by the author Esteban Ortiz-Ospina

7.6 Other evidence including public and political Interest

There is intense public and political interest in lifestyle, wellbeing and happiness. This is illustrated by a quick web search on Happiness Index which shows (provided by S&P Global):

- [The World Happiness Report](#)
- [Happiness index by country, around the world | TheGlobalEconomy.com](#)
- [Ipsos Happiness Index 2025](#)
- [World Happiness Report | Gallup](#)
- [Happiness Index: What Is It And How Does It Work?](#)
- [Happiness and Wellbeing Indices - Global Wellness Institute](#)
- [Happiness and Life Satisfaction - Our World in Data](#)

Other literature includes a recent London School of Economics discussion paper by Kreel and MacKerron (2024) which measured happiness, wellbeing and life satisfaction while undertaking each type of activity.

7.7 Measuring UK wellbeing

The importance and popularity of wellbeing is illustrated by the work that goes into measuring and monitoring it. For example, the S&P Global UK Consumer Sentiment Index (CSI) Monthly Monitoring Survey of about 1,500 households has been reporting financial wellbeing continuously since 2009. S&P Global provided the following information:

The CSI survey measures UK households' perceptions of their financial situation as a proxy for financial wellbeing, (not on broader happiness/wellbeing of households, as that would include other factors such as mental and physical wellbeing). Nevertheless, for a snapshot of financial perceptions/wellbeing, using the headline index and/or the sub-components outlined below would provide a useful steer, particularly if comparing to long-term averages as we do in the Report, to hint if current perceptions are historically strong or weak. Each month, a panel of 1,500 UK households responds to a questionnaire consisting of 11 main questions (there are additional questions which cover geography, age, gender and etc). These 11 questions are designed to capture various aspects of household financial health and sentiment. Respondents can choose from three options for each question, usually "improve," "no change," or "deteriorating." The responses are then converted into diffusion index values, similar to the methodology used for the Purchasing Managers' Index (PMI). Below is an excerpt from the press release explaining on how to read the diffusion index values which vary around the 50.0 "no-change" level, with readings above 50.0 signalling an improvement and readings below 50.0 a deterioration. Survey indices have been seasonally adjusted using the US Census Bureau X-12 programme."

The responses are then grouped into the following five sub-components of the CSI:

- **Household Financial Index:** This index reflects households' views on changes in their monthly financial situation and their expectations for future financial wellbeing.

- **Spending Sentiment Index:** This index gauges any changes in disposable income over the month and households' perspectives on making major purchases.
- **Labour Market Sentiment Index:** This index asks households about their job security, perceptions of business activity in the workplace, and whether their income from work has increased.
- **Debt Sentiment Index:** This index assesses whether households have observed changes in their debt levels over the month, their views on the demand for new loans, and any changes in loan accessibility.
- **Savings Index:** This index measures how households perceive changes in their savings levels over the month.

Example:

From the October 2025 data, with the below showing how the CSI sub-component, Household Finance Index is calculated as: (Current finances (44.7) + Expected finances (50.4))/2 = 47.5

The other indices are calculated similarly. Finally, the average of the five CSI sub-components provides the headline CSI Index, offering a comprehensive overview of consumer sentiment in the UK. Its calculation is as follows: (Household Financial Index (47.5) + Spending Sentiment Index (41.2) + Labour Market Sentiment Index (54.2) + Debt Sentiment Index (50.1) Savings Index (44.2))/5 = **47.4**

S&P Global Consumer Sentiment Index and components

50 = no change on prior month, seasonally adjusted.

	Sep	Oct	High/low
Consumer sentiment index	47.8	47.4	2-month low
Household Finance Index	48.0	47.5	2-month low
Current finances	45.2	44.7	2-month low
Expected finances in 12 months' time	50.8	50.4	2-month low
Spending Sentiment Index	41.1	41.2	2-month high
Cash available to spend	42.9	42.4	3-month low
Views on making major purchases	39.4	40.0	15-month high
Labour Market Sentiment Index	55.2	54.2	3-month low
Job security	54.0	52.5	3-month low
Activity at work	57.1	55.0	3-month low
Income from employment	54.4	55.1	10-month high
Debt Sentiment Index	50.0	50.1	2-month high
Level of debt*	50.9	49.7	8-month low
Need for unsecured credit*	50.9	51.7	4-month high
Availability of unsecured credit	51.7	51.6	3-month low
Savings Index	44.6	44.2	2-month low

* Inverted in index calculation.

8 AABM model architecture with life events

The location of homes, jobs, schools as well as household income and car ownership are very important to policy-makers so have received special attention by modellers.

The SM takes account of these in the trip end models. The trip generation model takes account of home location in the forecast planning data input by changing the households and population in each zone for the forecast year. It takes account of employed residents and school children for each of the school types: primary, secondary, tertiary in the forecast planning data input to the trip generation model. Jobs are input as planning data and get processed by the trip attraction model into trip attractions for each zone. Car ownership is usually forecast for households with zero, one, two or more car owning households depending upon various factors including GPD growth, household income and trend forecasts of national vehicle license registrations (eg at DVLC).

8.1 The AABM framework

Within the AABM framework they are modelled in more detail by considering them as long-term choices which can be modelled using RUM choice models within a lifestyle context which start with the synthetic population. Households make long-term choices (such as choice of home/ job/ school location, car purchase) and they are increasingly being incorporated into AABMs as a better way of modelling these decisions (than for example land use transport interaction (LUTI) modelling) – again using RUM concepts. These choices are often geared around life events, such as leaving home, getting a partner, starting a family, children going to primary school, then secondary and tertiary, children leaving home, parents downsizing, retiring. So this is modelled in the AABMs lifestyle sub-model (Davidson 2015, 2016, 2018). The lifestyle model sits on top of the activity generator sub-model and below the population synthesiser in the typical AABM model architecture (see figure 7.1).

8.2 The AABM synthetic population

An AABM is driven by a synthetic population comprising a list of households with the people that are in each household together with attributes about the household (eg household income, car ownership, type of dwelling), attributes about each person and attributes of each vehicle owned by household members.

Certain population synthesiser methodologies are more likely to be suitable than others especially for appraisal. Some methodologies can introduce excessive ‘noise’ which may be acceptable for some modelling applications but are unlikely to be acceptable for appraisal especially those that introduce unwanted differences between base and forecast year. These methodologies also do not lend themselves to modelling life events.

For example, one common population synthesiser methodology, draws households from a household travel diary to meet certain zone targets such as the number of households, people, employed residents and cars in the zone. This process is repeated for all zones to synthesise the population over the whole study area. To forecast the future year population, this process is repeated with future-year zone targets. This methodology produces different household combinations for the same zone in different years which therefore produce different forecasts – even if the zonal targets do not change. The drawings seldom meet the zonal targets exactly while some variants of it have a stochastic component. All of these contribute to the model’s

stochastic 'noise'. This form of population synthesiser introduces unwanted differences between base and forecast year which may prejudice the forecasts. This can create problems for forecasting which may be acceptable for some model applications but are unlikely to be acceptable for appraisal. They also are not suitable for modelling life events. A more suitable population synthesiser is described later.

In the synthetic population each person is considered an agent although, depending on the modelling needs a household or a car could be considered as agents too. Each agent has associated attributes which describe it together with actions which it can perform which interact with other agents and the environment within which it operates.

Attributes of each person can include the following: age, gender, income, ethnicity, employment status (eg employed full or part time, unemployed, student, retired, carer etc), driving licence holding, education level, profession, relationship with other household members (eg child, parent etc), type of mobility impairment, what type of school they go to, whether they own a car. Attributes about each vehicle owned could include: vehicle type (car, van, motorcycle, bicycle), type of fuel (eg petrol, diesel, electric, hybrid), emissions profile etc. This data is typically obtained from a household interview survey and other attributes can be included if and when necessary. The attributes are used in modelling as independent variables throughout the set of AABM sub-models. The AABM puts all decisions and decision probabilities onto the synthetic population as the agent progresses through the hierarchy of choice sub-models. They are therefore available for tabulating all the intermediate and final model outputs. If other attributes are needed, then the analyst has various options as shown in table 8.1.

Method	Description
1 probability	Attributes can be synthesised from a known distribution by monte-carlo simulation perhaps segmented by the attributes already present on the synthetic population. For example, if the future number of EV's in the study area is known, then this can be put into a cumulative distribution and monte-carlo used to decide whether each household's car is an EV perhaps dependent on the age of their current car on the basis that older cars are more likely to be replaced than newer ones
2 database	Other data could be used to augment the synthetic population and monte-carlo used. For example if the household travel diary data from which the synthetic population was drawn, did not elicit the car fuel-type (eg diesel, petrol, EV hybrid, EV plugin) and the model was required to model a zero or low emission zone with tariffs dependent on the fuel type, then the proportions of each fuel type could be taken from the DVLA database for vehicles registered in the study area and patched-onto the synthetic population using the method outlined in 1 above. Vehicle manufacturers publish the emissions profile of the make and model of each vehicle so this could similarly be patched-onto the synthetic population. If the synthetic population is maintained throughout the whole modelling sequence including the assignment (as it should with all AABMs), then the model will forecast the emissions of each pollutant on each link in the study area as well as

	its carbon footprint. This method was used successfully in the Abu Dhabi STEAM model.
3 survey	A survey could be undertaken to collect the new data together with data to key it into the synthesised households. For example if the household travel diary data from which the synthetic population was drawn, did not elicit the type of parking at the employees workplace (eg dedicated parking space, competition for limited parking spaces, no parking and subdivisions thereof) then a household survey could be commissioned to elicit the data which could be spliced-onto the synthetic population as above. Later waves of the household diary survey could incorporate the additional questions

Table 8.1 Methodologies for synthesising additional attributes for a synthetic population

8.3 Modelling life events with AABMs lifestyle modelling

The idea behind this is that decisions about where to live, which job to take, which school the children should go to, are often triggered by life events within the household such as when a household has children, when they reach nursery, primary or secondary school age, if or when they go to tertiary education, when they leave home, when they get a partner, when they have their own children, when the parents retire and so on. Life event changes can also be triggered by changes in job or other changes such as those of parents or grandparents. These lifestyle changes are not the only times when these decisions change.

There are various different variants of the lifestyle model but in principle, they have two parts as follows:

- 3) Forecasting the type of life event and when it happens – the life event trigger. (population forecaster in figure 8.1)
- 4) Forecasting the decisions which ensue from the triggered life event (lifestyle model in figure 8.1).

Forecasting the life event trigger draws on the ideas from cohort survival model methodology which takes the (in our case synthetic) population and ages it one year to produce the population which is one year older. This process is repeated each year for the forecast period eg in 5 year steps up to the final forecast year (say) after 30 years.

Cohort survival models are an established methodology for forecasting populations such as the UK's. During one year, a proportion of households will have a life event which can then be used to trigger changes in the household's decisions. For example, a proportion of households would have a new baby with that proportion depending upon such things as the ages of the mother, the location of the household and possibly other factors. This proportion can be given by a model which can be estimated from snapshots of the current real population over time. So, for example, from one decennial census year to the next, the women in the English southwest region between the ages of 20-25 gave birth to x number of babies from which a birth rate of y babies per 1000 women can be derived. This birth rate can be segmented by other variables in the census. This birthrate can be applied to each household in the synthetic population to determine its probability of having a baby. Monte-carlo

simulation can be applied to this probability to determine if the household has a baby or not.

Each year everyone in the synthetic population gets a year older. In some cases, the relationship would be deterministic for example when children come of the stipulated school age, they naturally all go to nursery/ primary/ secondary school. When young adults leave school with X qualifications, they have a chance at getting a job which may depend upon the youth unemployment rate. The youth unemployment rate can be got from the census (or a household travel diary survey) by knowing the proportion of young unemployed in the population.

The cohort survival model methodology can be applied to other lifestyle decisions such as the model for a person to retire. Moving house could be triggered by needing more space with growing children, income etc.

RUM choice models can be used to forecast the decisions which ensue from a life event trigger. The location of the new house/ job/ school etc could be determined with a destination choice model with transport access a key determinant. These behavioural relationships are already well understood and modelled with RUM choice models. When young adults leave home or find a life-partner they make decisions about their home location which may depend upon their, and their partners, job locations. These decisions can be cast as choice models with the transport networks as part of the utility functions and maybe other parts from where they currently live, access to friends/ relatives/ social/ leisure/ greenspace etc facilities. For all this segmentation is important.

Buying a new or used car, or disposing of an existing car can be modelled using the conventional relationships in the SM or it could be better modelled within a choice modelling framework whereby then the life event to buy a car is triggered, then the car choice alternatives are elucidated and their attributes quantified in the utility functions, the logit model probabilities calculated and the monte-carlo decision made in the usual way. Household income change could be a function of their job, profession, GDP growth and other factors.

These relationships can be put in place now and can be refined as more becomes known about the behavioural mechanisms behind them. They are currently being researched, especially in the US, and some may need further research to improve upon them, especially in the UK/ European context where behaviour may be quite different to the US. These lifestyle changes are not the only times when these decisions change but they can all be modelled with RUM choice models of one form or another.

Lifestyle models like this could be quick to take into account trends in the population. For example, driving license ownership for young people has been dropping for some time. It would take a while for it to be detectably significant in reducing car travel, but lifestyle modelling would provide a framework for its early detection and incorporation into our travel forecasts.

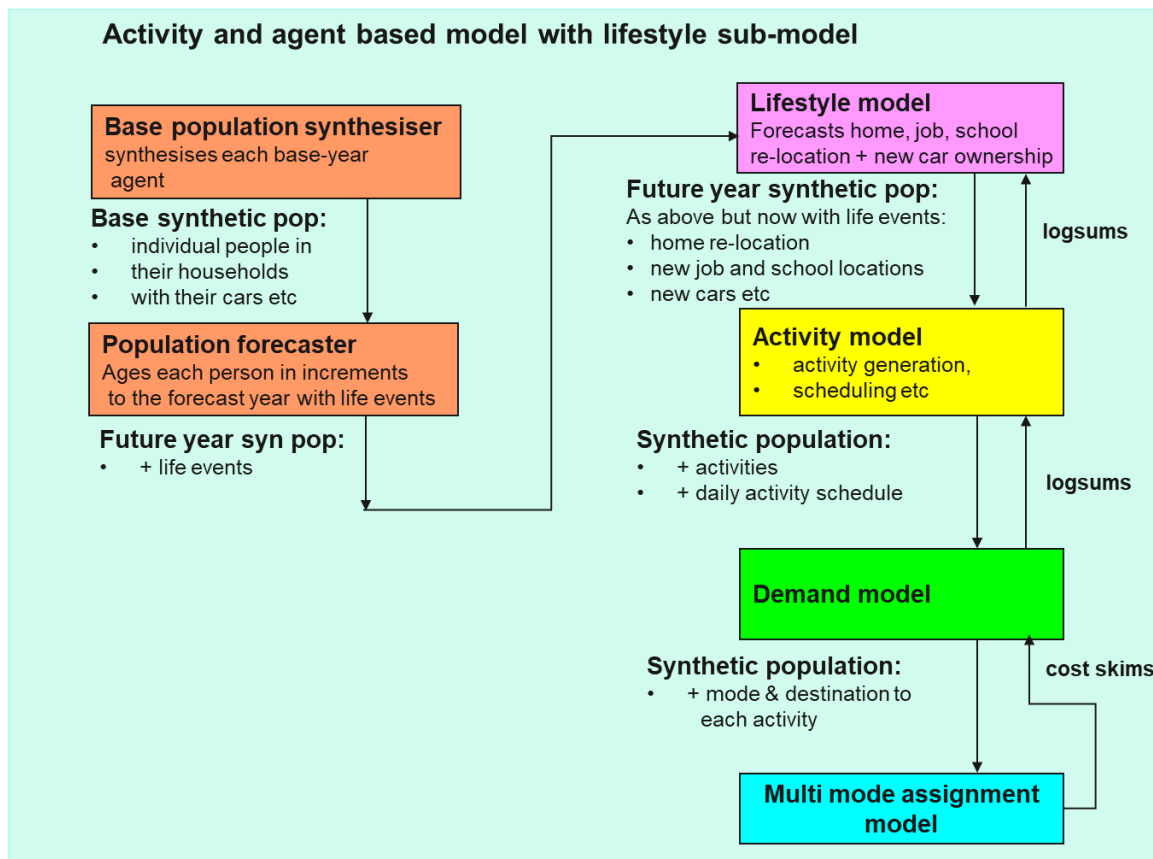


Figure 8.1 AABM model architecture with lifestyle sub-model

8.4 The AABMs activity generation model

There are various forms of the activity generation model but they are generally driven by the characteristics of the household and the people in it, with deterministic algorithms supported by logit utility functions. It takes each member of the population within the context of their household and produces the set of activities the person, together with the other household members, undertake in a typical day. The typical day would need to be defined for example during term-time non-holiday periods (eg 'shoulder months')

If the household had a worker then the activity generation model, generates a work activity which could take into account whether the person is on holiday, ill or otherwise doesn't undertake the activity. If their work activity is generated, then this could be an in-home or out-of-home activity and if the latter it could be to their normal place of work or somewhere else. This can be modelled with simple probabilities (**simple approach**) from a household activity/ travel diary or it could involve other mathematical forms with independent variables such as a logit choice model to produce the probabilities (**modelled approach**). Monte carlo simulation can be used to turn the probabilities into decisions which select one outcome among all the alternatives. Other activities can be generated using methodologies along similar lines.

The presence of children would deserve special attention, children under 5 years old don't go to school while those over 5 and under about 10 generally go to school in

term-time and do not undertake activities and travel on their own – they are generally escorted by a parent. Between about 10 years old until they leave school, children go to school in term-time, undertake their own activities and usually travel locally on their own. The activity generator would generate the school activity and if necessary, the need for an escort activity by a parent. These relationships can use the simple or a modelled approach, generally followed by monte-carlo simulation to select one set of activities.

The other activities, such as shopping, social, leisure, restaurant etc would be generated either using household diaries and either the simple or modelled approach together with monte-carlo simulation. The activity generator could also generate other aspects of the activity such as its duration, whether escorted etc. The net results would be a set of activities undertaken by every member of the household in a day. This process would be repeated for all households in the study area and stored into the base year synthetic population database.

When forecasting some AABM implementations have the activity generator and scheduling sub-models generate a new set of activities and their activity schedule for each forecast year. Which could be entirely different from previous forecast years. This would not work for appraisal because it could create too much stochastic 'noise' which could swamp the CS time savings and lead to unreliable results. It is therefore desirable to minimise the stochastic noise by identifying changes from the previous forecast year's activity schedule using an incremental methodology. These changes would then correspond to changes in actual choice-making behaviour due to changes in the household's circumstances which could be properly-reflected in the CS time savings.

In forecasting, the activity generator acts on the activities of the previous forecast year preferably in an incremental methodology. This is needed in appraisal to minimise the stochastic 'noise' effect and ensure that differences between years are actual differences in activity generation rather than the activity generator simply generating different activities due to stochasticism. Activities generated for the previous forecast year would be examined by the activity generator in conjunction with the forecast synthetic population and the lifestyle model to see if they had changed. If they have then the activity generator would generate the new activities, delete the ones which are not now undertaken and change those that need changing. For example, in forecasting 5 years on, a primary school child would be going to secondary school so their activity would change from primary school to secondary school. This would be undertaken at a different destination which may also affect the schedule of other household members.

8.5 The AABM activity scheduling model

There are various forms of the activity scheduling model but they are generally driven by the characteristics of the household and the people in it with deterministic algorithms supported by logit utility functions. The activity scheduler takes each household's activities, defines where they are to be undertaken (if not defined already),

in which sequence, what time they start and end and whether undertaken with other household members. It outputs a daily activity schedule for the household together with where the activity takes place.

Different modelling systems have different approaches to the activity scheduler sub-model. The day is divided into time periods of (say) 48 half hours. They could be finer with 10 or 20 minute periods or they could be hourly depending upon the level of temporal detail required in the model. An activity scheduler would generally take the important activities first such as the work and school activities and schedule the other household and person activities around them. The important activities are generally geared to their 'supply' side, so office hours for office workers, shop opening times for shop workers, school opening hours, nursery opening times etc. There is generally some flexibility in these supply side constraints which could be dealt with on a simple or modelled approach with unavailable time alternatives simply removed from the choice set. Having ascertained the probability of the activity being started in each time period, monte-carlo simulation can be used to decide on one activity start time. The activity end time could be computed from the start time and activity duration (which is generated with the activity in the activity generator). Other activities can be scheduled around the important activities including considering the escort part using the simple or modelled approach – again unavailable alternative time periods are removed from the choice set.

The activity scheduler uses the travel time to help determine the sequence of activities and hence the activity schedule. This introduces a level of complexity because travel time depends upon the mode of transport and whether the person can use a car which in turn depends upon whether the household car(s) are in use by other household members. In addition, it may find that some activities cannot be fitted-in to the daily schedule because of excessive travel time between the activity sequence. Different AABM implementations deal with these complexities differently but there is generally feedback between activity generation and household scheduling which deals with these situations.

The net results would be a schedule of activities undertaken by every member of the household in a day. This process would be repeated for all households in the study area and stored into the synthetic population database for the base year.

In forecasting the activity scheduler acts on the activity schedule for the previous forecast year, plus the changed activity generation, lifestyle and synthetic population in an incremental methodology. This is necessary to reduce the stochastic 'noise' and ensure that changes are due to behavioural changes. If the household's activities haven't changed and congestion hasn't built-up to such an extent that the activity schedule for the previous forecast year can't be undertaken, then the activity schedule would be unchanged. If they have changed, then the activity schedule is rerun being cognisant of the previous activity schedule. For example, if the primary school child now goes to secondary school which is further away, then instead of a parent escort walking to primary school, they have to drive with the only family car, taking it away

from the working adult so they have to buy another car. Alternatively one adult has to escort the working adult to the station by car in which case (young children can't be left unattended) the children have to be in the car too unless they are already at school. Clearly the feedback process is complicated and some AABM implementations struggle to get this right.

8.6 AABM validation

Validation is as important for AABMs as it is for the SM although with different emphasis. AABM logit model coefficients are usually estimated using discrete choice maximum likelihood logit model estimation, as are some SM. This process estimates elasticities directly on local data with statistical evidence for their efficacy such as the coefficients' 't' statistic and various model fit statistics based on the proportion of the logsum explained by the model (eg the rho bar squared, AIC or BIC statistics). This should bear more weight than overall elasticities such as quoted in TAG so the latter, while worthy of comparison with, should not override the former.

AABMs have another validation opportunity offered by the reasonableness of the behavioural mechanisms of individuals. This would involve taking an individual in the population and tracing their decisions together with the values of the variables used in their decision-making. The analyst would need to report on them clearly and in such a way as the reader can see that that person would indeed make those decisions for their activities under those levels of fare, travel time, car availability, income level, rest of the activity schedule etc. A set of typical people can be selected in this way to illustrate the reasonableness of those in different circumstances. The non-modeller can relate to the decisions because they would be making similar decisions themselves. This is a persuasive feature to illustrate the voracity of the model and to convey to others – particularly non-modellers – that the model represents reality.

AABM's are best applied without final pivoting ie as absolute whereby the sequence of trips and tours which come out of the model gets assigned directly and that they do not go through a pivoting process to change an origin-destination 'observed' trip matrix. Absolute assignment allows the assigned flows to be directly traced back to the individual people who are on that link which allows the full set of segmentation variables to be used to tabulate and analyse link flows. If the variable is on the synthetic population file, then it can be used for link analysts such as equity analysis to see who gains and who loses from the transport scheme. If the emissions characteristics of each vehicle are in the synthetic population then the emissions and air quality of the link can be forecast. If it includes fuel type/ drive train then the forecast will give the number of EV's/ hybrids/ diesel/ petrol vehicles using the link and if they are entering a ULEZ charging zone they can be charged differently. This different charge could affect their choice of vehicle/ mode/ destination/ route and maybe their activity schedule or whether to work at home or not. This feedback would be modelled in the AABM but would be lost if the demand was pivoted.

Because of the AABM being absolute, this places more need for assignment validation which on the one hand would ideally be more detailed meso or microscopic and support more detail on the time-dependency part but less of the average hour part but on the other hand would be absolute and hence more difficult to match simple counts. For AABMs the assignment model validation criteria needs much more careful treatment and needs to take account of these features.

So we suggest that TAG be revised to deal with AABM validation in more detail.

9 Including wellbeing, life satisfaction and happiness in an AABM framework

Activity and agent based modelling offers a framework within which to quantify the effect of a transport intervention on people and households' wellbeing, life satisfaction, and happiness. Although wellbeing, life satisfaction, SWB and happiness are distinct concepts in themselves, for brevity we are collectively using the term wellbeing. Such aspects as household income, job, home accommodation, schooling and car ownership can be successfully modelled with AABM lifestyle modelling and as shown above, lead to improving wellbeing. This chapter provides some suggestions on how this might be done.

9.1 Using AABM lifestyle for modelling wellbeing

Some of the determinants of wellbeing such as income and whether a person is employed or not would be provided by the lifestyle model. Lifestyle modelling also forecasts home location, job location, commuting, schooling and vehicle ownership. These are needed to forecast wellbeing so AABM lifestyle modelling can be used to forecast these aspects of wellbeing.

Other aspects not currently addressed by AABM lifestyle modelling, but which are important for wellbeing, such as a person's health, could be incorporated into the lifestyle modelling framework. Each person's health would need to be incorporated into the base year synthetic population and this could be accomplished by knowing the proportion of the population with each type of ill-health for each cohort in the population (eg from census data) and putting this on the synthetic population using one of the methods in table 8.1. In forecasting, the probability of falling ill could be calculated from knowing the proportion of the population cohort who became ill (eg from census data, medical records, or those receiving health-related benefits for the first time etc). This could be applied to the population forecaster to forecast an ill-health event ie whether the person became ill. This may trigger other life events such as loss of job or reduction in income or disposing of one family car. The lifestyle model would pick this up and mark the person as ill and deal with the other life events as probabilities or - if more is known about the behavioural decisions – as choice models. Again segmentation would be important here.

Having run the AABM model, its synthetic population will contain details of commuting so this aspect of wellbeing will have been modelled. It would hold details of home/school etc location then it would forecast measures of accessibility and access to greenspace (with the help of a GIS database of greenspaces). If the AABM also forecast emissions such as described above (see the air quality example in table 8.1 method 2), then it would forecast air quality and noise.

This covers most of the influences on wellbeing and if other behavioural mechanisms are required then there are various methods for developing models of them. These methods include standard stated preference methods for developing behavioural mathematical relationships which are currently unknown. They involve 3 steps as follows:

- 1) Focus groups to find the attributes upon which the behavioural relationship depends together with the language to describe them, the market segmentation needed to separate people into distinct market segments which have similar

choice-making behaviour and the attribute levels at which people trade between the various alternatives.

- 2) Stated and Revealed preference survey(s) to estimate the coefficients of the utility function connecting the attributes with RUM discrete choice estimation. There would be a different set of coefficients for each market segment
- 3) Measurements of the proportion of each market segment in the population under consideration.

This would help facilitate using these models in appraisal like the other RUM choices. This could bring-into appraisal the idea of valuing improvements made in people's lifestyle, wellbeing and happiness. So as to bringing-forward schemes which offer people real improvement in their lives such as the example of our school bus which allows parent 2 to become economically active.

9.2 Wellbeing appraisal

Having used the AABM lifestyle model to forecast the components of wellbeing for the DN and DS scenarios, the appraisal process needs to apply measures of wellbeing and devise a metric with which to value wellbeing improvements (or deterioration). There are various wellbeing metrics in current use including subjective wellbeing (SWB) but this topic needs further research if it is to be integrated into appraisal.

10 Providing the data and tools for AABM appraisal

The workshop suggested that it would be a good idea if DfT could provide any AABM data and tools to aid scheme promoters, avoid duplication and provide standardisation. Appraisal needs to be proportionate and not every scheme will require AABM-type appraisal.

This section provides suggestions on how DfT might help the process by preparing a set of data and tools which may comprise of developing a national activity, wellbeing and lifestyle model. This could potentially augment and eventually replace the national trip end model. It would forecast the future changes in activities, wellbeing and lifestyle to provide trip ends for the existing aggregate models and provide the future-year synthetic populations for AABMs which are consistent for appraisal. It could also model government policy priorities, forecast revenue (eg from EV taxation), help plot the path to transport net zero, help devise levelling-up strategy etc.

10.1 Architecture of a National lifestyle AABM with data and tools

The national activity, wellbeing and lifestyle model would use the synthetic population, activity generator and activity scheduler described in chapter 8, vehicle agents and cover the lifestyle changes, for the whole of the UK (see figure 10.1). It would need to be sensitive to transport supply changes, so the National AABM would use National transport networks.

The National AABM could be connected to the driving and vehicle licensing agency's database (DVLC) from which it could automatically generate a set of vehicle agents which could be appended to represent the vehicle of each person in the synthetic population. The vehicle agents would retain the details of each vehicle such as it drive train, fuel type, range, carbon and other emissions profile. This would be carried right through the assignment model so as to forecast the emissions on each highway link in the networks. This could be used to forecast emissions and air quality policies such a Zero Emission Zones (ZEE) or Ultra Low Emission Zones (ULEZ). This model architecture was used successfully recently in a major model in the Middle East where it helped devise urban emissions policies.

Scheme promoters would receive a synthetic population from which they could extract their area of interest rather like they do now with the National trip end model's trip ends. A set number of scenarios might be run by DfT and their corresponding synthetic populations created and provided to scheme promoters but with proper behavioural response modelling and forecasting. It could also be used in conjunction a scheme to provide its wellbeing metric.

10.2 Devising National Policy with the National lifestyle AABM

DfT could use the National AABM to test National and regional policies by changing any of the model inputs including the following:

- New rail, bus etc corridors and services including high speed rail

- Fares, fare structures such as railcards, season tickets, mobility as a service (MaaS) etc (the AABM has almost infinite segmentation possibilities), eg free off-peak fares for the elderly or mobility impaired.
- Behavioural responses to changes in travel attitudes such as home-working, regional policy such as levelling-up, economic prosperity, jobs, homes, wellbeing, happiness etc.
- Policies which speed-up changing the vehicle fleet such as EV take-up, CAV. The model could forecast revenue raised from taxation eg from road use charging, fuel taxes or by charging EV's per vehicle mile, and many more.
- As well as all the conventional land use and transport supply changes commonly the province of the SM.

The demand part of an AABM generally runs much quicker than the assignment part and the National AABM could be configured to run even more quickly for example the whole UK population could be run through the lifestyle, activity generator, activity scheduler, demand model and provide a set of tabulated output for example in under 30 minutes. This would mean situating the National AABM in the cloud with a User Interface (UI) which would allow the non-modelling user to run the model with a selection of preconfigured policy inputs plus a limited amount of network and possibly other parameter changes. More detailed runs would need to be performed by the trained modeller.

10.3 Workplan to deliver the National lifestyle AABM

The skills to develop this National lifestyle AABM are rare, so the model development should be divided into a set of smaller work-packages each undertaken by a specialist team, each team from a different organisation. The first work-package should be an initial project to design the architecture of the whole completed model including drafting the sub-model components, sub-model connections, sub-model variables, inputs, outputs, mathematical relationships, utility functions. It should review what already exists and plan a development path for its integration. Other work-packages would cover each sub-model.

Each sub-model team would write its own code to a common open-source standard in a popular scientific language such as 'R' or python. The interfaces would have been defined by the model architect using a standard such as a common API with standard json files. Code to have proper version control on a standard code repository such as gitlab with test-oriented development and a full CI/CD pipeline to ensure quality and eliminate bugs from the outset. This is envisaged as a serverless cloud application with its own web browser UI.

This architecture should then form the basis of a pilot to build the model for a small area using the simple approach described in section 8.4 so as to get the whole model structure working. The aim should be to put the pilot model in place comprising all the components to ensure it operates correctly.

Each sub-model work-package can then be researched individually with a set of small individual sub-model research work-packages for researchers and consultants so as to produce a more sophisticated sub-model which encompasses more behaviour and

explanatory power. This would allow universities, consultants and research establishments to research better models (eg with PhD students) which could eventually feed through into improving the National model incrementally over time at low cost.

The simple approach pilot model can be expanded geographically to represent the whole UK. The time-critical parts of the model software would need to be rewritten at some point to parallel process it and speed it up to reduce run time with the aim of processing the whole UK population in a few minutes. The simple approach sub-models can incrementally be replaced by their more sophisticated counterparts as the specialist teams deliver their improved sub-models.

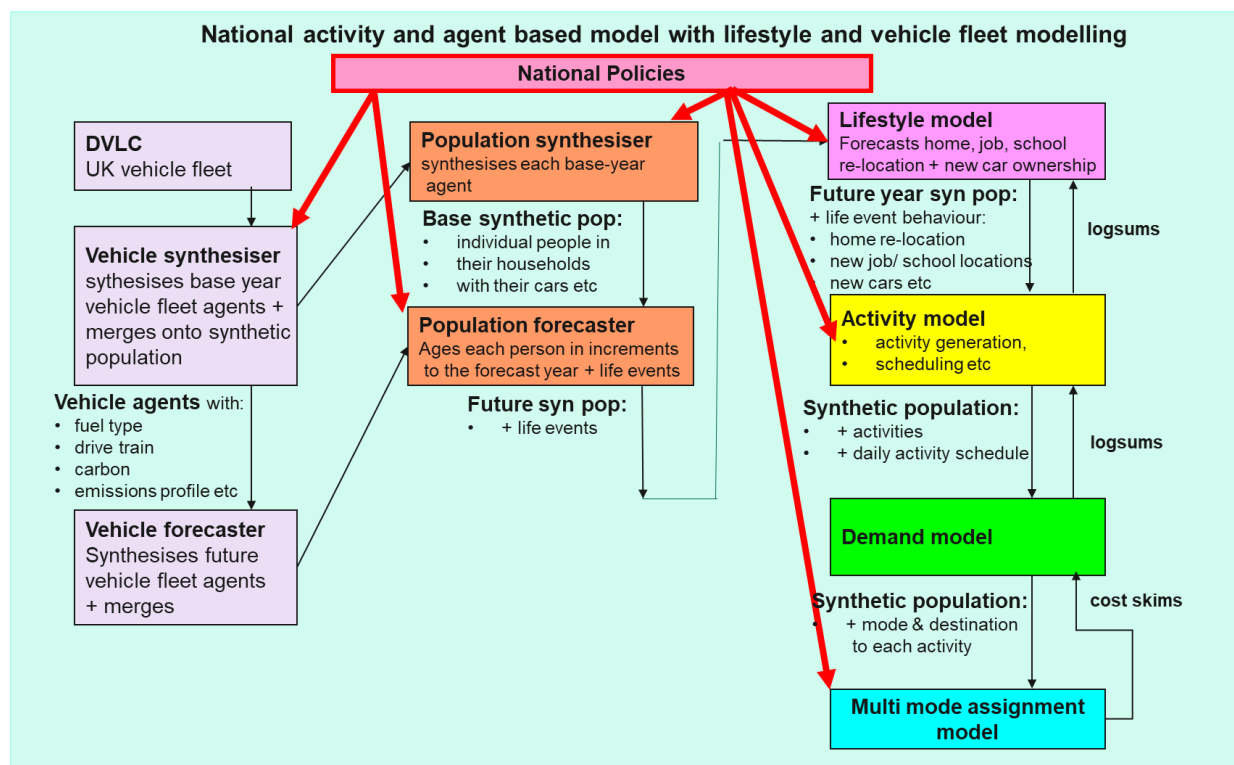


Figure 10.1 National lifestyle AABM model architecture with fleet modelling

10.4 Adding wellbeing appraisal to the National AABM lifestyle model

To add wellbeing to appraisal would need various other features to be added to the National AABM including health, impairment, access to greenspace etc (see figure 10.2). This would require these aspects and variables to be added to the model in some form or other.

Health, impairment etc could be added to the synthetic population from some form of health/ impairment database which contained a representative sample of people with the relevant different types of health/ impairment etc. This would result in the health impairment being appended to each person in the database. Their life events would be forecast with an upgraded lifestyle model to model whether/ how this changes in each person over time and differently between the DN and DS scenarios.

To include such aspects as greenspace would require a geo-database of greenspace with attributes such as area, capacity, diversity etc so that lifestyle decisions can be based on proximity to greenspace. This would need to be sensitive between the DN and DS scenarios.

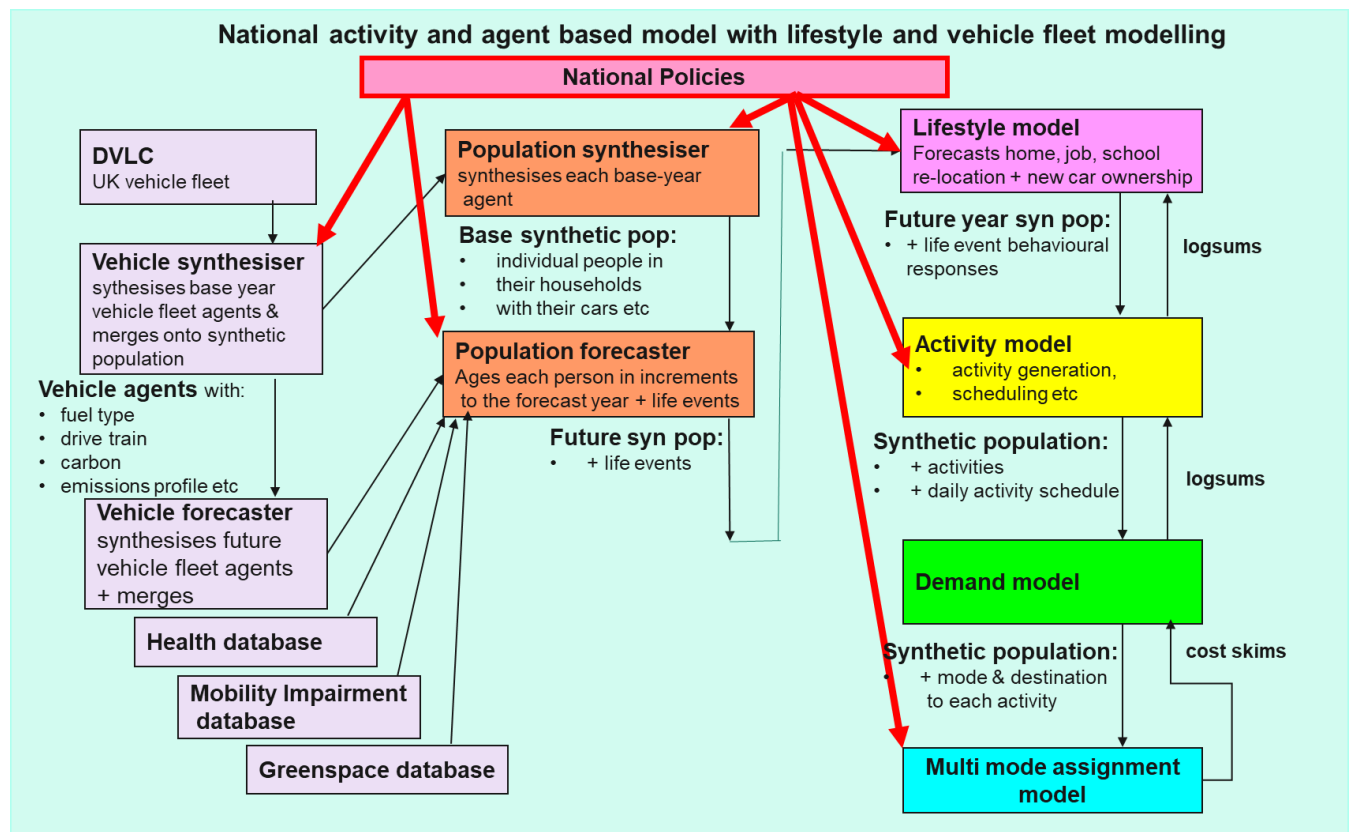


Figure 10.2 National lifestyle AABM model architecture with wellbeing and fleet modelling

10.5 Data requirements for the National AABM lifestyle model

The lifestyle, activity generator and activity scheduler can initially probably be mostly built from the census + NTS. The lifestyle components which use the cohort survival methodology would best be developed in conjunction with the government organisation responsible for the UK's population projections. The connection to DVLC would presumably require some input from their IT department. Datasets for health, mobility impairment and greenspace would need to be identified as part of the model architecture development. It would be best if the pilot and initial roll-out to the rest of the UK with the simple method (as in section 8.4) were developed from existing data sources, if necessary, making assumptions to plug gaps. This model can then be used to identify the weakest parts of the model and resources can then be focussed on that and identify the data needed. Household panel data may be required at some point for some of the life event behavioural modelling.

11 Rethinking appraisal objectives

So far, this report has identified what AABMs could provide appraisal and what would it offer to improve appraisal. However, there was a suggestion from the workshop, that we may need to re-think appraisal from the top-down by examining the ideal appraisal objectives, irrespective of whether or not they can actually be reliably delivered. It does not suggest that they are implemented. It is sometimes constructive to view things from an outside vantage point. This chapter sets out some ideas to start a possible discussion on this interesting topic. Much, if not all, is covered in some way by current appraisal. AABM could provide a suitable modelling and appraisal framework for the following aspects

11.1 The economy

The importance of the economy in people's lives is encapsulated in the quote from Bill Clinton's policy strategist who said "It's the economy stupid". Following this vein of thought, it seems that the transport scheme's contribution to business and the growing economy is the most important objective for politicians and policy-makers. On this objective, appraisal should prioritise transport interventions which help grow the economy. It could perhaps be that CS and VTTS is an appropriate measure of the transport intervention's contribution to the local economy..

11.2 Wellbeing

Maintaining and improving people's wellbeing is central to policymakers and politicians as outlined above. It already has several candidate metrics such as SWB and is measured in the UK already. It may be that jobs and housing could be wrapped-up in the one wellbeing objective.

11.3 Wellbeing: jobs

Improvements in the local economy filters down into giving people jobs which improves their overall household prosperity. A recent European Transport Conference (ETC about 2020) workshop, with all the UK and several EU governments present, identified what politicians and policy makers were most interested-in from models. The message came through crystal-clear was jobs, jobs, jobs and then perhaps housing, health and schooling. Whether or not improvement in the economy leads directly into jobs, whether those jobs are high-quality and long-term etc is a question which may be measured by the economy objective, or it might not. If not, it will require its own objective perhaps as part of wellbeing.

11.4 Wellbeing: housing

Housing is not directly the province of transport scheme appraisal. In some cases, especially for land-use and transport interventions such as a land use/ transport planning, strategy and policy, housing could change and be relevant. In which case there may be a case for including a housing objective in the appraisal process. If it doesn't change and isn't affected between DN and DS scenarios then, it would drop out of consideration in appraisal. This objective would need to take account of which segments of the population need which type of housing (eg young people leaving

home need low-cost homes while professional commuting households with children can afford larger houses).

11.5 National policy objectives

Government has certain national policy objectives such as ensuring travel is sustainable in the long-term, levelling-up, equity, improving air quality, carbon reduction, reducing accidents etc. AABMs can help to model most of these which may help to improve their quantification.

12 Conclusions

This report has outlined the architecture of AABM's with a view to initiating some nomenclature, standardisation and to help devise appraisal methodology. This architecture replaces the Standard Model's (SM) trip end model with the following AABM sub-model sequence:

1. Population Synthesiser: which produces a Synthetic Population for base and each forecast year which contains a complete list of every person in the study area, grouped into their household, together with attributes about them, their other household members, household cars, income, employment status, school, socio-economic group, driving license holding, season tickets etc
2. Activity Generator: which considers each person in the synthetic population and generates their activities considering for example that children will generate a school activity, a worker will generate a work activity, people will generate shopping, social leisure activities etc. This could be as simple as drawing from a probability distribution or be could be dependent on attributes with a logit model to generate the probability distribution. The net result for each person is a set of probabilities for each activity and a decision as to which activities were actually undertaken. The decision is usually made by a random draw from the probability distribution (ie Monto-Carlo simulation). This sub-model would also forecast the activity duration.
3. Activity Scheduler. which considers each persons' daily activities and schedules them. Usually work and school take precedence over other activities. This can use some form of logit choice model with time intervals as the alternatives such as the 48 half-hours in a day. Certain alternatives could be excluded for example to limit school activities to be scheduled during school opening times. The logit probability distributions can be turned into decisions using Monte-Carlo simulation.

The output from this sequence can be a set of probabilities or one decision which would comprise the daily activity schedule. This schedule would then be applied to the mode/ destination and possibly other choice sub-models. The output would comprise the synthetic population which retains all the details from step 1 above plus all the probabilities and decisions added by the other sub-models 2 and 3 above. This is normally held in a database and contains all the richness of individuals, their activities, activity schedule (start and end times and activity duration), activity locations, mode(s) to get there and all their other decisions. This can be input to appraisal to compute the benefit to each individual. This can be tabulated to analyse use of the transport system, for equity, air quality and other analysis such as electric vehicle traffic flows. It can also be built into trip matrices and assigned in the normal way

This report describes three methods to use AABMs in appraisal by converting the AABM output into SM Consumers Surplus (CS) travel time savings output and applying it to the current appraisal methodology with TUBA. Care must be taken to ensure consistency with the SM. Current appraisal uses the difference between two large numbers (the vehicle hours for the DN minus the DS) so slight fluctuations between these two numbers can swamp the difference. This can occur in a number of ways with the SM as well but with AABMs, microsimulation stochasticity can also cause it, so care must be taken to limit it. The report outlines a number of strategies for dealing with this. These need to be tested in practice and their theory examined to ensure they follow CS correctly. The three methods are as follows:

1. Build trip matrices from the synthetic population's decisions for input to TUBA
2. Apply the TAG CS to each member of the synthetic population and build benefit matrices.
3. Apply the TAG CS to each member of the synthetic population, tabulate over individuals for example to investigate equity, with the sum giving benefits.

This report describes including the value of the activity in appraisal. This would extend the current value of travel time savings (VTTS) methodology, to separate from it the value of the time spent undertaking the activity while travelling (VAWT). This would enable VTTS to be measured from the skims and enable VAWT measurable changes between DS and DN to be monetized separately. The report also describes valuing the activity at the destination (VAAD) which would allow these potential benefits to be monetized and would allow VAWT to be converted into VAAD (or vice-versa). Including the value of the activity in appraisal would need careful research to isolate and clearly define, individual activities and measure their perceived value in such a way as to avoid overlap between them and VTTS. They would need to be reliably measured, probably with stated (SP) and revealed preferences (RP), avoiding overlap with VTTS while ensuring complete coverage. Under this scheme, the time valuation would therefore comprise:

1. The value of the travel time savings (VTTS) excluding the activity itself. This is unchanged from current practice except excluding any value of:
2. The value of the activity while travelling (VAWT) excluding any VTTS
3. The value of the activity undertaken at the destination or origin (VAAD)

This report described the potential inclusion of Wellbeing, Life Satisfaction and Happiness in appraisal, preferably with its own metric. This would need further research

This report outlined ideas for a potential complete top-down rethink of appraisal objectives (see chapter 11). Whether these can be considered to be covered by current appraisal methodology, whether current appraisal can be adapted to include them, whether appraisal needs to change or whether they are irrelevant needs to be discussed. If they or something like them are to be adopted, research will be needed to provide the necessary quantification and appraisal methodology. The report ideas are as follows:

1. The Economy: the transport scheme's contribution to business and the growing economy could be considered the most important objective for politicians and policy-makers. On this objective, appraisal should prioritise transport interventions which help grow the economy. It could perhaps be that CS and VTTS is an appropriate measure of the transport intervention's contribution to the local economy. Or economists could devise better measures.
2. Wellbeing: It may be that life satisfaction, happiness, jobs and housing could be wrapped-up in the one wellbeing or maybe they are best kept as separate objectives as follows:

- a. Life satisfaction and happiness: Maintaining and improving people's life satisfaction and happiness could be considered central to policymakers and politicians. It already has several candidate metrics such as SWB and is measured in the UK already.
 - b. Wellbeing jobs: Improvements in the local economy filters down into giving people jobs which improves their overall household prosperity. Whether or not improvement in the economy leads directly into jobs, whether those jobs are high-quality and long-term etc is a question which may be measured by the economy objective, or it might not. If not, it will require its own objective perhaps as part of wellbeing
 - c. Wellbeing housing: Housing is not directly the province of transport scheme appraisal. In some cases, especially for land-use and transport interventions such as a land use/ transport planning, strategy and policy, housing could change and be relevant. In which case there may be a case for including a housing objective in the appraisal process. If it doesn't change and isn't affected between DN and DS scenarios then, it would drop out of consideration in appraisal. This objective would need to take account of which segments of the population need which type of housing (eg young people leaving home need low-cost homes while professional commuting households with children can afford larger houses).
3. National policy objectives: Government has certain national policy objectives such as ensuring travel is sustainable in the long-term, levelling-up, equity, improving air quality, carbon reduction, reducing accidents etc. AABMs can help to model most of these which may help to improve their quantification.

This report describes the Data and Toolset which DfT could provide to make appraisal with AABM's more efficient and effective. This would ensure compatibility between schemes, unify strategic and economic appraisal cases, support early stage optioneering, help develop National Policy and devise transport strategies to deliver it. This report outlines a potential AABM appraisal toolset which is described in more detail in chapters 8 to 10. The toolset includes the following features:

1. Preparation of a synthetic population of the whole country
2. Using cohort survival modelling techniques to evolve the synthetic population into the future, complete with behavioural changes induced at an early age.
3. Using lifestyle AABM techniques to model long term choices such as home, school and work locations, and major purchases such as cars.
4. Outputs would provide forecast trip ends for the National Trip End Model/ TEMPRO as well as bespoke synthetic populations for local AABM's
5. The model would also enable DfT to run "what..if" scenarios to hone National Land Use and Transport Policy and devise strategies for achieving it.

This report describes some of the implications for AABM model validation and realism.

13 Recommendations

This chapter makes recommendations about the way DfT can take these report ideas forward into action and change if it wishes. The preferred approach is to move forward by researching and developing on a series of fronts including: top-down, bottom-up and researching the middle-ground, all at once so that each approach can inform and adapt-to the others. No one approach will achieve the desired objective because that objective is to be defined by what is achievable and what is to be achieved is defined by the objective and the way to get there. These recommendations therefore are intertwined, each informing the other so that we get where we want to be, not where we don't want to be, and we have a way of getting 'there'. 'There' being a better modelling and appraisal methodology. (Recommendations are numbered in sequence below ie 13.2 'Test different AABM appraisal methodologies' is recommendation number 2.)

13.1 Rethink appraisal objectives

This is the top-down approach to determine where we are going. It will identify the objectives for appraisal including what appraisal is for, what should be measured, how those measurements will be used; should there be just one measure or several? Is the BCR as it stands suitable or does it need other measures or does it need to be adapted or is it only suitable for certain cases? The resulting objectives should be easily understood with easy-to-understand metrics (even if the method of calculating them is complex). The suggested starting point is given in the conclusions and chapter 11. These need to be debated within government in consultation with practitioners and academics. Government sets the National policy objectives so, if this is to be adopted, these will need to be reviewed. The debate can be at the usual forums including at conferences.

13.2 Test different AABM appraisal methodologies

This is the bottom-up approach to determine what is possible. This report describes methods for converting AABM output into SM output suitable for TUBA although these lose important AABM detail. It describes various methods for using the CS approach for individuals in an AABM synthetic population. These can be tested in current AABM models such as Bertie and AB-MoTiON and workable solutions developed. Initially this may involve losing some of the richness of AABM output but they can be refined and incrementally improved. This will develop a set of test-bed AABM's to test-out the suitability and limitations of different AABM architectures. They will be used to test the results from the recommendations 3, 4 and 6. The suggested starting point is given in the conclusions and chapters 4 and 5.

13.3 Research and measure the value of activity time

This research is to measure the value of activity time (VAT). It will identify the different types of activity, define them sufficiently well for them to be both modelled in an AcBM and measured with for example stated (SP) and revealed preferences (RP) or in other ways. Define whether we need the perceived, resource or other time value(s). Investigate the research literature to see what research has already been done or is being done. Axhausen, Jara-Diaz and others (see references) seem to be active in this field. Assemble existing activity time measurements, document and publish to be used in recommendation 2. Undertake qualitative and quantitative SP/RP research and surveys to measure VAT firstly coarsely then with more refinement when the coarse measurements are shown to stack-up to testing. This should test for things like

non-linearity (eg whether 1 minute is valued the same if the activity is undertaken for 20 minutes or 2 hours); the whole-day activity value, whether activity time is additive etc. At key stages VAT should be passed to recommendation 2 practitioners for testing.

13.4 Develop the wellbeing metrics and appraisal methodology

This develops the appraisal methodology for Wellbeing including Life Satisfaction, Happiness plus the contribution to it provided by having a good Job and a nice Home to live in. It will develop the economics of including these in appraisal, the metrics to adopt, their measurement together with how to value them either with or without monetisation. This builds on the ideas in the conclusions and chapter 9.

13.5 Research the economics of the appraisal objectives

This research is linked to recommendation 1 to ensure that the objectives meet sound economics. Of particular note is the De Serpa assumption that all leisure travel time is valued the same (see a discussion of this in Appendix B by John Bates). This assumption is made for SM appraisal. Is it suitable for AABM's? How does this square with valuing activities? This research develops the sound economics for recommendation 6.

13.6 Develop the AABM modelling methodology for appraisal

This develops AABM modelling methodology and their pathway to appraisal. It is expected that there may be different potential AABM architectures suitable for different transport problems or it may comprise a toolkit of sub-models to be wheeled-out to address different behavioural choices (such a Zero Emission Zones (ZEZ) or Congestion charges (CC)). This recommendation will develop the AABM modelling methodology to support recommendation 7. It will develop AABM validation standards including assignment validation, demand model realism and other model checking methods. It will deal with convergence issues and stochasticism. It will also investigate the various alternative AABM software including commercial and open-source software. It will investigate the use of different data sources including GPS and MND. This recommendation builds on the AABM architecture, nomenclature, standardisation and methodology started in the conclusions and chapter 4. It is the bridge between recommendations 1 and 2 using the emerging patterns from recommendations 3, 4 and 5.

13.7 Develop AABM appraisal Data and Tools

This recommendation is to develop the data and tools for AABM appraisal. For the SM, these have been developed by DfT and serve several purposes including standardising the forecast travel demand, standardising appraisal and for National policy testing. This report sets out the details in the conclusions and in chapter 10.

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Appendix A Workshop notes

Workshop: Appraisal and Activity-based Modelling

Held online on: 24/07/2025

Notes taken by: Peter Davidson and Rob Culley (Peter Davidson Consultancy Ltd)

Present:

Iven Stead	DfT
Nila Sari	DfT
Paul Hoad	DfT
Peter Davidson	Peter Davidson Consultancy Ltd
Rob Culley	Peter Davidson Consultancy Ltd
Glen McAdam	National Highways
Stephen Cragg	Transport Scotland
Collins Teye	Transport for London
Tim Price	Transport for London
Gerard Casey	Arup
Sam Price	Arup
Dom Duke	Arup
Aruna Sivakumar	Imperial College London
Peter Jones	UCL
Tom van Vuren	Van Vuren Analytics
Patrizia Franco	Systra
Siamak Khorgami	AECOM
David Simmonds	(independent)
Firuz Sulaimi	TfWM
Lou Mason-Walsh	Cambridgeshire County Council
Steve Newby	Cambridgeshire County Council
Richard Batley	University of Leeds
Paul Hanson	(independent)
Steve Hunter	Steer Davies Gleaves
Pawel Kurcharski	Jacobs

The notes which follow are summarised from detailed notes taken at the time of the workshop, a recording and its transcription. They are not necessarily direct quotes from what people said.

Discussion Part 1 – Applying the current appraisal methodology

Delegate O:

National Highways' (NH) research with Arup and AECOM on forecasting with ABMs was in line with TAG guidance. Transitioning from forecast to appraisal and understanding the implications.

Challenges Identified: calibration and validation standards, convergence and model noise.

Opportunities: equity analysis, better representation of full-day and weekly travel patterns.

Delegate E: 24-hour ABM gives better emission results and data from health benefits of active travel. He noted that values of time can be different in modelling from those used in appraisal and that this is expected and acceptable. Models reflect behavioural values and appraisal uses equity weighted values

Delegate V: Tricky working ABM into current appraisal framework. Two Key Dimensions:

1. Purpose of Appraisal: Are we trying to fit ABMs into the current appraisal framework, or should we rethink appraisal to leverage ABMs' full potential?
2. Model Functionality: Distinction between activity based modelling and agent based simulation. Each has different implications for appraisal.

Stochasticity and Aggregation: ABMs' stochastic nature complicates traditional appraisal.

Rule of Half relies on aggregate demand curves and may not apply cleanly to individual-level analysis. Tracking individual agents before and after interventions challenges traditional appraisal logic. Alternative Approaches: Logsum-based appraisal may be more appropriate for ABMs. It can incorporate activity valuation and avoids the need to isolate components like time savings. Strategic Direction: Urged clarity on whether the goal is to adapt ABMs to current appraisal or develop new appraisal paradigms. Without this clarity, methodological development remains uncertain.

Delegate B: Beyond Traditional Metrics: While early exercises may show similar aggregate results (e.g., journey time savings), the real value of ABMs lies in moving beyond these traditional metrics. Current Priorities: Modern transport schemes focus more on resilience, carbon, and distributional impacts than just time savings. Call for Innovation: Warns against being anchored in legacy appraisal methods. Suggests that if economists were given ABM outputs from scratch, they'd likely develop new valuation frameworks. Transition Mindset: Emphasizes the need to let go of outdated methods and embrace new approaches where appropriate.

Speaker 1: Persistent Challenges: Many issues raised (e.g., disconnect between model outputs and appraisal inputs) are not new—they already exist in current appraisal practice.

Loss of Detail: As outputs are disaggregated (e.g., by mode, time, cost), important behavioural drivers are often lost. Trust in Higher-Level Outputs: Suggests that appraisal is most reliable at the highest model level, where more behavioural detail is preserved.

Delegate F: Are we building ABMs as a replacement for 4-stage models or for something different? What do they give other than travel time benefits? Two-Pronged Approach: Bottom-Up: Validate ABMs by showing they can replicate traditional appraisal results for common schemes. Top-Down: Start from policy goals (e.g., health, equity, carbon) and ask how ABMs can best support appraisal of those

impacts. Strategic Shift: Advocates for rethinking appraisal to align with the broader insights ABMs can offer, rather than forcing them into legacy frameworks.

Delegate M: Traditional models are about travel, not what people are doing.

Distinguishing Metrics: Emphasizes the need to separate resource-based metrics (e.g. carbon, accidents, total time) from economic value metrics (e.g. consumer surplus).

Resource metrics can be aggregated reliably from individual agents, whether through matrices or directly from model outputs. Challenges with Economic Appraisal: Consumer surplus becomes problematic in disaggregate models due to the lack of direct representation of activity value. Traditional models infer value from travel behaviour, but ABMs can model activities directly, offering potential for new economic valuation frameworks. Strategic Direction: While it's useful to show that ABMs can replicate traditional results (e.g. journey time savings), the real value lies in moving beyond those methods. Questions the usefulness of extending current appraisal approaches too far into ABM territory.

Delegate H: Activity Focus: Emphasizes that ABMs are about modelling activities, not just trips. Some schemes may be irrelevant to evaluate using ABMs. Missing Conceptual Foundations: Points out the lack of a clear economic narrative for valuing activities in ABMs. Modelling Diversity: Notes that logsum-based nested models are common but not universal—other ABM structures exist and should be acknowledged.

Delegate J: Policy Context: Notes that the Department for Transport is currently consulting on its Appraisal, Modelling and Evaluation Strategy. Suggests that the outcomes of this consultation could help frame the future direction of modelling and appraisal. Acknowledges the tension between waiting for policy clarity and the need to continue progressing methodologically.

Discussion Part 2 – Extending the current methodology

Delegate E: Traditional appraisals often miss wider societal benefits, such as CO₂ reduction, air quality, and accident reduction. There's a growing shift toward evaluating transport's broader impacts on the economy and society, not just on travellers. ABM allows tracing indirect benefits, like a school bus enabling a parent to work full-time—benefits previously unaccounted for.

Delegate L: Jara Díaz's work on valuing time across activities (work, leisure, travel) is foundational but shows inconsistencies in VTTS results. These studies require complex, multi-source data collection (activity, mobility, expenditure surveys), which is resource-intensive. Emphasized the need to align valuation methods with appraisal metrics, especially within Random Utility Models (RUM).

Delegate G: Today's data fusion techniques and post-pandemic behavioural changes (e.g. hybrid work) make ABM more feasible. ABMs can model activity shifts across days and locations, capturing impacts like redistributed congestion due to

homeworking. These dynamics are not captured in VTTS-based models but are crucial for modern urban transport planning.

Delegate J: Despite 20 years of effort, many still equate BCR (Benefit-Cost Ratio) and VTTS with the entire business case. Emphasized the need for industry training and mindset change to adopt broader appraisal frameworks.

Delegate A: ABM offers a comprehensive framework linking population, travel, land use, and networks. However, practical implementation depends on data availability and clarity on what's feasible now vs. in the future. Suggested developing a tiered framework: what can be done with current data, what's possible with more data, and what remains out of reach.

Delegate Z: Appraisal involves two key steps - to get a view of behaviour change and then work out its economic impact. Concerns were raised about validation of ABMs and whether current knowledge is sufficient to model behaviour at a highly disaggregate level. There is resource intensity of implementing new methods, even in well-resourced authorities. The need for proportionality in appraisal—balancing rigour with operational feasibility.

Delegate P: Questioned whether ABM adoption is an evolutionary step (gradual integration into existing frameworks), or a paradigm shift requiring a complete overhaul of current appraisal methods. Expressed concern about capacity and understanding across local authorities and whether the approach is scalable.

Delegate G: Argued that lack of current skills shouldn't be a barrier. Emphasised the importance of industry-academia collaboration to build capability. Highlighted ongoing academic work (e.g. PhD research) that will feed into industry readiness over time.

Delegate V: Acknowledged that a paradigm shift is likely inevitable, but will take time. Suggested intermediate steps: Start with agent based simulation without full activity modelling. Use traditional appraisal methods alongside new models to build familiarity and evidence. Emphasised the need to prepare foundational elements now to support future transformation.

Discussion Part 3 – Exploring the potential for further opportunities

Delegate V:

Should transport be our go to solution for improving people's lives?

Delegate J: Pedestrianisation opposed by retailers and then accepted – need to engage better with the public in appraisal as in “This is what your community will look like”. It will help people to decide how to lobby policy makers.

Delegate E: Validation should go beyond behavioural accuracy to include public and political acceptability. Activity-Based Models (ABMs) offer new opportunities to assess exposure to environmental harms (e.g. air pollution, noise, danger) and benefits (e.g. active travel). A new Medical Research Council-funded hub aims to integrate public health indicators into transport appraisal, leveraging ABMs for richer, individual-level insights.

Delegate I: Warns against building land use models solely from a transport perspective; a holistic approach is needed. Raises concerns about stochastic variation in models—especially for infrequent decisions like residential relocation—where randomness can significantly affect outcomes.

Delegate L: Mentions DfT review of well-being literature.

Delegate B: Offers a devil’s advocate view: uncertainty and stochasticity are not flaws, but valuable tools for understanding real-world variability. Critiques the industry’s historical forecasting performance, urging more experimentation and iteration rather than excessive caution. Advocates for practical trials of new methods to better anchor models in behavioural reality.

Delegate A: Emphasizes the importance of equilibrium in transport modelling as a foundational principle, especially for conducting reliable policy and “what-if” analyses. Suggests that while innovation is welcome, core modelling principles like equilibrium should only be replaced with clearly superior alternatives. On stochasticity, he notes that random number generation is manageable in demand modelling through the use of fixed seeds, ensuring reproducibility and systematic sampling from distributions.

Delegate H: Raises a question about the impact of randomness in different stages of agent based models (ABMs), such as synthetic population generation, activity generation, and trip outcomes. Suggests that UK-based studies (e.g. Cambridge) might already contain evidence on how stochastic variation affects model outputs across different population groups and stages.

Delegate X: Echoes concerns about overreaching expectations of modelling as a panacea. Advocates for cross-departmental dialogue, suggesting that organisations like TfL and DfT should engage with other government bodies (e.g. GLA) to align modelling innovations with broader policy goals and ensure integrated problem-solving.

Delegate P: Why shouldn’t we include travel time savings with agents?

Delegate G: You may be willing to travel further to avoid an area where you don’t feel safe or where you can walk through a park. This can’t be modelled.

Delegate N: Added that isolating travel time savings from broader utility functions is complex and may not reflect true behavioural motivations.

Delegate L: Highlighted equity concerns, noting that assigning uniform value to travel time across income groups may be problematic, especially for non-work travel.

Delegate R: Concluded by reiterating that the workshop aims to gather expert insights. The process is exploratory, starting with modelling and potentially evolving appraisal methods over time.

Texts From Mural Board

Part 1: Applying the current appraisal methodology in activity based and agent based models

Delegate F first thought - what has been done by others elsewhere? Is there experience with Peter's solution 1 - this where I would start., incl as the benchmark for other methods

Existing Approach : What about converting the individual trips into matrices as required by TUBA (current standard approach)?

Delegate O NH are doing some research. Results will be benchmarked against the RTMs, and the AMATs. Lots of things that could go wrong of course - different cal/val, different convergence standards. Also, plenty of opportunities - as Delegate S says - equity analysis! Can we do anything new or get other econometrics to inform decisions. What is the expected impact of stochasticity on methods 2 and 3? Could method 1 be done at a more disaggregate level to capture some of the personas with different valuations?

Delegate M: I think some worked hypothetical examples would help to explain what the issues are

Delegate N: Interested in quite what we mean by current appraisal methodology - I think there might be a different answer depending on whether we mean the underlying theory, or the steps we take to separate different mode, time and charge impacts for DfT reporting tables surely for solutions 2 and 3 individuals choice of trips (even if schedule is fixed) will change. at the individual level presumably non-linearity in the demand -supply curve will render simple 'rule of a half' / trapezium rule integration too inaccurate. Only a solution to the new mode problem if we put Sugden approach to one side.

Delegate Q: good for road pricing

Delegate N: TUBA is applied (atm) to results from the assignment model - but I don't think these will fully represent the individuals' impacts (because the different parts of the trip chain will be separated?) Appraisal with dynamic traffic assignment is currently not addressed in TAG - does it lead to many more time periods to be assessed, or can we take a better estimate of the average as the main benefit?

Delegate F I like the logsum (or accessibility) approach as it gives us lots of flexibilities especially given that it can be converted into time or cost.

Delegate N: I think a more important question than 'do they give the same answer' is 'are they representing all of the factors which the model is taking into account when evaluating individual's choices'

Delegate J - Need to be careful we don't have the tail wagging the dog. Models and Appraisal are in lock-step. We make decisions in how to do appraisal based on what models can do. If model approaches change, we can re-think how we do appraisal.

Delegate F - I think the difference between modelled and appraisal VOTs is a wider issue in appraisal, and deserves TASM attention and advice. And weightings too. TASM is already looking at distributional weightings, but TAG is quiet about using databook values being applicable to modelling or appraisal or both (correct me if I am wrong).

Delegate G: As the focus on AABM is on the activities rather than travel time, travel choice are driven by different drivers, especially in active travel and in the case of new modes, travel choice will differ as personal preference drives the changes and VoT in the demand model is altered by including these personal preferences in the AABM, therefore the methodology should consider this change. Validation of AABMs will be key. Our Cambridge model is certainly not near validated well enough to run any appraisal on at present.

Delegate Y: Validating it to an acceptable level would be costly.

Delegate H: The focus should be on activities rather than TTS. How transport interventions will affect people's activity participation and then travel. also, the joy/penalty for activity engagement will be different for different individuals

Part 2: Extending the current appraisal methodology

Delegate O: Likes the idea of extending the current methodology, and valuing the activity of travelling itself particularly for active travel schemes. Can also be used for better sync between strategic case and economic case.

Delegate M: Given TAG is "guidance" isn't there flexibility in methodology anyway. The main issue surely would be whether there are new categories of outputs at the moment our economic theory underpinning (economic) appraisal is 'indirect'. That is the value of time saving is attributed to activities that could be taken if not spent making a journey. If we are able to turn this on its head and directly measure the value of time spent undertaking the activities, we would have a foundation to exploit measures generated from activity based models

Delegate Q: the VTTTS captures the value of saving time and putting it to some other use. It therefore already internalises the value of (a change in) activity. I think we need to develop and set out a theory of valuing activities (probably from Jara-Diaz as Richard says), and integrate this with the current paradigm as best we can, extending it as necessary. We should retain a firm grounding in welfare economics for anything we do to innovate appraisal with AABM

Delegate N: general principle is 'if we can model it robustly and explain it (to the satisfaction of decision makers) then it can be appraised. As long as there is some measure of traveller/consumer surplus - it can be valued (doesn't just have to be time). General principle for me is 'if we can model it robustly and explain it (to the satisfaction of decision makers) then it can be appraised. As long as there is some measure of traveller/consumer surplus - it can be valued (doesn't just have to be time). This discussion is still very much driven by valuing travel and activities, and not enough about wider outcomes (increased productivity, health outcomes, etc).

Delegate F: Can we start from those outcomes? Will we be able to model it and value it?

Delegate AA: Cambridge Uni has an agent based model to value health. Love the idea of valuing activities, but how much more utility is got from the beach at Nice compared to the beach at Skegness? Isn't this much more about destination choice modelling (is every job the same?), that applies to all models? Yes it does apply to all current models too but not currently aware of any way to bring that activity utility into the choice model. ABM makes that a possibility. Appreciate you don't have access to the new DfT Connectivity Tool (Greg Haigh talked about it at Modelling World), but at the moment, it appears that the postbox at Alton Towers carries the same weight as a leisure destination as Alton Towers itself.

Part 3: Opportunities which activity based and agent based modelling could open up

Delegate I: regarding Delegate A's point about setting the random number seed and being able to reproduce results; that's a start but not sufficient, it has to be possible to achieve consistent random numbers across multiple model runs, so that the differences we appraise are strictly due to the intervention we want to test, not to the Monte Carlo elements. I can dig out an old paper which elaborated on the problem and one possible solution I think we need more research on alternative versions of highly successful concepts we want to replace like equilibrium convergence, validation etc. Otherwise, we may just be doing analytics.

Delegate F: I thought that Moshe Ben Akiva had valued happiness?

Delegate G: Moshe Ben Akiva focuses on forecasting population and changing of lifestyle with Sim Mobility, there is a wider literature on valuing Health and Wellbeing from Cambridge university, (James Woodcock) and Munich.

Delegate F - we must separate out how we use AcBMs different way of operating better to value wider benefits that just travel time, to how we carry out appraisal. I think we are discussing the former?

Delegate O: Is there a way we can still use ABMs notion of utility for informing early stage optioneering; even in the eventuality that we can't precisely/robustly monetise it.

Delegate G: something that we did not touch upon but it's linked to forecasting synthetic population is how we connect evolving lifestyles and personas in order to predict travel patterns evolution and identify those measure that could contribute to better lifestyles (not sure if there is literature for it but I will find this out)

Delegate R Responding to Delegate O: I think we are saying ABMs can be used at early stage of appraisal, ie optioneering, strategic case. I agree with that, and the outcome from this discussion should be proportional to that - what kind of quantification is useful at that stage? isn't there then a danger of there being a dead end? That the approach taken doesn't have a path on to what we might need to do next?

Voting

Idea 1: Applying travel time savings to agents

YES

Delegate M: Yes. (Not sure why I wouldn't, given travel time savings are core benefits). I say yes - but of course include other things and make sure in the modelling you can identify each element.

Delegate F - yes, but only if bench-marked against AcBM model outcomes having been translated into a more traditional appraisal framework

Delegate O: Yes - like Delegate F once they've been benchmarked

NO

Delegate N - including because I would think that there is quite a lot of difficulty with isolating time savings from the overall utility functions

Delegate I: If you can't isolate individual items from the utility function then I think this would be a barrier to such a models use. How are you going to isolate things like distance which relates not only to cost but also to Carbon

Idea 2: Valuing the time spent on doing activities

YES

Delegate I: Yes, if we do so instead of valuing travel time savings. The value of a travel time saving is (partly or wholly) the value of gaining the time to do something else instead, so including both would be double counting. But valuing (or at least thinking about) what people will do with the saved travel timing may help to improve valuing it. For example, a travel improvement that gives someone an extra quarter hour's sleep in the morning would probably be more valuable than one giving them an extra quarter hour at the office?

Delegate O: Yes in some instances - there is a clear rationale for something like cycling / walking where you could be getting JT disbenefits but clearly the user feels a benefit from the activity itself (need to make sure not double counting journey quality / health etc though, but for some modes of travel it is clear that the travel activity is the 'leisure') subject to development of underpinning theory with robust valuation of marginal changes of time spent undertaking distinct activities.

NO

Delegate M: No. Time spent on activities surely are likely to be fixed (same as fixed land use in most modelling). So would cancel out in DM &DS. We probably cover this anyway in the ROH when applying VDM surely?

Idea 3: Valuing wellbeing, happiness and life satisfaction

YES

Delegate M: If the powers that be want to include wellbeing, happiness or life satisfaction I have no objection, provided they are measurable, there is good guidance about them, and they are kept as specific categories (or a single category) in the AST. Does this imply monetising these or just having these as a separate metric? If monetised, would they be included in Level 3 benefits? with reservations about

proportionality - the effect of transport on individuals' happiness is (likely to be) very small .may be better use of resource to focus around setting out activity schedules for personas or similar to explain the nature of impacts that may arise.

NO

Delegate M: Don't we already cover this within the context of how we use "willingness to pay" valuation.

Delegate N - not without making sure that the impacts are separated from the existing VOTs and with a change to cross-departmental funding of projects...

Delegate O: I voted no just because I'm less convinced on this one about how we deal with double counting from the impacts we are already appraising in economic appraisal.

But as stated elsewhere I do think there is a rationale for using some econometric value from an ABM output in early-stage decision making.

Delegate N - also because we would need to take care that all wellbeing/etc impacts were valued - and not just those for travellers. The delivery and existence of transport infrastructure (whether a bypass or railway eg through a rural area or a transit system through an urban area) can have significant negative impacts on happiness (eg if it runs through your back garden/farm or constrains your business premises). If these impacts are included we need to consider them for everybody.

Email responses

Delegate V sent an email on 28th July, with further thoughts as below.

1. I think it would be hard to conduct appraisal at an individual agent level (by comparing behaviour of individuals with and without scheme). Whilst understanding changes in individual choices will be very useful in policy analysis, appraisal at this level will face the challenge associated with the factors that drive choice in logit models and their incomparability with generalised costs skims from assignment models.
2. For this reason, if we want to use ROH, we will need to continue to aggregate agents into matrices, assign using a static assignment and then appraise using ROH in a traditional way (although there are ways in which simulations with Dynamic User Equilibrium, such as those in mesoscopic models, can be used, but this is not the crucial point) – key point is that ROH works well with aggregate demand curve, not agents.
3. But the addition of activities to the choice mix, will make the application of ROH impossible too, because choices will not be driven solely by time differences and the VTTS-based benefits will not make sense anymore. So this raises the point about the valuation of activity, which Peter already laid out during the workshop.

4. I sympathise with the concerns raised on the call that this poses some very challenging questions for the use of VTTS in appraisal (it is a proxy for any kind of benefit people derive from travel time savings, and to some extent the activity at the end of the journey). Whilst the valuation of activity, happiness, wellbeing, etc would be the ideal position (economists will agree that if we can, valuing them and putting them in the BCR is preferable), getting there for appraisal purposes will be a very complex endeavour that may not be successful, and any transition towards it would need to be managed carefully not to undermine the current VTTS-based framework in the meantime.
5. For these reasons, it would seem most achievable in the short-term to focus on undertaking appraisal using agent based simulation framework (without extending to activities just yet):
 - a. Any aggregate 4-stage model can be converted to agent based simulation (and if it is a like-for-like model structure, it will provide the same demand responses in aggregate). This will already improve Distributional Impacts Analysis for instance and be a step-change for policy analysis but will avoid pitfalls of expanding appraisal framework to activities.
 - b. Key questions to tackle here is the “stability” of model outputs with and without scheme in a simulation environment, where model responses are stochastic. I feel this was a major omission from the discussion at the workshop. Some people will say: “ah, that is just uncertainty”. Agree, but we already know that using CAS in decision making is a challenge, so will we really be able to explode the dimensions of uncertainty with hundreds of simulations where each provides a different answer? Focussing on handling this single issue would already be a big achievement. Looking at various ways of applying simulation so that it provides ‘crisp’ model responses to policy will be critical in my view. Some software packages already do that!
 - c. The above point would allow an almost immediate application of AgBMs in appraisal by aggregating matrices and applying ROH and allow us to focus on the other questions. But we should also make clear that even with AgBMs still aggregating inputs into TUBA, people should make sure that their AgBMs cover the same responses that the traditional 4-stage models do. For instance, if we say to people using aggregate 4-stage models that VDM is important and needs to cover mode choice and destination choice as a minimum with expected elasticities to fuel and fares – why should AgBM not be able to produce the same for the purposes of using it in appraisal?
 - d. Another worthwhile question to explore here would be the use of logsum as an alternative method of undertaking appraisal. Logsum can elicit the benefit from available choices in the way that is fully

consistent with the demand model formulation, so this could become a mechanism that enables (*) switch to appraisal over individual agents rather than ROH and (**) potential extension of the framework to AcBM in the future. But logsum will require tackling the whole range of questions about 'modelling' vs 'appraisal' VoT and may lead to a conclusion that by wanting to retain appraisal-specific VTTS, this move is not possible. But some choice models, do use appraisal VTTS, so perhaps it could....perhaps the answer is treating logsum outputs as an 'additional' metric that captures 'other' things that VTTS cannot.

However:

6. Even without going into appraisal, the exploration of Value of Activity (let me call it VoA) will be a worthwhile exercise as it will likely be needed to build proper AcBM model functions (none of the models on the market is AcBM – activities are fixed and are simply a different word for journey purpose at the moment). To add activities to the utility function, we will either need their VoA (so that utility can be expressed in generalised cost terms) or have activity coefficients in choice models. The latter would be very hard to obtain, which is why I think the VoA route is more likely.
7. So exploring VoA and “VTTS minus activity elements” is going to be needed even for the sake of modelling, and before we move to appraisal. And this is where this work could still add a lot of value.

So I think a very useful and possibly more manageable way forward now would be:

- Tackle stochasticity first and have it ticked off so that we can move forward to other elements.
- Indicate that initially people should just aggregate their AgBM (again – none of them is AcBM yet!) to assignment and continue with ROH, but some demonstration testing in 'real' models that have traditional assignment would be useful.
- Indicate that similar model responses would be needed from AgBMs if they were to be used in appraisal.
- Tackle the question of building AcBM utility/generalised cost functions using VoA etc. This will flush out a lot of questions that will lay ground for better understanding of the potential issues with the full valuation of VoA + adjusted VTTS for appraisal.

It may be that we stop with a hybrid approach, where for appraisal we use traditional VTTS based methods using aggregated matrices from AgBMs (probably excluding the activity dimension from the models for appraisal) but leveraging AgBMs power to improve DIA and the detailed impacts of the policies. Then the policy analysis can be enhanced further by 'turning on' activity choices in these models, but that would not

necessarily need to proceed to benefit valuation in the traditional sense – I think this approach would be more manageable, fraught with less danger for the currently established framework and attract fewer comments about this being a ‘paradigm change’. It could even be presented as a roadmap, with some uncertainty around getting to the end state.

Email:

One example is a demand model for a large metropolitan area – where rather than Public Transport sub-modes being composited. the demand model took inputs from them separately and applied some further parameters to represent choice between them

The issue being that when running appraisal for public transport passengers, there are factors which explain the choice between public transport sub-modes which aren’t included in the modelling – and therefore the appraisal (the ‘worst’ cases showed users shifting mode for a disbenefit – which goes against all of the economic theory). That was a bespoke model – but all the focus was on allocating demand to sub-modes and not on representing passenger benefits from doing so. Given that this was UK context and DfT funding was being sought – that isn’t good enough!

Second example is a well-used public transport assignment model (off-the-shelf) – which has some impressive capabilities when it comes to assigning passenger flows onto different PT services (including services of different sub-modes eg bus/rail/tram). But the outputs from that model, which form the inputs to TUBA, just do not match the richness of that process. Eg model assigns majority of passengers to a new transit system – showing that this is an attractive option. In terms of the generalised time outputs, the advantage of introducing these new services is borderline insignificant – in part because the wait time component derivation includes all available services, including those which are so relatively unattractive that no demand is assigned. (The point being an increase in frequency from 15 to 20 services gives a much smaller wait time improvement than from 8 – viable – to 13 services

These are just two examples where modellers (model developers, including of the software) haven’t sufficiently thought what appraisal needs might be. I do have something of a concern that for your study you have asked the modellers to answer a question, which really needs appraisal specialists to be considering (from outside the agent/activity based model community)

Appendix B Review comments and references

B.1 Kay W Axhausen

22 May 2025 – 2 February 2026

Lucas Meyer de Freitas used the log sum approach together with MATSim results for his thesis. He can send you the paper. The mode choice includes cycling, e-bikes, and fast e-bikes. In addition we did integrate a full blown choice model for cycling route choice. See Meister's PhD thesis.

Looked at your report. Interesting mixture of issues the DfT wanted to know more about. In terms of additional things (1) Might be worth looking at. The work combines travel and time use. This approach 2) Estimates the utility of the whole day schedule. She did first estimate for her thesis and EBikeCity.

- 1) Hössinger, R., Aschauer, F., Jara-Díaz, S., Jokubauskaite, S., Schmid, B., Peer, S., ... & Gerike, R. (2020). A joint time-assignment and expenditure-allocation model: value of leisure and value of time assigned to travel for specific population segments. *Transportation*, 47(3), 1439-1475.
- 2) OASIS (Pougala, Hillel and Bierlaire) for the papers see: <https://ebikecity.baug.ethz.ch/teilprojekte/j.html>

Given the recent experience with massively changing VOTs depending on context, one has to wonder about our trust in theory.

B.2 John Bates

14 January 2026

While there are many things that I could say about this "Research Report", I will confine myself to two major issues: the treatment of time savings and the use of ABM models to provide useful appraisal data.

Time Savings

The argument that VTTS needs to be supplemented by what are termed VAWT and VAAD (p 18) is fundamentally flawed. In section 5.3, the author cites DeSerpa as suggesting valuing travel time as well as activities, but a careful reading of DeSerpa would show that this is incorrect. The relevant source for the theory underlying VTTS is that in MVA *et al* (1988) section 3.3, which extends DeSerpa's analysis. While the whole section is relevant here, for the sake of brevity I merely cite the most important paragraphs:

3.3.5 Our approach will be similar to that set out in Bruzelius (1979), in that we will base it on a modified version of the model suggested by De Serpa (1971,1973). This involves including time spent in various activities in the direct utility function.

3.3.9 We now make allowance for the fact that for certain activities (of which travelling to work is a good example), individuals are compelled to spend more time than they would ideally wish. This notion is basically due to DeSerpa, and he describes it as the 'technological constraints'. In DeSerpa's model, each commodity has associated with it a minimum time requirement, assumed to be proportional to the amount consumed; the constraints then imply that the time

spent on consuming an amount x_i must be at least as great as the time requirement.

3.3.15 We can now draw an important distinction between those activities for which the minimum time requirements are binding and those for which they are not. In the latter case, individuals are freely willing to commit more time to these activities than is strictly required. In the spirit of DeSerpa's (1971) classification (based on Tipping (1968)), we shall refer to these activities as 'pure leisure activities', and to those activities where the time constraints do bind as 'intermediate activities'. It is clear that with this definition, most types of travelling will be an intermediate activity.

3.3.21 Now the essential point that must be appreciated is that while we have shown that 'pure leisure' time has a value (i.e. the 'resource' value), in that utility is derived from it, there is no value, at the margin, to a saving in leisure time. Any time saved in one leisure activity can only be used in another leisure activity, and will have the same valuation. Thus the consumer will not be prepared to pay to save (pure) leisure time, since he cannot increase his utility by so doing.

3.3.22 We have been careful to refer to the marginal valuation of time in an activity, rather than the value of it, in order to avoid this confusion. While leisure time has a non-zero marginal valuation, the value of saving leisure time is zero. The next step is to observe that for intermediate activities, the marginal valuation of time in the activity is less than the resource value, and indeed for most kinds of travelling will be negative. It is clear from Eq (3.8) that the difference between the marginal valuation of time spent in an intermediate activity i and the resource value is ψ_i/λ . By reducing the amount of time spent in activity i and transferring it to leisure, it is possible to increase utility, by a unit amount equal to the difference between the marginal valuations of time spent in the activity and time spent in leisure. Hence ψ_i/λ represents the value of saving time in activity i and transferring it to leisure (what Truong & Hensher (1985) refer to as "the value of transferring time"). It is this concept which is conventionally referred to as the "value of time" in transport appraisals.

There is a deficiency in the MVA *et al* analysis in that it does not make allowance for activities to be carried out simultaneously (eg travelling and working), and some expansion of the theory is needed to deal with this. However, this will **not** result in adding VAWT and VAAD to VTTS. As the author (Davidson) notes, the observed empirical reduction in VTTS over time can be explained by the increased opportunities to use travel time "productively". While a full theory of time allocation will be interested in VAWT and VAAD, this has nothing to do with the appraisal, which is concerned with valuing the **savings** in travel time.

Use of ABM

I should qualify my remarks at the outset that I am not up to speed with the latest developments in ABM, though I believe that I have a reasonable understanding. Underlying my concern is that while it is constantly claimed that ABM can provide much more information than conventional models, I have never received an explanation as to how this can be done in less time than is required for conventional

models. Something must be being omitted from ABM, and my suspicion is that this relates to the supply side (interaction with networks, congestion, crowding etc.).

In my understanding, ABMs work with a population sample, and simulate a number of choices, typically using logit models. Essentially this is a Monte-Carlo approach, and the treatment of randomness is critical to the credibility of the output. A logit model will provide a **probability** of choice, rather than a deterministic outcome. If a deterministic outcome is attached to the member of the sample by means of a random number draw, it will be necessary to make a large number of replications in order to obtain a reliable outcome.

While the report makes references to the problem of “stochasticity”, and this was clearly recognised at the workshop, it hardly produces a clear solution. There are vague references such as “The model can be restructured so as to minimise stochasticism such as using incrementation” [p 15], but this can be considered as a major issue which will impact even on a simple comparison with the “standard model” for appraisal purposes.

The weighting of the sample to obtain an overall population is not discussed – this is not trivial. Any measure of benefit needs to be calculated for the aggregate population. In addition, the treatment of assignment, which requires the aggregation of agents in order to represent congestion etc., remains unclear. In various places (eg pp 14, 15) it is suggested that individual agents’ characteristics could be related to links but no discussion as to how this could be achieved is given.

Finally, many of the claims made for ABM are completely unsubstantiated. For example, on p 13 it is suggested that modelling parking could use costs related to activity duration, while on p 14, for a number of issues which “arguably” can’t be modelled with the “standard model” ABM could “allow these to be appraised on the same basis as conventional transport interventions”. The cited paper by Clarke, Culley & Davidson (2008) sets out a complex hierarchical model (with mode choice, time period choice, destination choice, time interval choice, car park choice) with no indication as to how such a hierarchy could realistically be established, together with a parking model which “allocates each individual trip to an individual parking space”. It would be necessary to crawl through all the details to have any faith in the outputs of such a structure.

Overall, this report makes wild claims for the value of ABMs with little supporting evidence, while its general discussion of benefit calculations is flawed. At this stage, the most that could be recommended would be to carry out a simple test of the basic methodology to see what is necessary (in terms of population sample and “stochasticity”) in order to replicate single year benefits.

B.3 Andrew Daly

4 February 2026

I have now had a chance to read your report with more care. It is indeed an impressive document and should help quite a bit in getting better modelling into practice. The ideas on the value of activities were new to me, so I haven’t commented on them, but I do have some comments on other parts of the report, which I hope will be useful.

- I think you can be more positive about activity based modelling in a very general way. By representing more of the relevant aspects of travel-related behaviour, you are building a model that is in principle better for investigating all travel-related policy, even measures that can be modelled by more classical methods. Activity-based and agent-based modelling have specific and separate advantages, and you can apply either, both or neither.
- On the other hand, I don't think you give sufficient regard to the more advanced modelling that has been undertaken that does not explicitly represent activities. In the UK, one could mention the models for London and the West Midlands, but there are quite a few others (see [Key reports - Alo 25](#), the presentations for FHWA give an overview). The key point here is that segmentation can be increased dramatically without using random sampling.
- You don't mention the idea of *seeding*, which I believe is key to reducing the impact of stochasticity on appraisals. By using the same random numbers for do-nothing, do-something and do-something-else, stochasticity can be reduced to a minimum without losing the benefits of random sampling (i.e. agent-based models). The level of sampling, i.e. whether an agent-based model represents the whole population or a sample that is smaller (or larger!) is also relevant here.
- I think you are too negative about pivoting. In our work for the Copenhagen activity model (called COMPASS, pivoting paper for ETC 2021 attached) we were able to develop a pivoting procedure that respected the structure of the ABM while maintaining the accuracy of the assignment matrices that local planners in Copenhagen insist on.
- I haven't been directly involved, but there is quite a bit of experience now with disaggregate (i.e. agent-based) assignment, which has the advantage that distributed values of time can be carried through from the demand model to the assignment.

Hope these thoughts might be of some use and thanks again for showing me this work.

- 1) A pivot point procedure in the COMPASS activity-based model for Copenhagen, Christian Overgård, COH ApS, Denmark, Andrew Daly, Alogit Software & Analysis Ltd., UK, Goran Vuk, GVM, Denmark
- 2) de Jong, G.; Daly, A.J.; Pieters M.; van der Hoorn A.I.J.M. (2005), The logsum as an evaluation measure: review of the literature and new results In: 45th Congress of the European Regional Science Association, 23rd -27th August 2005, Vrije Universiteit Amsterdam

B.4 Paul Hanson

3 February 2026

Overall my perception is that your paper is a useful contribution. That said I would make three main comments.

- First I think that you fail to expose the limitations of the appraisal methodology currently applied to 'standard' transport models. We are not, I think, in a place of comfort where we can make marginal improvements. We have significant issues with our existing methods that need resolution. I would suggest that your Section 3 should be extended to explain the need for change.
- Secondly, while I broadly agree with the general thrust set out in your Section 5, I would suggest that it would better be redrafted. There is I think some unnecessary ambiguity in your conclusions and there are limitations in our current use of VTTS, following my concerns about the validity of underpinning assumptions, they should be brought out.
- Finally, while your section 4 and sections 6 onwards set out optimism on the ability to develop suitable capabilities, you should acknowledge that there are a range of methods/approaches. I think that you are giving too much focus on the benefits of disaggregate (agent based) assignment, and insufficient weight to the importance of explicitly modelling activity scheduling behaviour, such as the importance of explicitly representing in home activities in reasonable detail. Some of your text / figures also seem, inappropriately, to indicate that activity schedules may be represented as fixed. Particularly for annualisation purposes I also think that it is no longer satisfactory only to represent a 'working weekday' in our models. I also think that while you appropriately bring out benefits of disaggregate modelling in providing flexibility in appraising specific population segments, you should also express limitations: the segments need to be large enough and the underlying model must represent any differential behaviours of the segment in question.

To expand a little on my first two points.

'Standard' model appraisal limitations

The standard transport model and associated appraisal methodology is based on simplifying assumptions. Given sufficient segmentation of individuals and their income, there was reasonable evidence that activity schedules were fairly stable during the mid / late part of the 20th century. During and since the 1990's, however, there has been both a decline in trip rates and a change in the time of day when trips for a given purpose are scheduled. The simplifying assumptions that trip rates and annualisation factors are fixed are no longer justified from the empirical evidence over the last 30 years.

While we do not have adequate survey data to estimate micro-economic models to allocate the exact cause of these trends, there is evidence that communications technology is a cause. From consideration of various data, I would attribute just over half the reduction in commuting trip rates to working from home (there have been other changes) and all of the reduction in shopping trip rates to adoption of 'online' shopping. While I have not found suitable data, I would also judge that the adoption of social media, online gaming, are also the main cause of the reduction in leisure related trip rates. I can see with advanced in technology (AI, etc) that these trends towards undertaking activities at home are likely to continue over the forthcoming decades.

My conclusion is that the simplistic use of transport models is problematic. Merely expressing uncertainty through different future trip rate assumptions is inadequate. I have not seen any research exploring how annualisation factors have changed over time and how this might be represented (other than as a forecast output of an activity based model with suitable functionality). We should be seeking to reduce forecast uncertainty by explicitly representing demand drivers and the associated changes in behaviour.

Values of time

The principle underpinning Evans/De Serpa is that we value time spent working and undertaking a leisure activity. It is the difference between the marginal value of additional time spent undertaking these activities and the time spent travelling to access the location where we undertake them that underpins our appraisal.

We take assurance from McFadden's work that demonstrates equivalence of the valuation derived from travel time changes. This, however, has implicit assumptions. There is no direct relationship between travel time to access a given activity and the time spent undertaking the activity the journey is made to access. Empirical evidence demonstrates, for example, that commuting time is negatively correlated with the amount of leisure an individual undertakes. Applying values of travel time savings to traffic model forecasts implicitly assumes activity schedules are fixed. We know that they have been changing. Even if we retain the use of 'standard' transport models we should be undertaking research into this issue. To my mind the adoption of activity based models (that adequately represent scheduling behaviour) offers an approach to resolve this issue.

Given a model that explicitly forecasts the time spent undertaking activities together with the value of time that we wish to attribute to the activities for appraisal purposes, the derivation of the overall valuation is straight forward, and importantly much easier to express and explain than the indirect valuation of travel time savings we currently use. The key challenge, thus, is expressing the activity specific value of time.

- It will vary by the length of time an individual spends undertaking the activity.
- It will vary between individuals, and we may, for equity reasons, wish to adopt different appraisal assumptions
- It will vary by context, taking travel time as an example, we have considered the level of crowding and of congestion. Analogous considerations will apply for other activities. The trade-off between longer travel times and activity location will be associated with the value individuals attach to activities in different locations. Individuals can also undertake more than one activity at the same time – we have discussions about the indications that values of travel time savings are reducing possibly because individuals are increasingly able to undertake productive activities during their journeys

We can see from Jara-Diaz work that while feasible it will be difficult to obtain robust direct valuation of activities. We had analogous issues using revealed preference data from travel surveys. Our solution, the use of stated preference experiments has numerous challenges, many of which we understand and address. I would suggest some research is needed whether a similar approach would enable sufficiently robust and direct valuation of activity specific values of time.

I suggest that de Serpa is too simplistic. If we take the assumption that the marginal value of the time spent undertaking an activity declines with time we spend undertaking that activity then we can introduce the concept of trade-off between a range of activities. The implication is that we attach higher value to doing a little of many activities. There is no need to assume we attach the same value to different leisure activities - just that we get 'bored' spending all our time on a single activity (and the total time for which we derive value from a specific activity varies). More than a quick email to expand - but hopefully clear where I am coming from.

Noting your comment on activity schedules changing between DN and DS, I would add a challenge whether it is feasible to consider consumer surplus for a single individual. I suspect that imposing constraints on randomisation would preclude modelling some behavioural responses or retaining probabilities across the full spectrum of choices would have severe memory / run time constraints and would accordingly be infeasible. I do not see this as an issue; we are not pretending to model an individual - merely the aggregate response of a segment of society. While worth a specific investigation, the fall back of using (segment specific) averaged activity value / duration would align with the standard 'rule of a half' methods we currently use.

My paper on the value of AABMs at ETC had some of the relevant evidence supporting my comments.

B.5 David Hensher

22-23 May 2025

On consumer surplus I am not sure why the behavioural formula will be any different as long as you can extract the relevant logsum equivalent before and after in an ABM? Re logsum see a paper on its merit under context dependency in:

- Context dependent process heuristics and choice analysis – A note on two interacting themes linked to behavioural realism, David A Hensher, Transportation Research part A 125 (2019) pp119-122

B.6 Glen McAdam

27 January 2026

Section 4.3: It is very good for market segmentation and certainly much better than conventional strategic models. But its 'goodness' depends on the quality of the synthetic population developed (for base, and for forecast years depends on the quality the available forecasting datasets). Its implicit, but I feel this section is missing the conclusion that the increase in market segmentation could lead to us doing much more thorough distributional impact analysis. With my most 'blue sky' optimistic thinking, if scheme promoters / policy wanted to, it could enable us to come out with different SMART objectives for schemes based on social equity improvements - these types of objectives are currently rare as they are not able to be modelled and evaluated as easily so not as easily measurable. This outcome is the basis of Chapter 11 and could be trialled here.

Section 4.4: I would phrase this not just as a weakness (although, agree, it can cause problems!) but as a potential strength, as the stochasticity enables you to do quick

sensitivity testing (e.g. it could be seen as a proxy for modelling random day-day variability). It could be a useful output to show that in the 20 DS's produced that all have better network conditions / agent utility than all 20 DM's produced (or only 17, or only 10, and so on). I would suggest, like with micro-sim models, that guidance will eventually need to suggest the potential to run many models for DM and DS and give advice on how to present the range of results; to quantify the impact of stochasticity. Clearly, it is much more of a problem to worry about, if the stochasticity between DMs is bigger than your (average) scheme impact.

Section 4.5: Frequently we don't have satisfactory data to build/validate off peak / weekend / summer models, so whether these are used in appraisal should be a question for the scheme promoter and DfT. I acknowledge that we frequently expand economic appraisal to cover 24/7/365 using expansion factors at present, and that there are problems with this, and that having a better 24/7 (and potentially 365) model would be the ideal!

Section 5.1: This doesn't have to fall within the definition of what a business would consider productive like answering emails. It can be people enjoying movies/music etc. That is a leisure activity that people can do whilst travelling. Value of Activity Whilst Travelling: I would also note that in the case of walking / cycling that there is some value in the activity OF travelling, i.e. physical activities that some people enjoy like walking / cycling, time spent in green space and so on (in addition to the other benefits - like physical activity benefits which results in reduced risk of mortality/morbidity) that people derive from these activities.

Section 5.1: The other theoretical problem with only using the value of travel time savings is that it only generates benefits if there are travel time savings on the network. Theoretically, our current paradigm doesn't generate benefits if the travel time is the same but allows people to depart a little bit later should that better fit with their desired travel plan (i.e. if people still travelled for 25 minutes but left 10 minutes later in the day). ABMs allows for better modelling of, and appraisal of, changes in micro time period choice. In conventional practise (certainly on large highway schemes) we only model and appraise macro time period choices. Academic literature shows that micro time period choice is a more common response to most highway schemes and something that, ideally, we would be capturing both in modelling and appraisal.

Chapter 7: This section could do with a concise introduction on how TAG currently recommends we deal with wellbeing, life satisfaction and happiness. In the context that this advice is mostly (for highway schemes) written in the knowledge that the evidence base will be a conventional strategic model. And then we can tell the story in this chapter of evidence of transports effects on such matters, and how AABMs deal with them in Section 8/9. It is worth expanding this section to also cover equity analysis, given it was covered in the workshop topics and is part of TAG social impact analysis chapter. To state the obvious, they are related but distinct topics:

<https://www.gov.uk/government/publications/tag-unit-a4-1-social-impact-appraisal>

<https://www.gov.uk/government/publications/tag-unit-a4-2-distributional-impact-appraisal>

Section 7.4 Biodiversity and greenspace wellbeing: Not in TAG but I think academia / other Gov departments have ways of quantifying the benefits of green space.: https://news-archive.exeter.ac.uk/research/articles/title_910082_en.html

Section 7.5: I feel like this is missing a section on happiness vs. transport connectivity. It would be possible to run a simple cross tab with happiness vs. transport connectivity on UK regions. From a quick visual review, it is interesting to note that some of the least connected areas/regions are some of the happiest, and report higher levels of well-being and lower levels of anxiety. It is not obvious to me how we'd model an individual schemes impact directly on the happiness metric due to its inherently subjective nature, even if we can see it positively impacts on a few causes of happiness like socialising, job access etc and so on (which is captured elsewhere in appraisal). As well as capturing some elements that may cause unhappiness: <https://www.ons.gov.uk/visualisations/nesscontent/dvc238/index.html>

Section 7.7: This section would benefit from a conclusion - what do we do currently, and then a signpost to where we discuss what can we do with an ABM that we can't currently (Section 9), and potential some risks / limitations. My main risks would be that some of the satisfaction/happiness scoring is only less directly related to transport, and if we can't tie it to a specific intervention, then appraisal / evaluation would suffer from attribution problems (as well as the more obvious self-reporting problems).

Section 8.6 AABM validation: As well as / as part of, model validation is it worth touching on realism testing. As with more conventional strategic models; it would be entirely possible to create a base model that passes certain validation criteria, that is not fit for purpose for forecasting, because it has been 'over-fitted' to the base situation. Or because it has arrived at the right answer in the base because in the model 'two [or more] wrongs (behavioural parameters, datasets or choice models) are making a right.'

- 1) Microeconomic Interpretation of MATSim for Benefit-Cost Analysis, Benjamin Kickhofer and Kai Nagel Chapter 51 MATSim manual
- 2) Phase 2 of research into Agent & Activity Based Models, April 2025 unpublished.

B.7 Sergio R Jara Diaz

9 July 2025

Thank you for your message, Peter. you might find it useful to look at the two attached pieces. One solves the issue of VTTS when activities on-board can be performed (short and rigorous), and the other is an empirical follow-up to my 2024 paper you mentioned; we find what persons do after an exogenous reduction in mandatory travel time (due to teleworking, for example). Hope it helps. Comments are welcome. Papers as follows:

- The value(s) of travel time savings considering in-vehicle activities, Sergio Jara Diaz, Transportation Research Part A 184 (2024) 104092
- Reallocation of time after an exogenous reduction in mandatory travel: transport, work, and leisure in Chilean two-worker two-gender households, Sergio Jara Diaz, Sebastian Astroza, Diego Candia, Monserrat Morales, Travel Behaviour and Society 38 (2015) 100925

B.8 Peter Jones

17 February 2026

Some thoughts from me:

1. When thinking about the implications for transport appraisal, activity and agent-based modelling have different implications. Very simplified:
 - a. Agent-based modelling affects the **level of disaggregation** at which behaviour can be modelled (e.g. individual pedestrians and vehicles in VISSIM) - and enables micro-level interactions to be captured (e.g. between vehicles)
 - b. Activity-based modelling affects the **kinds of indicators** that can be captured, rather than the level of disaggregation (e.g. measures of exposure, time uses...)
2. I'll focus my comments on the potential of Agent-based, Activity-Based Models (AABM) to enhance appraisal.
3. Consumer surplus-related issues:
 - a. Although the standard consumer surplus figure (e.g. Figure 3.2) shows trip volumes on the horizontal axis, as far as I am aware - and I could be completely wrong! - in most applications of four-stage models trip generation rates are fixed. I think what is actually estimated from such models is things like changes in vehicle kms (as a result of changes in generalised cost). Noting that, at an aggregate level, elasticities can be used to estimate changes in trip volumes, and then relating this to the rule of a half to estimate benefits. Conversely, with AABMs, people may choose a different activity pattern in response to a policy change - which may result in changes in daily trip rates (as well as distances, by mode) at an individual level. This provides opportunities to ascribe different monetary values to these changes for different individuals, based on personal characteristics, trip purposes and modes, rather than applying a blanket value.
 - b. Good idea to use the choice probabilities from AABM, rather than the simulated choice outcomes, where practical.
4. Valuing activities
 - a. This is a highly valuable consequence of using AABMs, not only technically but also because it changes professionals' perspective: it focuses people's minds on the destination activities (treating travel as a derived demand), rather than just the linking trips - travel diaries could always have been used to look at time spent shopping, etc, but this was rarely done.
 - b. Good idea to separate estimation of a 'true' value of travel time savings/losses from the value of activities undertaken while travelling. Not only will the signs be opposite (at least within certain ranges), but the distributions of size of benefit in relation to duration are likely to be different. We might also move away from focusing on marginal time savings and losses and pay more attention to the total value of 'desired' activity durations; this concept is clear in the case of an in-mode activity (e.g. checking emails or report writing) and probably for shopping and eating; but there is evidence that there is an optimum travel time

separation between home and work, for example. This also raises the question of whether we should measure mode comfort separately.

- c. As noted by Peter, a whole new area of benefit would be captured by valuing activities at (non-home) destinations, such as in a pedestrianised shopping street - to offset time losses by diverted car trips - and also to take into account the 'comfort' of different street environments (possibly linked to 'Healthy Streets' scores. This issue clearly arose in appraising street design schemes in the EU 'MORE' project. In Lisbon, cutting off one arm of a large roundabout and introduce two-way traffic flow (e.g. as at Old Street roundabout) made the green space more accessible and more attractive, but there was no way of estimating the additional trips attracted to this enhanced green space, nor the additional time spent there and nor the ££ benefit - whereas the delay to motor traffic was readily quantified and valued. This links to wider issues about valuing Place - which I know interest DfT.
 - d. One issue is whether/how to value in-home activities - likely to be particularly relevant in relation to working from home - and the 'comfort' of performing the activity in home. Huge potential for exploring this, IF the AABM includes in-home activities.
5. Other potential opportunities
- a. I agree that there are real opportunities to dive into well-being and happiness issues, linked to activity participation/duration and some representation of the 'comfort' issues I raised earlier.
 - b. One completely new element that can be introduced with AABMs are measures of exposure - to unsafe conditions, air quality, social interaction, etc. - which provide a new dimension when considering distributional impacts
 - c. Finally, and Aruna and I have both raised this; we could estimate resource consumption associated with each activity (e.g. energy, water...) and use AABMs to provide a cross-sector tool to look at overall, aggregate resource implications of certain policies or consumer trends (e.g. working from home).

B.9 Pawel Kucharski

21 January 2026

The report is a great read, and its value goes well beyond appraisal considerations. I particularly like the sections discussing details of population synthesizers and setting out thoughts on the AABM architecture with life events and how this could be used suggests – this will go some way towards demystifying AABMs end capability building in the industry – thank you Peter for this download of knowledge. I am also glad that the challenges associated with stochasticity were noted.

While reading Section 4, I tried to imagine what the appraisal based on agent's choices could look like in practice. I agree that for a single agent the benefit collapses to the difference between P1 and P0. This is straightforward if the agent chooses the same mode in Do-Nothing and Do-Something – the cost difference represents difference in the cost of travelling by this mode (say, lower with congestion on highway). But if they change mode, P0 may represent the cost of travel by, say, bus and P1 by car. The generalised costs skimmed from assignment models will be incomparable and the

mode shift will take place for a range of reasons such as additional/different utility terms in the choice models, not reflected in the assignment cost skims, randomness of choice, or in case of AcBMs the choice of activity. This means that without accounting for these the choice will appear illogical and can result in appraisal results that contradict improvements made. Even, when activity is taken out and the model collapses to AgBM, such illogicality can still arise due to differences between costs skims and utility formulation.

In aggregate models, ROH looks at aggregate markets – it appraises change “within mode”. In theory, the sum of each agent’s benefit’s / dis-benefits should add up to aggregate benefit for the aggregate market. However, the issue here is that agents’ choices are simulated stochastically and so some appropriate “average” cost for an agent in Do-Nothing and Do-Something would need to be derived, or we’d need to run appraisal as many times as the number of simulations and then aggregate. This could be computationally challenging, although not impossible. But when we add traffic simulation, we will face a further dilemma whether to aggregate its outputs to some kind of average cost skim per time slice (mesoscopic assignment models have such capability) or retain the individual agents’ paths (if we were to link it to the population database). But this explodes the dimensions as there can be many paths chosen stochastically. Handling it probabilistically (using outturn probabilities from choice models) would lead to probability weighted average cost skims and that is not the correct weighting (the correct weighting across choices is provided by the logsum -this has been proven before). So, a different way of handling stochasticity is needed – either a method of aggregating benefit across all simulations or fixing stochasticity differently. An interesting attempt is the fixed random utility component method (RUF) implemented in (some commercial - editor) software. It always returns logical choices in response to network improvement but retains randomness of choice that stems from the random utility component in the logit models. So retains the properties of the aggregate logit models (including similar outturn elasticities). This may not necessarily remove the issues associated with comparing agents before and after choices and incompatibility between cost skims and utility formulation but has the potential to help avoid having to look at thousands of simulations. The usability of it in appraisal would need to be explored though.

So I agree that there is a need for an empirical piece here that looks at this and tries to establish what would need to be in place for either of these approaches to work and compare with it a standard model. To make sure the comparison is possible, we would need to put activity modelling aside for now so that VTTS differences can be understood better.

B.10 John Rose

23 May 2025

Attached is the paper I referenced about MATSim as well as the paper I presented at THREDBO:

- Kickhofer, B and Nagel, K. 2016. Microeconomic Interpretation of MATSim for Bene_t-Cost Analysis. In: Horni, A, Nagel, K and Axhausen, K W. (eds.) The Multi-Agent Transport Simulation MATSim, Pp. 353–364. London: Ubiquity Press. DOI: <http://dx.doi.org/10.5334/baw.51>. License: CC-BY 4.0

- A New Transport Model of Activity Choice, John Matthew Rose, and Andrea Pellegrini

Looking at the MATSim paper, they appear to have the theory sorted. I only scanned it, but didn't see any obvious errors.

With respect to the paper I wrote, there was a severe page limit which meant that a lot of things are missing. The model itself is not designed for this, as simply models the time allocation in each activity type, but not the sequence. Hence, to do it this way, you require a scheduling model to map out the sequence of activities as well as another model to model the number of activities. For the later I used an ordered logit (but probably a count model would be better), and for the former a simple Gibbs sampler when generating each of the agents. This was based on the marginals from the empirical survey we collected. A few months ago, I tried to develop a model to do all these simultaneously. I think I have the theory to do so, but as my main job is in sustainable transport, this is not something I have had time to work on since.

As an econometrician specialising in choice modelling, I have gone down the rabbit hole of approach 3 out of curiosity. As an economist, the fact that it is derived from micro-economic first principles of consumer choice, I find personally appealing. Its not designed to be applied to networks however in its current form. Its also worth noting that the origins of the model are in environmental economics from the 80/90s, and further developed in marketing in the early 2000s before Chandra developed a closed form of the model in 2008.

I sort of come at the ABM from a different perspective.

1. Every transport economics textbook says that transport is a derived demand – derived from the activities people want to take. Hence, it makes sense to me to start with modelling activities. Whilst the 4SM sort of does this by having commuting, non-commuting and employer business trip segments (some models may have more or less), I sort of see this somewhat artificially.
2. I'm starting to have trouble with the concept of VoT, which drives 4SMs.
 - a. Every survey I write, irrespective of what it is about, I ask a question about how people understand the costs of car travel (I also do PT on occasion). Between 4% and 20% (but mostly closer to 4%) actually understand marginal costs. The rest of the population are clueless.
 - b. Economics is broken. Once we paid cash for everything, but now with CCs, there is a disconnect between pricing and consumption. This is very clear when it comes to transport. Say I'm in a two person HH with one car. I pay \$X at the bowser and fill the car up. I drive the car 4 times, my partner 6 times, me another 3 times, and her another 6 times. What was the cost to her? Now I get that VoT is not the actual cost but the value of time, but if someone is not paying for something, what is the marginal utility of cost to them? Worse still, what if my partner doesn't work. The VoT is the work/leisure trade-off, but she doesn't work in paid employment. It is easy to compute this for workers, but when you drill down to people who are not working, it isn't really as simple as saying, that the trade-off is what they potentially could earn if they did work.

- c. I look at the average weekly earnings approach to computing VoT that is sometimes used, and just want to stab myself in the eyeball with a dull spoon. Looking at Wardman's work, he described where these values come from, its embarrassing. They were computed from a meta analysis of UK studies (SP and RP) from the 80s and very early 90s. The employer business trips VoT we use (145% of hourly adult AWE here in Australia) from memory was derived from a single study involving long distance rail journey (I believe Scotland to London but would have to check). So now, we use this value for a business journey of 10 minutes within a city. You can't make this stuff up.

Hence, I'm not coming at this from a forecasting perspective, but rather a theoretical perspective. Do ABMs forecast better? I don't know, maybe. Maybe not. We won't know until we get enough of them. I'm not a real fan of approach 2 as I find it too heuristic based, and if we just want to predict, I find them more akin to machine learning – yes you can predict well, but what is going on under the bonnet is often undiscoverable.

B.11 David Simmonds

20 January 2026

Introduction

This note provides some brief comments on the “Think Piece: Appraisal using Activity and Agent Based Models”, prepared for the Department of Transport by Peter Davidson, and circulated for comment by the Department in December 2025.

It is not a full review or critique of the thinkpiece document.

Comments

Section 4.4: The argument that AABMs can support the existing appraisal approach requires that all the factors influencing choice are represented in the “cost” variable (the vertical axis in Figure 4.1). At the very least the use of AABMs would seem to need extension of conventional analysis, along similar lines to that being considered in the current project on appraisal when land-use change is taken into account. Maintaining compatibility with conventional transport appraisal might severely limit the design of AABMs and prevent them from realising their other benefits.

This limitation seems to be accepted for example in section 5.5, which considers fitting an AABM into a random utility model (RUM) structure. Other parts of the document refer specifically to logit models. It was pointed out 25 years ago that using microsimulation models to implement a logit model is inherently inefficient 1 (See section 3.2 in *A new look at multi-modal modelling: conclusions and recommendations*. Report prepared for DETR by DSC, ITS, MVA and John Bates, 2001. Many of the other issues raised in that report remain relevant.).

Section 5.1: There have been cases where urban public realm improvements have been appraised using fairly conventional models and have shown significant benefits. AABMs are not needed to do this, and AABM methods do not in themselves make it any easier to measure or model the value of such schemes.

One detailed point on section 5.2: subtracting VAWT from VTTS is only reasonable if we are sure that the estimates of VTTs don't already include some allowance for working while travelling (whether in SP survey responses, or inherent in RP data). Also worth bearing in mind that "working on the train" isn't new – people travelling on business, and some commuters, have always worked on trains, at least since carriage suspension and lighting made it practical to read and write. For some business users, there should (theoretically) have been an increase in VTTS (i.e. rail travel time was a greater penalty) during the period between email becoming the routine means of business communication and wifi access on trains becoming standard.

Section 6.4 "AABMs offer a transformative approach to transport appraisal by enabling ... top-down alignment with broader national policy goals like health, equity, and carbon reduction". That appears to be making some very sweeping and as yet unsupported claims for AABMs (whilst not denying that conventional models also struggle with these issues).

Section 8.1 claims that "Households choices (such as choice of home/ job/ school location...) are ... increasingly being incorporated into AABMs as a better way of modelling these decisions (than for example land use transport interaction (LUTI) modelling)". I would be interested to know the basis for this claim. Section 8.3 seems only to suggest that such choices could be incorporated into an AABM – and what it suggests is simplistic, omitting other things that need to be considered and that are represented in existing LUTI modelling (such as the housing market). More generally, the discussion in section 8.3 is trivial to the point of being misleading – to take just one example, it is just about possible to calibrate a cohort survival model on "snapshot" data, but to do so ignores many of the most important questions such as future birth and death rates. The same kind of criticism applies to chapter 11.

Chapter 12: I am not sure it is correct to say that "The workshop endorsed all of these methodologies" – and if "The workshop suggested a complete top-down rethink of the appraisal objectives", it is not clear that endorsement of including VAWT and VAAD within existing TEE is relevant.

Stochasticity

The various references to the stochasticity of AABMs (which are generally Monte Carlo microsimulation models – and inevitably so if simulating random utility choice functions) recognize the problem but do not fully address it. Again, the issues have been considered in work done for the Department some years (or decades) ago. One suggestion – which was originally put forward in relation to microsimulation LUTI modelling but is equally applicable to AABMs - was to use multiple runs of stochastic models to generate synthetic data on which to calibrate deterministic models for use in the later stages of policy analysis and appraisal. (This suggestion was developed in the SimDELTA project carried out for DfT circa 2005-7 and summarised in Feldman et al (2010): A microsimulation model of household location, in Pagliara, Preston and Simmonds (eds): Residential Location Choice. Springer, Berlin.)

Conclusion

It is understandable that this think-piece is positive about AABMs, but its excessive claims for their advantages and its superficial treatment both of potential problems in AABMs themselves and of the appraisal issues makes it unconvincing. I am sure

AABMs have something to contribute to analysis and appraisal, but the way forward needs to be plotted more cautiously, considering how best to bring together the different strengths of conventional transport models, AABMs, LUTI and SCGE models, and others.

B.12 Aruna Sivakumar

24 July 2025

Just to briefly state my view, which I believe is well represented by others:

1. I don't believe that aggregating consumer surplus calculations from each model and agent in the ABM model system is the correct way to be doing this. If you want to use the rule of a half for consumer surplus calculations then either (a) you will need to build an aggregate model on top of the ABM, or (b) you will need to explore the use of logsums for calculating consumer surplus and investigate whether the entire model system can be represented with a logsum
2. I don't see a technically elegant way of forcing the ABM model system to work with TUBA, other than the above options
3. Instead, I think the ABM model system opens the possibility of using other forms of 'impact analysis' along several dimensions, which needs to be developed into a rigorous framework (the New York MTC model may be a good example here)
4. As with any travel demand model, the results of the ABM are more reliable as a 'change'/delta rather than as absolute forecasts

B.13 Iven Stead

1 June 2026

Just catching up and adding some points - report looks good.

1. The RoH does not hold at the individual level - it is only for aggregates, and it only applies where choice is not deterministic i.e. is stochastic. Bates 2004 attached has a good explainer of this.
2. I agree with valuing activity benefits directly, and for me this is the crux of what makes ABM appraisal methods interesting. For example my initial thought going into this was that we could simply base appraisal on the activity utilities which inform the ABM's assignment to activities throughout the day. We would need to think about how to represent constraints correctly - as these should have an economic interpretation I think. It may be helpful to go back to the original time allocation theories of the 1960s-70s here to inform the conceptual basis (see first 2 attachments).
 - a. My feeling is that when the value of activities on offer does not change between the DM and DS then the usual value of time approach is valid, without any explicit consideration of the utility value of different activities; but that ABM offers scope for a more refined approach. For example, we could more explicitly represent the scheduling constraints people face, rather than having a simple segmentation of VTTS by purpose; and define an underlying VTTS as a function of the person's characteristics and those constraints. Happy to discuss.
 - b. When the value of activities increases in the DS, then ABM appraisal would allow us to directly value this – and this would be in the vein of what your write up gets at [@Peter Davidson](#).

- c. There is also an interesting possibility to use some evidence on wellbeing for different activities, as an alternative normative basis for appraisal – see this research for example.
 - d. Just for info, we prepared the attached PhD proposal with Aruna Sivakumar that touches some of these questions around time use (3rd attachment has some initial thinking on that, and 4th attached has a paper relating to it from Imperial).
3. I think the Daly logsum paper may be the attached (5th attached). Interested to know which paper if it's not.

One thing I forgot to mention in relation to mixed logit that may be relevant when simulating for ABMs is: what *is* the error distribution we are drawing from:

- Usual logit models assume unobserved variation in inherent utility per choice (mode, destination etc) – so assuming the variation is in ASCs.
- Or we characterise as per mixed logit and taste variation for the identified characteristics in the model (e.g time and cost utilities, and thereby VOTs).

I think both have appraisal implications. The regular logsum handles the first case. A quick read around suggest there have been attempts to develop logsums for mixed logit:

https://eprints.whiterose.ac.uk/id/eprint/2017/2/ITS28_The_logsum_as_an_evaluation_measure_UPLOADABLE.pdf, page 16.

References as follows:

- 1) Bates (1987) Measuring Travel Time Values with a Discrete Choice Model, The Economic Journal Vol 97 NO 386 June 1987 pp 493-498
- 2) A Theory of the Economics of Time, A. C. DeSerpa, The Economic Journal, Vol. 81, No. 324 (Dec., 1971), pp. 828-846, Oxford University Press on behalf of the Royal Economic Society.
- 3) Productive use of travel time – initial thoughts on future direction, June 2024
- 4) A framework for joint modelling of activity choice, duration, and productivity while travelling, Jacek Pawlak, John W. Polak, Aruna Sivakumar, Transportation Research Part B 106 (2017) pp153-172
- 5) The use of logsums in welfare estimation: application in PRISM, Serbjeet Kohli, Andrew Daly (2006)

B.14 Collins Teye

18 February 2026

This report is rich with innovative ideas and provides thorough coverage of both current practice and the future direction of ABM development and application. I am particularly impressed with Section 4 and Figure 2, which clearly articulate the value of ABMs over traditional four-step models and present a well-structured, standardised framework for ABM architecture. This framework is especially valuable because it offers a coherent way to organise the many modelling choices available at each level of an ABM, while still allowing flexibility for methodological advances.

Figure 2.1. Activity- and agent-based model architecture compared to the standard model. This figure follows the same conceptual framework as AB-MoTiON and can be

considered as a standard ABM framework. Similar to the traditional four-step structure, multiple modelling approaches can be applied at each level of the hierarchy. For example, in the four-step model, trip generation can be implemented using categorical analysis, regression models, or trip/tour frequency models based on logit formulations. Establishing this type of framework is an important step toward standardising how ABMs are developed. It provides a consistent structure within which different modelling methods can be selected, compared, and refined, while still allowing the flexibility needed to incorporate behavioural detail and methodological advances.

The report also offers insightful guidance on how ABMs can be used in appraisal contexts, highlighting their ability to capture behavioural responses, distributional effects, and complex system interactions that conventional models struggle to represent. In addition, it introduces forward-looking ideas on extending ABMs to incorporate broader dimensions of human behaviour and wellbeing, including the valuation of activities, lifestyle choices, and major life events. These concepts push the boundaries of what transport models can represent and open the door to more holistic, person-centred approaches to policy analysis.

Overall, the report not only consolidates the state of the art but also sets out a compelling vision for the next generation of ABMs.

Specific comments on logsums:

The report states: *“Nesting the various choice models in a hierarchy connected by their logsums is the generally accepted only way to configure these decision dependencies”*.

My response:

1. The logsum approach works reasonably well when the hierarchy is shallow—typically mode and destination choice—because the structure is stable, the number of alternatives is limited, and the behavioural assumptions are relatively clean.
2. However, this framework does **not** translate neatly to disaggregate models such as Activity-Based Models (ABMs). In practice, very few operational ABMs implement a strict, fully nested structure with logsum linkages across all sub-models. When we attempt to estimate such models, the logsum coefficients at higher levels often become statistically insignificant, have the wrong sign, or take on implausible magnitudes. This is a strong signal that the theoretical nesting structure does not align well with the behavioural richness and heterogeneity captured in ABMs.
3. The logsum is only one way of representing the expected utility (or expected cost) of a lower-level choice set. While it has a solid theoretical foundation in random utility maximisation, it is not always the most practical or interpretable measure in an ABM context. Alternative formulations—such as the **probability-weighted sum of costs across alternatives**—often perform better empirically and are easier to interpret. In ABMs, where transparency and behavioural plausibility are essential, using expected cost rather than expected utility can make the model more intuitive and easier to validate at each level of the decision process. It is also intuitive as it produces a cost measure in real units (minutes or £), less sensitive to scale issues like the logsums and easier to **sense-check** and validate with stakeholders.
4. Overall, while nested logit structures remain conceptually appealing, their practical usefulness diminishes as models become more disaggregate, more behavioural,

and more complex. ABMs typically require more flexible, empirically stable ways of linking sub-models than strict logsum-based nesting.

$$\tilde{c} = \sum_{k=0}^n P_j c_j$$

5. A much simpler alternative to above expected cost is to make use of the fact that decisions are made at each level so the ‘cost’ of the chosen alternative becomes the expected cost. $\tilde{c} = c^*$ Cost associated with the chosen alternative.

This approach though simple and intuitive can create problems such as discontinuities when the “best” alternative changes as it ignores the probability distributions

Specific comments on stochasticity:

The report states: ***“One of the disadvantages of AABMs flows from their stochastic nature. These choice probabilities could be used in appraisal instead of the decisions which would avoid this stochasticity problem “***

My response:

The stochastic nature of Activity-Based Models is, in my view, one of the most valuable features of practical ABM systems. Unlike traditional aggregate models, which produce a single deterministic outcome for each zone or segment, ABMs embrace randomness as an essential representation of real human behaviour. The use of random number seed means that results can always be reproduced. Fixing the random number, number seed is similar to fixing and using the estimated model parameters in all forecast years. The random numbers must be generated in a way that ensures the share of each alternative—whether calculated by summing the predicted probabilities or by summing the simulated choices—remains approximately equal. In other words, the stochastic process should reproduce the intended choice proportions without introducing systematic bias. People do not make identical choices when placed in identical circumstances, and ABMs reflect this by allowing variability in decisions such as activity participation, timing, mode, and destination.

This stochasticity delivers several other important benefits:

- Behavioural realism Randomness captures the inherent unpredictability of human decision-making. Even with the same socio-economic characteristics and accessibility conditions, individuals may choose differently. ABMs reproduce this natural variation rather than forcing artificial uniformity.
- Richness of emergent patterns Stochastic interactions between individuals, households, and the transport system can produce emergent behaviours that deterministic models simply cannot replicate. These emergent patterns often align more closely with observed travel behaviour.
- Improved calibration and validation. The ability to run multiple Monte Carlo iterations helps identify whether the model is structurally sound or overly sensitive to specific assumptions. If results are stable across runs, confidence in the model increases.
- Flexibility for future extensions Stochastic frameworks make it easier to incorporate new behavioural processes, such as learning, adaptation, or day-to-day variability, without breaking the model structure.

In short, stochasticity is not a nuisance or a modelling artefact—it is a core strength of ABMs. It allows them to represent the diversity, unpredictability, and complexity of real travel behaviour in a way that deterministic frameworks cannot match.

B.15 Peter Vovsha

22 May 2025

Regarding economic appraisal, it is not emphasized in the US compared to the UK. I'm sending you several publications/presentations of mine and others. The one that was presented at the Modelling World (1) conference is the most recent and relevant.

- 1) Reconciling behavioural richness of Activity-Based models with the rigorous requirements of economic appraisal, P, Vovsha, G Vyas, D Florian Modelling World 2022.
- 2) This technical memorandum summarizes the San Francisco Tour-Based Micro-simulation Model (SFCTA Model), the FTA New Starts User Benefit measure as currently implemented in the SUMMIT software, and the implications for measuring User Benefits in the SFCTA Model. J Freedman 25/06/2003.
- 3) Application of microsimulation model for user benefit evaluation of transit projects, P Vovsha, D Schmitt, Transport Research Board Conference January 2007
- 4) Application of the MORPC micro-simulation model for the user benefit evaluation for Transit Project. P Vovsha D Schmitt, TRB annual meeting and publication in Transport research record November 2006.

B.16 Tom Van Vuren

5th January 2026

Thanks for sharing this, and the opportunity to respond. There is a lot in here and I admit having not read everything in detail. I have focused on the conclusions and recommendations.

Overall I agree with the direction of the report, but I feel that both the Executive Summary and the Conclusions and Recommendations would benefit from a more structured presentation, focusing on a real plan of action, possibly RAG coded.

From memory, and (I think) aligned with the report, I think this should include:

1. Using ABMs to feed current appraisal structure
2. Developing an agent-based TUBA version using the population synthesizer
 - a. Dealing with convergence issues of a simulation based model
 - b. Model validation standards
 - c. This can all be tested and reported using a number of existing ABMs
3. Expanding appraisal using what ABMs can offer over and above current methods
 - a. Fundamental research on what to include, methods and suitable values from surveys or international literature
 - b. Avoiding double-counting

It's all there but at the moment the report says mainly what was discussed rather than what should now be done. If the Executive Summary and Conclusions and Recommendations would have a clear plan, I expect the impact of the report to be greater, and be of more use to TASM in setting the direction of travel.