A layman’s guide

to transport modelling practice in England

by

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Why a layman's guide?

Many infrastructure and policy decisions are supported by transport modelling. Models aim to reflect the responses of the overall transport system and its users to changes in conditions: population growth, increased congestion, parking policy affecting the availability and price of parking, a new road or rail scheme, etc. All local authorities, National Highways, the Department for Transport, HS2 use models – both to access funding but also to meet statutory requirements.

Transport modelling is complex. Models take years to build, weeks or sometimes months to operate, and generally rely on commercial and expensive software packages. Transport modellers are highly trained experts in their field. It is not easy for a layman to access the concepts, to understand the jargon, let alone access the actual tools that are used. Even open access transport models, which are developed more and more but are less used in practice (yet), require expertise in both the principles that underpin the models, and the way in which these are coded.

This layman's guide may help remove some of the obstacles for non-experts to take part in the democratic processes around such transport decision making, and put them on a more equal footing with experts. It is a living document, which can adapt to requests from users for information on evolving topics, refer to new processes and documents, provide examples if helpful.

What is (Web)TAG?

Many questions from experts and non-experts are directed at TAG (which used to be called WebTAG) – the DfT's Transport Analysis Guidance. It is what it says on the tin: good practice guidance on how to carry out the analysis of transport projects and policies that require approval or funding.

The guidance has been developed over many years, and keeps evolving. For example, recently a new set of guidelines was produced on how to handle future uncertainty, through the use of scenarios. Inevitably, all new guidance adds to TAG's volume, and the overall documentation now stands at more than 1,000 pages. TAG is also very technical, which does not help accessibility for those that are not working in the field. Internationally, many countries have adopted guidance similar to TAG, and in my view, the modelling of transport projects and plans is better off with the guidance, than without.

But you don't have to read all of it and understand it in detail. There are three levels of guidance:

- For the senior responsible officer (SRO)
- For the technical project manager (TPM)

- For the appraisal, modelling, and evaluation practitioners

You should begin by reading the guidance for the SRO and TPM. This sets the scene for the reason behind TAG, and how it is to be used in the development, modelling, appraisal and evaluation of transport policies and projects. Reading the guidance for practitioners will generally only be useful when diving deeper into the model that is used, and wanting to understand why it produces the results it does, and possibly challenging its fitness for purpose.

This layman's guide only deals with the modelling aspect. There is also a TAG databook, containing many of the government's assumptions on how travellers perceive different transport options, the anticipated future development of the country such as the economy or car ownership, but mainly related to the valuation of the impacts of projects and policies in appraisal. As I will discuss later, the greatest uncertainty in transport modelling is in the assumptions made about the future, so the TAG databook is an important resource to be aware of and comfortable with.

Does TAG apply everywhere?

TAG originates in the need to model major transport interventions, generally road or major public transport projects. TAG is guidance, and if used well, stimulates a way of thinking about how to approach the analysis of transport plans, projects and programmes. It sets a minimum standard for what is considered good practice in transport modelling that requires government funding and approval:

- In terms of methodology
- In terms of assumptions used about current and future influences on the transport system
- In terms of proving that the model reflects reality well

This mean that TAG does not need to apply in every model application, or that alternative methods or assumptions are not allowed. In reality, practitioners will use TAG as their handbook, as it is easier to defend a method or assumption that adheres to TAG. And many (peer) reviewers of any model application tend to use 'TAG compliance' as their test.

However, there are good reasons to diverge from pure TAG adherence: a project or policy may not be well reflected by the kinds of model that result from following TAG to the letter. Examples are projects that focus on active travel or behaviour change. The TAG principles of good practice still apply – in the trade we talk about models that follow the spirit of TAG:

- Founded on published theory
- Using solid data
- Showing a minimum fit to observations in the here and now

- With defensible assumptions about the future
- And sensitivity tested to changes in these assumptions

The key point is that, just because a model has followed TAG guidance to the letter, it does not imply that this is the only, or the best way of modelling its impacts. But a challenge should focus on the reasons why a departure from the standard methods and assumptions in the guidance, is in this case appropriate.

And in Wales and Scotland, separate guidance has been developed in ScotTAG and WelTAG. Both tend to be less prescriptive, and at first sight leave more space for alternative analytical approaches. Having said that, because they lack detailed modelling guidance, in application many practitioners tend to revert to TAG for this.

What is a transport model?

So what is a transport model? In its simplest form, a transport model is a mathematical representation of the complex reality that is the transport system, and the people who use it. Like almost all models, they are created to improve understanding, and not to complicate or conceal.

The field of transport modelling is around 60 years old, and originated in the United States, mainly to plan their long-distance road network. As a result, there is a bias in transport modelling towards techniques that are better at reflecting longer distance movements and those made by road. But improvements have been made in our understanding and representation of travel by other modes, and a good model for projects that affect (or are affected by) public transport or active mode alternatives, will reflect this.

The model consists of mathematical relationships between those things that affect the need for travel, how people (and goods) choose to travel, and the characteristics of the transport system and particularly the attractiveness of available alternatives. For example:

1. The amount of travel generated is a function of the population, their age and employment status, their car ownership levels, as observed in travel surveys
2. The modes that people use are modelled as a function of what we call generalised costs: the fares on public transport, the congestion on the roads, how easy it is to cycle
3. Where people travel to is a function of the attractiveness of going there, for example the number of jobs, square metres of shopping space, the existence of a school, but also affected by how difficult it is to get to this location. Newton's gravity model is a useful analogy: the attraction between two objects is a function of their size and distance.

4. The route that people take through a network is affected by how long a route is, how much time it takes and how much it costs. This is easily pictured for a road trip, but also applies to routes that public transport or active travellers choose.

The form of these relationships, and their parameters, were usually estimated by surveying people, by asking them directly or observing the choices they make in different circumstances. These days many studies use values that have been derived from national sources, from previous studies, or by using data from the TAG databook. As a result, they may not reflect local preferences very well, although there is little evidence that these are very different between locations in the UK. In any case, all models need to show that they validate well, that they reflect observed demand, traffic flows, delay times etc.

The difference between transport and traffic models

It may sound pedantic, but it is important to make a difference between transport and traffic models. Whereas traffic models try to reflect what happens on the roads, and therefore mainly reflect vehicles, transport models focus on what people do. In terms of the four stages above, traffic models only deal with the fourth, assignment stage. That means that often the impacts of a policy or plan on modes other than by road are ignored, or calculated in a simple manner.

Most of the UK is covered by a transport model of one form or another, often called a strategic transport model. Examples are PRISM in the West Midlands, MOTION in London and SHRTM in Hampshire – but also SEWTM covering South East Wales or Transport Scotland's LATIS models. They tend to be owned by a public sector body, operated by consultants, cover large areas at differing level of detail, but in principle cover all transport choices available to people – generally the four-stages above. In some cases, these may be extended to include location choice, departure time choice, or even whether to travel or not. Strategic transport models are better suited at looking at non-car-based alternatives and increasingly, local authorities develop their own strategic transport models, to support decision-making around decarbonisation, public transport investment, or cycling policy.

Traffic models on the other hand tend to focus on modelling what happens on the roads in greater detail. They still need to estimate how much traffic is expected to exist in future. Sometimes this is done by using a strategic transport model as described above, and sometimes by using national predictions of car demand growth, for example those in TEMPro, the DfT's trip end model presentation program, which have been calculated in the Department's National Trip End Model (NTEM). In both cases, the impacts of detailed local alternatives to a road scheme tend to be modelled quite coarsely – data is less abundant and the geographic scope of both NTEM and strategic models tends to be insufficient to reflect short distance trips well (for which walking and cycling are reasonable alternatives).

TAG provides advice on when to use more complex and more expensive (data, time, costs) strategic models, rather than just TEMPro.

National Highways has developed and uses for most of its road schemes their Regional Traffic Models or RTMs. These are a bit more sophisticated than pure traffic models, as they allow for a change in the choice of destination as a result of the road scheme, and in the choice of mode between road and public transport, by using a model called DIADEM. DIADEM was developed by DfT specifically for a more comprehensive assessment of road projects. It uses TEMPro to estimate traffic growth, and (certainly in the case of the Regional Traffic Models) tends to be applied to a quite coarse spatial definition.

What is a good transport model?

Defining whether a transport model is good or bad is inevitably subjective. And that should not be determined by whether a promotor or an objector disagrees with the results! Modellers tend to go through a quite meticulous process, almost scientific, to prove that the model is suitable for its purposes. This is an important point: a model can be good or bad; but even a good model can be bad if used in the wrong way.

TAG was developed to avoid bad models being developed and good models being used poorly. There are a number of distinct steps to doing so:

- Establish the purpose of the model
- Collect the right data
- Estimate and calibrate the model to observed conditions
- Validate the model to independent data, including its ability to forecast
- Obtain and agree forecasts of future changes

In principle, every transport project or policy could require its own specific model, in terms of the model's functionality (for example, can mode choice be ignored?), spatial detail (for example, can all trips be adequately reflected, or just short trips, or mainly medium to long trips) and segmentation of the population (for example differentiating by age or income). For cost and time reasons, this is often not done, and an existing model is used – directly or locally refined.

Irrespective of a new model being used, or an existing model being applied, the modeller needs to show that their tool is appropriate for the scheme that is assessed. TAG recommends that an Appraisal Specification Report is produced, which contains the arguments why the model used is fit for purpose.

An important step in proving that the tool is defensible and robust is by building a representation of today's transport patterns. To do so, base year data needs to be collected, for two reasons:

- To be able to estimate the current demand for travel from which to forecast into the future
- To test if the model in application can reflect today's traffic conditions, to validate the tool for use

Traditionally, current travel patterns were derived by interviewing people in their homes, at bus stops and rail stations, or en-route at the roadside. These surveys were expensive and disruptive, and only captured a small portion of the population. Increasingly, current demand for travel is now estimated from mobile phone derived data, and TAG provides guidance on how to do that well.

To test if a model reflects today's transport patterns and traffic conditions well, the models are applied in the base year (which can be now or a few years back, but generally less than 5-6 years and post-COVID) and checked against more easily observable things such as flows on roads, queue lengths, boardings and alightings at bus stops or rail stations, or mode shares against observations in the National Travel Survey (NTS).

The base year model rarely first observations well at the first attempt, and an amount of estimation or calibration is required. This may involve refinement of the representation of network characteristics, for example road junction details or bus routes, frequencies and fares, adjustments to the parameters that govern choices such as the relative importance of travel distance vs travel time, or changes to the estimated travel demands that were derived from surveys. The latter is often done through matrix estimations from counts, and is governed by TAG expectations on how much so-called origin-destination or trip matrices are allowed to change as a result.

Calibration relies on comparing the modelled results against observations; generally a second step, validation, takes place to provide insights into whether the calibrated model also compares well against observations that were not used in the calibration step. In practice, these two steps are not always rigorously separated: for example, parameters of a well-calibrated model that does not fit the validation statistics well, will be adjusted with the aim of improving validation.

But of course a transport model is not built to create a copy of today – its main purpose is to forecast how the transport system might change in the future, and how travellers respond to those changes. Validation of a model's forecasting performance is also governed by TAG, which prescribes a number of tests to show that the model responsiveness to drivers such as fuel cost changes or public transport fare changes are reasonable. These so-called elasticities are expected to fall within a certain range. There are three problems with these tests:

- The observations that underpin these expectations are quite old, and were limited to a few studies only

- The acceptable range is quite wide, and the tests are not very taxing; most models easily meet these criteria
- The elasticities relate to model (cost) components that are easy to measure (such as fuel costs), but have only an indirect effect on the choices that travellers make. There are no TAG realism tests linked to, for example, road user charges or parking charges – these must be derived from fuel cost elasticities, with further assumptions made.

Transport modelling software

Given its complexity, and therefore danger of errors in calculations, almost all transport modelling is done using off-the-shelf software, rather than being coded from scratch. Up till now, most of these software packages have been commercially developed, but increasingly open source software is used (although mainly in the support of interventions less well covered by commercial packages, such as active travel policies and interventions, and much less so for larger road and rail schemes).

It is impossible to list all software products used in practice, and this list will be extended over time. I give only limited detail for each of these – my main aim is to present the main tools you might come across, and help you understand these are software products to build models, not models themselves. The hyperlinks may help you find further information. I also avoid making any judgments about their relative strengths and weaknesses – these products are developed further all the time, and it's not the software that's used that determines a model's fitness for purpose, but the assumptions made in its estimation, implementation and application. Where possible, links to webpages are provided, although

a) understanding these may require substantial technical knowledge, and

b) the hyperlinks to commercial packages will be generally aimed at sales rather than providing technical details

An important note: just because a model has been developed using off-the-shelf software, that doesn't automatically mean that it is a good model; nor that a simpler calculation using Excel or even a hand-held calculator is a bad model. In all cases its fitness for purpose needs to be proven.

AimSun – originally developed as a microsimulation model of road traffic, AIMSUN has been extended to also cover highway and public transport assignment, plus relatively simple four-stage variable demand modelling (https://www.aimsun.com/aimsun-next/)

CUBE – a set of software tools that is generally used to operate multimodal and demand responsive strategic transport models (https://virtuosity.bentley.com/product/cube/). CUBE

has a number of sibling software components such as CUBE Land (land use modelling) and COBE Cargo (for modelling freight)

DIADEM – DfT developed variable demand modelling software, used by National Highways in their Regional Traffic Models, and regularly found s a minimum viable product in other strategic transport models as well (https://tagsoftware.co.uk/DIADEM)

EMME – a set of software tools that is generally used to operate multimodal and demand responsive strategic transport models (https://www.bentley.com/software/emme/). EMME has a number of sibling software components such as EMME Agent (activity-based modelling) and DYNAMEQ (dynamic route choice and assignment modelling)

LEGION – a pedestrian simulation tool, also referred to as a people movement simulator.

National Transport Model (NTM) – the multimodal and demand responsive transport model used by the DfT for its national forecasts. Not software but an application of the four-stage principles in software similar to CUBE, VISUM or EMME (I think it's developed in MEPLAN, but that's not really relevant). A thorough description is here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/946061/DfT-National-Transport-Model-Analytical-Review-accessible.pdf

SATURN – probably the most widely used traffic model in the UK, underpinning the NH Regional Traffic Models or the so-called HAM models (Highway Assignment Models) at TfL (https://saturnsoftware2.co.uk/)

TEMPro – DfT's Trip End Model Presentation tool, is used to interrogate the National Trip End Model's results, for example by year or geographical area (https://www.gov.uk/government/publications/tempro-downloads)

TRANSYT – a traffic simulation and signal optimization model, used for individual junctions or small networks (https://trlsoftware.com/products/junction-signal-design/transyt/)

TUBA - The TUBA (Transport User Benefit Appraisal) software is used to carry out the economic appraisal of transport schemes in accordance with the Department for Transport's TAG guidance. Not modelling in the strict sense of the word, and not discussed in detail here (https://tagsoftware.co.uk/TUBA)

TRICS – an abbreviation for Trip Rate Information Computer System, this is used to calculate trip rates for new developments, based on surveys of similar developments elsewhere. Its website states that the software can be used to validate and challenge; and there is a risk in using this kind of information that the numbers can be gamed. The website includes a useful good practice guide (https://www.trics.org/Default.aspx)

VISSIM – a microsimulation tool for road traffic, closely associated to VISUM (its strategic modelling sibling).

VISUM – a set of software tools that is generally used to operate multimodal and demand responsive strategic transport models. The VISUM software has a number of sibling components such as **VISTRO** (signal optimisation and traffic impact analysis) and, **OPTIMA** (traffic management), **VISSIM** (microsimulation and **VISWALK** (pedestrian simulation). This is a good starting point: (https://www.ptvgroup.com/en/products/ptv-visum)

WITA - This software calculates what we call the wider impacts of transport appraisal. Whereas TUBA focuses on what are sometimes considered the first order effects of a scheme of policy (impacts on travel times, safety, emissions, health) WITA tries to capture employment, investment and productivity effects of such schemes that are not already included in the TUBA calculations. Where economic regeneration is an implicit aim of the intervention, these benefits can be substantial, but the uncertainty around their quantification is much greater than for, say, travel time or accident impacts (https://tagsoftware.co.uk/WITA)

Further reading

Yaron Hollander (2016): Transport modelling for a complete beginner, CtThink! (2016)

Tom van Vuren: "Transport Modelling - Mad Eye Moody or Severus Snape?", Branchout, No 186 (Spring 2022), pp 17-18,) https://www.rtpi.org.uk/media/11034/branchout-spring-2022.pdf

Jaspers (2014): The use of transport models in Transport Planning and Project Appraisal https://jaspers.eib.org/LibraryNP/JASPERS%20Working%20Papers/The%20Use%20of%20Transport%20Models%20in%20Transport%20Planning%20and%20Project%20Appraisal.pdf

Note on the author

Tom van Vuren is a Chartered Transport Planning Professional with almost 40 years of experience in transport modelling, both as an academic and as a consultant. He has built and used transport models around the world. He is a Board Member of the Transport Planning Society and a Visiting Professor at the University of Leeds.