Introduction to Modelling

TAG Unit 3.1.1

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Department for Transport

Transport Analysis Guidance (TAG)

This Unit is part of a family which can be accessed at www.webtag.org.uk

Contents

1 Modelling

1.1 Introduction

1.1.1 *Summary Advice on Modelling* (TAG Unit 2.4) should be read before reading this TAG Unit. It includes a discussion of the general principles of transport modelling, the general principles of land-use modelling, and the choice of modelling approach.

1.1.2 This TAG Unit and related TAG Units provide more detailed advice on these topics and is structured as follows:

in Section 1.2, the **principles** of model selection are discussed at somewhat greater length; and

in Section 1.3

- references are given to selected **source documents**, where further details of different modelling approaches can be found,
- some information is given on the **datasets** available from the Department for model development,
- attention is drawn to the Department's **national models** which should be used in the creation of models for the studies, and
- lastly, brief note is made of **software availability** and the need for **specialist modelling knowledge** in the development of suitable models for the studies.

1.1.3 In addition, there are TAG Units which relate to this TAG Unit, as follows:

Transport Models (TAG Unit 3.1.2) outlines (a) the general principles of **transport** modelling, (b) spatially detailed transport models, and (c) spatially aggregate transport models. Outline advice on forecasting is also provided;

Land-Use/Transport Interaction Models (TAG Unit 3.1.3) outlines (a) the general principles of **land-use** modelling, and (b) the different forms of land-use/transport interaction models;

Freight Modelling (TAG Unit 3.1.4) provides some notes on freight modelling; and

Data Sources (TAG Unit 3.1.5) provides some notes on sources of travel demand and transport supply data suitable for model building.

1.2 Principles of Model Selection

General Principles

1.2.1 To recap, the choice of modelling approach will depend on a number of potentially conflicting factors:

the nature of identified problems and their likely solutions;
the definition and size of the study area;
the likely number of options to be tested;
the availability of data and existing models;
the need to update and (re)calibrate models
the need to conduct new surveys
the timescale for model development; and

the required accuracy and robustness of results/recommendations.

1.2.2 Whether an over-arching ‘strategy’ needs to be developed before the ‘plan’ is devised may also influence the form of the models adopted.

1.2.3 For obvious reasons, the tighter the timescale and the resources, the more the availability of existing data and models will be critical in selecting a model. Even if extensive resources are available, limitations on timescale mean that the scope for new data collection will be very limited, while developing a completely new model will mean that much detail will have to be sacrificed.

1.2.4 Aside from these resource issues, the main impact of the modelling approach taken is on computation. Assuming reasonably generous resources for modelling, the more options that need to be tested, the more the model turnround time will be an issue. Ultimately, this is a relative matter: the increase in computing power and falling hardware costs means that it may be feasible to ‘buy one’s way out’ by running the model on more than one machine at once. Nonetheless, this may cause severe logistic difficulties.

1.2.5 As well as the turnround time *per se*, there are also issues of computer memory. Though once again it is possible to buy additional hardware in the form of memory, this is in principle a more severe constraint. Given that iterative procedures are involved, the performance in terms of computing effort will depend critically on whether the relevant data can be held in memory or whether extensive use needs to be made of input-output procedures.

1.2.6 The two main areas where a decision is required at an early stage are the level of spatial detail and the representation of purpose/person-type variations (segmentations) in the demand functions. A secondary decision relates to the number of modes and time periods. Unfortunately all these dimensions are **cumulative** (at least, multiplicative) in their impact, so that a high degree of resolution in any one dimension may result in unacceptably slow computation speeds, even when the others are substantially aggregated.

1.2.7 In assessing some of the more radical transport policies, it is likely to be necessary to model responses in rather more detail. The possible need to segment the travelling population means that, with today's computers, spatial detail may have to be foregone if unacceptably long model running times are to be avoided. In general, transport **strategies** may be developed using models with relatively few numbers of zones and simplified representations of transport networks, although as computers improve so modelling at greater spatial detail will be possible.

1.2.8 On the other hand, modelling transport networks for the appraisal of transport **plans** requires considerable spatial detail. Zone sizes need to be small, which implies large numbers of zones. Road networks need to contain all the main traffic-carrying roads, and public transport networks need to include all rail, underground, and bus services. For manageable run times to result with models of this degree of spatial complexity, with the computers currently available, some simplification of the demand modelling is unavoidable. Thus, rather than representing the different types of traveller in a disaggregated way, only a few trip purposes, broken down by car availability, are distinguished. Again, as computers improve, so it will become possible to treat more types of traveller separately.

1.2.9 The trade-off between the level of detail of the supply modelling against the level of detail of the demand modelling is shown diagrammatically in Figure 1. In a nutshell, given a large study area and today's computers, one can have **either** detailed demand modelling **or** detailed network modelling, but not both, if acceptable model run times and computing costs are to be achieved. For smaller study areas, the need to compromise will be reduced.

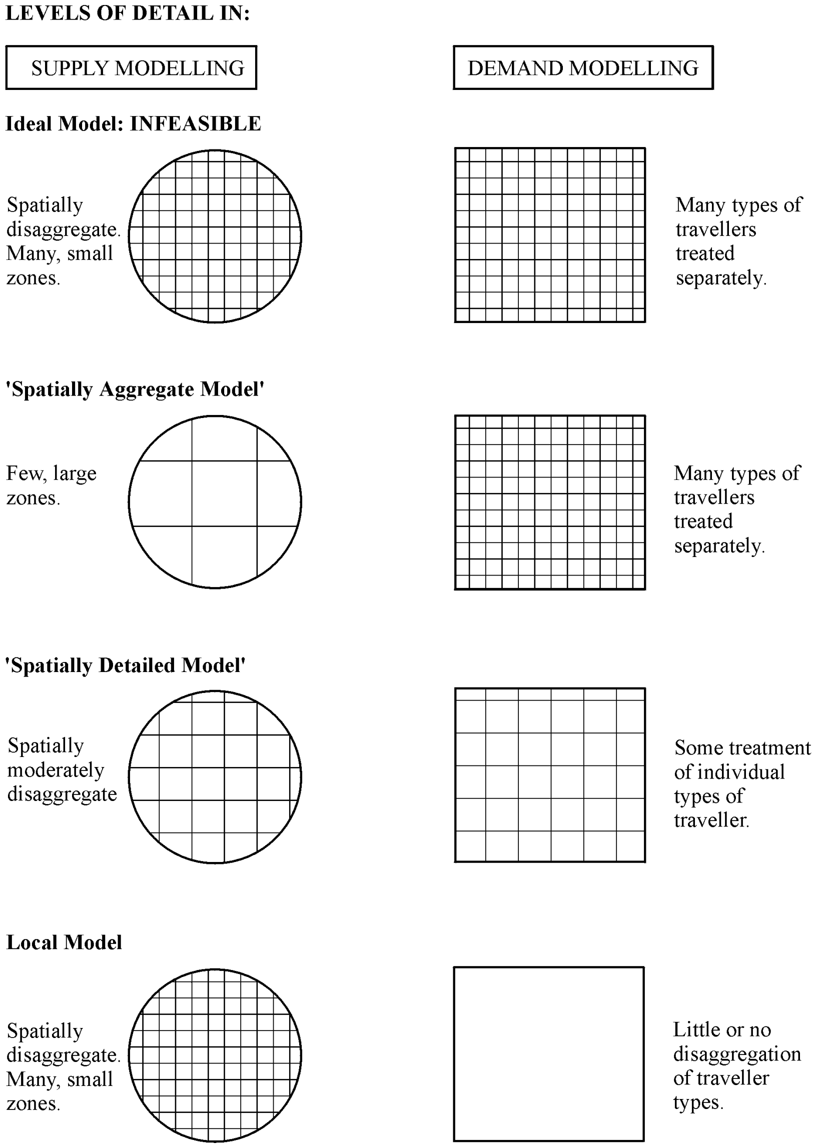

Figure 1 **The Trade-off Between the Detail of the Supply Modelling and the Detail of the Demand Modelling**

1.2.10 These two aspects are now discussed in more detail.

Spatial Representation

1.2.11 In general, the study areas listed in *Multi-Modal Studies: Introduction to GOMMMS* (TAG Unit 1.2) fall into two rather different categories: some of them are of a ‘regional’ character, in that they represent relatively self-contained areas with problems that could be addressed by a variety of wide-scale solutions, while others are more a ‘collection’ of typical highway schemes that are being grouped because of their contiguity, and hence interdependence, rather than because they have particular coherence *per se*. The modelling approaches to these two categories are likely to be inherently different.

1.2.12 In any case, an important principle to establish at the outset is that the definition of a study area does not, in itself, define the area which should be **modelled**.

The modelled area must be selected in the light of the problems to be addressed, and the impact of likely solutions.

1.2.13 A simple example should suffice. Suppose that the interest is in a particular urban area, and that the identified problem is the severe off-peak congestion in the city centre. A solution might be to remove short-term parking in the centre. If the main effect was to divert travellers (e.g. shoppers) to other competing urban centres, then it would be reasonable to include such centres within the modelled area, even though there is, perhaps, no interest in the transport impact on these centres.

1.2.14 The demand and supply processes explained in *Summary Advice on Modelling* (TAG Unit 2.4) and *Transport Models* (TAG Unit 3.1.2) need to be set in a geographical context. In general terms, the demand process relates to a system of **zones** and the movements between them, while the supply process consists typically of **links** in a network. The interaction of demand and supply also requires an interface, whereby movements between zones are assigned to paths through the network.

1.2.15 The supply process needs to 'collect' the different elements of demand which make use of particular links. Hence the network must be, in some way, connected to the zones, and the scales of representation need to be compatible.

1.2.16 Because zoning is essentially a form of geographical aggregation, it is not possible, except in a very approximate way, to make **geographical** distinctions within the zone. This has the important consequence that, while it is feasible to connect a zone to the network with more than one centroid connector, it is not possible, for example, to introduce a western and an eastern connector with the implication that one will be used by the western parts of the zone and the other by the eastern. The entire zone is considered to be notionally concentrated at the centroid.

1.2.17 For this reason, in particular, it is generally desirable to have both zones and network at as fine a level of detail as possible: in this way, the problem is avoided. There is reasonable guidance available as to the level of network detail required for congested assignment models: for example, the IHT's *Guideline on Developing Urban Transport Strategies* suggests that "*all roads that carry significant volumes of traffic*" should be included, and, more generally that networks "*should be of sufficient extent to include all realistic choices of route available to drivers*". Guidance as to zone size is harder to find, but the integrating characteristic is that noted earlier, that the entire zone is assumed to act as if concentrated at the centroid.

1.2.18 There is, of course, a limit as to how much detail needs to be represented, and in general it is unnecessary to extend this level of detail beyond the 'area of interest', however this may be defined. Hence, standard modelling practice is to define the area of interest, and represent anything outside it at the coarsest acceptable level. Within the modelled area, there will usually be a predisposition to a high level of detail.

1.2.19 The interface between demand and supply can lead to some problems. If the area of interest is well-defined, then it can be expected that the boundary for both systems will coincide: i.e. inside the boundary, both zones and network will be detailed, and outside they will be coarse (though it is feasible that there may be an 'intermediate' region or annulus around the area of interest). However, some other considerations will usually need to be taken into account.

1.2.20 Firstly, movements **between** the internal and external areas need to be represented at some level of detail, for two reasons. Firstly, it is necessary on the demand side for general reasons of consistency. This is essentially related to trip rate stability and destination choice: if only internal movements are defined as trips, then zones near the border will have (apparently) lower levels of trip-making. Further, the ability to model changes affecting destination choice for such zones will be inconsistent depending on whether the changes, related either to travel costs or travel opportunities, occur in relation to internal or external zones.

1.2.21 Secondly, there is an impact on the supply side (network), since clearly internal/external movements (in either direction) impact on the modelled area network. From the network point of view, there is a further complication, relating to ‘through traffic’. In other words, there are some external/external movements which will impact on the modelled area network. There are usually questions of **routeing** which make the definition of the relevant cells something of a problem.

1.2.22 Putting all this together, the matrix cells can be defined which, **at some level of representation**, need to be included in the model, using the letter A to denote internal to internal movements, B for movements between internal and external areas, and C for **relevant** external to external movements. Implicitly, the level of representation, both spatially and ‘behaviourally’, decreases as one moves from A to C.

1.2.23 In the standard situation, the primary emphasis is probably on the **network** and the first choice of internal area will be defined in terms of that. It will then need to be considered whether the implied definition of A-type trips is consistent. Clearly, this will not be the case if the primary attraction for most zones just within the boundary is outside the boundary, or if the zones just within the boundary are the primary attraction for zones outside the boundary. Thus, there are likely to be (outward) adjustments to the first estimate of the boundary: these need to be based not only on the current levels of interaction, but on the **potential** level of interaction in the light of proposed policies.

1.2.24 Having defined the modelled area, and the associated system of external zones and network, the next problem to be confronted is one of **scale**. Hitherto, a high level of detail has been assumed. However, for at least some of the proposed multi-modal studies, the general guidelines given earlier would lead to an ‘excessive’ number of zones and links, where the term ‘excessive’ relates to issues of computer storage and run-time, and to some extent to past experience and convention.

1.2.25 Clearly this needs to be viewed in conjunction with other questions of scale, relating to the number of ‘segments’ or ‘user-classes’. However, while there may be scope for reducing the segments and user-classes, it is assumed that this has been done as far as possible, and that the problem of scale remains. In this case, some form of spatial aggregation will be required.

1.2.26 The nature of the spatial aggregation leads essentially to a choice of model. In TAG Unit 3.1.2, the distinction is made between ‘spatially detailed’ and ‘spatially aggregate’ forms of transport model. This distinction correlates conveniently with existing corpuses of research and experience, although there is, in reality, more or less a continuum between these two categories.

1.2.27 Given the importance of convergence, stressed in TAG Unit 3.1.2, there are considerable advantages in maintaining a model system which is defined on a single level of spatial detail, and the two categories of ‘spatially detailed’ and ‘spatially aggregate’ model systems respect this. It is more difficult to devise an effective strategy for establishing a converged solution when the demand and supply are operating at substantially different spatial levels.

1.2.28 Nonetheless, it may be the case that the practical requirements for aggregation are in conflict with some of the modelling aims. For example, certain kinds of environmental effects are relatively ‘global’ (e.g. CO_2 emissions), and can be adequately modelled at a more aggregate level. Others, such as noise, or particulates, are highly specific to the detailed location in which they occur, and can most sensibly be assessed at a relatively detailed spatial scale. When such conflicts arise and are seen to be important, one option is to define a **hierarchical** spatial system, and apply appropriate interfaces between the different spatial levels.

1.2.29 Such hierarchical systems are, in fact, quite common. For example, the London Transportation Study model has a hierarchical zoning system, with 1603 zones at the most detailed level. Most of the model, however, including the entire demand forecasting system and the highway assignment, operates at a ‘compressed’ zone system (districts) of which there are 529. The most detailed zoning system is only used for public transport assignment, to take account of the detailed location of bus stops and stations: this requires 1272 zones, since external zones are aggregated. The networks are of course compatible with the zoning systems with which they are used.

1.2.30 Such hierarchical zoning systems are part of the nature of the compromise that is required when the ideal scale of the model becomes impractical. As a matter of principle, it is probably the case that the detail is more important at the network level than at the zoning level (in terms of the demand model). Hence, a possible approach is to model demand at a coarser level, but to disaggregate the travel matrices for the supply model. This involves a further interface between demand and supply. A potentially serious problem requiring special attention is ensuring that the coarser level supply model is compatible with the fine level model.

1.2.31 An example of this approach is the work done to investigate parking control strategies in Bristol (Coombe *et al*, 1997). In the model developed for the work called ‘TRAM’ (Bates *et al*, 1997), the zoning system and the networks operated at a coarse level. At this level, TRAM enabled a number of strategies for controlling parking to be appraised. In subsequent work, the demand changes predicted by TRAM were fed down to spatially detailed road traffic and public transport assignment models so that detailed analysis of the effects of the parking strategies could be undertaken. A similar approach was adopted in the appraisal of congestion charging in London (Bates *et al*, 1996).

1.2.32 Note that the zone size will define the category of ‘intrazonal’ trips, and these will generally be treated differently within the modelling process (because they are not assigned to the network, if for no other reason). According to the National Travel Survey (NTS), 58% of all trips are less than 3 miles in length, though a high proportion of these are classified as ‘short walk’ trips. But even if such trips (on the NTS definition) are excluded, the proportion is 45%, and it rises to 81% at 10 miles. To give some idea of scale, if the whole of England were to be divided into equally-sized zones with an effective ‘radius’ of 3 miles, there would be approximately 1800 such zones.

1.2.33 With the exception of the spatially aggregate models in TAG Unit 3.1.2, most transport models have a number of zones in the middle hundreds and rarely, if ever in this country, exceed 1500 zones. On the basis of experience, then, it would be wise to plan for a maximum level of zoning detail compatible with around 500 zones: a clear justification would be needed for exceeding this.

Dimensions of the Demand Model

1.2.34 Mode choice and choice of time of day give rise to two dimensions of the demand model. The remaining dimensions may be termed segmentation: they relate to the modeller's interest in dividing overall travel demand into a number of independent categories, based on journey purpose and person-type.

1.2.35 As far as mode is concerned, given a multi-modal context, it can be expected as a minimum that car, public transport and non-motorised modes will need to be distinguished. Whether further distinctions need to be made will depend on the particular circumstances of the study: for example, if there is interest in cycling, it will certainly be necessary to separate cycle and walk among non-motorised modes. The choice between public transport 'sub-modes', where it exists, may be treated explicitly in the demand model **or** at the assignment level.

1.2.36 In the case of time of day, there are two pertinent questions. Firstly, is there an interest in looking at effects in different time periods (as opposed, say, to working with 24-hour averages)? Secondly, are some of the policies time-specific in their impact, such that they may well induce time-switching? If the answer to either question is "yes", then some recognition of different time periods is required, though only when the second question is answered in the affirmative does it become obligatory to model the **choice** of time of day (in passing, it should be noted that this adds significantly to the overall complexity). The different performance of the morning and evening peaks means that there is usually some interest in distinguishing these two periods: this implies a minimum of three periods, allowing for the interpeak.

1.2.37 Modelling two peak periods and an average interpeak period would be standard practice. However, there are some circumstances where that would not be appropriate. For example, in the case of a very large area to be modelled, and a large number of options to test, a model which treated three periods of the day separately may take much longer to run than the 14-hour period generally available over night. In this sort of case, some compromise is necessary and modelling the day as a whole (that is, the period from the start of the morning peak period to the end of the evening peak period) might be a way forward. Note that this would not mean necessarily that congestion effects could not be represented; they could be crudely modelled by use of averaged speed/flow relationships.

1.2.38 Turning now to segmentation issues, there are strong grounds for distinguishing purpose in the demand model, since the inherent responses are different. A **minimum** of three purposes is required: home-based work, employers' business, and other. A more reasonable breakdown is:

home-based work;
home-based employer's business;
home-based other;
non-home-based employer's business; and
non-home-based other.

1.2.39 The home-based other category is often segmented further into, e.g., shopping and personal business, visiting friends and relations, social and recreational, or a distinction is made between 'essential' and 'discretionary' travel. Also, home-based education is sometimes split out from home-based other. The value of adopting this finer degree of segmentation in the case of a largely interurban study would need to be carefully considered. If a land-use/transport interaction model is to be used, there can sometimes be value in separating travel to work by 'blue collar' and 'white collar' workers. Advice on journey purposes can also be found in the DfT's *Design Manual for Roads and Bridges* (DMRB), Volume 12.2.3.

1.2.40 As far as person-type is concerned, given the multi-modal context, a minimal segmentation is between persons in non-car-owning and car-owning households. Because this is only a crude measure of car availability, car-owning households may be split between those with one car and those with more than one, or, with more effort, introducing a further category based on the number of drivers relative to cars, as typified in the following scheme, used in the Dutch National Model[1] and the LTS91 Model (see Fearon, 1998):

households with no cars;
households with one car and one driver;
households with one car and > 1 driver; and
households with >1 cars.

1.2.41 Any further dimensions, based on the person, will generally be **additional** to the car ownership dimension.

1.2.42 Putting all this together, the total dimension of the demand model may be calculated as

$$Z^2 \times M \times T \times P \times S$$

where Z is the number of zones, M is the number of modes, T is the number of time periods, P is the number of purposes, and S is the number of person-types. Assuming, as more or less a minimum, that $Z = 500$, $M = 3$, $T = 3$, $P = 4$ and $S = 3$, we obtain a total size of 27 million cells. This is before account is taken of network implications.

1.2.43 Although there are some opportunities for saving space, it must also be borne in mind that both demand and cost matrices are required, and that the nature of the convergence process means that some intermediate estimates need to be retained. Hence, the figure given is not the total size of the problem, but merely an indication of the scale.

1.2.44 Since the numbers assumed are in most cases on the low side, it will be clear that, compared with what might be considered the ideal model specification, compromises will often be necessary in at least one dimension.

A Model Typology

1.2.45 There are many ways in which models could be categorised, and what follows is not intended to be in any way exhaustive. In addition, it is deliberately restricted to the types of model which have some ‘track record’ in terms of practical application.

1.2.46 All the models discussed in this TAG Unit and in TAG Units 3.1.2 and 3.1.3 are essentially of the equilibrium type, though in the case of the land-use/transport interaction models described in TAG Unit 3.1.3 the term ‘equilibrium’ needs to be interpreted in a dynamic context. Thus they all distinguish supply and demand, and have a procedure for the interface between them. They all have a structure which can be more or less directly related to the ‘four-stage’ model (trip generation, trip distribution, modal choice and assignment), in some cases with an additional ‘stage’ relating to the choice of time of day.

1.2.47 The land-use/transport interaction models have some distinctive components, and it makes sense to discuss them separately (in TAG Unit 3.1.3). For the purely transport models, as already discussed, a key distinction is made according to the level of spatial aggregation. According to current practice, the spatially aggregate models compensate for the aggregation by including much

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[1] note that the Dutch National Model also allows for whether the individual in the household holds a driving licence

more segmentation detail: conversely, the spatially detailed models keep segmentation to the minimum.

1.2.48 For small study areas, it is possible that (if not now, then in the near future) the 'ideal' level of detail may be feasible. In most cases, however, it will be necessary to decide on whether to sacrifice segmentation or spatial accuracy. While the two groups of models are ultimately not that different (and are beginning to come together), they have tended to be used in rather different ways, and for that reason alone, it is useful to discuss them separately.

1.2.49 The spatially detailed models, which are often loosely referred to as 'four stage' models (though, as noted above, nearly all models in the transport field can be viewed in this way), are briefly described in TAG Unit 3.1.2. The spatially aggregate models, which are often referred to as 'strategic' or 'policy' models, are described in TAG Unit 3.1.2.

1.2.50 Before leaving the topic of model typology, there are two other important distinctions which should be referred to. The first is the distinction between 'aggregate' and 'disaggregate' methods, and the second is the distinction between 'incremental' and 'absolute' models. Like all terminologies, these distinctions tend to carry with them a number of conventions which are more related to their practitioners than to the inherent differences in the model philosophies. Ultimately, these distinctions are less important than the questions of dimension.

1.2.51 The distinction between spatially aggregate and spatially detailed models has been discussed above. The following paragraphs discuss aggregate and disaggregate methods. It is important not to confuse these two concepts. The distinction between 'aggregate' and 'disaggregate' methods is concerned with the way in which models are specified, calibrated, and used. In principle, disaggregate methods attempt to model at the level of the individual, while aggregate methods model groups of individuals. In practice, there are severe limitations to disaggregate methods once the full spatial dimensions are introduced, so that truly disaggregate methods are most effective at the 'trip generation' level. The practical application of disaggregate methods to mode and destination choice is essentially at a zonal (i.e., aggregate) level, even though the models themselves are estimated at the individual level.

1.2.52 The central issues in forming an assessment of the pros and cons of disaggregate methods are as follows:

the criteria which apply to **analysis** (i.e. model estimation) are different from those relevant to building forecasting models (i.e. model application);

disaggregate methods are to be preferred when analysing data with a view to identifying explanatory variables (though if these are limited/pre-specified, a more aggregate analysis will achieve the same result);

in most cases, the specifications of demand models based on aggregate and disaggregate methods can be made very similar; and

disaggregate methods facilitate the retention of segmentation information through the modelling sequence (though this may not necessarily be needed or practical).

1.2.53 Given the diminishing returns in terms of explanatory power from adding further variables to a model once the key factors have been identified, plus the practical difficulties of forecasting a large number of variables, it seems likely that in most cases the preferred level of detail will be well inside the spectrum bounded by 'fully aggregate' and 'fully disaggregate'.

1.2.54 The second distinction, between absolute and incremental models, has a number of ramifications. Key to the discussion is the general inability of purely 'synthetic' models to generate matrices of movements which are sufficiently close to 'observed' patterns. This has led to the use of the demand model to estimate **changes** which can then be applied, in various ways, to an observed matrix. In this way, the direct forecast of demand is not used as such. Such model applications have been described as 'incremental' or 'marginal'.

1.2.55 In some forms, the base observed matrix is directly incorporated within the demand function as a 'pivot': by design, the demand model then generates the base matrix when no cost changes are forecast. However, by the introduction of appropriate 'calibration constants', it is possible to specify a purely 'synthetic' model which will also generate the base matrix: ultimately, this is a question of mathematical convenience.

1.2.56 The more important issue is the relative reliability of the 'observed matrix' and the model estimate. The reality is that it is prohibitively expensive to observe all the cells of the matrix, especially when account is taken of all the additional dimensions (of mode, time of day, on the one hand, and purpose and segments on the other). In addition, there are questions of temporal variability (seasonal, day-to-day, etc.). Thus, except in models that are very aggregate spatially, 'observed' matrices drawn from survey data are likely to contain a very high proportion of empty cells. Most forms of incremental model have the property that such cells will remain empty, in the face of policy changes. While this may be a reasonable assumption when the travel which the cell represents is truly infeasible, it is not reasonable if the cell is empty merely because of sample limitations.

1.2.57 Based on current knowledge, the best approaches seem to be as follows.

Spatially aggregate transport models generally calculate incremental changes in demand **in proportion** to the base demand forecast exogenously. Given the high degree of spatial aggregation at which these models work, this approach is considered satisfactory.

However, a different approach is considered more appropriate in the case of spatially detailed transport models. These will generally produce forecasts of absolute trip levels. To preserve the subtleties of the base year trip matrices, which are likely to have been derived from substantial amounts of observed data, incremental matrices of **differences** between the base year observed and synthesised trip matrices should be calculated and added to the synthesised forecast year trip matrices prior to assignment.

The above descriptions only outline basic approaches and a number of extensions to, and variations of, the resulting methods are used in practice.

1.3 Further Guidance on Modelling

1.3.1 Many details of the model building process have had to be omitted from this Guidance. In this section, a number of sources of further information and data are presented, as follows:

- source documents on models;
- the Department's travel demand and transport supply datasets;
- the Department's national car ownership and trip end models; and
- the availability of software and advice on the need for specialist modelling knowledge.

Source Documents on Models

1.3.2 This section briefly summarises the contents of the following source documents which may be of use to those developing models for the Studies:

- Volume 12 of the Design Manual for Roads and Bridges (DETR, DMRB);
- Guidelines on Developing Urban Transport Strategies (IHT, 1996);
- Strategic Transport Modelling and Strategic Multi-Modal Studies by John Fearon Consultancy for the DfT (Fearon, 1998); and
- Review of Land-Use/Transport Interaction Models by David Simmonds Consultancy and Marcial Echenique and Partners for SACTRA (DSC and MEP, 1999).

1.3.3 **Traffic Appraisal Manual, DMRB Volume 12.1.1.** The *Traffic Appraisal Manual* (TAM), setting out the recommended practice for the traffic modelling of trunk road schemes, was first published in 1981 and last reprinted in August 1991. In recent years, the Department has released new advice on modelling as separate, free standing, parts of the DMRB, withdrawing parts of the TAM as appropriate. Nevertheless, those parts of TAM which have not been withdrawn remain valid and relevant. The TAM relates specifically to trunk roads in England, although in practice the document has been used as a reference source for all forms of traffic modelling work in the UK. It has been designed so that those intending to carry out traffic modelling are provided with a logical progression through its chapters, with important cross-references to other material.

1.3.4 The Traffic Appraisal Manual gives detailed guidance on the following aspects:

- steps in carrying out a traffic study;
- definition of the study area;
- alternative model forms and their applicability;
- survey methodology and analysis;
- production and calibration of a base year trip matrix;
- assignment methods and procedures;
- assessment of errors in the base year model;
- model validation, including a discussion of national model validation and validation of local models;
- local traffic forecasting, consistency with national forecasts, and the treatment of uncertainty;
- operational appraisal of the impacts of a scheme;
- economic appraisal in relation to fixed and variable matrices;
- presentation of the results of a traffic appraisal;
- before and after monitoring of scheme implementation;
- estimating traffic flow where modes other than car are significant;
- techniques for appraisal of trunk road schemes in urban areas (but see also DMRB Volume 12.2.1, discussed below); and
- techniques for appraisal of smaller trunk road schemes.

1.3.5 Appendices to the *Traffic Appraisal Manual* include advice on sampling procedures, definition of statistical terms, modal choice equations, and referencing of DfT computer software.

1.3.6 **Traffic Appraisal in Urban Areas, DMRB Volume 12.2.1.** The purpose of this document is to review the current best practice for urban traffic appraisal techniques in the context of trunk road assessment, and to extend the general guidance set out in the Traffic Appraisal Manual (DMRB, 12.1.1) to the urban setting and the more congested interurban situations which involve complex traffic interactions.

1.3.7 Chapter 2 provides an overview of the main issues regarding the use of urban road traffic appraisal techniques, and guidance in setting the modelling objectives. Chapter 3 reviews the types of data that are usually required for the traffic appraisal of an urban trunk road scheme, and gives guidance on how such data are to be collected and presented. Chapter 4 seeks to examine in detail the methods involved in developing a traffic model for urban trunk road appraisal, and Chapter 5 describes how the base year model can be developed to produce traffic forecasts for various future situations. Chapter 6 reviews the various forms of appraisal that are applicable to urban trunk road assessment, and highlights issues relating to traffic modelling.

1.3.8 A set of appendices are included covering the areas of: reporting on traffic surveys; local model validation reporting; report of forecasting; use of sub-time periods and time slices; speed/flow relationships; techniques for representing peak spreading; traffic growth constraint techniques; and model convergence.

1.3.9 **Guidance on Induced Traffic, DMRB Volume 12.2.2.** This document contains guidance for **highway** appraisal in the context of induced traffic (i.e., accepting the need to reflect variable demand procedures). It is not specific on the sources of induced traffic, though its recommended elasticities take account of the relative effects of mode choice, time of day choice and frequency.

1.3.10 The procedures recommended would be entirely applicable in cases where **no** explicit account of other modes is necessary. The demand models, which are of the ‘simple elasticity’ type, relate to the highway mode only, and are implicitly for all purposes combined. The document outlines more conventional modelling approaches, recommending their use for more complex schemes, but does not discuss these methods in detail.

1.3.11 The recommendations on forecasting are generally in line with the advice given earlier in this chapter, but for the highway mode only. However, relatively little guidance is given on convergence procedures.

1.3.12 **TEMPRO 4.2 Guidance Note.** This document describes the multi-modal National Trip End Model which can provide forecasts of planning data, car-ownership and the resultant growth in trip-making by different modes of transport. These datasets are made available through TEMPRO which is software designed to provide projections of growth over time for use in local and regional transport models. Availability of datasets can be checked on the TEMPRO website at www.tempro.org.uk.

1.3.13 **Institution of Highways and Transportation’s Guidelines for Developing Urban Transport Strategies.** Chapter 6 of this document aims to give a comprehensive review of the models for transport strategy appraisal and development in the urban context. The relevant sections have already been referred to in earlier parts of this chapter. The description of the modelling is of general relevance, but it is, by intention, confined to the urban case. For this reason, it has relatively little to offer on the choice of zoning and network detail that might be required for some studies. On the other hand, it goes into the principles of assignment in some detail.

1.3.14 While it acknowledges the importance of convergence for the supply-demand equilibrium, it is less forthcoming on how it may be achieved. In this respect, ideas, and to a lesser extent, practice, have advanced since the document was issued.

1.3.15 **Strategic Transport Modelling and Strategic Multi-Modal Studies, John Fearon Consultancy.** This Report, which was commissioned by DfT, had an objective to undertake a technical review of existing large-scale transport and land-use/transport interaction models, so that those making the choice of modelling approach in the Studies may do so in a more informed manner.

1.3.16 In a detailed Appendix, the Report reviews eight models of a general 'strategic' nature:

- LASER (a spatially aggregate land-use/transport interaction model for London and South-East, built using the MEPLAN package);
- GMSPM (a spatially aggregate land-use/transport model for Greater Manchester, built using the START and DELTA packages);
- LTS91 (a spatially aggregate multi-modal model for London, built using the TRIPS package and bespoke software);
- NAOMI (a spatially detailed 'variable matrix' highway model for M25 corridor, based on SATAST, a development of the SATURN suite);
- NNMS (the Dutch National Model System);
- SSM (a spatially detailed multi-modal model for Southampton);
- KTTS (a spatially detailed multi-modal model for Kent Thames-side, built using TRIPS software); and
- PLANET (strategic rail model for London and South-East region, built using the EMME/2 package).

1.3.17 Chapter 4 of the Report provides some general guidelines as to an appropriate level of detail in the case of the largest Multi-Modal Study area, the London to South-West and South Wales study. A particular point in this long-distance context, is the definition of time period, since journeys from one end to the other may not be completed within any one 'conventional' time period. Chapter 5 begins by noting a number of areas of potential difficulty, given the current state of knowledge.

1.3.18 **Review of Land-Use/Transport Interaction Models by David Simmonds Consultancy and Marcial Echenique and Partners.** This review was prepared in response to a Brief issued by SACTRA. The Report begins by outlining the scope of land-use/transport interaction models, and the range of available models (this material is summarised in *Land-Use/Transport Interaction Models* TAG Unit 3.1.3). It continues with a more detailed comparison of the different models, in terms of their responses to change, their representation of economic actors' decisions, and their representation of market systems. It then goes into a number of more detailed questions raised by SACTRA, particularly to do with the identification of economic impacts and the measurement of benefits.

1.3.19 The Annexes provide additional material on the models and packages mentioned in the present Report, and on a range of other models of significance for research and future development but of less practical relevance.

Data Sources for Model Development

1.3.20 DfT has a number of **national** datasets, use of which, where practical, is recommended in order to assist the process of maintaining consistency between studies:

- the TEMPRO planning data;
- Census journey-to-work trip matrices;
- rail matrices from CAPRI data;

- indexes and depositories of roadside interview survey datasets;
- traffic counts; and
- the NARNAS dataset of motorways, trunk and principal roads.

Further details of these datasets are given in *Data Sources* TAG Unit 3.1.5.

National Models

1.3.21 DfT has produced two models - a car ownership model and a multi modal trip end model - and these should be used in the studies unless there is good reason for supposing that they are not entirely appropriate and that a better and cost-effective alternative can be identified. An earlier version of the National Trip End Model is documented in section 12.2.3 of the Design Manual for Roads and Bridges (DMRB). That document has been superseded, and is replaced by the TEMPRO guidance note which can be down loaded from the web. Development of these national models has required the preparation of an associated zoning system.

National Zoning System

1.3.22 2001 Census data on population, households and car ownership is available to a fine geographic level. In order to make use of this information, and ease the transfer of data between studies, it is recommended that studies base their zoning system on 2001 Census geography, i.e. each model zone should correspond with one or more Census areas. Census geography provides a number of nested levels - Regions are made up of counties, counties consist of a number of districts, districts are divided into wards.

1.3.23 DfT has developed “NTEM zones” as an additional level intermediate between districts and wards. Outside the metropolitan areas, where a district is entirely rural or entirely urban it is treated as a single zone. Each urban settlement with greater than around 10,000 population becomes a zone, and the remaining rural area is divided into sensible portions (e.g. to avoid “doughnut” shapes). Within the metropolitan counties, non-built-up areas are distinguished, and the main cities separately identified. Planning data projections, car ownership and trip end forecasts are published at the NTEM zone level.

1.3.24 **National Car Ownership Models.** The current car ownership model is based on that used in NRTF97, but has been changed to be responsive to car purchase and ownership costs and includes a company car effect.

1.3.25 The basic model, which is described in Annex C of the “TEMPRO guidance note”, provides the **national** car ownership forecasts used in the National Transport Model. It was developed from joint National Travel Survey and Family Expenditure Survey (FES) data, and presents household car ownership as a function of income, household categories (relating the numbers of retired persons, non-retired adults, and children), area type (5 levels of urbanisation), level of employment, ownership cost, running cost and an annual trend based on ‘licences per adult’. Saturation level by household and area type are estimated directly from the. The model produces forecasts of the number of households with 0, 1, 2, and 3+ cars.

1.3.26 **National Trip End Models**. NTEM is now a fully integrated part of the National Transport Model framework developed by the Department for Transport. The equations used in the NTEM model are described in Annex D of the TEMPRO guidance note. The NTEM model is now considerably more detailed spatially than the previous NTEM as well as including trips by all modes (rather than just car) and having greater segmentation of traveller types. The NTEM model starts from the basis that each one-way trip by any mode has two trip ends. The model works by relating the number of trip ends in each zone to a range of demographic and land use factors, such as the number of households with cars in each zone, and the number of people employed in each zone.

1.3.27 Trips are categorised as either home based (HB), having one end of the trip at the place of residence; or non-home based (NHB), having neither end of the trip at home. The purpose of the trip is determined by the destination purpose of the trip; except where the destination purpose is home in which case the origin purpose is used. Fifteen purposes are recognised: Home-Based Work, Home-Based Employer's Business, Home-Based, Education, Home-Based Shopping, Home-Based Personal Business, Home-Based Recreation/Social, Home-Based Visiting friends & relatives, Home-Based Holiday/Day trip, Non-Home-Based Work, Non-Home-Based Employer's Business, Non-Home-Based Education, Non-Home-Based Shopping, Non-Home-Based Personal Business, Non-Home-Based Recreation/Social and Non-Home-Based Holiday/Day trip. NTEM also provide tripends by six modes (Car drivers, car passengers, rail, bus, walk and cycle) and six time periods (morning peak period, inter peak period, evening peal period, other weekday periods, Saturday and Sunday).

1.3.28 The NTEM operates at a high level of disaggregation, with each combination of eleven person types and eight household size / car ownership categories – 88 combinations - having their own trip rate for each of fifteen purposes. The trip rates are derived from National Travel Survey (NTS), and are not varied as analysis of NTS data suggests that trip rates for the categories defined are stable over time.

1.3.29 The attraction ends of all trips are distributed across wards according to land-use indicator statistics. For example, for commuting trips, the statistic used is total employment. For shopping trips, it is total retail employment. For trips to visit friends and relatives at their home, it is total households.

Software Availability and Specialist Modelling Knowledge

1.3.30 Software for spatially detailed models is readily available from a number of providers. There are a wide range of road traffic assignment modelling packages available, and at least three public transport assignment packages that would meet the requirements for multi-modal modelling. Experience within consultancies and local authorities of the use of these models, mainly in free standing form, is quite extensive. For simple demand modelling exercises, there is also a range of proprietary software available, some of which can be tailored to a specific model's needs.

1.3.31 Software relating to spatially aggregate models is more specialist, particularly in the case of the approach which employs area speed/flow relationships and fixed routes. Knowledge of construction techniques for such models is restricted to a relatively small number of individuals in specialist consultancies. Specialist techniques are required both for the assembly of the supply representation, and for constructing and handling the high degree of demand segmentation. A number of companies have developed specialist software which they have applied on model building exercises for which they have direct responsibility. Such modelling systems have in a number of cases been handed over for other organisations to use, but cases of model building by third parties are very rare.

1.3.32 A similar situation exists with respect to complex applications of the spatially detailed approach. Here knowledge of techniques to handle features such as time of day choice, public transport crowding and operator response, and overall demand/supply convergence, are restricted to a relatively limited number of people.

1.3.33 Software and expertise in relation to land-use modelling, whether for comprehensive land-use/transport packages or for land-use models which can be fully integrated with separate transport models, is available from only a very small number of firms. There is some experience of using such models in university transport departments, but recent experience has shown that the main sources of land-use modelling software and associated experience are in the commercial sector.

2 Further Information

The following documents provide information that follows on directly from the key topics covered in this TAG Unit.

For information on:	**See*:***	**TAG Unit number:**
Types of study area covered by the guidance	*Multi-Modal Studies: Introduction to GOMMMS*	TAG Unit 1.2
Modelling Introduction	*Summary Advice on Modelling*	TAG Unit 2.4

3 References

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4 Document Provenance

This Transport Analysis Guidance (TAG) Unit is based on Chapter 2 of *Guidance on the Methodology for Multi-Modal Studies Volume 2* (DETR, 2000).

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