NRA
An tÚdarás um Bóithre Náisiúnta
National Roads Authority

Project Appraisal Guidelines

Unit 5.2 Construction of Traffic Models

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Construction of Transport Models

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1 Introduction

Overview

1.1. This PAG Unit provides detailed guidance on the development of traffic models for use in the appraisal of transport infrastructure. The guidance addresses the scoping and construction of transport models which reflect transport demand and supply in a 'Base Year'.

Transport Models

1.2. A transport model is a computer-based representation of the movement of people and goods (trips) around a transport network. It is intended to provide an indication of how trips will respond, over time, to changes in that transport network. These changes may be due to growth in the number of trips or due to changes in the transport network itself i.e. the building of new roads or public transport infrastructure.

1.3. In order to try and predict what will happen over time, it is necessary for the model to make assumptions about how people will react to these changes. A model can therefore never be precise about the future and should never be presented as such.

1.4. The creation of a transport model can be costly and time consuming particularly in terms of the collection of the necessary data. Thus, it is sensible to consider what form or scale that model should take.

The Role of Transport Models

1.5. A transport model can serve several functions. It can aid the design of a scheme, it can help determine what the most appropriate option for a scheme is and it can provide the necessary outputs for the economic and environmental appraisal of a scheme.

1.6. Within the context of these guidelines, the primary function of a transport model is to inform the economic and environmental appraisal of a scheme.

1.7. One of the benefits of using a transport model is that it can ensure that a variety of schemes, or scheme options, are considered on a consistent basis. An objective of these guidelines is to ensure that all national road schemes evaluations follow the principles discussed herein and therefore enable the NRA to consider schemes on a like for like basis.

1.8. The modeller must always remember that studies are carried out to enable investment decisions to be made and explained, as well as to inform the environmental appraisal of the scheme, and any work that does not further these objectives is wasteful. The practitioner also has a duty to the decision maker to provide information that is robust and does not imply levels of accuracy that are not achievable in practice. They must also ensure that any differences identified between alternatives are real and not a product of the techniques used in the appraisal.

1.9. Furthermore, it is important that the scope for using existing models and data is carefully considered and that new models and data are up to the task. Careful consideration should be given, before resources are committed to data collection and model building, to the nature of the options that are likely to be tested and the required level of detail of the analyses. In short, the model must be fit for purpose and unnecessary complexity should be avoided.

2. Requirements of a Transport Model

2.1. A transport model needs to be capable of reflecting, to an acceptable degree, the existing transport situation as observed on the ground. This can be measured in terms of trip patterns, numbers of vehicles on roads, journey times experienced and the location and extent of any queuing.

2.2. Additionally, the model needs to have a mechanism whereby it can reflect forecast growth in the numbers of trips being made and also the changes in transport infrastructure (e.g. new roads) which occur over time.

2.3. In considering the scope of the transport model, the following basic questions need to be addressed:

- What is the nature of the scheme to be assessed?
- Where is the scheme located and in what sort of environment?
- What is the likely area of influence of the scheme?
- What modes of transport are likely to be affected by the scheme?
- What outputs are required from the modelling process?

2.4. The answers to these questions should lead towards a decision as to whether a model is required and, if so, what form it should take.

3. Model Types

3.1. There is a wide variety of scheme types that may be subject to appraisal ranging from refurbishment of existing infrastructure, through minor junction improvements up to major new road schemes. It is clearly not sensible to adopt a ‘one size fits all’ approach when it comes to developing transport models to assess this range of schemes. Furthermore the geographical location of the scheme will also impact on the decision of what type of modelling is appropriate.

3.2. A range of bespoke transport modelling software types is available. It is also possible in some circumstances to use spreadsheet or database techniques to develop relatively simple models but this approach is generally not recommended and would require approval in advance from the NRA prior to the commencement of any work.

3.3. The PAG considers a number of model types in terms of its modelling approach, suitability, data requirements, outputs and likely resource impact (i.e. time and expertise required).

3.4. The model types considered fall into three levels of transport functionality as follows:

- Static models, which reflect traffic volumes on the basis of link flows. Such models do not attempt any route assignment, and hence are only applicable for small networks where no change in traffic flows will result from a proposed scheme. Static models tend to comprise isolated junction models or linked junction models. They can also comprise micro-simulation models where there are no route choice algorithms built into the model;
- Assignment Models which allocate demand matrices through traffic networks, thereby replicating route choice by vehicles for each origin-destination pair; and
- Variable Demand Models, which replicate demand responses where they might be expected as a result of a scheme, for example in larger towns and cities with congested road networks. These demand responses considered here comprise changes in trip rates, choice of destination and travel mode. Major schemes within dense urban areas which have competing modes of transport, such as Dublin, are likely to warrant a variable demand modelling approach.

4. Static Models

Isolated Junction Modelling

4.1. This type of software considers traffic as discrete packages of vehicles moving from one arm of the junction to another. They are based on empirical capacity, queuing and delay formulae and model time slices which the user defines. Typically three model periods will be considered, a morning peak, an average inter peak hour and an evening peak. Within that model period, the user can split the flow into time segments (e.g. 15 minutes) but the flow level is considered constant within each segment. The principle is illustrated in the following diagram where the dotted line represents the actual flow profile over a period and the solid lines indicate the various fixed level segments which approximate to the actual profile.

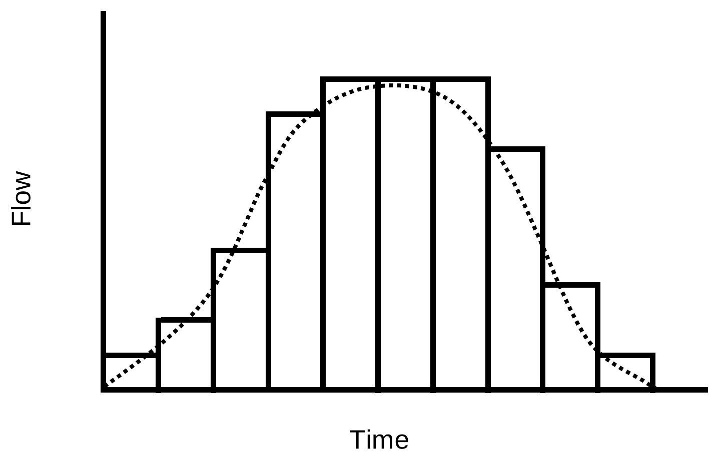

Figure 5.2.1: Time Segments in Flow Profiles

4.2. By definition, there is no route choice within the models and they do not consider interaction with the rest of the network.

4.3. The most commonly used packages are:

- PICADY (for simple priority or 'give way' junctions);
- ARCADY (for roundabouts);
- RODEL (also for roundabouts);
- OSCADY (for signal controlled junctions); and
- LinSig (also for signal controlled junctions and linked junctions).

4.4. This kind of approach is suitable for schemes which are limited in scale to one junction and where there is little or no interaction between traffic at that location and adjoining junctions or other parts of the network. They are also appropriate for junction improvement schemes in more complex locations where the scale of the improvement is such that changes in traffic routeing are likely to be minimal.

4.5. The empirical formulae which underpin isolated junction modelling are based upon junction geometry and so a prerequisite for this type of modelling is detailed geometry of the existing and proposed situations. Details of the precise measurements that are required are given in the relevant software manuals.

4.6. In terms of traffic data, a matrix of turning movements is required for whatever time period is being modelled. Any alterations to the pattern of movements, due to the improvement scheme, or to the magnitude of those movements, due to growth over time, needs to be determined exogenously by the user.

4.7. The models will also typically provide estimates of delay per vehicle which is a key output for any subsequent economic analysis.

4.8. Whilst there is an inevitable learning curve with any new software, these packages are relatively simple to use and should not pose any problems to a competent transport professional. Each of the software manufacturers offers training courses on a regular basis and technical assistance is readily available.

4.9. The most significant cost requirement in terms of data is likely to be obtaining the base turning count information. This will typically involve a manual turning count together with some automatic traffic counts to determine day-to-day variations.

4.10. Where signal controlled junctions are activated by a UTC System (e.g. SCOOT/SCATS), the modeller will need to input a 'typical' staging and phasing into the junction model which reflects the UTC operation during the modelled period. Note that 'optimising' the signal settings of a junction cannot be deemed to be a mitigation measure in itself if the signal settings are already deemed to be optimised by the UTC system – as the theoretical optimisation as dictated by a junction modelling programme can be difficult to achieve.

Linked Junction Modelling

4.11. Where this type of situation arises, there are two possible solutions. Linked traffic signals can be modelled using TRANSYT or LinSig, or alternatively using micro-simulation techniques.

4.12. TRANSYT and LinSig make the following assumptions about the area which is being modelled:

- Junctions within the network are primarily signal controlled (some priority junctions can be included in TRANSYT);
- All the signals have a common cycle time or a cycle time of half this value;
- The details of each junction are known in terms of minimum stage times and stage allocations; and
- Each individual traffic stream (e.g. flow between junction or turning movement at a junction) has a known flow rate that is constant over the relevant period.

4.13. The road network is modelled as a series of 'nodes' or junctions connected by 'links'. Each distinct traffic stream leading to a node is represented by a link. The programme is then capable of determining the optimum set of signal timings for a network of junctions.

4.14. It should be noted however that whilst TRANSYT and LinSig will flag up where queuing back from one junction to another is an issue, it will not always account for this in reporting junction performance. This is because, in common with many transport modelling packages, it assumes 'vertical queuing' i.e. any vehicles queued at a node are contained at the node rather than stretching back along the link.

4.15. There will be circumstances, particularly when considering signal-controlled junctions, where the flow arriving at one junction is directly linked to the capacity and green times available from the upstream junction. In these circumstances, it is not appropriate to consider each junction in isolation. This is because any predicted increases in throughput at a junction may not materialise if the upstream junction is operating as a bottleneck controlling the input flow. This can be illustrated by the following simplified example:

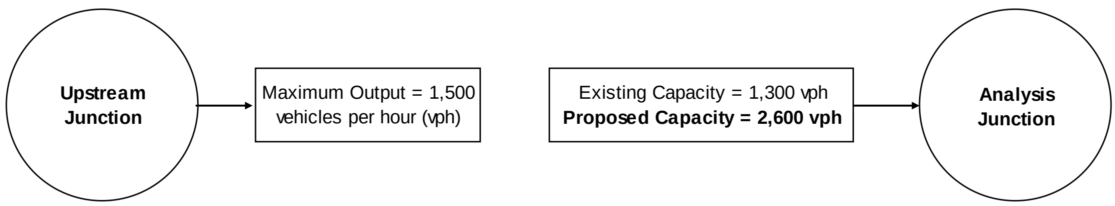

Figure 5.2.2: Linked Junction Example

4.16. In this example, just modelling the analysis junction in isolation would suggest that the proposed scheme would increase capacity by 100%. In reality, the constraint imposed by the upstream junction means that the effective capacity is limited to 1,500 vph or an increase of just 15%.

4.17. The data requirements are similar to that required for an isolated junction model but with the following additional elements:

- Details of the signal controller constraints (e.g. minimum green and stage times); and
- Information with regard to link lengths and travel time or distances between junctions.

4.18. Although outputs from junction models differ across alternative software packages, the main indicators which feed into the economic analysis are:

- Flow on each link;
- Delay on each link; and
- Mean maximum queue length.

4.19. Some of the concepts within TRANSYT and LinSig (linked junctions) can be quite difficult for the inexperienced user to grasp and it also requires a fair degree of familiarity with the principles of traffic signal controllers. However there are training courses available and technical support from the software suppliers.

4.20. The scale of data collection required is clearly related to the scale of network that is being modelled. Experience has shown that it can be difficult to obtain details of signal timings for existing networks and if on street surveys are required, this can prove time consuming.

4.21. Where signal controlled junctions are activated by a UTC System (e.g. SCOOT/SCATS), the modeller will need to input a ‘typical’ staging and phasing into the junction model which reflects the UTC operation during the modelled period. Note that ‘optimising’ the signal settings of a junction cannot be deemed to be a mitigation measure in itself if the signal settings are already deemed to be optimised by the UTC system – as the theoretical optimisation as dictated by a junction modelling programme can be difficult to achieve.

Micro-simulation Modelling

4.22. Transport models have traditionally provided an aggregated representation of traffic, typically expressed in terms of total flows per hour or some other time segment as referred to earlier. In such models, all vehicles of a particular group obey the same rules of behaviour. Micro-simulation models consider individual vehicles, the movements of which are determined by using various rules such as car following, lane changing and gap acceptance. They are becoming increasingly popular for the assessment of traffic management and control systems.

4.23. In theory, micro-simulation models provide a better, and 'purer', representation of actual driver behaviour and network performance. They are the only modelling tools available with the capability to examine certain complex traffic conflicts (e.g. merging, complex junctions, shockwaves and effects of incidents). In addition, there is the appeal to users of the powerful graphics offered by most software packages that show individual vehicles traversing across networks that include a variety of road categories and junction types. This visual representation of problem and solution in a format understandable to layman and professional alike can be a powerful way to gain more widespread acceptance of complex strategies.

4.24. The packages originally worked on fixed, user-defined routes but the more sophisticated models now incorporate assignment algorithms which allow individual vehicles to determine their optimum route through the network. The principles of assignment are discussed more fully in a later part of this section.

4.25. There are a number of packages available but the most common currently used are:

- AIMSUN;
- Paramics; and
- VISSIM.

4.26. The techniques are particularly well suited to the detailed simulation and operational assessment of junction interaction as, unlike other model approaches, blocking back of queues is explicitly modelled.

4.27. The techniques were originally developed for looking at small urban networks and are still perhaps best suited to that type of environment. It is not expected that micro-simulation will be used to support the appraisal of new road schemes, other than those in heavily trafficked situations, or where traffic management proposals form a major part of a scheme intervention.

4.28. The creation of input files which describe the layout of the network can be a very time intensive task. Link lengths and widths have to be measured, the number of lanes determined, junction layouts specified, signal locations and timings entered and public transport stops and priority lanes identified.

4.29. Given the level of detail required to accurately define the network, the magnitude of the data collection exercise can be considerable and therefore the scale of the model should be kept as small as possible whilst satisfying the needs of the study.

4.30. Once the geometry of the network has been defined, vehicles have to be added to the model. The number of vehicles is traditionally defined by specifying origin-destination (O-D) data. The collection of O-D data for input into micro-simulation models is a very time consuming and expensive task. It is usually done by placing observers on entrances and exits to the network to identify trip origins and destinations, either by number plate matching or roadside interviews.

4.31. Micro-simulation modelling does require a degree of expertise and if this is not immediately available, then sufficient time will be required for training and staff development.

4.32. Given the complexity of micro-simulation models, it is not surprising that they take longer to run than standard junction models. The principles behind the operation of micro-simulation models also require that a number of runs are undertaken for each scenario that is being considered and this has an impact on the time taken to complete the assessment.

5. Assignment Models

5.1. Assignment models consider the transport system in terms of demand, in the form of trip matrices, and supply in the form of a road network. They are often referred to as macroscopic as they operate on the basis of aggregate traffic flow rather than individual vehicles. This approach assumes that average conditions apply and that all modelled vehicles making the same trip will experience the same conditions.

5.2. Micro-simulation models can also be used as assignment models, typically for small urban networks. Nevertheless, micro-simulation models should not be used primarily as assignment models in anything other than relatively small local areas.

5.3. Trip matrices represent a simplified view of the patterns of movement across a study area. The area is split up into zones whereby each zone contains a similar land use (e.g. housing estate) and is of a suitable size so that all of the elements within that zone can be considered to arrive or 'load' on to the network at a common point. To use the housing estate example, if there are a number of minor roads which all access the main road at one junction then it may be suitable to group all those roads, and the houses therein, into one zone. Each zone will be an origin for some trips and a destination for others. In the earlier example, the housing estate will be an origin for many trips in the morning peak, as people leave their houses to go to work but will also be a destination for certain trips, such as the delivery of a household item. Hence, the use of the term origin destination (OD) matrices.

5.4. The trip matrices will contain all of the movements in the study area for the time period being considered (typically one hour). But there may also be more than one trip matrix for that area as it is common to distinguish between vehicle types, e.g. cars versus trucks, and also between trip purposes, e.g. commuting from home to work and leisure.

5.5. The network is represented by a series of links, or sections of road, between nodes, or junctions. Each link in the network will have an associated capacity based on the number of lanes available to traffic and usually a speed flow curve. This defines how the speed of vehicles on the road alters as the number of vehicles change. Clearly, as the number of vehicles increases, the speed decreases. The way in which junctions are handled varies between software packages. Some consider junctions as simple nodes with no associated delay; others mimic the way in which junction modelling software operates, albeit in a simplified fashion.

5.6. There are a number of ways in which the trip matrices can be loaded or assigned to the road network. The most common involves an iterative process whereby an equilibrium solution is sought before the assignment is complete. At each iteration, each OD pair (or conceptually each driver) considers all of the feasible routes to get from their origin to their destination and selects the best option, usually based on a combination of time and distance, based on the current network conditions. Those conditions are a function of the current flow levels and the link characteristics (e.g. capacity and speed flow curve).

5.7. The current most commonly used assignment packages are:

- VISUM;
- EMME/2;
- SATURN; and
- TRIPS (now incorporated within CUBE).

5.8. These types of assignment models are well suited to relatively large, typically inter-urban, networks. They are capable of dealing with route choice and are therefore particularly appropriate when considering a new link or a significant junction improvement.

5.9. Assignment models require a definition of the network, in terms of link length, link standard (e.g. single carriageway, dual carriageway, motorway, etc.) and speed in terms of an appropriate speed flow curve, and a demand matrix of trips. As mentioned previously there may be a number of trip matrices depending on the trip categories which are required to be modelled.

5.10. The exact nature of the output is specific to the type of software being used but the following are available from all standard packages:

- Flow on link (disaggregated by user class / vehicle type);
- Travel time on link; and
- Network wide performance statistics such as total vehicle kilometres and total vehicle hours.

5.11. In assessing model outputs, there can be significant differences between the demand flow (those wishing to travel along a link during the period) and actual flow (those who manage to make that trip during the period) in congested conditions. Where there are significant differences between these two figures, it means that network constraints are preventing all vehicles who wish to from reaching that point. This can be an important issue in terms of scheme design.

5.12. Most packages also have associated database or calculation modules which enable the user to generate indicators based on any combination of model output and network, or matrix, component.

5.13. For a fixed demand economic assessment using COBA, the primary output from the modelling process is a series of flows on links; COBA will then recalculate link times and vehicle operating costs itself together with accident statistics.

5.14. As the models are working at an aggregate level the network coding is not as critical as with more detailed models. Typically, it is possible to scale link lengths from maps although carriageway standard (e.g. number of lanes) may require site visits if good aerial photography is not available. Similarly it may be necessary to undertake site visits in order to code up junction arrangements.

5.15. The development of a trip matrix can be a costly and time intensive process if the modeller is starting from scratch. Origin Destination surveys are likely to be required which can then be supplemented by matrix estimation techniques which rely on link based traffic counts.

6. Variable Demand Models

6.1. All of the modelling approaches discussed thus far assume that the volume of trips using the road network does not alter as a consequence of the scheme being assessed. Traffic may change their route as a consequence of a scheme, if an assignment model is being used, but the volume of trips from A to B will not change.

6.2. Variable demand modelling works on the premise that any change to transport conditions will, in principle, cause a change in demand. Travel will become faster or slower, cheaper or more expensive, and this will be reflected in the generalised costs of travel for some journeys. Generalised cost is the sum of both time and money cost, and any modelling of demand will depend upon how the generalised cost of travel changes. As an example a road improvement which removes delays for those travelling by car means that the generalised cost of some journeys will reduce. Therefore some people will decide that the journey is now acceptable, whereas before they were less likely to make it so the total number of people taking advantage of the scheme will be more than would have travelled without the improvement.

6.3. The demand responses which are modelled within a variable demand environment are:

- Change of route (already covered in standard assignment models);
- Change of destination or origin (trip distribution);
- Change in the number of trips made (trip frequency);
- Change from car to public transport or vice versa (trip mode); or
- Change to time of travel (trip period).

6.4. They may be addressed using full demand modelling or by an elasticity approach. In full demand modelling, it is common to adopt a hierarchical approach in order that different responses have a different order of priority. An example is shown in the figure below.

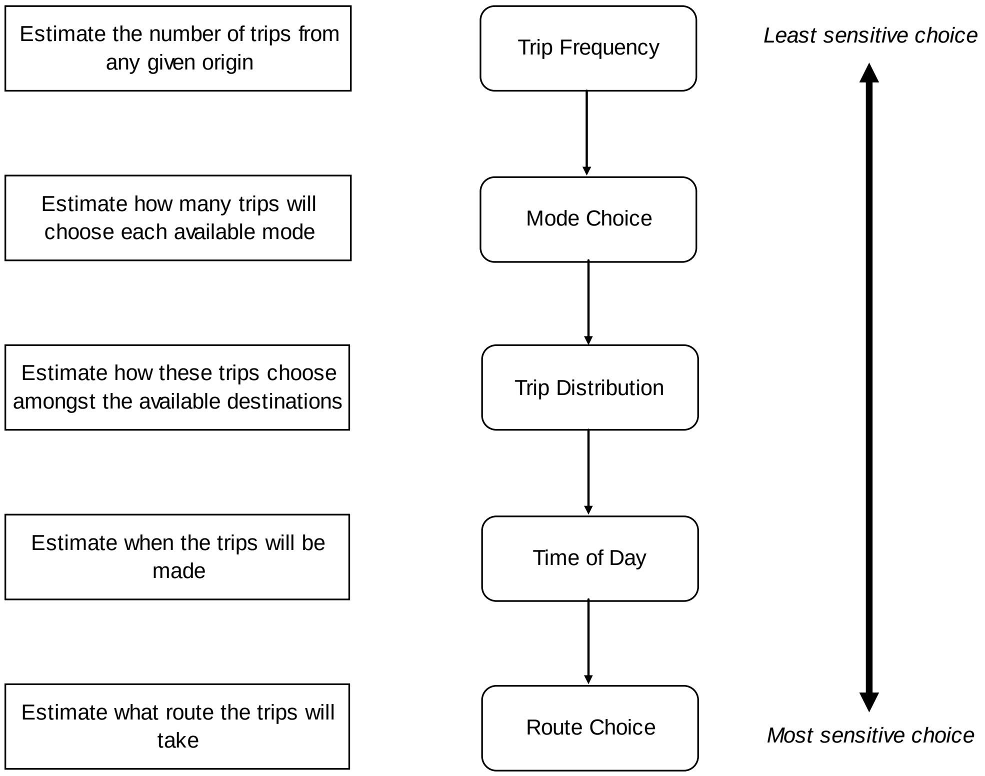

Figure 5.2.3: Hierarchal Approach to Full Demand Modelling

6.5. In an elasticity or own-cost elasticity approach, all of these responses are considered as one. Furthermore it assumes that travel demand for any OD pair is a function of the cost for only that pair. The change in cost can take a number of forms but the most common is the power formulation because it is considered well behaved computationally and simple. It assumes that a proportionate change in trips is related to a proportionate change in costs.

6.6. The main shortcoming of an elasticity approach is that it cannot replicate the changes in trip lengths which are forecast by trip distribution models and there has been concern that they cannot adequately estimate mode or time period choice.

6.7. Variable demand modelling is necessary when the following conditions are fulfilled:

- Mode choice is likely to be a significant issue; or
- Changes in trip costs are so large as make distribution a significant issue.

6.8. It is not expected that variable demand modelling will be used on many NRA projects requiring appraisal other than for new roads or major upgrades in heavily trafficked urban situations.

6.9. For full variable demand modelling, the complexity increases and suitable parameters need to be defined for each response. Research in the UK has suggested some illustrative values but once a variable demand model has been constructed, it is essential to ensure that it behaves "realistically", by changing the various components of travel costs and times and checking that the overall response of demand accords with general experience. If it does not, then the values of the parameters controlling the response of demand to costs should be adjusted until an acceptable response is achieved. This recognises the large and unavoidable uncertainties in some of the parameter values, and the importance of reflecting local conditions in relative values.

6.10. The data requirements are dependent on the variable demand approach that is to be adopted. For an own cost elasticity approach, the only additional requirement over standard assignment model requirements is the provision of appropriate elasticity values. Advice should be sought from NRA on appropriate values to be used.

6.11. The outputs from variable demand models are similar to those for standard assignment packages but will additionally provide information on the demand responses for the scheme being assessed. So there will be outputs relating to the volume and location of trips redistributing, changing mode etc.

6.12. The economic analysis of variable demand is handled in a fundamentally different way to that for fixed and puts a greater onus on the ability of the assignment model. All of the required outputs for the economic element are matrix based and include:

- Trip matrices (disaggregated as required);
- Time skims (i.e. origin zone to destination zone average trip times); and
- Distance skims (i.e. origin zone to destination zone average distances).

6.13. Building a variable demand model is a significant undertaking and should not be instigated without prior approval from the NRA. As stated above, there are considerable uncertainties in the appropriate parameter values to be adopted and homing in on suitable local values can take a considerable amount of time. It is also not a task to be undertaken by any other than highly experienced modelling practitioners.

7. Defining the Scope of a Modelling Exercise

Type of Model

7.1. The nature of the scheme, e.g. junction improvement versus new road link, will provide the first indication of what type of modelling is required, although it will also be important to consider the location and the prevailing environment. As an example, a fairly major junction improvement in a rural area with a sparse road network is likely to only require an isolated junction model. The same kind of scheme in a dense urban environment may cause significant re-routeing effects and even, potentially, impact on other modes. As a consequence, a reassignment model would be the minimum requirement. Table 5.2.1 summarises the scope of the three levels of models identified in the PAG.

Table 5.2.1: Criteria for Scoping of Transport Models

Category	Static Models	Assignment Models	Variable Demand Models
Description	Manual assignment calculations using fixed demand flows. Can comprise spreadsheet modelling, junction modelling or static microsimulation modelling.	Models which use a fixed traffic demand matrix, and assess impacts of reassignment only.	Models which include consideration of demand responses (Trip Generation, Distribution and Mode Share).
Nature of Scheme	• Non-major schemes (<€5m) • Road safety schemes • Localised improvement	• Major schemes (>€5m) • New roads • Significant upgrades to existing roads • Rural areas • Small urban areas	• Major schemes (>€5m) • New roads • Significant upgrades to existing roads • Major urban areas
Likely Impacts of Scheme	• Rural road networks with no route-switching • Single or multiple junctions in urban areas with no route-switching	• Schemes which will lead to changes in routing • Areas with limited public transport • Areas where induction or suppression of traffic is not anticipated • May use microsimulation models to model complex merging/shockwaves	• Schemes which will generate traffic impact • Major urban areas where congestion will exist • Schemes which lead to large reductions in journey time • Areas where induction or suppression of traffic is anticipated • Schemes which will increase competition with public transport

7.2. If it is decided that a junction model (isolated or linked) is sufficient, then the remaining issues with regard to scope will be:

- The definition of suitable model time periods; and
- The choice of model years to be assessed.

7.3. As the modelling process will inform the design of the scheme as well as contributing to the appraisal, the model periods should cover the times when the impact of the improvement is likely to lead to user benefits. This is likely to include, as a minimum, the morning and evening peak periods but may also include the inter peak and, in certain circumstances, busy periods during the weekend. It should also be noted that any economic assessment needs to consider both positive and negative impacts. The addition of, for example, traffic signals to a junction may result in additional delays compared to the 'do-minimum' scenario and this should be considered when determining what time periods need to be modelled.

7.4. The model years need to include, in addition to the base year, the scheme opening year and suitable design and forecast years as a minimum. Additional years may be required if there are significant changes to the network or trip patterns (e.g. as the result of a development nearby) in the intervening period.

7.5. If it has been determined that an assignment model is required then issues with regard to the scope of the model will include:

- The extent of the road network to be modelled;
- The level of detail of road network required;
- The definition of an appropriate zoning system;
- The number of vehicle type / user class matrices required;
- The definition of suitable time periods; and
- The number of model years to be assessed.

7.6. All of these questions need to be addressed with reference to the basic purpose of the model: what is it trying to assess and what questions does it need to provide answers for?

Extent and level of detail of the road network

7.7. The extent of the road network will be a significant factor in determining the overall resource required to undertake the modelling work and so it should be that area within which impacts are expected and no larger. One of the main purposes of an assignment model is to investigate the extent and impact of changes of route as a consequence of a scheme. Therefore it must be of sufficient extent to allow all reasonable and significant reassignment movements to occur.

7.8. The study boundary should also be carefully chosen to ensure that any potential competition between route corridors can be captured, as this can significantly effect the appraisal.

7.9. If there is an existing model of the area, even if it is quite old or of a coarse nature, then it should be possible to code in a representation of the improvement scheme to identify the extent of any reassignment effects and thereby the area of influence. The magnitude of the effects from an older model may not be quite correct but the routes themselves are likely to be reasonable.

7.10. If there is no existing model then the area of influence will need to be determined by judgement and local knowledge although there are tools available which can assist. For example, commercially available route planner software can be used to determine existing route times and distances. Also, the National Traffic Model can be used to assist in determining the modelled study area.

7.11. The level of detail required will probably vary across the network. In close proximity to the scheme, it will be necessary to include all main roads, as well as those minor routes, or roads in residential areas, (including 'rat-runs') that are likely to carry critical traffic movements, either in the base year or in future years. Local authorities will normally be aware of the common 'rat-runs', but some independent assessment may also be required. Junction modelling will also be required in those areas close to the scheme where junction capacities have a significant impact on drivers' route choice, and where delays are not adequately included in the speed-flow relationships applied to network links. However, the network will often be sparser towards the boundary of the area and only needs to be capable of ensuring that traffic is using the correct main routes on the approaches to the scheme. Junction modelling is unlikely to be required in these areas unless there are particular key junctions where route choices are made and where the junction capacity is critical.

Zone systems

7.12. The size and number of model zones is a critical factor in determining the realism and accuracy of the traffic model and also how long the model takes to run. If zones are too large, the model will be unable to estimate traffic flows to the required level of accuracy, however good the quality of the trip matrix data. On the other hand, if the zones are too small, the sample sizes in the cells of the matrix will be small also, affecting the accuracy of the trip and flow estimates.

7.13. It should also be noted that intra-zonal trips (i.e. those taking place entirely within the same zone) are not assigned to the model network. If zones are too large, this may lead to a significant underestimation of traffic flows, both on links and at junctions, and this in turn could seriously distort the pattern of flows and delays given by the assignment model. This is a particular problem in urban traffic models that use capacity restraint assignment techniques. Similar distortions, particularly in the modelling of junction turning movements, can also occur if zone sizes are not compatible with the level of network detail included in the model.

7.14. In a similar fashion to the network, zones sizes should generally be smallest towards the centre or focus of the model area and increase in size the closer to the model boundary they become. They should also seek to follow, or be capable of being aggregated to, administrative boundaries as this can prove useful when using other data such as population or household information.

User Classes

7.15. Where a fixed trip economic appraisal is to be undertaken, COBA will determine the appropriate split of vehicle type and journey purpose for each link in the study area and apply these to the total vehicle flows as output by the traffic model.

7.16. It is therefore only necessary to provide sufficient disaggregation of matrices to ensure the model can accurately reflect route choice and provide whatever additional output may be required for operational or other analyses. In that context, it is unlikely to be necessary to provide anything more than car and heavy goods vehicle matrices. The route choice of these two users can be very different and details of heavy goods vehicle patterns may be required for other environmental purposes.

7.17. Where schemes involve tolling, disaggregation of demand into travel purpose and income segments may also be warranted.

Time periods

7.18. In order to facilitate an accurate cost benefit appraisal, the model needs to provide as accurate an estimate as possible of 12 hour or 24 hour flows on the network. In most instances, the traffic patterns will be significantly different for the morning and evening peaks and different again for the inter peak period. It is recommended that most assignment models should therefore include:

- An AM Peak Hour (weekday);
- An average Inter Peak Hour (weekday); and
- A PM Peak Hour (weekday).

7.19. Variable demand assignment models should also ideally include an off-peak (weekday) model, and a weekend model. This is due to the fact that the appraisal software of choice, TUBA, cannot calculate benefits for periods which are not modelled.

7.20. The choice of which hour(s) to use in each case will be informed by an analysis of traffic flow data in the area, particularly in close proximity to the scheme. This analysis will also inform how the model flow periods are combined in order to provide daily flow estimates. In those areas where the AM and PM peak lasts longer than one hour, it is best practice to use multiples of the peak hour to calculate the peak period flow and combine this with the inter peak to produce 12 hour and then daily flow estimates.

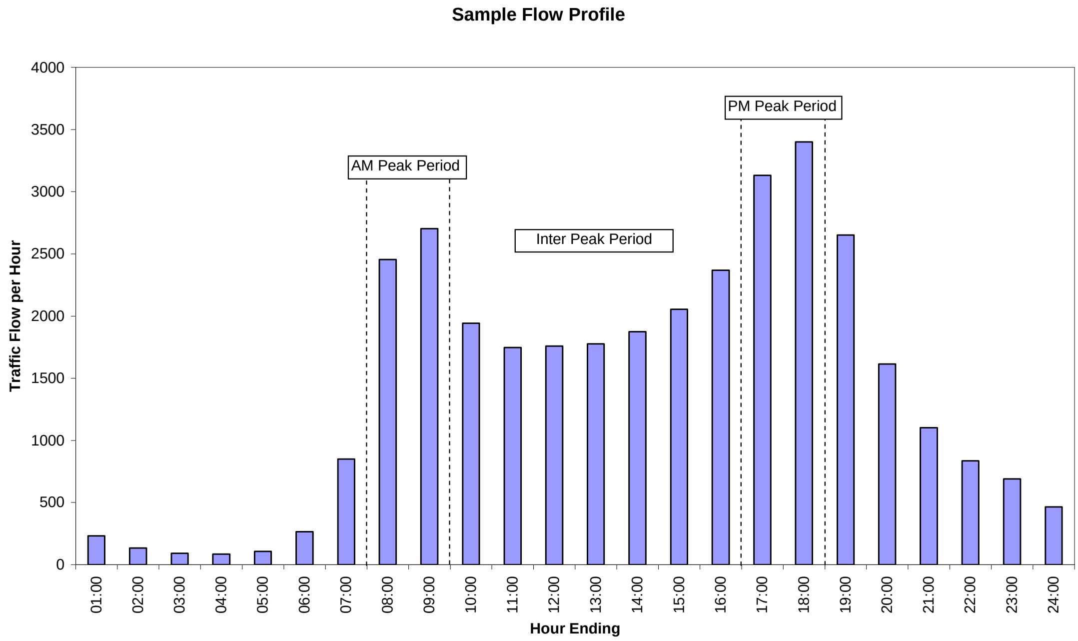

Figure 5.2.4: Example of Daily Flow Profile

Modelled Years

7.21. The modelled years are dictated by both the design requirements and by the necessary inputs to appraisal. The traffic model needs to include the following as a minimum:

- Base Year;
- Opening Year;
- Design Year (Opening Year + 15 Years); and
- Forecast Year (Opening Year + 30 Years).

7.22. Additional years may be required if there are significant changes to the network or trip patterns (e.g. as the result of a development nearby) in the intervening period.

8. Base Year Model Development

Network Building

8.1. Network descriptions for assignment models will often need to include both link and junction details. Links are generally described in terms of:

- Nodes at each end of the link (i.e. junctions or changes in standard);
- Link length;
- The speed-flow relationship (if any) appropriate for the link;
- Link capacity (if not defined by speed-flow relationships or junction details); and
- Any restrictions to particular vehicle types using the link.

8.2. In urban areas it may also be necessary to consider the impact of traffic management measures such as bus lanes, traffic calming, parking controls and cycle lanes on the capacity and operating characteristics of individual network links.

8.3. The usual requirements for junction coding, where this is required, are:

- Junction type (traffic signals, roundabouts, priority);
- Number of approach arms, and their order (in terms of entry link references);
- Number and width of traffic lanes on each junction approach, and the lane discipline adopted (including prohibited turns); and
- Any additional data required to describe the operational characteristics of the junction (e.g. saturation flows, signal timings and phasing, turning radii and gap acceptance characteristics).

8.4. The level of network detail required will be greater in the core area close to the scheme and decrease as the distance from scheme increases. In the core area it will be necessary to include all main roads, as well as those more minor routes that are likely to carry critical traffic movements, either in the base or future years. Capacity restraint should usually be applied throughout the core area and separate junction modelling will also be required in those parts of the model where junction capacities have a significant impact on drivers' route choice, and where delays are not adequately included in the speed-flow relationships.

8.5. In the wider model area, the network description will need to cover all routes necessary to feed traffic to the boundary of the core area in a realistic way (i.e. with realistic distances and speeds). Care must be taken not to encourage unrealistic reassignments to routes that could avoid the core area, especially if fixed speeds are specified on external network links and no capacity restraint is applied, as is sometimes the case.

8.6. In most packages, special links (usually referred to as 'zone connectors') are used to load traffic onto the model network. The position of these connectors is often a critical factor in achieving realistic results from the assignment model. In the core area, they must be located as realistically as possible, and in particular must not be connected directly into modelled junctions, unless a specific arm exists to accommodate that movement. If zones are significantly larger than implied by the detail of the network, it will often be impossible to locate zone connectors realistically. This may lead to distorted traffic flows on nearby links, and turning movements at nearby junctions, which may themselves distort traffic patterns elsewhere in the network. In urban areas in particular, zones should be small enough to avoid this type of problem.

Matrix Building

8.7. The production of base year trip matrices forms the foundation for the forecast year trip matrices used in scheme appraisal. They can be created from scratch but will often be based on an existing model which may be an older one from the area, or from a regional model, or a model from an adjacent scheme.

8.8. When matrices are constructed from roadside surveys, the trips are defined by the place the trip started and the place the trip finished, and the trip purpose of each end. This is known as an Origin-Destination (O/D) based matrix. Assignment models use this form of matrix.

8.9. An alternative way of looking at the pattern of trips is to consider the factors that produce or attract trips, i.e. on a Production-Attraction (P/A) basis, with home generally being treated as the "producing" end, and work, retail etc as the "attracting" end. Trip production is usually defined as the home end of a home based trip or the origin of a non home- based trip. Trip attraction on the other hand is defined as the non-home based end of a home-based trip or the destination of a non home-based trip. Changes in these P/A trip end forecasts over time or by scenario will lead to changes in the trip pattern. This definition of the trip matrix has normally been used in modelling travel demand and is a prerequisite for full variable demand modelling.

8.10. Base year trip matrices are typically assembled using some combination of the following procedures:

- O/D data factoring, whereby old origin to destination data is scaled, preferably to new traffic counts at the old RSI locations or at screenlines;
- Matrix construction, whereby new OD data is used to calculate the observed movements of a trip matrix;
- Matrix infilling, which relates to the estimation of unobserved trip movements, either by using parts of another matrix, or by the use of a model (e.g. gravity model);
- Matrix manipulation where observed and infilled parts of a trip matrix are combined; and
- Other matrix manipulations required to obtain origin to destination matrices for assignment such as matrix estimation techniques.

8.11. There is an important difference between these techniques. Matrix construction and infilling can be carried out separately for different trip purposes and/or vehicle types, but matrix updating based on count data can only be applied to vehicle types.

8.12. There are two main methods of deriving trip matrices for individual time periods:

- Constructing matrices directly from the origin to destination data relating to the specific period; or
- Constructing matrices by combining specified proportions of the all day (12 or 16-hour) Production/Attraction matrices for each trip purpose.

Assignment of Trips to a Network

8.13. Once the network, zoning system and trip matrices for a model have been constructed, the next stage is to 'assign' or 'load' the trip matrices on to the network. Each trip will choose the best route through the network based on a combination of time and distance. Clearly, as more trips are loaded on to the network, speeds will fall and the choice of 'best route' may change. Models therefore work on an Interactive basis and seek to find an equilibrium.

9. Model Calibration and Validation

Overview

9.1. Validation and calibration are separate concepts although they are frequently confused with one another. Two accepted definitions are as follows:

- Calibration - the estimation of the parameters of a chosen model by fitting to observations; and
- Validation - the assessment of the validity of a calibrated model, either by the qualitative comparison of estimates produced by the model with information not used as a constraint in the model calibration, or by the direct estimation of the accuracy of model estimates.

9.2. It is important that the information used in calibrating the model, including count data for matrix estimation, is kept separate from that used for validation if the validation is to be a true independent test of the model.

9.3. In reality these two elements are part of an iterative process. If the results of the validation checks are not satisfactory, then the modeller will review the inputs and coding within the model and adjust as required in order to achieve a better representation of reality. The number of iterations required is usually proportional to the complexity of the model.

9.4. It is neither possible nor practical to produce a perfect model. However it is also true to say that if a model cannot adequately reflect the existing situation, then any forecasts from that model should be treated with a high degree of scepticism.

9.5. The guidance supplied here applies to the calibration and validation of all model types, including static, assignment and variable demand models, whether they are constructed using macro-simulation, micro-simulation or junction modelling software.

Model Calibration

9.6. As briefly described above, the calibration process involves the estimation and subsequent adjustment of parameters used with a model to fit observations.

9.7. For a simple junction model, this may involve adjustments to theoretical saturation flows to ensure that observed queues and delays are reflected in the model. In the case of more complex assignment models the number of parameters and data elements clearly increases and the following represent some of the more common elements that may require adjustment:

- Route choice parameters (the balance of time versus distance);
- Link capacities;
- Speed flow relationships;
- Junction capacities; and
- Trip matrix elements.

9.8. The final element, of adjustments to the trip matrix, is often undertaken using matrix estimation techniques available as part of most assignment software packages. These techniques take a prior estimate of the trip matrix and then adjust that in order to match a set of 'target' observed counts.

9.9. Care must be taken with this sort of approach as matrix estimation will almost inevitably result in a solution but it is rarely a unique one. It is therefore necessary to ensure that sufficient count data is held back from this process to enable an independent check to be undertaken as part of the validation process.

9.10. When comparing model and observed counts, the magnitude of the observed volume is clearly important when deciding on what is a reasonable error. Therefore, in addition to considering percentage or absolute differences, the GEH statistic (a form of the Chi-squared statistic) is also used as it incorporates both relative and absolute errors. The GEH statistic is:

$$GEH = \sqrt{\frac{(M-C)^2}{0.5 \times (M+C)}}$$

where M is the modelled flow and C is the observed flow.

9.11. The criteria and associated acceptability guidelines to be used in the calibration of models are outlined in Table 5.2.2.

Table 5.2.2 Calibration Criteria

Criteria and Measures		Acceptability Guideline
	<u>Assigned hourly flows compared with observed flows</u>	
1	Individual flows within 15% for flows between 700 & 2,700 v/h.	More than 85% of cases
2	Individual flows within 100 v/h for flows less than 700 v/h.	
3	Individual flows within 400 v/h for flows greater than 2,700 v/h.	
4	Total screen line flows (> 5 links) to be within 5%.	
5	GEH statistic: (i) individual flows – GEH < 5 (ii) screenline totals – GEH < 4	More than 85% of cases
Notes: Screenlines containing high flow routes should be presented both with and without such routes.		
<u>Modelled journey times compared with observed times</u>		
6	Times within 15% or 1 minute if higher.	More than 85% of cases

Model Validation

9.12. The process of model validation determines how well the model estimates compare with reality as reflected by observations made on the ground.

9.13. When presenting validation evidence, the estimated accuracy of the survey observations should be quoted whenever possible and that of model estimates where available. Providing information on the estimated accuracy will allow meaningful conclusions to be drawn (e.g. the average of the model estimate lies within the 95% confidence interval of the independent observation).

9.14. In order to determine a model's suitability, clear thinking is required about the intended use. The accuracy of any model, indeed even count data, cannot be expected to represent reality except within a range or tolerance. Moreover, it is often not necessary to go to great lengths to reduce that range and seek apparently greater precision. It is far more important to ensure that:

- The degree of accuracy is adequate for the decisions which need to be taken;
- The decision makers understand the quality of the information with which they are working; and
- That they take the inherent uncertainties into account in reaching decisions.

9.15. The types of validation checks which may be undertaken on a model are dependent on the model form but typical examples include the comparison of model outputs and observed data for:

- Turning proportions at junctions;
- Flows on individual links;
- Flows across screenlines or cordons;
- Queues at junctions;
- Journey times along critical routes; and
- Routeing through the network.

Validation Standards

9.16. The output from an assignment model can be used to assess the performance of the whole modelling process although it should be remembered that any poor performance may be due to a number of factors including:

- Errors in the trip matrix;
- Coding errors in the network; and
- Incorrect route choice parameters.

9.17. The two elements of assignment validation are comparisons with traffic counts and journey times. The count comparisons can be done at an individual link level or by looking at groups of links as screenlines. Criteria are outlined below.

Table 5.2.3: Validation Criteria

Criteria and Measures		Acceptability Guideline
	Assigned hourly flows compared with observed flows	
1	Individual flows within 15% for flows between 700 & 2,700 v/h.	More than 85% of cases
2	Individual flows within 100 v/h for flows less than 700 v/h.	
3	Individual flows within 400 v/h for flows greater than 2,700 v/h.	
4	Total screen line flows (> 5 links) to be within 5%.	
5	GEH statistic: (i) individual flows – GEH < 5 (ii) screenline totals – GEH < 4	More than 85% of cases
Notes: Screenlines containing high flow routes should be presented both with and without such routes.		
Modelled journey times compared with observed times		
6	Times within 15% or 1 minute if higher.	More than 85% of cases

9.18. It is important though to note that these are purely guidelines. A model that does not meet these criteria may still be considered acceptable if the discrepancies are within survey accuracies and the more significant discrepancies can be shown to be not important to the scheme. Similarly, a model that meets the criteria but which has significant discrepancies on the key links may be considered unacceptable. The onus is on the modeller to use the Traffic Modelling Report as a means of making the case to the sanctioning authority that the results of the modelling work are robust and fit for purpose.

9.19. Fitness for purpose will be influenced by the stage the project has reached. As an example, at route selection, the model must be capable of providing a platform whereby alternative schemes can be assessed on a consistent basis but it may not be necessary to be of sufficient quality that it could provide robust detailed turning movements at the scheme junctions.

9.20. Conversely, when the model is to be used to determine the preliminary design, and the requirements of land acquisition, the ability to identify the detailed impacts of the scheme will be important.

9.21. In all cases, data used for model calibration should be distributed across all road types and classifications with particular focus on those areas with high volumes or expanding congested conditions.

Junction Models

9.22. The requirement for model calibration and validation also extends to junction models although they can be combined into a single process for models of this type. A number of criteria should be used including, at a minimum, those in Table 5.2.4.

9.23. The comparison of stopline flows is particularly important for junction models, particularly where congested conditions exist in the base year. Where stopline flows are validated, but with significantly lower levels of queuing in the models as compared to surveys, it is likely that observed stopline flows (actual flows) are being used to reflect upstream flows (demand flows) in the modelling, and that the much higher demand flow in reality is not being captured. In such situations, the modelled flows should be increased until the measured level of queuing is reflected in the models, as this will allow upstream demand flows to be approximated.

Table 5.2.4: Junction Model Validation Criteria

Criteria and Measures	Acceptability Guideline
Mean Maximum Queue length (m) per traffic lane	± 15%
Signal timings and Intergreen periods (s)	Modelled = Observed
Stopline traffic flows (passenger car units) per arm	± 2%
Journey Time (for linked junction models)	±10%