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# TII Publications

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# Project Appraisal Guidelines for National Roads Unit 5.1 - Construction of Transport Models



**PE-PAG-02015**
October 2016

PE Planning & Evaluation

**Technical**

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**TII Publications**

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# Contents Table

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| | |
|---|---|
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# 1. Introduction

## 1.1 Overview

This PAG Unit provides detailed guidance on the development of transport models for use in the appraisal of transport infrastructure. This Unit assumes the reader will be aware of transport modelling principles and will have an adequate level of professional expertise. The guidance addresses the scoping and construction of transport models being developed in support of Transport Infrastructure Ireland (TII) National Road schemes.

## 1.2 Transport Modelling Hierarchy

A transport model is a computer-based representation of the movement of people and goods (trips) around a transport network potentially operating at various levels of detail and scale. Transport models can cover large geographical regions all the way down to single junctions. They are 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: for instance large scale schemes such as the building of new roads or public transport infrastructure; to minor schemes such as junction improvements.

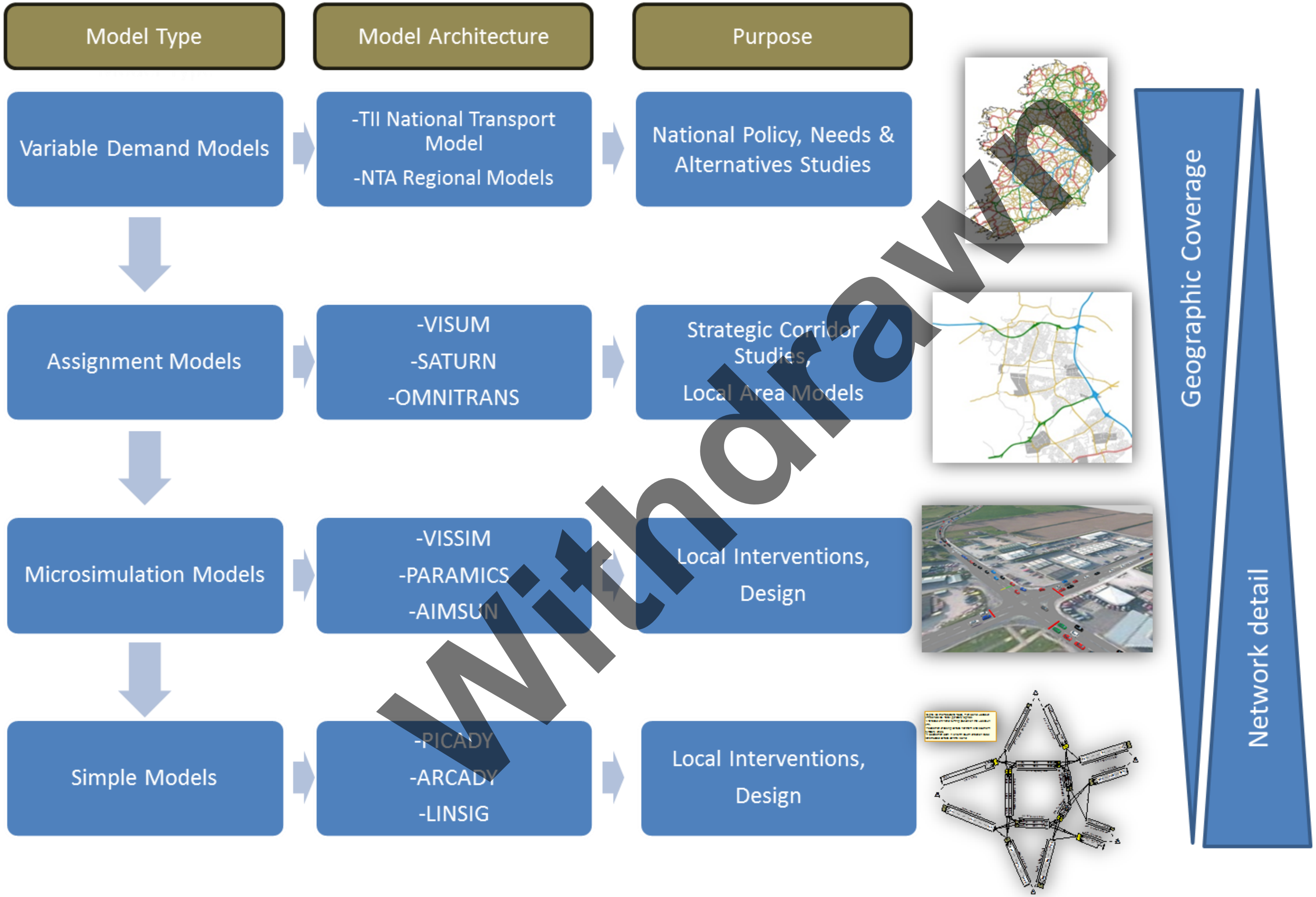
Therefore, there is a wide variety of scheme types that may be subject to appraisal. It is not appropriate to adopt a 'one size fits all' approach when it comes to developing transport models to assess this range of schemes. Furthermore the geographical location of the scheme will also impact on the decision on the type of modelling that is appropriate.

A range of bespoke transport modelling software tools are available. The model types considered fall into four levels of transport modelling functionality, and are as follows:

- **Simple 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 the distribution of traffic flows will result from a proposed scheme. Simple 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;
- **Microsimulation models**, which simulate individual driver behaviour. Such models are suitable for complex interchanges and congested urban areas;
- **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. The 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.

Figure 5.1.1 below provides a reflection of the hierarchy of transport modelling, generally encountered by TII with respect to National Road schemes. Data exchange should operate between different levels of modelling to promote analytical consistency.

**Figure 5.1.1: Modelling Hierarchy**



For the most part, transport models developed in support of National Road schemes either form tests within a variable demand model, or involve the development of a bespoke assignment model. The requirement for variable demand modelling either using the TII National Transport Model or the National Transport Authority (NTA) Regional Models should be explored as part of the scoping process and Project Appraisal Plan.

It is not anticipated that any additional variable demand models will be developed outside of those mentioned above. Therefore, the focus of this guidance is on assignment models and their calibration and validation. Microsimulation modelling is not referred to explicitly within this Unit, however many of the principles of the Unit are equally applicable irrespective of model type.

## 1.3 The Role of Transport Models

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

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

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

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 scheme evaluations and appraisals follow the principles discussed herein and therefore enable TII to consider schemes on a like for like basis.

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 at an early stage.

Transport modelling 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.

Furthermore, it is important that the scope for using existing models and data is carefully considered. 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 appropriate and unnecessary complexity should be avoided. Finally, evidence should be of suitable quality to inform the decision making process, compiled using proportionate resources. The risks of using disproportionate time and resources can be minimised by specifying the model scope correctly from the outset. This should be explored and finalised via the Project Appraisal Plan.

# 2. Requirements of a Transport Model

A transport model needs to be capable of reflecting, to an acceptable degree, the existing transport situation as observed on the ground.

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

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?
- What are the main modelling risks (for example, the risk of errors in inputs) and how can these risks be mitigated?

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. Defining the Scope of a Modelling Exercise

## 3.1 Type of Model

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 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 rerouting effects and potentially, impact on other modes.

As a consequence, an assignment model or test within one of the available variable demand models may be required. If the appraisal is only required to capture re-routing then an assignment model is sufficient. However, if the appraisal also requires the capture of mode share, travel demand and induced demand effects then a test within the available variable demand models is required. Table 5.1.1 summarises the scope of the four levels of models identified.

**Table 5.1.1: Criteria for Scoping of Transport Models**

| Category | Simple Models | Microsimulation Models | Assignment Models | Variable Demand Models |
|---|---|---|---|---|
| **Description** | Manual assignment calculations using fixed demand flows. Can comprise junction modelling or static microsimulation modelling. | Models of complex intersections and arrangements, often in congested urban networks. Microsimulation models simulate the behaviour of individual vehicles. | Models which use a fixed demand matrix, and assess impacts of reassignment only. Assumes average conditions apply to all vehicles. | Models which include consideration of demand responses (Trip Generation, Distribution, Mode Share and Time of Travel) i.e. a change in transport conditions may result in a change in demand. |
| **Modelling Packages** | • PICADY (for simple priority or 'give way' junctions);<br>• ARCADY (for roundabouts);<br>• RODEL (also for roundabouts);<br>• OSCADY PRO (for signal controlled junctions); and<br>• TRANSYT (for signal controlled junctions and linked junctions);<br>• LinSig (also for signal controlled junctions and linked junctions). | • PTV VISSIM;<br>• Paramics;<br>• AIMSUN. | • PTV VISUM;<br>• SATURN;<br>• EMME. | • Model architecture available in the form of:<br>- TII National Transport Model;<br>- NTA Regional Models. |
| **Nature of Scheme** | • Minor schemes;<br>• Road safety schemes;<br>• Localised improvement. | • Major Schemes & Minor schemes in urban areas;<br>• New interchange or upgrade to interchange;<br>• Merging and weaving arrangements;<br>• Lane closures;<br>• Localised improvements in urban areas. | • Major schemes;<br>• New roads;<br>• Significant upgrades to existing roads;<br>• Large inter urban networks;<br>• Rural areas;<br>• Small urban areas. | • Strategic studies;<br>• Major schemes;<br>• New roads;<br>• Significant upgrades to existing roads;<br>• Interventions / traffic management in major urban areas;<br>• Public transport schemes;<br>• Intermodal impacts;<br>• Land use planning tests;<br>• Road pricing tests;<br>• Tests concerning infrastructure management e.g. tolling and multi point tolling;<br>• Tests concerning government transport policy, e.g. fuel price changes. |
| **Likely Impacts of Scheme** | • Rural road networks with no route-switching;<br>• Single or multiple junctions in urban areas with no route-switching. | • Model complex merging/shockwaves and incidents / closures;<br>• Areas with public transport;<br>• Schemes which will lead to changes in routing and behaviour; | • Schemes which will lead to changes in routing;<br>• Areas where induction or suppression of traffic is not anticipated. | • Schemes which will generate traffic impact;<br>• Major urban areas where congestion will exist;<br>• Schemes which lead to large reductions in journey time; |

| Category | Simple Models | Microsimulation Models | Assignment Models | Variable Demand Models |
|---|---|---|---|---|
| | | • Incidents where there is interactions between junctions e.g. blocking back of queues. | | • Areas where induction or suppression of traffic is anticipated;<br>• Schemes which will increase competition with public transport;<br>• Mode choice is likely to be a significant issue;<br>• Changes in trip costs may be large. |
| **Demand Inputs** | • Demand can be input by 15 minute segment in passenger car units (pcu). | • Demand can be entered by time segment;<br>• Demand can be assigned dynamically;<br>• Requires 'warm up' and 'cool off' periods. | • Aggregated demand entered generally by hour;<br>• A number of user classes (e.g. Light vehicles and Heavy vehicles) and trip purposes (commuting, work, and leisure) can be modelled. | • TII & NTA demand inputs for a variety of journey purposes and a variety of modes are based on: demographic & economic models, car ownership models, trip attraction generation models, and trip distribution models;<br>• Incorporates projections for horizon years. |
| **Prior requirements** | • Comprehensive junction geometry measurements;<br>• Junction Turning Counts;<br>• Queue lengths to complement traffic counts (which measure throughput rather than demand);<br>• Details of signal control in place, staging and phasing data at existing signalised junctions. | • Adequate 'warm up' and 'cool off' periods;<br>• Junction Turning Counts, origin-destination data and queue lengths;<br>• Detailed junction and link geometry;<br>• Details of signal control in place, staging and phasing data at existing signalised junctions;<br>• Detail on public transport network and stops;<br>• Detail on priority lanes;<br>• Scheme investment alternatives. | • Extensive transport data including: Automatic Traffic Counts, Junction Turning Counts, Origin-Destination data, queue lengths, and journey time surveys;<br>• Refined zone structure based on land use;<br>• Link lengths, link standard (cross section), speed;<br>• Demand matrix of trips by time period and user class;<br>• Major scheme investment alternatives;<br>• Land use proposals/scenarios to be tested. | • Agreement with relevant authority concerning model access and usage;<br>• Agreed modelling plan with relevant authority;<br>• Major scheme investment alternatives;<br>• Land use proposals/scenarios to be tested. |
| **Main Indicators / Outputs** | • Flow on each link;<br>• Delay on each link;<br>• Mean maximum queue length;<br>• Ratio of flow to capacity (RFC) and Degree of Saturation (DoS). | • Visual representation of issues;<br>• Journey times / travel times;<br>• Queue lengths;<br>• Delay;<br>• Vehicular throughput by link and junction;<br>• Average speed. | • Demand and actual link flows by user class per peak hour modelled;<br>• AADT flows;<br>• Travel time by link;<br>• Average speed by link;<br>• Time skims (i.e. average trip time between origin zones and destination zones for each user class);<br>• Distance skims (i.e. average trip distance between origin zones and | • Demand responses (volume and location of trips redistributing, changing mode, changing time of departure);<br>• Demand and actual link flows by mode and user class per peak hour modelled;<br>• AADT flows;<br>• Travel time by link;<br>• Average speed by link; |

| Category | Simple Models | Microsimulation Models | Assignment Models | Variable Demand Models |
|---|---|---|---|---|
| | | | destination zones for each user class);<br>• Network wide performance indicators such as total vehicle kilometres, total network travel time, total network delay and total network average speed. | • Time skims (i.e. average trip time between origin zones and destination zones for each user class of private and public transport);<br>• Distance skims (i.e. average trip distance between origin zones and destination zones for each user class of private and public transport);<br>• Toll skims (i.e. tolls as a result of traversed tolled links between origin zones and destination zones for each user class):<br>• Estimates of fare revenues;<br>• Network wide performance indicators such as total vehicle kilometres, total network travel time, total network delay and total network average speed. |
| **Scoping Issues** | • What is the model trying to assess?<br>• Definition of time periods;<br>• Choice of Model years. | • What is the model trying to assess?<br>• Extents of transport network;<br>• The number of vehicle type / user class matrices required;<br>• Definition of time periods;<br>• Choice of model years. | • What is the model trying to assess?<br>• The extent of the road network to be modelled?<br>• The level of detail of road network required?<br>• The definition of an appropriate zoning system?<br>• The number of vehicle type / user class matrices required?<br>• The definition of suitable time periods?<br>• The number of model years to be assessed? | • What is the model trying to assess?<br>• Will scheme alternatives / government policies result in modal shift?<br>• The extent of the road network to be modelled?<br>• The level of detail of road network required?<br>• The definition of an appropriate zoning system, if necessary?<br>• The number of vehicle type / user class matrices required?<br>• The definition of suitable time periods; and<br>• The number of model years to be assessed. |

## 3.2 Extent and Level of Detail of the Road Network

Irrespective of the model type, the extent of the transport network (area of influence) to be captured within the model is a significant factor in determining the overall resources required to undertake the modelling work. The modelled transport network should be the area of influence within which impacts are expected and no larger. For instance, 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.

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

For National Road schemes, the TII National Transport Model is the primary tool to assist in determining the model study area. Model runs of the National Transport Model with and without proposed schemes in place can be used to provide an initial indication of the area of influence of a scheme and hence the potential geographical boundary of the study area.

Alternatively, it may be possible to use other existing regional transport models (such as those developed by the National Transport Authority) to determine the modelled study area.

If an existing local area model is available from a previous study, even if it is quite old or of a coarse nature, then it should be possible to code in a representation of an indicative 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 fully reflect the degree of impact but the routes themselves are likely to be reasonable.

The level of detail required will generally 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.



## 3.3 Zone Systems

The size and number of model zones is a critical factor in determining the realism and accuracy of the transport model, particularly assignment models, 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.

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 since they are modelled as starting and ending at the same point. 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 alter the pattern of flows and delays given by the assignment model.

This is a particular problem in urban transport models that use for example detailed junction modelling 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. Reducing zone size will minimise these problems but will increase the complexity of the model and will increase run times.

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 towards the extremities of the model. They should also seek to follow, or be capable of being aggregated to, administrative boundaries, such as CSO Small Areas and Electoral Divisions, as this can prove useful when using other data such as population or household information. Within the constraint of the administrative boundaries, natural barriers to movement (rivers, railways, motorways and other roads) should be taken into account. Zones should also comprise areas of similar land use and should also be designed to minimise the number of zone connectors necessary for each. Care is required to ensure that the average zone size increases gradually and it is important that sudden changes in zone size are avoided.

It is also important to ensure that the resultant number of trips to and from individual zones near the centre or focus of the model should be approximately the same for most zones; and that the number of trips to and from each zone be some relatively small quantity to avoid unrealistically high loads appearing at some points in the network.

## 3.4 User Classes

It is 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 generally acceptable to model light vehicle 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.

Where schemes involve tolling, disaggregation of demand into travel purpose and income segments may also be warranted. However, it is important to note that, as a rule of thumb, doubling the number of user classes will approximately double model run times. Therefore, the value of adding additional user classes should be considered carefully.

## 3.5 Time Periods

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 models, irrespective of type, should therefore include:

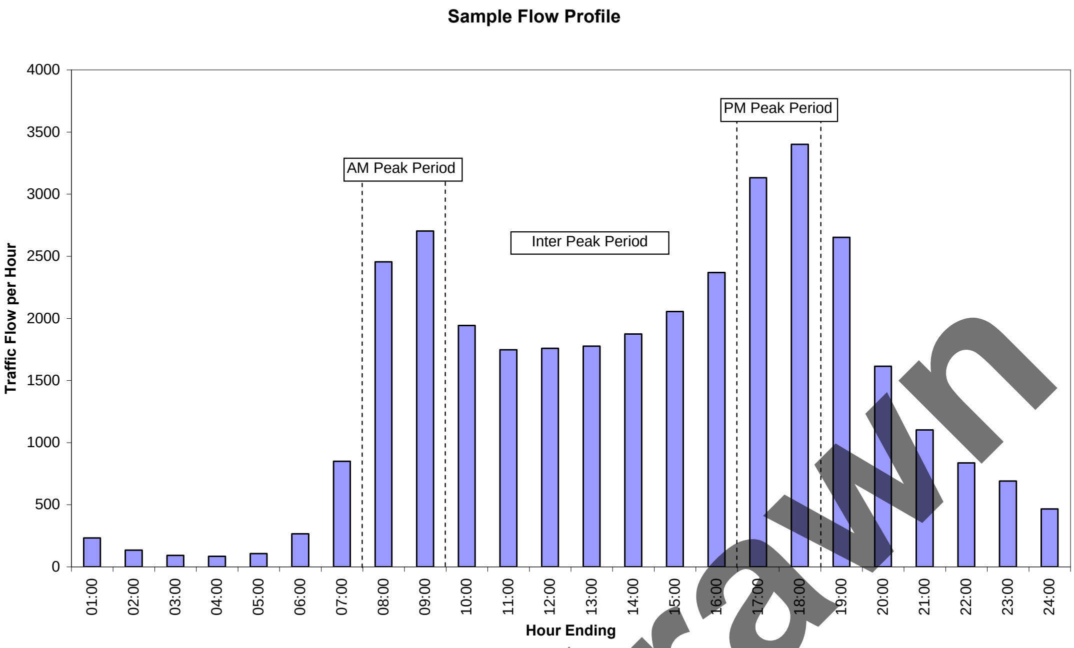
- An AM Peak Hour (neutral average weekday);
- An average Inter Peak Hour (neutral average weekday); and
- A PM Peak Hour (neutral average weekday).

In certain circumstances an off peak or weekend peak model may be required. This is due to the fact that the appraisal software of choice, TUBA, cannot calculate benefits for periods which are not modelled.

The choice of which hour(s) to use in each case will be informed by an analysis of traffic flow data in the form of Automatic Traffic Counts and TII Traffic Monitoring Units within the study area, particularly those in close proximity to the scheme. This analysis should designate the periods, generally AM and PM peaks where aggregate traffic flows clearly indicate a peak period with the Inter peak being a period between the two peaks during which the flows are almost constant.

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 5.1.2: Example of Daily Flow Profile**




## 3.6 Modelled Years

Irrespective of model type, the modelled years are dictated by both the design requirements and by the necessary inputs to appraisal. The transport 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).

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.

## 3.7 Generalised Cost

Within assignment models, the demand for travel, represented by trip demand matrices are applied to the available transport network. The route choice of trips is based on the generalised cost of each route option, generally represented by a combination of time, distance and road user charges, as follows (for vehicular travel on the road network):

Generalised Cost = Value of Time * Time + Vehicle Operating Cost * Distance + Road User Charges

The values of time and vehicle operating costs should be calculated using the values available in PAG Unit 6.11: National Parameter Values Sheet.

## 3.8 Capacity Restraint

Within assignment models, capacity restraint is the process utilised by which model speeds, and therefore model travel times and generalised costs, are adjusted so that they are consistent with the assigned traffic flows. Capacity restraint can be applied by the use of:

- Link based speed / flow relationships;
- Flow / delay modelling of junctions; or
- A combination of both.

Junction modelling is required where junction capacities have a significant impact on route choice and where delays are not adequately represented by speed / flow relationships applied to network links.

Speed / flow relationships developed and used within the TII National Transport Model may also be used within standalone assignment models, these relationships allow for effects of road geometry and other attributes to be taken into account.

# 4. Base Year Model Development

## 4.1 Overview

This section is generally focussed towards the development of assignment models. Again, microsimulation modelling is not dealt with explicitly, however many of the principles of the following paragraphs are equally applicable.

## 4.2 Model Cordoning

Creating a cordon model from a strategic donor model is often the starting point in developing a local area assignment model. Cordon models are generally created from a larger strategic model e.g. the National Transport Model. Note that the road based travel element of the National Transport Model has been developed to represent the average AM Peak hour (07:00 – 09:00) and an average Inter Peak hour (12:00 – 14:00).

Prior to creating a cordon model, establishing the extents of the study area for the local assignment model is vital. The study area should be identified using for instance, the 2050 High Growth National Transport Model version within which a Do Something version (scheme in place) is tested. The extents of the cordon model should be defined by changes in link flows. Care should be taken to ensure the extents of the cordon model are not too tightly drawn and the resultant model is sufficiently large to assess all potential Do Something variants.

Following the cordoning process and due to the general nature of the strategic donor model, it is expected that the road network be further refined to ensure an enhanced reflection of the road network and its characteristics. It is also expected that the zoning system and demand matrices from the donor model also be refined to improve the representation of trip patterns.

## 4.3 Network Building

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.

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.

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).

The level of network detail required will be greater in the core area close to the scheme and will 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.

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.

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. Zone connectors should not cross barriers to vehicular movement. 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. As a consequence, efforts should be made to minimise the number of connectors from individual zones, multiple connectors can lead to assignment instability and model convergence problems. Connectors from adjacent zones should not connect to the network at the same point.



## 4.4 Matrix Building

The production of base year trip matrices forms the foundation for the future year trip matrices used in scheme appraisal. They can be created from scratch but will often be based on:

- a cordon from a larger strategic model,
- an existing model which may be an older one from the area,
- from a regional model, or
- a model from an adjacent scheme.

In the case of an older local area model, the trip matrix may need to be re-validated using more recent count data.

Bluetooth and Automatic Number Plate Recognition surveys can aid the construction of matrices; trips are defined by the place of trip origin and the trip destination within the study area. This is known as an Origin-Destination (O/D) based matrix. Assignment models use this form of matrix.

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. It is not however, generally required, in the production of local area models.

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.

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.

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.

## 4.5 Assignment of Trips to a Network

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.

The aim of assignment models is to reach equilibrium such that generalised costs and traffic flows are in balance, under the assumption that individual users will seek to minimise their own costs of travel through the network. The underlying principle is expressed as Wardrop’s First Principle of Traffic Equilibrium, which may be stated as:

Traffic arranges itself on networks such that the cost of travel on all routes used between each OD pair is equal to the minimum cost of travel and all unused routes have equal or greater cost.

A number of assignment procedures/algorithms are available within the various transport modelling packages designed to achieve Wardrop’s First Principle of Traffic Equilibrium. Further information can be obtained within the relevant user manuals for the various packages.

## 4.6 Measures of Convergence

In assignment models, the assignment of demand onto a network alters the condition of the network (the level of congestion and hence the journey time). Therefore, the network state is recalculated after each assignment and the assignment is repeated until a stable condition is reached.

The final assignment is defined as the point when the difference between subsequent assignments is below a specific threshold (convergence). In practice, perfect convergence will not usually be achieved in assignment models. Failure to achieve acceptable convergence to equilibrium can lead to highly misleading results.

The convergence indicators provided by a number of different software packages vary, as does the availability of a facility for the user to control the assignment process to ensure a given level of convergence. Common convergence indicators include:

- 'Delta' or '%GAP': The difference between the costs along the chosen routes and those along the minimum cost routes, summed across the whole network, and expressed as a percentage of the minimum costs. This indicator is considered to be the most appropriate (truest) measure of assignment convergence.
- 'P' or 'P2': The percentage of links on which flows (given by 'P') or costs (given by 'P2') change by less than a fixed percentage between successive iterations. The percentage of links with minor changes in flow or cost provides an insight into the stability of the assignment as opposed to the degree of convergence. In other words these measures are not sufficient indicators of convergence in their own right.
- 'Epsilon': The degree to which the total area under the cost/flow relationships is minimised.

The most appropriate convergence measures and the values generally considered acceptable for use in establishing a base model are provided in Table 5.1.2 below.

**Table 5.1.2: Summary of Convergence Measures and Base Model Acceptability Guideline Values**

| Measure of Convergence | Base Model Acceptability Guideline Values |
|---|---|
| **Delta and %GAP** | < 0.1% or at least stable with convergence fully documented and all other criteria met |
| **% of links with flow change (P)<1%** | Four consecutive iterations > 98% |
| **% of links with cost change (P2)<1%** | Four consecutive iterations > 98% |

## 4.7 Route Choice Analysis

Prior to calibration, it is important to check and document route choice for each user class within each modelled period. The ability of the model to accurately represent route choice within the network depends on the quality of network coding and capacity restraint procedures. Issues may be related to zone structure, zone connectors, link and accuracy of junction delays and the accuracy of trip matrices.

It is not possible to examine the routing of all zone pairs. However, movements between key zones should be assessed focussing on key areas of population and / or employment. Plots of minimum path routes are a useful way of identifying potential issues or demonstrating the plausibility of the transport model. An example of a Route Choice Analysis between Dublin and Ardee from the National Transport Model is shown in Figure 5.1.3.

Observations on route choice may not be available; therefore these checks should examine route choice based on plausibility and local knowledge. As such these checks cannot be regarded as true validation; nonetheless remedial action should be taken to address any instance of implausible route choices.

**Figure 5.1.3: Route Choice Analysis – Dublin to Ardee (Example from National Transport Model)**

# 5. Model Calibration and Validation

## 5.1 Overview

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.

In advance of the calibration and validation processes, a comprehensive checking and cleaning process of observed datasets should be undertaken. 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.

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.

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 projections from that model should be treated with a high degree of scepticism.

The guidance supplied here applies to the calibration and validation of all model types, including simple, microsimulation and assignment models, whether they are constructed using macro-simulation, micro-simulation or junction modelling software. The model calibration and validation processes should be comprehensively documented within the Transport Modelling Report, in accordance with PAG Unit 5.4: Transport Modelling Report.



## 5.2 Network Calibration

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

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.

The final element (following adjustment of the network coding and relevant mathematical functions), is adjustments to the trip matrix i.e. matrix estimation (discussed in the following paragraphs).

This should only be undertaken once the modeller is assured that the network and mathematical functions within the model are operating correctly.

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.

When comparing modelled 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.

The criteria and associated acceptability guidelines to be used in the calibration of models are outlined in Table 5.1.3. Comparisons should be presented for each user class and each modelled period.

**Table 5.1.3: Calibration Criteria**

| Criteria and Measures | | Acceptability Guideline |
|---|---|---|
| Assigned hourly flows compared with observed flows | | |
| 1 | Individual flows within 100 v/h for flows less than 700 v/h. | More than 85% of cases |
| 2 | Individual flows within 15% for flows between 700 & 2,700 v/h. | |
| 3 | Individual flows within 400 v/h for flows greater than 2,700 v/h. | |
| 5 | GEH statistic:<br>individual flows – GEH < 5 | More than 85% of cases |
| Modelled journey times compared with observed times | | |
| 6 | Times within 15% or 1 minute if higher. | More than 85% of cases |



## 5.3 Matrix Estimation

Matrix estimation is the process by which the number of trips between zone pairs is adjusted to improve the match between assigned and observed flows along a modelled link. It is good practice to avoid manipulation of the demand matrices until all other possible modifications have been made. In this way the modeller can be assured that the network coding and relevant mathematical functions are operating correctly. This will avoid a situation when a matrix manipulation seeks to find a matrix that hides errors in the network coding or assignment functions.

Using transportation modelling software, it is possible to perform this operation at numerous locations in a single matrix estimation run, thus adjusting sections of the trip matrix to match observed demand. In the case of VISUM this matrix estimation tool is referred to as 'TFlow Fuzzy', in the case of SATURN it is referred to as ME2.

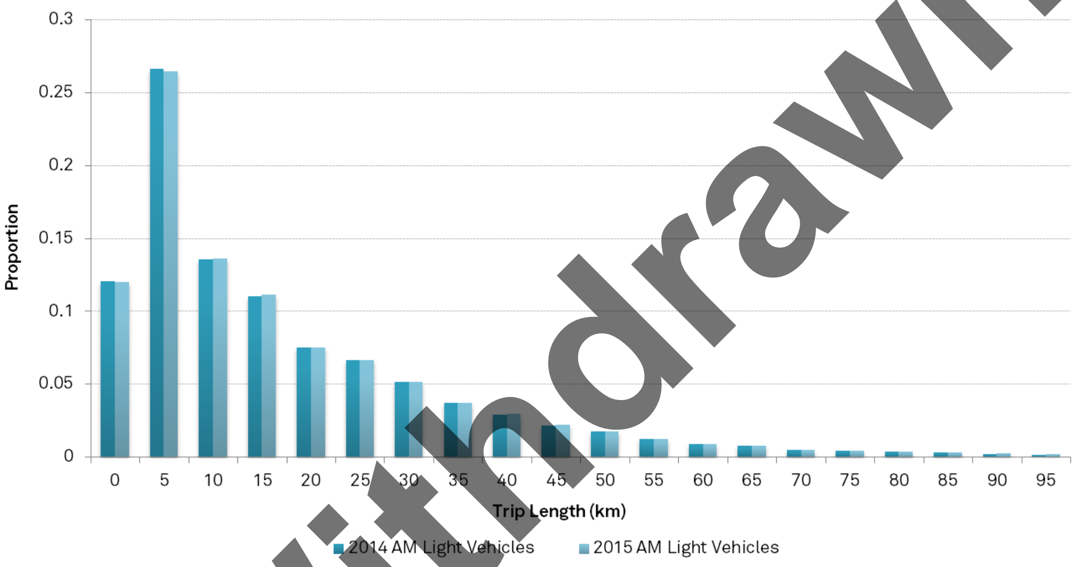
The general process across all transportation modelling packages requires the setting of numerical parameters and constraints including tolerance values (calculated as a percentage of observed volumes) in order to ensure accuracy within the subsequent matrix estimation process. A cautious approach should be adopted when undertaking matrix estimation and the changes brought about by the process should be monitored, refer to the following paragraphs for further detail.

## 5.4 Trip Matrix Calibration

### 5.4.1 Trip Length Distribution Check

An assessment of trip length distributions should be undertaken to ensure they have not been adversely affected by the matrix estimation (ME) process. This assessment should examine the prior and post (ME) matrices for the each of the user classes within all modelled time periods. This assessment will identify whether the matrix estimation process has targeted certain movements. An example of a trip length distribution check is illustrated in Figure 5.1.4 below.

**Figure 5.1.4: Sample Trip Length Distribution**




Any significant variations in trip length potentially brought about by matrix estimation should be examined further, in order to establish whether such variations are important or statistically significant. In such instances, the post calibration matrix should be revisited.

A coincidence ratio can be used to compare two distributions by examining the ratio of the total area of those distributions that coincide. The coincidence ratio is defined as:

$$\mathrm{CR} = \frac{\sum\{\mathrm{Min}\ (\mathrm{TLDs}, \mathrm{TLDf})\}}{\sum\{\mathrm{Max}\ (\mathrm{TLDs}, \mathrm{TLDf})\}}$$

Where TLDs is the source trip length frequency and TLDf is the final trip length frequency. A desirable range for the coincidence ratio is between 0.7 and 1.0 where a ratio of 1.0 suggests an identical distribution.

## 5.5 Screenline Analysis

An additional check on the quality of trip matrices should be undertaken by comparing modelled and observed flows across screenlines by vehicle type and modelled time period. The criteria and associated acceptability guidelines to be used in relation to screenlines are outlined in Table 5.1.4.

**Table 5.1.4: Calibration Criteria**

| Criteria and Measures | Acceptability Guideline |
|---|---|
| Total screen line flows (> 5 links) to be within 5%. | More than 85% of cases |
| GEH statistic: screenline totals < 4 | |
| Notes: Screenlines containing high flow routes (such as motorways) should be presented both with and without such routes. | |

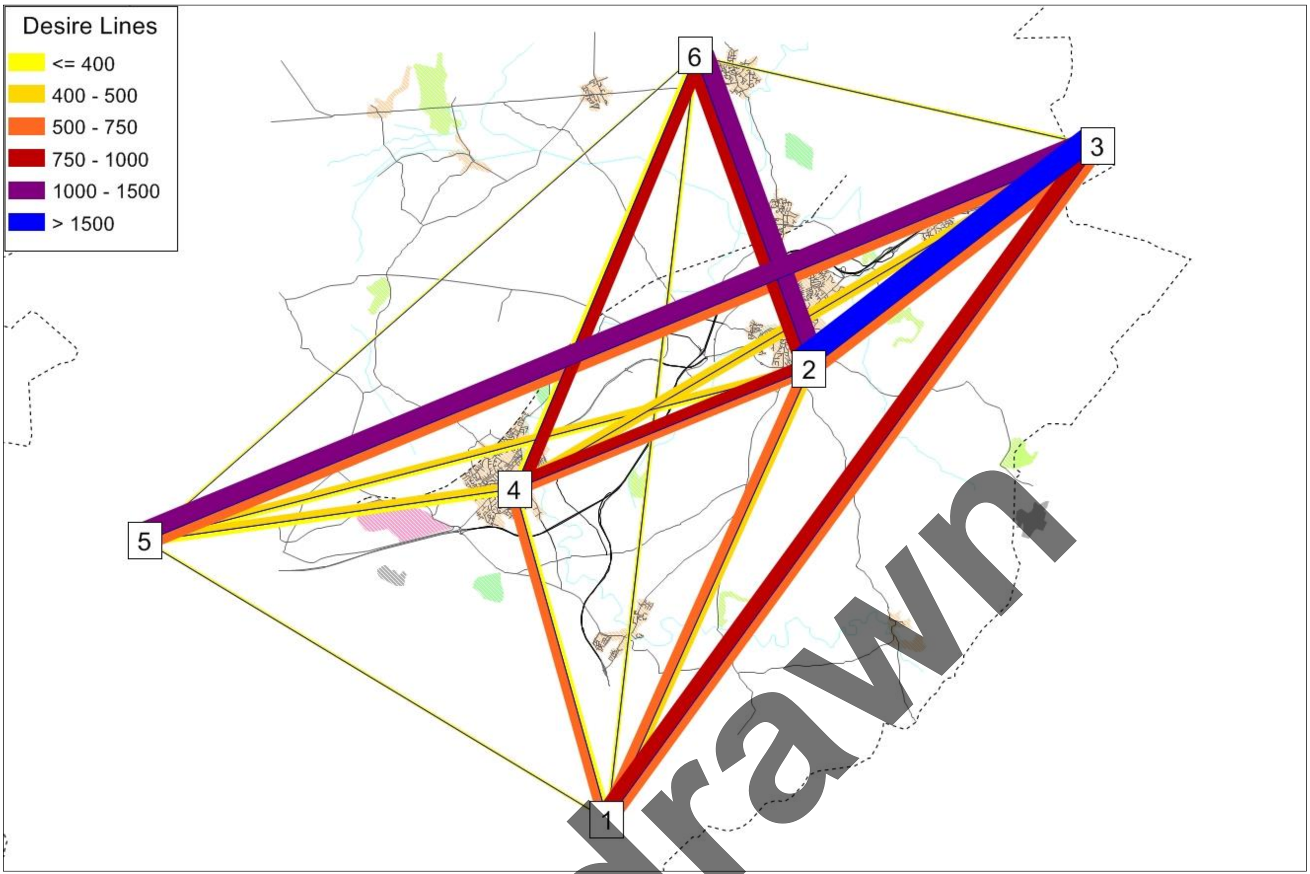
## 5.6 Origin-Destination & Desire Line Analysis

A validation of modelled trip matrices can be undertaken at a sector to sector level (e.g. collection of zones forming areas within the transport model), with additional detail at a zonal level if necessary using origin-destination data for each modelled time period. This demonstrates whether a model presents a good understanding of travel patterns within the study area. Origin-destination data collated through Bluetooth or Automatic Number Plate Recognition surveys should be utilised in this regard. The results of the origin-destination analysis should be presented in a tabular format.

It is recommended that modelled origin-destination patterns are compared against measured patterns based on the percentage split of destinations from each origin-destination survey location. A target deviation limit of ± 25% within more than 85% of samples should be attained.

As a final high level check on the trip matrices, a review of travel patterns within the modelled study area should also be undertaken to understand the dominant movements. This can be attained through an analysis of the key desire lines within the transport models. This analysis may highlight dominant demands and by-pass movements during each of the modelled peaks. These diagrams should use colour and bandwidth thickness to illustrate compatibility between observed and modelled desire lines. An example is provided in Figure 5.1.5.

**Figure 5.1.5: Sector Desire Lines Example**






## 5.7 Network Validation

The process of model validation determines how well the model estimates compare with reality as reflected by observations made on the ground. Care should be taken to ensure that sufficient quality count data is retained for the validation process.

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.

In light of the above, it is 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.

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; and
- Journey times along critical routes.

## 5.8 Validation Standards

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.

Comparisons of link flows, journey times and turning movements at junctions are key validation exercises, and form a check on the quality of the network and assignment. The count comparisons can also be done at an individual link level or by looking at groups of links as screenlines. The criteria associated with the validation of transport models are outlined in Table 5.1.5. Comparisons should be presented for each user class and each modelled period.

**Table 5.1.5: Validation Criteria**

<table>
<tr><th colspan="2">Criteria and Measures</th><th>Acceptability Guideline</th></tr>
<tr><td colspan="3"><u>Assigned hourly flows compared with observed flows</u></td></tr>
<tr><td>1</td><td>Individual flows within 100 v/h for flows less than 700 v/h.</td><td rowspan="3">More than 85% of cases</td></tr>
<tr><td>2</td><td>Individual flows within 15% for flows between 700 & 2,700 v/h.</td></tr>
<tr><td>3</td><td>Individual flows within 400 v/h for flows greater than 2,700 v/h.</td></tr>
<tr><td>5</td><td>GEH statistic:<br>individual flows – GEH < 5</td><td>More than 85% of cases</td></tr>
<tr><td colspan="3">Notes: Screenlines containing high flow routes (such as motorways) should be presented both with and without such routes.</td></tr>
<tr><td colspan="3"><u>Modelled journey times compared with observed times</u></td></tr>
<tr><td>6</td><td>Times within 15% or 1 minute if higher.</td><td>More than 85% of cases</td></tr>
</table>

The onus is on the modeller to use the Transport 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.

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 a variety of 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.

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.

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

## 5.9 Accuracy of AADT Estimates

A lot of time is concentrated on the generation of transport models which produce a reflection of peak hour conditions. However, an important additional element of information generated by transport models is estimates of AADT. The estimates of AADT are generally produced by applying expansion factors to the modelled period flows which generally comprise of one or both of the AM and PM peak hours, and the Inter peak. These expansion factors are derived from traffic data within the model study area. Further detail in relation to the development of expansion factors for short period traffic counts is provided in PAG Unit 16.1: Expansion Factors for Short Period Traffic Counts.

The resultant AADT flows will be utilised within the safety appraisal process (see PAG Unit 6.4: Guidance on Using COBALT for further detail) and will also likely be referred to within model related publications. Furthermore, AADT flows may form inputs to environmental models such as air and noise assessments; and are also utilised to determine road cross section and road make up. In light of this, it is important that the modelled AADTs match observed volumes in the 'base case' as closely as possible. Therefore, there is a need to validate the accuracy of the modelled AADTs against count data from which AADT values can be derived.

Therefore, it is recommended that modelled AADT flows are compared against measured AADTs using a suitable tolerance e.g. ± 15% (where observed AADT flows are greater than 700) within more than 85% of samples. Instances where observed AADTs are less than 700, modelled AADTs within ± 100 vehicles are considered acceptable. If comparisons of AADT show a high level of correlation between modelled and observed values, then model adjustment may not be necessary. However, if comparisons of AADT show unexpected variations between modelled and observed values, it may be necessary to make adjustments to the peak hour models in order that more accurate AADT estimates are produced.

## 5.10 Junction Model Validation

Should a simple junction model be developed in support of the appraisal of a TII scheme, there is a need to ensure that such a model is also calibrated and validated, although these processes can be combined into a single procedure for models of this type. A number of criteria should be used including, at a minimum, those in Table 5.1.6.

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.

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 a Urban Traffic Control (UTC) system – as the theoretical optimisation as dictated by a junction modelling programme can be difficult to achieve.

**Table 5.1.6: Junction Model Validation Criteria**

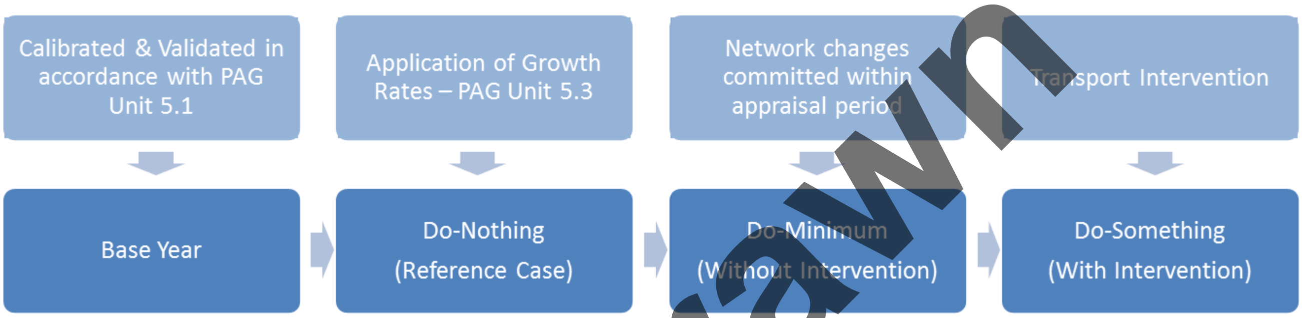
| Criteria and Measures | Acceptability Guideline |
|---|---|
| Mean Maximum Queue length (m) per traffic lane | ± 15% |
| Signal timings and Intergreen periods (s) | Modelled = Observed |
| Stopline traffic flows (passenger car units) per arm | ± 2% |
| Journey Time (for linked junction models) | ±10%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

# 6. Treatment of Future (Opening & Horizon Year) Networks

Projecting the usage and performance of transport networks is a critical component of transport appraisal. Transport models are also used to assign transport demand projections with a view to determining how travel patterns of demand will change over time. The development of transport demand projections for application within transport models is discussed separately in PAG Unit 5.3: Travel Demand Projections.

Figure 5.1.6 below shows the transport model structure necessary to assign transport projections and inform a transport appraisal. The process begins with the development of a 'reference case' (Do-Nothing scenario) by factoring the base year demand to each future year required.

**Figure 5.1.6: Transport Model Structure for Transport Demand Forecasting**




A 'without intervention' (Do-Minimum scenario) is then developed off the Do-Nothing scenario, which includes planned or committed transport network changes within the study area, anticipated to be completed within the appraisal period. The Do Minimum scenario provides the platform which will enable the assessment of any transport interventions or policies proposed. In certain circumstances, it is accepted that the Do-Minimum may actually be a Do-Nothing scenario.

'With intervention' (Do-Something) scenarios are then developed in which the impact of various schemes and policies can be tested and compared against the Do-Minimum scenario. With respect to the Do-Something transport network, it will be based on the Do-Minimum network, the only difference between the Do-Minimum and Do-Something scenarios will be the presence of the intervention itself and any necessary reclassifications of downgraded roads.

The inputs related to generalised cost should be adjusted in each scenario to take account of the future year assessed. The recommended growth in factors pertaining to generalised cost is given in PAG Unit 6.11: National Parameter Values Sheet. These factors must be used to update the base generalised cost assumptions in forecast years and must be the same in the Do-Minimum and Do-Something scenarios in order to allow comparability.

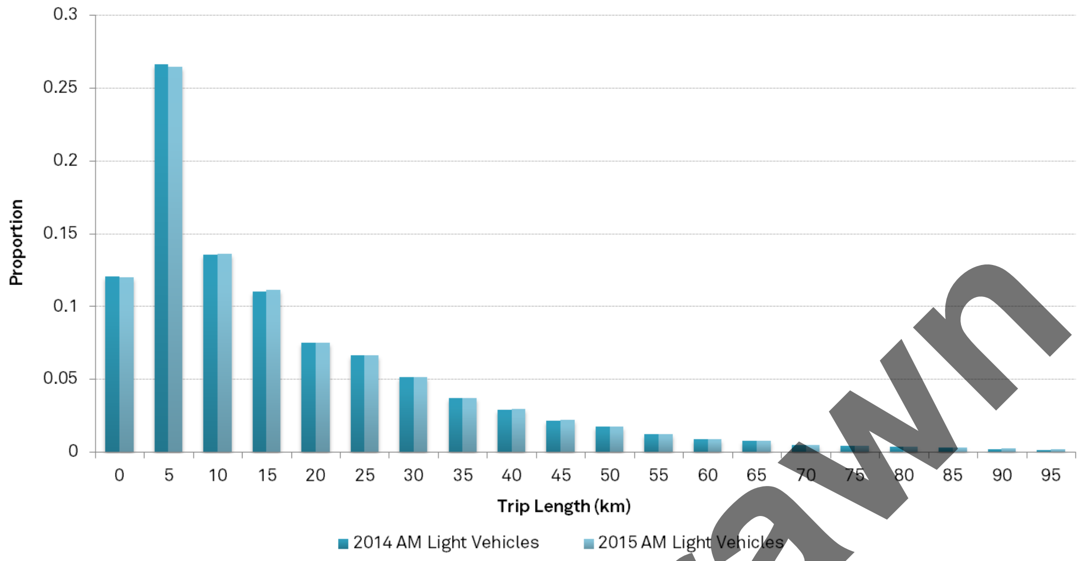
## 6.1 Assessing Modelled Traffic Projections

Applying projections to the model network, allows it to predict what may happen if the Do-Something scheme was built, and how this compares to what would happen if it was not.

However, in advance of constructing the Do-Something model, it is recommended to undertake an assessment of the impact of traffic growth within the Do Minimum horizon year models on key demand indicators to verify that the outputs from the traffic growth process are sensible.

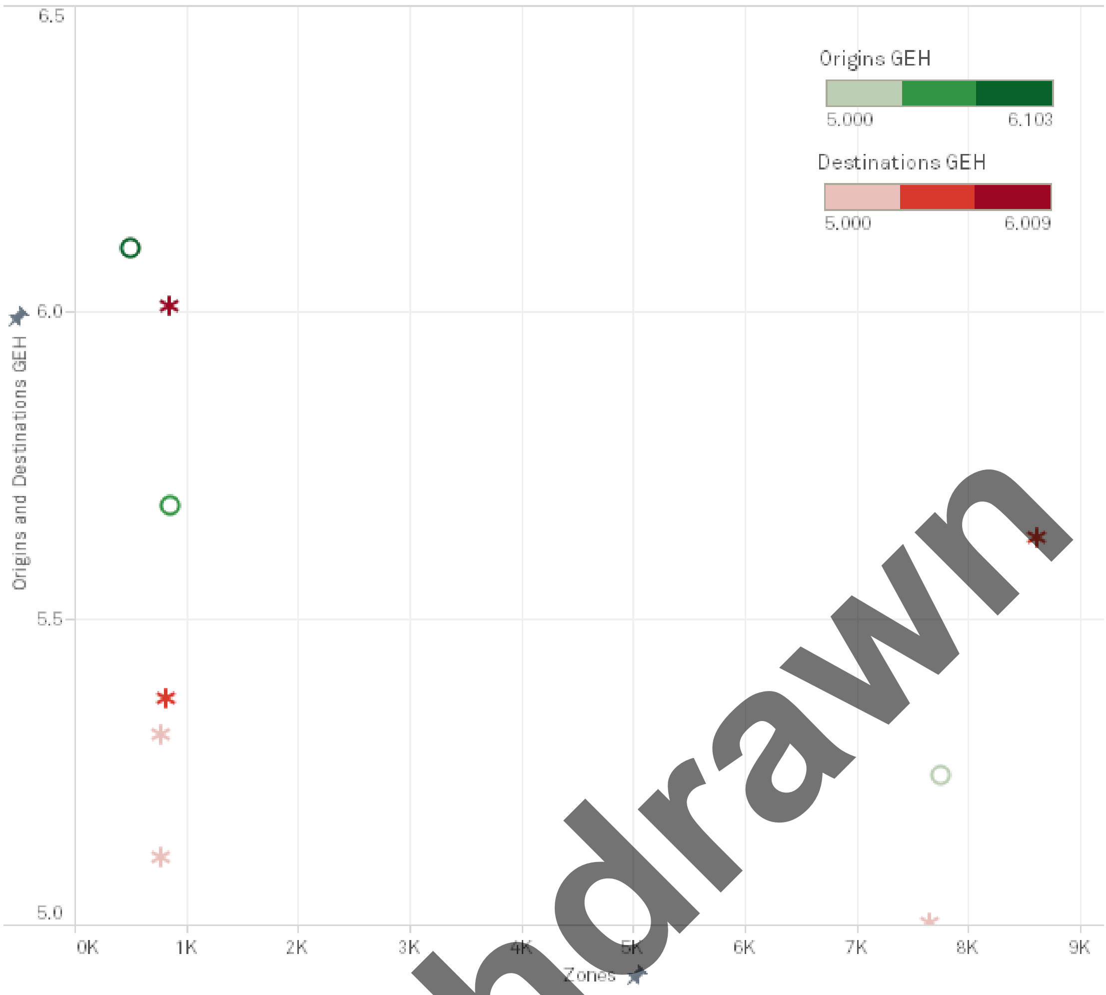
A comparison of Trip Length Distribution (TLD) in the Base and horizon year (Do Minimum models) represents a check that the outputs from the traffic growth process are sensible. The proportion of trips in the various time bands should be similar between the base and the horizon year, (e.g. no significant change in short trips). An example of how this assessment could be presented graphically is shown in Figure 5.1.7 below.

**Figure 5.1.7: Sample Trip Length Distribution**




An assessment of the Trip End Growth (TEG) between the Base and horizon year demand (Do Minimum models) during each time period will also determine if there are any significant changes in demand at zonal level compared to the overall growth between the two scenarios. In order to assess the true magnitude of Trip End Growth, the GEH statistic must be applied to the Base and horizon year trip ends in order to take account of not only the difference between the Base and future year demand, but also the magnitude of the difference. A GEH statistic exceeding 10 requires investigation. An example is illustrated in Figure 5.1.8.

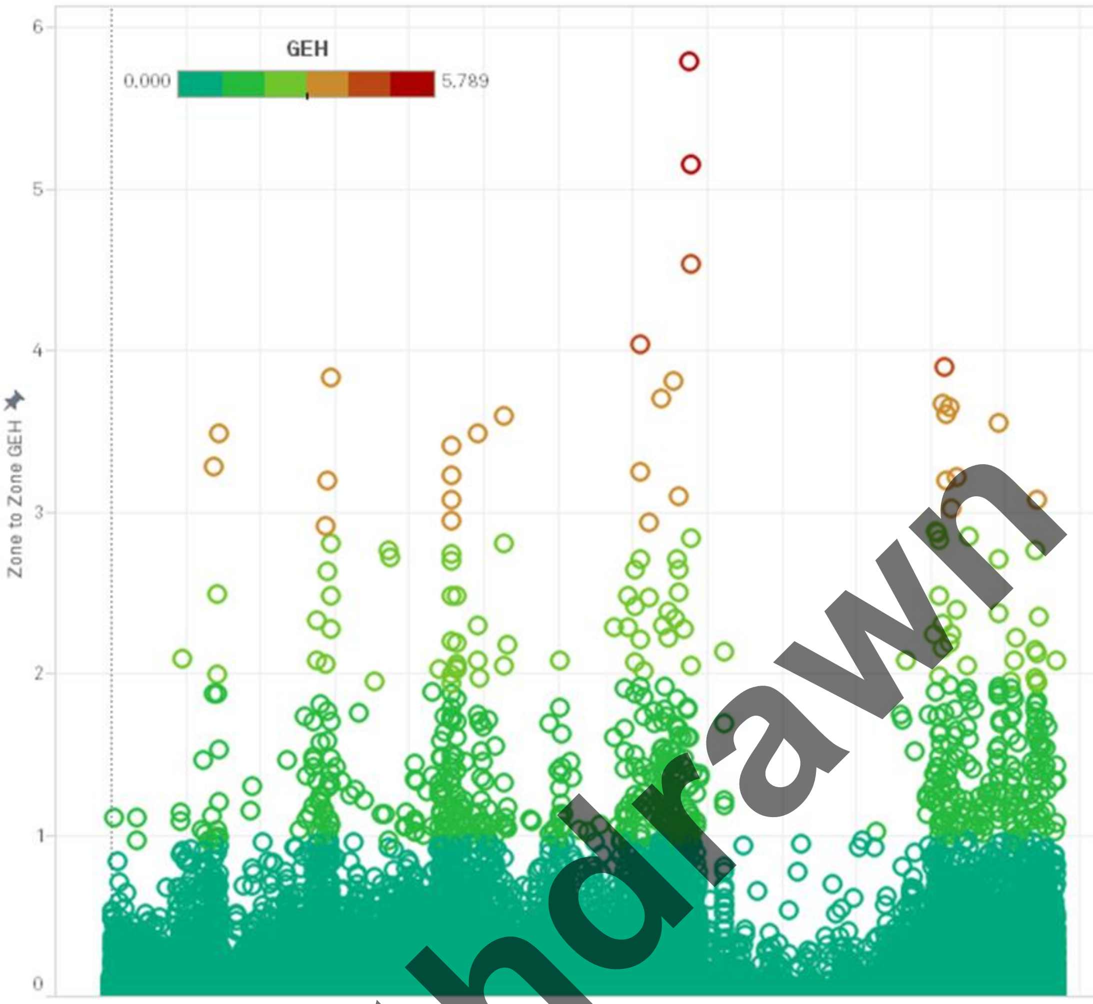
**Figure 5.1.8: Trip End Growth Comparison Example**






The same procedure as is recommended for Trip End Growth should also be undertaken for zone to zone growth during each time period i.e. for each origin-destination pair, an example is shown in Figure 5.1.9. Again, a GEH statistic exceeding 10 should be investigated.

**Figure 5.1.9: Zone to Zone Growth Comparison Example**



# 7. Versions of Transport Modelling Software

Software providers very often offer new versions of their software for a variety of reasons including the introduction of enhanced features or the release of software patches to address specific issues. It is therefore important for the modeller to keep abreast of these developments and choose the most appropriate software version for the model being developed.

It is also essential that the software version does not change between the calibration of the base model and the production of a proposed model. Even with identical inputs, it is common for different software versions to produce different results. It will invalidate a previously validated model if it is used in a software version different from the one in which it was originally developed.

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