Transport
Roads & Maritime
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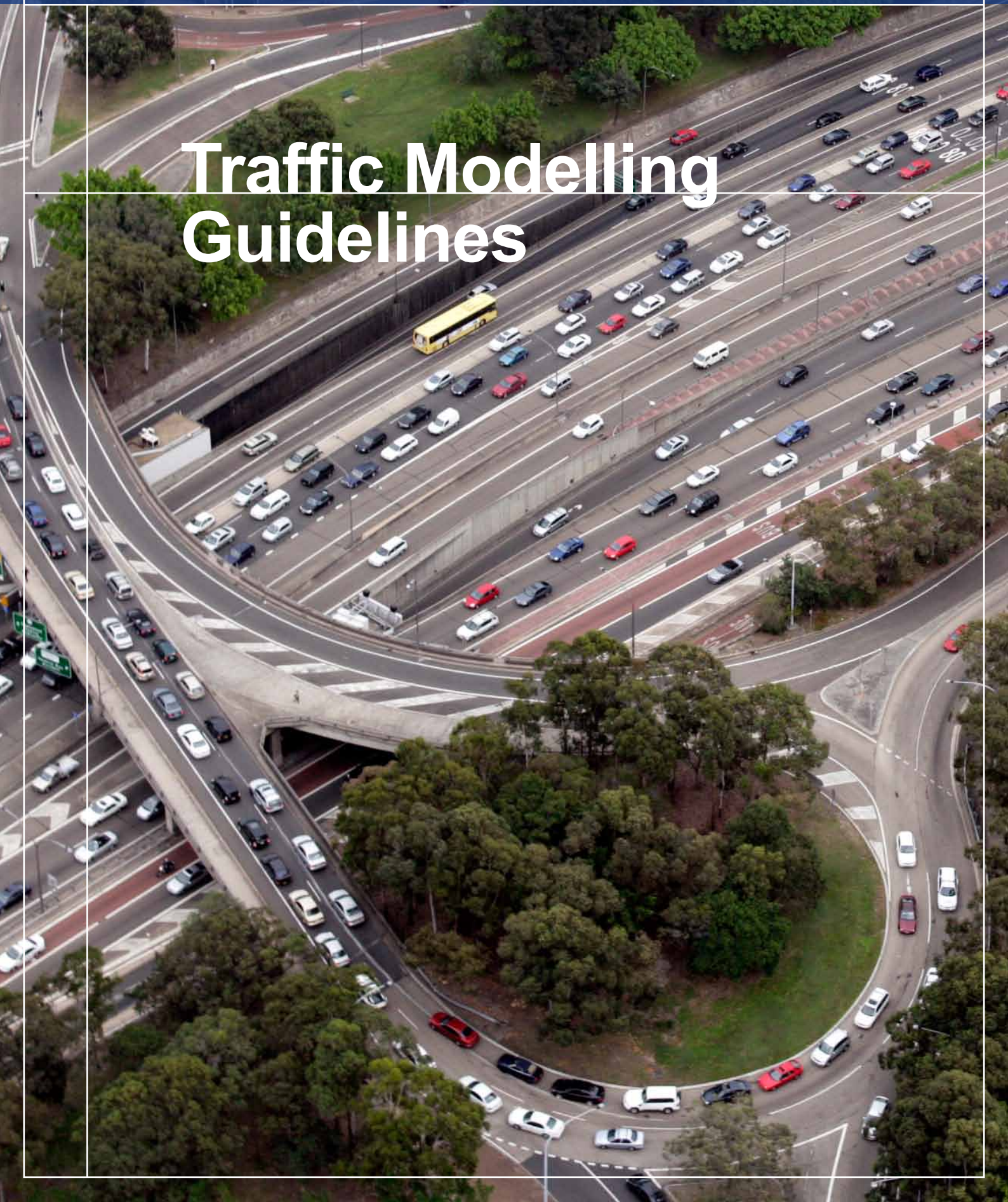
NSW GOVERNMENT

Traffic Modelling Guidelines



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Traffic Modelling Guidelines

Transport Roads & Maritime Services

Roads and Maritime Services
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"All models are wrong some are useful."

George Box

NSW Roads & Maritime Services (RMS) has developed these guidelines to develop consistency in traffic modelling practice and promote high quality model outputs that will lead to high quality project design.

The development of these guidelines has been influenced by a number of sources including:

TfL – Transport Modelling Guidelines Version 3

RMS – Paramics Microsimulation Modelling Guidelines

New Zealand Transport Agency (2010) Economic evaluation manual (Volume 1)

SIDRA Solutions – SIDRA Intersection User Guide

The guideline is presented into two parts:

Part A provides an introduction to the various levels of traffic modelling outlines the appropriate usage of modelling and provides a framework for model selection. This section also outlines the model process and describes general model requirements.

Part B is designed for modelling practitioners and provides guidance on modelling practice. Each chapter describes one level of modelling including appropriate modelling standards and fitness for purpose descriptions. Sub-sections are dedicated to each of RMS' accepted modelling software.

RMS has a number of internal modelling stakeholders. All of these stakeholders were included in the development of these modelling guidelines:

- Traffic Management branch.
- Network Operations branch.
- Transport Planning branch, Sydney Region.
- Infrastructure Development branch.
- Bus Network Development.

Other NSW Government stakeholders involved in the development of these guidelines include The Bureau of Transport Statistics from Transport for NSW.

RMS also wishes to acknowledge the input from the private sector in the development of these guidelines including:

Australian Centre for Commercial Mathematics, UNSW; AECOM; GHD; Halcrow, SKM; SMEC; and Transport Modellers Alliance.

Disclaimer

Roads and Maritime Services (RMS) makes no representation or warranty in relation to these Traffic Modelling Guidelines, as to the accuracy or completeness of the information contained within it, or the accuracy or completeness of any model outputs as a result of its use.

The Traffic Modelling Guidelines, or any model outputs are in no way binding on RMS and may not be appropriate for your specific needs or circumstances.

The Traffic Modelling Guidelines only provides the minimum level required for model development, calibration and validation. Some models (for example, models to be used for financial analysis) require more stringent standards and it is the responsibility of the user to ensure that the models they develop are fit for their intended purpose.

The Traffic Modelling Guidelines are only relevant in NSW and the purpose of the Modelling Guidelines is to act as a guide for use by modellers and managers undertaking work for RMS. Any use of the Traffic Modelling Guidelines outside of RMS work and the jurisdiction of NSW is at the users own risk.

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Amendment record

Please note that the following updates have been made to this document.

Amendment No	Page	Description	Issued	Approved By

Part A – Modelling matters

1 Introduction

1.1 Background

RMS is the NSW State Government agency responsible for:

- Improving road safety.
- Testing and licensing drivers and registering and inspecting vehicles.
- Managing the road network to achieve consistent travel times.

The road network that RMS manages includes:

- 18031 km of RMS-managed State roads, including 4323 km of National Road Network, for which the Australian Government provides a funding contribution, and 147 km of privately-funded toll roads.
- 2970 km of regional and local roads in the unincorporated area of NSW.
- 5190 bridges and major culverts and 23 tunnels.
- 3867 traffic signals and more than 12000 other road traffic facilities, systems and corridor assets.

RMS utilises a set of software tools and guidelines to accurately assess network conditions and plan future operations.

1.2 Purpose of this manual

The purpose of this manual is to provide guidance in modelling to both RMS staff and those undertaking work for RMS in order to develop consistency in traffic modelling practice and promote high quality model outputs that will lead to high quality project design.

This guideline is specifically designed to provide guidance without being prescriptive or limiting the modeller building the model. A proportion of the content of the manual is designed to make the model scope, building, submission, review and approval as transparent as possible for all parties without inhibiting the practitioner in the technical construction of the model.

There are several globally recognised published documents that detail the technical aspects of model calibration and appraisal. These documents are acknowledged as valid documents and it is not intended that this manual supersedes or emulates them. Some issues arising from these documents have been incorporated into this manual in the context of RMS applications as required.

In developing these guidelines, RMS commissioned a number of expert service providers and instigated Modelling Guidelines Working Groups comprising RMS, Transport for New South Wales (TfNSW) and various expert service providers to assist in the development of each section of the guideline.

It is intended that the manual be periodically reviewed and updated as required so that it is current, useful and relevant for practitioners and incorporates the latest thinking and advancements in traffic and transport modelling.

2 Levels of traffic modelling

2.1 Background

Increasingly as traffic modelling software evolves, restricting these developments to the traditional concepts and definitions of traffic modelling levels becomes problematic. In recognition of this and to provide clarification to both:

- Modellers providing services to RMS.
- Project managers assessing impacts of their projects.

RMS have identified model levels based on, five levels of modelling that can be used to describe the various applications of models to NSW traffic conditions. Historically within NSW, traffic and transport modelling has been undertaken at five distinct levels of scale and detail, utilising a number of modelling packages:

- ***Strategic models*** – EMME (Sydney Travel Model STM).
- ***Highway assignment models*** – EMME, TransCAD, Dynameq, VISUM, Aimsun, CUBE, OmniTRANS.
- ***Microsimulation models*** – Paramics, VISSIM, Aimsun, Commuter (strictly speaking some of these software now employ nanoscopic agent-based simulation).
- ***Corridor models*** – LinSig, Transyt, SCATES.
- ***Single Intersection models*** – SIDRA.

In addition to these five levels of modelling it is recognised that there are a number of modelling packages that are scalable in both network size and detail (and can therefore be considered as applying to two or more modelling levels) some examples that have been applied in NSW include: VISUM, Aimsun, CUBE and OmniTRANS.

2.2 Strategic models

Strategic models cover large areas generally with limited detail. They use complex algorithms and mathematical formulae to determine delay and travel time (these models have traditionally been deterministic but on-going research in this area includes stochastic applications). Strategic models are generally multi-model models that examine broad transport demands.

Currently the Sydney Strategic Travel Model (STM) run by the Bureau of Transport Statistics provides the majority of Strategic Modelling for the Sydney Greater Metropolitan Area. Inputs to the STM include:

- Household travel survey (HTS) data.
- Journey to work (JTW) data.
- Population and employment (current and projected).
- Freight movement model (FMM) data.
- Parking survey data.
- Road, rail, bus and ferry networks.

The STM is a series of models and processes that attempt to replicate, in a simplified manner, people's travel choices and behaviour under different scenarios based on tour legs (rather than trips) providing for better insights into journeys involving intermediate destinations and non-home based travel.

Outputs include:

- Trip tables (for use in other models such as highway assignment models).
- Network speeds.
- Public transport flows.
- Public transport travel times and costs.
- Station usage estimates.
- Vehicle Kilometres of Travel (VKT).

Due to their large area and limited detail, strategic models are best used for broad network evaluation and demand forecasting.

2.3 Highway assignment models

Due to the strong links between highway assignment models and strategic models it is recommended that the zoning system used in highway assignment modelling is consistent with (or has a direct equivalence to) the strategic modelling.

Highway assignment models require two key inputs:

- Network – the model network incorporates physical characteristics of the road network such as number of lanes, link length and road hierarchy.
- Demand – demand for Highway Assignment Models can come from two sources:
  - Strategic models – where output trip tables from strategic models are used as input to highway assignment models.
  - Traffic generation/distribution models – where trip tables are developed from first principles using traffic generation and trip distribution models.

For the purposes of these guidelines highway assignment models can be considered at two levels described below.

2.3.1 Macroanalytical (Strategic highway assignment)

These models are similar to those used in strategic modelling, however they only examine vehicle flows. The models generally include more detail than a strategic model and should include some level of intersection delay (most commonly intersection approach delay applied to links). These models are generally based on a traffic equilibrium assignment. Typically in NSW these models are in EMME or TransCAD. Other software packages include CUBE Voyager, VISUM, Aimsun and TRACKS.

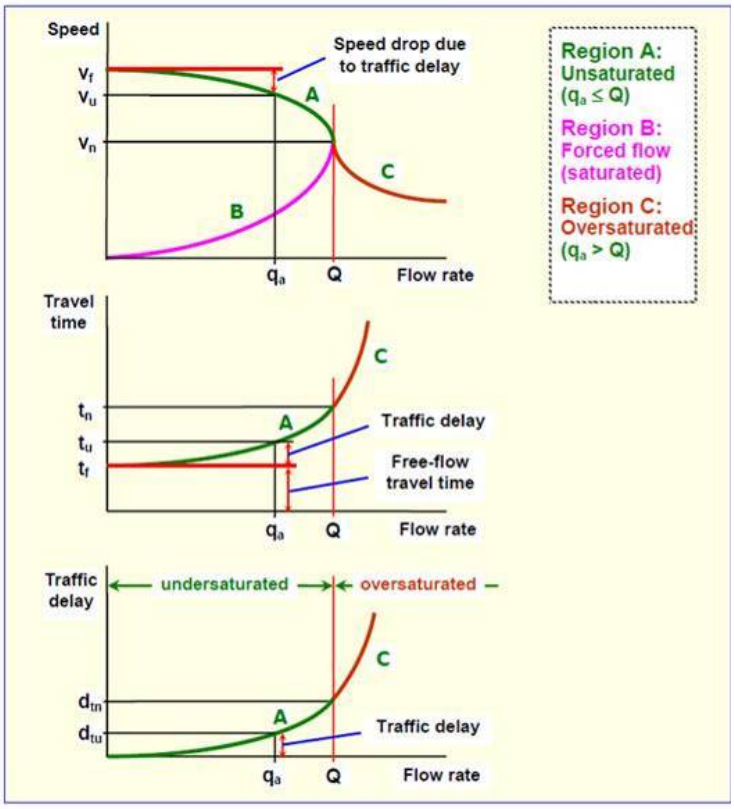
2.3.2 Mesoscopic simulation (Meso highway assignment)

These models cover large areas and include intersection details to more accurately reflect intersection delay. At present they are not used extensively in NSW. Mesoscopic models can use an equilibrium assignment but may also include the ability to dynamically model route choice. Examples of mesoscopic modelling packages include Dynameq, VISUM, Aimsun, CUBE Avenue and OmniTRANS.

Macroanalytical highway assignment models combine the network and demand using volume delay functions (or speed flow curves). These functions calculate travel time (or speed) on a link based on a prescribed formula and the modelled volume over capacity (v/c) ratio. Figure 2.1 illustrates the form of these prescribed formula for speed, travel time and traffic delay when plotted against flow rate.

Mesoscopic highway assignment models use a variety of techniques to assign the demand to the road network. Mesoscopic models can use a combination of volume delay functions, shockwave and queue propagation algorithms as well as intersection delay calculations when assigning demand to the network.

Mesoscopic modelling can be lane-based or link-based (depending on the level of detail required and software employed) and can use a dynamic (where paths change throughout the model period) or a fixed stochastic assignment technique.



Source: SIDRA Output Guide (Figure 25.5) Akcelik and Associates

Figure 2.1 Volume capacity curves

2.4 Microsimulation models

Microsimulation models are dynamic, stochastic, discrete time modelling techniques that simulate the movement of individual vehicles based on car-following, lane changing and gap acceptance algorithms that are updated several times every second. These vehicle-to-vehicle interactions provide the basis for calculating delays.

Their flexibility allows the modelling of complex traffic operations. Microsimulation models can use combinations of “all or nothing”, stochastic or dynamic traffic assignment depending on the model purpose. Examples of microscopic modelling packages used in NSW include Paramics, Commuter and VISSIM. Aimsun has is also been used in other jurisdictions.

The advantage of this type of modelling is that the build-up and dissipation of queues and their effect on surrounding congestion and travel times is sensitively modelled. This type of modelling can provide a better representation of queuing, congestion and delays in at-capacity urban networks. The real-time on-screen simulation of individual vehicles also makes microsimulation a useful tool when presenting traffic modelling to a non-technical audience.

The level of detail in microsimulation models is also reflected in the detail required for network and demand coding. Microsimulation models require significant network detail (including link, intersection and signal operation detail). Fine detail in demands (including zoning and fleet characteristics) is also a requirement for microsimulation.

The increased level of detail required for simulation modelling also increases data requirements. Detailed traffic surveys including turn movements, travel times and queuing should be undertaken for microsimulation modelling.

If demand matrices for microsimulation are required (as some microsimulation software allows for direct coding of turn movement proportions without the need for matrices) then they can come from a number of sources including:

- Highway assignment models – although these will almost certainly require some refinement to obtain the level of detail required for simulation modelling.
- Manual estimation – traffic surveys and manual estimation techniques to develop a trip matrix.
- Matrix estimation – using (where available) a package's trip table estimation function or some other automatic methods for generating tables based on available data.
- Future traffic flows can be estimated using highway assignment models or by applying growth factors as appropriate.

2.5 Multi-intersection models

Multi-Intersection models are typically used for the analysis and optimisation of a corridor or small network. Corridor models can either be analytically or simulation based. Corridor models will provide optimised signal timings under infrastructure and demand scenarios, however some of these modelling software require the user to define an appropriate phase sequence. LinSig is RMS' preferred multi-intersection model however other examples include TRANSYT and SCATES. VISUM, VISSIM, OmniTRANS and Aimsun are also capable of providing optimised signal timings either directly or through interfaces with LinSig and TRANSYT.

Due to the nature of the models, traffic surveys must be undertaken at all intersections to be modelled. Other critical data collection includes signal operation, queue observation and saturation flow measurement (or estimation).

Future traffic flows can be estimated using highway assignment models or by applying growth factors as appropriate, although highway assignment models should only be used to estimate traffic growth as they are generally too coarse to adequately produce detailed turn movements.

2.6 Single intersection models

Single intersection models are used at isolated intersections or where the effects of coordination are not required to be modelled explicitly. Single intersection models will provide optimised signal timings under infrastructure and demand scenarios, however the user must generally define an appropriate phase sequence (note that a number of single intersection software packages allow for phase optimisation but these are not generally used in NSW). SIDRA is the most commonly used single intersection modelling software in NSW and can automatically remove phases from the phase plan if a more effective intersection operation results.

Undertaking option assessment in a single intersection environment can have significant time and cost saving advantages. However, if the intersection influences (or is influenced by) another intersection or downstream queuing then corridor or microsimulation modelling of a preferred option should be undertaken to ensure network effects are adequately considered.

Single intersection modelling requires traffic surveys of the intersection to be modelled including traffic flows, signal operation and queuing.

Future traffic flows can be estimated using highway assignment models or by applying growth factors as appropriate, although highway assignment models should only be used to estimate traffic growth as they are generally too coarse to adequately produce detailed turn movements.

2.7 Sydney Coordinated Adaptive Traffic System (SCATS) portfolio products

While not considered as a separate level of modelling, the use of SCATS products in simulation models has demonstrated benefits in congested networks. Their need for application should be considered against the additional resources (and costs) required to include their functionalities in the development of traffic models. Only microscopic simulation models have so far been linked to SCATS products.

2.7.1 Sydney Coordinated Adaptive Traffic System (SCATS) in simulation

SCATS in Simulation (SCATSIM) provides RMS with a method of testing SCATS operation in an offline environment. SCATSIM models require the user to have a detailed understanding of both microsimulation and SCATS.

SCATSIM models should be used were SCATS operation is critical to the function of the network being tested or where changes to SCATS operation are proposed. As SCATSIM models require significant input from RMS personnel, they require the agreement of the Network Operations staff prior to commencement.

2.7.2 SCATS ramp metering system (SRMS)

Ramp metering is used to manage the on-ramp flow of traffic onto motorways when traffic demand exceeds capacity. SRMS is fully adaptive, integrates with SCATS and can implement metering in response to actual traffic demand and incidents on the motorway.

As greater emphasis is placed on managing the existing road network efficiently the need for models to reflect benefits of SRMS is likely to become significant.

2.7.3 Public Transport Information and Priority System (PTIPS)

The progression and reliability of on-road public transport is a crucial element of the road traffic network that is likely to require proper representation in models. While emulations of this software have been applied to models in the past there may be a need to include this functionality as part of corridor and network models in the future.

2.8 Model integration

Where a project is using multiple levels of modelling, some level of model integration may be appropriate. The type of information that is most useful for integration is model inputs such as network configuration or demands. Passing information from a higher level model to a more detailed model is relatively straight-forward as this information tends to act as an upper bound constraint that informs the development of the detailed model.

Passing information from more detailed modelling to higher level models can create inconsistencies between areas that include more detail than the surrounding network. Unless modellers can prove that increased detail in a specific area does not influence route choice in surrounding areas, the passing of information from detailed models to high level models is not recommended.

2.8	Project managers and modellers should understand which level of modelling is appropriate for their particular study and be aware of the problems in passing information from detailed models to high level strategic models. RMS SCATS portfolio products are likely to have an increasing role in model development and their inclusion should be balanced against the likely increased costs (and RMS resources) of the modelling study.

3 Appropriate use of modelling

Before deciding on the appropriate level of modelling, the first decision to be made is whether modelling is necessary. Transport modelling can be expensive and there may be better value for money achieved by means other than modelling.

Several key questions require consideration in determining if modelling is necessary. These questions include:

- What is the project objective?
- Why is the analysis required?
- What are the characteristics of the project being analysed?
- What questions should the analysis answer?
- What are the road network features and traffic characteristics?
- Are traffic problems identified?
- What are the scenarios to be studied/tested?
- What are the design years?
- Who are the recipients of the result /who will approve the model?
- What is the extent of the model required?
- What data and information are required for the model and are these data available, affordable and practical?
- What modelling outputs are required?
- What is the peak period (or representative time period that covers project criteria) to be modelled?
- What are the potential benefits/uses of the model beyond the project?
- What previous relevant experience modelling work has been undertaken in the vicinity and is it appropriate to re-use it?
- What are the risks and implications of likely errors in the modelling results?

Preliminary analysis using first principles, simple analytical methods or site visit may be sufficient to answer the above questions. If preliminary analysis is deemed not to be sufficient then modelling may be required.

Once it is determined that modelling is required, the next step is to determine the most appropriate level of modelling. The use of the appropriate level of modelling is critical in determining the success of a modelling project. The use of inappropriate software can lead to poor project outcomes as well as significant cost and delays.

When assessing the level of modelling to be used consideration must be given to:

- Traffic.
- On-road public transport.
- Pedestrians.
- Cyclists.
- Road network features.
- Traffic control systems.
- ITS applications.
- Environment.

Austroads has developed a tool for assisting in appropriate model selection under Austroads Project NS1371 “Guidelines for Selecting Techniques for the Modelling of Network Operations”. This process has been used as a starting point for model selection in this guide as it is recognised that a simple table cannot adequately convey the subtleties of real world situations.

The key areas for consideration in selecting the most appropriate tool for modelling purposes are described below.

3.1 Inputs

All inputs required for the study should be identified. The quality and coverage of these inputs should (ideally) align with the project objectives (eg, if a project involves possible signalisation of an intersection within a small network study area then turning movements at that intersection should be collected together with other critical locations across the network). Inputs can be categorised into two main areas:

Demand inputs – describing the type of demand that is required for the study. This includes:

- Structure of the demands (eg origin-destination demands, turn movements, link, cordon and screenline flows).
- Time period demand requirements (peak hours, design hours, daily, seasonal and future year).
- Profiling (level of demand within the modelled periods).
- Number of vehicle classes (car, truck, bus, taxi, pedestrian and cyclist).
- Trip purposes (journey to work, business, education, leisure etc).

Network inputs – network inputs include all inputs on the supply side. This includes:

- The network geometry.
- Intersection controls.
- ITS devices.
- Public transport priority.
- Parking and lane/turn restrictions.

The level of network detail required for the study is crucial in determining the required level of modelling.

3.2 Scope

Four key scope areas should be identified:

Geographic extents – A project may have consequences for traffic flow beyond the immediate vicinity of the works. Care must be taken to ensure the geographic scope is adequate to address all potential issues (including impacts of potential options). Wherever practical the model should include the network adjacent to the area being tested with the level of congestion or congestion relief dictating the extent of the model. The model needs to capture the existing causes of congestion in the local network. If these are not contained within the proposed model boundary it can be difficult to capture the effects these critical bottlenecks have on the project and prevent testing of possible improvement options at those locations. The proposed project itself may influence traffic beyond the physical extent of the changes as well as the study area. Local knowledge of the network is invaluable in identifying the extent of the likely impacts and as such it is recommended that advice be sought from RMS Network Operations staff when defining the model boundary in problematic areas.

Timeframe – Modelling timeframes also require careful consideration. All project phases requiring assessment or design should generally be tested for the AM and PM peak periods at a minimum. In certain locations it may also be necessary to examine additional time periods (eg Saturday midday in the vicinity of a shopping centre or design hour volumes in regional areas) or more generally to capture the full effects of network events under consideration (eg a reversible lane study requires an adequate

period to capture the duration of the effects of the reversible lane changes). If using simulation models the start (warm-up), end (warm-down) and duration (calibration period) of models must adequately represent traffic loadings on the network.

Traveller response – the level of traveller response required in the model will be a key determinate in assessing the appropriate level of modelling. Responses could include trip generation changes, trip distribution changes, mode shift, route choice (either pre-trip or dynamically in-trip), toll choice and drivers having perfect or imperfect network knowledge.

Required functionality – certain types of models are more suited to some functions. The options to be assessed may vary from demand management through major infrastructure to minor signal operation changes or incident modelling. The level of modelling should be selected based on the required outputs.

3.3 Outputs

Four key scope areas should be identified:

Required outputs – the type and form of outputs should be reviewed as the levels of modelling all produce different outputs. Outputs can range from global network statistics to individual movement delays.

Required accuracy – the level of accuracy of a model will be dependent on a number of factors (eg bay length sizing on arterial corridors are directly dependent on accurate predictions of turn volumes and their variability but small block grid networks generally only require the general pattern of traffic movement to match acceptable criteria because of the numerous opportunities for turn movements to occur). More detail does not necessarily mean more accuracy. However, some modelling tools are more suited to detailed analysis due to their ability to control a wider range of network characteristics and demand behaviours.

Cost – the overall cost of a project must be considered. Modelling can be expensive and while it may only be a small proportion of a total project cost, these costs are usually presented early in the project development. Generally more detailed models are more expensive, both in terms of model development and data requirements, although judicious assessment of geographic extents can limit these costs.

Audience – a technical audience requires a different output to a non-technical audience. Some model types require knowledge of traffic engineering while others are visual requiring little technical background.

A full outline of the modified Austroads Model Selection Tool is found in Appendix A.

The model selection tool provides a guide only. In some instances overriding factors may influence the choice of modelling tool. In all instances the level of modelling chosen for a project should be discussed with an experienced modeller.

The model selection tool provides guidance to the level of modelling required. The choice of modelling software is reliant on many other factors. RMS maintains preferred software at each level of modelling. However, this does not preclude the use of other software in NSW.

3.3	Is modelling necessary or can an analysis of traffic operations and simple hand calculations suffice? The level of modelling chosen for a project should be discussed with experienced modellers.

4 Traffic modelling brief

A detailed modelling brief is required for every project. Key areas to be included in the project brief are outlined in the following sections.

4.1 Background

Provide a background to the project. The project background gives the modellers the context required to develop appropriate models. It should include a statement about where the project is in the scheme development lifecycle (eg, pre-feasibility, feasibility, concept design or detailed design).

4.2 Objective

An outline of the study objectives since, setting clear objectives is critical as models are developed to meet project objectives/outcomes. Objectives should reflect study purpose and explicitly state the purpose of the model including the information that is required from the model and the required accuracy of results. They can also include discussion on the risks that the study faces together with how these may be addressed within the study.

The most important consideration when setting the project objective is that if this objective changes during the modelling project, the entire modelling process may require adjustment or refinement resulting in probable scope and fee changes.

4.3 Contract process

Details of the contract process are required in the project brief. This should include whether the modelling project is to be undertaken using RMS' "Traffic Modelling and Ancillary Services Panel".

4.4 Proposed model structure

This should reflect the suggested level of detail for modelling (based on preliminary analysis of modelling requirements). This may include a designation such as SCATSIM requirements. In some instances the appropriate level of modelling can be determined in discussions between RMS and the service provider.

4.5 Scope

All traffic models should have a clearly defined scope prior to commencement of modelling. The scope should at a minimum include:

Geographic extents – as described above, a project may have consequences for traffic flow beyond the immediate vicinity of the works. The geographic scope must be wide enough to address all potential issues (including impacts of potential options). Wherever practical the model should include the network adjacent to the area being tested.

Time periods – Modelling timeframes also require careful consideration. All project phases requiring assessment or design should be tested for the AM and PM peak periods at a minimum. In certain locations it may also be necessary to examine other time periods (eg, Saturday midday in the vicinity of a shopping centre or design hour volumes in regional areas).

Data collection – data collection includes the requirements for:

- *Site inspections* (all projects should involve a site inspection during each time period to be modelled) and a requirement should be the provision of a site inspection report as an appendix to the Base Model Development Report.
- *Data* from Government sources:
  - RMS.

  - Transport for NSW.
  - Other departments.
- *Surveys:*
  - Turn movement counts.
  - Tube counts.
  - Origin Destination Surveys.
  - Other surveys.
- *Previous studies or related documentation.*

Costs for data collection should be shown separately from professional time costs in the response to the brief.

Calibration and validation requirements – Model calibration and validation should be undertaken (at a minimum) in accordance with RMS Modelling Guidelines. Further requirements may be required should the project purpose warrant further detail.

Future network development – Requirements for future year modelling, specifying the number of future years to be modelled. The requirements for the development of future year demands should also be considered.

Option testing – Description of options to be tested (or at a minimum the number of options to be tested). If the modelling is to be used to assist in the development of options this should also be discussed.

Output requirements – Details of required modelling outputs. These may include: network operational statistics, intersection operation, travel times, queues, congestion measures, traffic flows, hot spots, crash analysis, economic analysis etc.

4.6 Timeframe

An outline the anticipated timeframe for the project should be indicated. In their response to the brief the service provider should provide a detailed timeline of tasks to achieve the project timeframe.

4.7 Milestones

Milestones for a modelling project should include:

- The completion of the Base Model Calibration and Validation Report.
- The development of future base case models.
- The documentation of Option Testing.
- Milestones provide an indication of hold points for model review.

4.8 Deliverables

Major deliverables generally include model documentation and the models themselves.

Model documentation should include two reports (although they may be combined into a single report):

- Base Model Development Report (BMDR).
- Option Assessment Report (OAR).

4.8.1 Base Model Development Report

The Base Model Development Report (BMDR) should document the level of calibration and validation of the base model and include:

- The model development process and methodology.
- Details of data collection and site visit observations.
- The level of model calibration based on:
  - RMS Modelling Guide.
  - Any other modelling criteria used.
- The model validation based on:
  - RMS Modelling Guide.
  - Any other modelling criteria used.

The report should include tables and figures to support the calibration and validation that may include:

- Link flows (by direction).
- Screenline flows (by direction).
- Turn flows.
- Travel times (by direction).

4.8.2 Option Assessment Report

The Option Assessment Report (OAR) should include:

- A summary of options tested, by year and time period.
- The Output Requirements defined in the Study Scope for each of the options.
- Any other information that the models provide that will assist in the assessment of the options.

4.8.3 Model

Upon completion of the project, the models shall be handed over to RMS.

4.9 RMS data

Provide details of any data that RMS will provide (including associated costs). This may include traffic count data, signal timing information, travel time information, previous modelling etc.

5 Model development process

Once modelling has been determined as the preferred analysis method. A project brief has been prepared and the appropriate modelling tool selected, there is a general process that should be followed to ensure a satisfactory project outcome.

5.1 Purpose

Developing models that are fit for purpose is the overriding aim of these modelling guidelines. The level of detail and accuracy required is dependent on the model's purpose. There may be several stages of project development where different levels of modelling accuracy are required. For example:

- Initial project development (pre-feasibility).
- Option assessment (feasibility).
- Concept design.
- Detailed design.

At each phase of the project passes, the required level of modelling accuracy increases. A model that was fit for purpose at the initial project development phase may no longer be fit for purpose for detailed design.

It is critical that purpose of a particular modelling task is defined prior to the development of a modelling project.

Even if all guideline criteria are met, a model may still not be fit for purpose. Detailed model checking and review is required prior to a model being considered fit for purpose. The level of checking and review will be dependent on the purpose of the modelling.

In developing a modelling brief, the purpose of the model should be explicitly stated together with a specification of the information that is required from the model together with an indication of the accuracy of that information. This provides the guiding framework from which the modelling study will form.

5.2 Network familiarisation

An important step in the development of a model is familiarisation of the modeller with the area to be modelled. This may include:

- Site visits and desktop inspections (see 5.2.1 below).
- Examination of local land use data.
- Inspection of aerial photography and mapping.
- Identification of surrounding network restrictions, construction activities and way finding signage that may affect route choice.
- Collation of recent or planned network or traffic control changes.
- Collation and inspection of available traffic data to ensure adequate data is collected and it is suitably reliable and consistent.

Some of these areas are discussed in more detail in the following sections.

5.2.1 Site visits

Site visits must be undertaken by the modeller for each period that is to be modelled as the dynamic nature of traffic flow, together with non-complying driver behaviour, cannot be adequately captured without first-hand observation. Desktop inspections (Google Earth, Nearmap, SCATS Access, GIS etc.), while providing useful information, are no replacement for physical site visits.

During site visits the modeller should:

- Observe traffic conditions.
- Observe network operations (including signal operations, non-standard traffic behaviour, and adjacent lane interactions).
- Observe local land uses and access to the road network.
- Identify problem areas and not just the symptom of problems.
- Confirm physical characteristics.
- Collect any relevant data for use in model calibration and validation.

A report on the site inspection should be included with the calibration and validation report. A site inspection checklist template is provided in Appendix B.

5.3 Data collection

5.3.1 Survey periods

Collection of data should be undertaken during periods where the traffic conditions are typical of the periods to be modelled. The typical period may not necessarily be a normal day but may require consideration of effects from:

- Day of week – select representative days (weekday/weekend, late night shopping, etc).
- Time of day – peak periods, off-peak, warm-up, warm-down.
- School holidays.
- Public holidays or special events.
- Traffic incidents or changes in traffic control.
- Adverse or abnormal weather conditions.

This list of issues will need to be critically assessed and monitored during any data surveys. If the target conditions are not met during the survey period, additional data collection may be required.

During data collection, modellers should ideally visit the site to observe and understand traffic conditions during survey periods or at least request that the survey company details salient traffic conditions as indicated in Appendix B.

5.3.2 Warm up and warm down periods

A warm up period is required for the application of simulation models (both micro and meso) as these modelled road networks have to be populated with traffic prior to any calibration period otherwise there would be an under representation of traffic demands both on the network (and potentially at the boundaries of the network). Conversely at the end of the calibration period the decay in traffic volumes can become critical to the assessment of scheme options in heavily congested conditions and a warm down period may also be required to assist in identifying scheme benefits. As a rule of thumb (although this should be verified for specific networks), if it is not feasible to extend the simulation period to cover the period of uncongested conditions prior to the peak period, then a warm up period of twice the longest trip length can be applied.

5.3.2	The warm up period should extend for long enough prior to the required model calibration period to demonstrate sufficient traffic densities/vehicle volumes exist on (and at the boundaries of) the network at the start of the calibration period. If inflated demands are used during the warm up period to shorten the length of time required to run the simulation prior to model calibration then adaptive control systems (ie SCATSIM) should be carefully monitored to ensure correct operation during the calibration period. The warm down period should ideally include the period when excess demand (from earlier in the peak period) completes their traversal of the network or traffic densities/vehicle volumes reduce to uncongested conditions.

5.3.3 Traffic demand and observed flow differences

A paper prepared by the Bureau of Transport Statistic (BTS) [7] investigated the variation in observed traffic count data in the context of its use as a validation data set. The study showed that significant differences between average counts depending on the inclusion of workdays, weekdays, public and school holidays. In the case where short term counts were collected, adjustments were recommended to account for the differences between the schooldays and workdays, based on available pattern station data, similar to the adjustment used to account for seasonal variation over the year.

It is common to use average (or mean) traffic count to calibrate or validate a model. However, based on the study's findings, it is suggested to use the median as this is less influenced by extreme values. In order to extract sensible median value, the sample size of the count data should be taken into account.

In addition to the variation in observed count data, the BTS paper also highlighted the fundamental differences between traffic counts, observed at specific location at a given point in time, and link volumes, produced by macroanalytical highway assignment models. This is not as significant an issue for the mesoscopic (and microsimulation) assignment models due to their dynamic (or time dependant) nature as their assignment methodology will tend to deal directly with this issue.

Traffic models are generally demand based. It is therefore important that the demand is counted and not simply the flow. Traffic counts generally measure the flow across a stop line. This may be inadequate for modelling application and the collection of data should be specified to ensure demands are counted wherever possible. The potential impacts of measuring flow instead of demand on traffic models were presented by RMS at the Australian Road Transport Research Forum in 2011 (ref).

5.3.3	To account for the difference between demand and flow, some attempt should be made to capture the extent of queues (representing the unmet demand on the network) adjacent to the study area during periods of congestion.

5.3.4 Ensuring quality surveys

As models are heavily reliant on the quality of data employed in their development it is the responsibility of the modeller to ensure that commissioned surveys are adequate for the study purpose and that quality concerns are addressed in consultation with the survey company.

Saving budget on data collection can often lead to models that do not satisfy the purpose for which they are developed and ultimately increase project costs due to increased modelling effort and uncertainty.

Specialised survey companies are often used for the purposes of data collection and can be very effective if properly briefed on the extent and quality of data required. Video collection is recommended as the traffic operations on the day of the survey can also be examined at a later date should discrepancies arise in subsequent analysis.

It is generally not recommended to undertake "spot counts" and then factor these to peak periods without definitive evidence that they are representative of longer time periods.

Careful consideration must also be given to the collection of queue lengths due to their subjective means of measurement. Queue length counts can often be unreliable as the definition of a queued vehicle varies between the various software packages and between surveyors. A recent source for practical definition of queue can be taken from HCM 2010:

> "[For vehicles entering a queued state] a *vehicle can be considered as having joined the queue when it approaches within one car length of a stopped vehicle and is itself about to stop".*
>
> "[For vehicles leaving a queued state] a vehicle should be considered to have left the queue when it has left the link in which it entered the queue – unless it changes lane to escape a queue."

But even this definition can be problematic to apply.

For RMS personnel undertaking traffic counts, RMS' Traffic Surveys Panel can be used and details of this panel are available from the Traffic Analysis Unit in Transport Planning Section in Sydney Region.

The nature of the traffic survey data required will vary for different types of models. Macroscopic models typically require less detail and greater coverage while microscopic models require more detail and less coverage. Table 5.1 details some of the traffic survey data that may be required for various modelling levels.

Often data collected from surveys can be compared against historical records and SCATS stop line detector counts to verify that surveys are representative.

Good quality survey data is essential to the production of accurate models and therefore more accurate forecasts. It is recommended that the modeller attends the site during the survey days to identify any unusual events that may impact on the data being collected (eg crashes, roadwork, adverse weather, etc). This helps the modeller understand the operational characteristics of the network under the surveyed conditions and aids in post processing of the survey data.

Traffic patterns can change in a relatively short space of time, particularly in urban networks, so it is essential to check that survey data remains current. Ideally traffic flows should be no more than two to three years old to ensure they are still representative of current volumes in the network. In urban networks applying historical growth rates to older data is not likely to be appropriate as it can be difficult to capture all of the contributing factors in any assumptions made when developing growth factors and accounting for the effects of changes in the wider network are extremely difficult.

Table 5.1 – Traffic survey types by modelling level

Survey Type	Model Applicability	Issues
Screenline counts	Strategic Highway assignment	Typically relies heavily on ad-hoc, historical data records. Adjustment or seasonality, average day effects required. Can involve in-fill from signal detector records – possible high error. Time profile data may be difficult to get.
Intersection counts	Highway assignment Microscopic Multi-intersection Single intersection	Classified into vehicle classes. Turning movements. Typically short term, although good time period data. Accumulated to short periods (eg 15 minutes). Often manual collection or data punch procedure, affected by daylight. May need adjustment to match up/downstream counts if no sources and sinks (side roads, traffic generators) are evident between them.
Tube counts	Strategic Highway assignment	Classified into standard Austroads vehicle classes, pedestrian also. Can be longer term to fill gaps in screenlines. Can provide data for background traffic variation and control counts. Automatic collection methods (loop detector counts). All of day collection. Can collect discrete event information for flow rate calculations.
Origin-destination survey	Strategic Highway assignment Microscopic Multi-intersection	Source of vehicle demand calibration or validation data. Costly surveys – labour or equipment (video) intensive, large number of simultaneous sites. Observations available from E-tag or Bluetooth readers. Prone to “match” error, particularly if full plates not recorded. Single day capture only. Video techniques preferred over manual collection to improve sample rate. Other possible sources include Journey to work data (ABS Census), Household travel survey data as well as purpose specific interview and questionnaire surveys.

Survey Type	Model Applicability	Issues
Queues	Highway assignment Microscopic Multi-intersection Single intersection	Length and duration of queues Practical simultaneous collection of many sites using video recording methods. Processing costly although videos useful for additional inspection of traffic behaviour. Single day capture only.
Journey time	Strategic Highway assignment Microscopic Multi-intersection	Floating car technique. Multiple runs in target time periods to produce statistically valid sample. GPS collection can identify and provide detailed speeds along path as well as the end of queue location. Congested and uncongested times can be collected.
Saturation flow	Highway Assignment Multi-intersection Single intersection	Surveys not commonly undertaken in Australia. Manual observations techniques or automatic tube classification counters could be used although in the latter case, some care would be required to place the tube at a suitable location. SCATS Maximum Flow data can be utilised.

The traffic flow data collection requirements will vary depending upon the scope, budget and type of network being assessed. Roundabouts for example, require origin destination type traffic flow data as the traffic volumes on each of the circulating sections of the roundabout directly impact upon approach capacities. Signalised intersections on the other hand can generally be modelled accurately using intersection counts. The general order of preference for traffic flow survey data for different intersection types is as shown in Table 5.2.

Table 5.2 - Hierarchy of traffic flow survey requirements

Intersection type / Order of preference	Roundabout	Closely spaced intersections	Signalised	Priority	Minor side road
1st	Full classified OD	Full classified OD	Partial classified OD	Partial classified OD	Classified turn counts
2nd	Partial classified OD	Partial classified OD	Classified turn counts	Classified turn counts	15 minute spot count
3rd	-	Classified turn counts	SCATS counts	SCATS counts	-

5.4 Base model development

Modelling of the existing base case situation is essential for the vast majority of projects. The base model is required for two key reasons:

- To enable accurate verification, calibration and validation (see key point 5.4 below for definition of these terms) of model parameters to ensure that the model reflects current traffic conditions and provides accurate forecasts of future performance.
- To provide a benchmark against which the effectiveness of the proposed designs can be compared.

The base model should be developed for the existing traffic conditions using recently collected data. Verification of the model network coding should be undertaken to ensure that the modelled network is correctly representing the physical and operational characteristics of the real world network (this is undertaken by comparing and refining the model network inputs to better reflect network characteristics).

Calibration is then undertaken to match model results to those that have been observed. This is generally an iterative process that requires model input and parameter adjustments to be undertaken after initial model results are produced.

After a recognised match between observed and modelled results is achieved then validation of the model can be undertaken by comparing another set of results from the model against independent observed data.

The level of calibration and validation required for base models is discussed in detail in Part B of these guidelines.[1]

If the base model is able to accurately represent the existing situation, then future model predictions can be afforded a higher degree of confidence. This is only the case if the original calibration parameters are maintained and the future option includes only the salient changes reflecting demand and network changes proposed under that option.

For this reason base modelling may not be necessary if any of these apply:

- Future options involve substantial changes to the network and traffic conditions.
- It is not possible to collect current operational data (eg when construction works are already underway).
- It is a new road or network or part of a master plan study.

In addition to a base model, a “do-nothing” or “do-minimum” scenario is often recommended, which considers committed road upgrades, land use developments and associated future year demands, but excludes any modifications associated with the project being assessed. Such a scenario represents a future year benchmark, against which the impacts of the project can be isolated and assessed.

5.4	**Model verification** – comparison and adjustment of modelled network coding to provide consistency with observed network characteristics and constraints. **Model calibration** – adjustment of the parameters of the model in order to optimise the agreement between observed data and the model's predictions. **Model validation** – comparison of model outputs against independent, observed data which were not used during the calibration process to provide confidence in the accuracy of the model forecasts.

5.5 Future model development

Future year models are developed where a project requires testing under forecast future traffic conditions. Analytical strategic models are generally used for long-term forecasting with simulation models generally used for short to medium-term applications.

Future models should be developed for a “do-nothing” or “do-minimum” scenario. The “do-nothing” scenario refers to the base model with future traffic volumes (and potential signal time changes only). While the “do-minimum” also includes other network enhancements unrelated to the project that may already be committed or recognised as likely to be committed. The development of a “do-nothing” or “do-minimum” scenario provides a basis for comparison to the future option scenarios.

[1] Calibration and validation is discussed in Part B of these guidelines at sections 9.12.9, 9.13.4, 9.13.5 and 9.14.3 for demand models, sections 10.2 and 10.3 for highway assignment, sections 11.3 and 11.4 for microscopic models, sections 12.11 for SCATSIM applications, sections 13.4 and 13.5 for corridor models and section 14.4 for isolated intersections.

Forecast traffic flows can be obtained from a number of sources:

- Growth factors (based on historic levels or predictions of future growth).
- Traffic generating development growth (based on local development plans).
- Higher level models (for example using forecast highway assignment model flows to apply growth to a microsimulation model).
- Land use models (such as inputs to the Sydney Strategic Travel Model).
- Care must be taken on the application of traffic growth (with two methods generally used: applying percentage growth or applying absolute growth).

Each of these methods has its positives and negatives and the use of appropriate demand forecasting should be discussed with RMS prior to application within traffic models. Where there is some doubt about the future demand estimates it may be worthwhile considering sensitivity tests to examine effects of a range of demand values.

Future infrastructure projects to be used in the “do-minimum” case should be determined in consultation with the RMS Manager Traffic & Transport Modelling.

Model parameters set in the existing situation base case model should generally not be altered in the development of the future scenario models.

5.6 Option assessment

Models are developed for each option to be tested. Option models should contain the minimum amount of changes to code and test the option. Parameters set in the base case and future case models should generally not be altered in the development of the options.

The performance of options should be compared to the relevant base case or future “do-nothing” or “do-minimum” models. Option testing model results should not be directly compared to observed data for the assessment of impacts.

The level of detail required for option assessment should be specified in the project brief.

Following calibration and validation of the base model, the model can be used for scenario testing. This can vary widely although essentially involves:

- The alteration of the base model to reflect a defined set of proposed or anticipated changes.
- The comparison of the scenario test model against the base model to determine impacts of the scenario.

A scenario may involve changes to one or more of the following:

- Additional road links.
- Physical road layout, geometry and line marking.
- Driver behaviour and system characteristics.
- Intersection control, including changes to traffic signal operation.
- Increased or changing demands.
- Traffic compositions.
- Road user charges.

It is important to identify both the primary and secondary changes within a scenario. Changes in demand (eg new development) may require alteration of traffic signal phasing and timing or the physical layout of downstream intersections. An upgrade project may reduce delays along a corridor to the degree that induced traffic may need to be assessed by increasing demands for particular origin-destination combinations.

Consideration of the scale of the scenario tests should be included in the initial scoping and specifications of the project brief to ensure that the models developed are capable of assessing the scenarios. The scenario testing may involve progressive application of model changes to separate the various effects and to account for positive and negative impacts for economic analysis.

5.6	RMS Manager Traffic & Transport Modelling can provide modelling requirements advice for specific projects on base case, do nothing, do-minimum and option assessments.

5.7 Outputs and reports

The required model outputs and reporting should be specified in the project brief. Two reports are generally prepared for modelling projects:

- Base Model Development Report (BMDR) which includes a description of model verification, calibration and validation as well as a statement about how well the models will satisfy the objectives of the brief.
- Option Assessment Report (OAR) which includes a description of option tests and comparison of model results.

Comprehensive and precise reporting is essential for traffic modelling as there is a natural scepticism of traffic modelling by people outside the profession (and in some cases by other modellers). This is understandable given that it is a complex and implicitly opaque process.

In order to overcome this scepticism (and to articulate the uniqueness of the particular modelling solution to the specific objectives that have been set for that project), a structured approach to reporting is essential. As well as assisting with the acceptance of model results, the model reporting also provides some transparency to a process that can be seen as a “black box” solution to complex problems.

The amount of reporting required should generally be in proportion to the modelling project scope and budget, as large, complex and multi-scenario projects require considerably more reporting effort than those with simpler, more limited model scope.

For larger, more complex models reporting should be undertaken progressively, starting with the model specification and updated with comprehensive working notes along the way to document changes. As stages of the modelling are completed, documentation and reports prepared at that stage will provide an historical record for projects that may extend for long periods or may see changes of project staff. The process of gathering information for technical reporting can also highlight issues that can be dealt with before becoming critical.

More specific requirements of model reporting are provided in Part B of these guidelines[2] for the various levels of modelling.

5.7.1 Base Model Development Report (BMDR)

The Base Model Development Report (BMDR) generally covers five distinct areas:

1. Network familiarisation (including site visit).
2. Model verification.
3. Model calibration.
4. Model validation.
5. Fit for purpose statement.

Network familiarisation (as described in section 5.2)

[2] Part B, section 10.5, section 11.8.3, section 11.10, section 13.6 and section 14.7 provide more specific details of reporting requirements.

Model verification (as described in section 5.2 and defined in section 5.4) should be documented to demonstrate that the modelled network elements correctly relate to the actual base network characteristics. Any changes that were required in the model to better reflect the actual network characteristics should be documented together with a discussion of any discrepancies encountered.

Model calibration (as defined in section 5.4) is generally where the majority of time can be spent in developing the base model and documentation should reflect this. Summaries of all relevant survey data and a history of the model development can be included. As any model review and auditing will rely on the report to explain how the model has been calibrated, the BMDR should focus on presenting traffic model inputs and detailing how the model has been developed to ensure that it represents existing conditions. In particular, the following should be included:

- Clear notes on site observations and measurements, covering both the physical network and observed vehicle behaviour. Where behaviour is specific to a particular time of day, this should be noted along with how it has been accounted for in the model.
- Descriptions of any data collection, including survey specifications, survey conduct notes, site locations and processed results.
- Network development procedure and contributing data sets such as GIS layers, aerial photography and other model databases.
- Calibration statistics and results.

This report will also include a statement about how appropriate the models are for testing the stated objectives of the study and to identify any weaknesses. This report also includes steps taken to verify model inputs and outputs.

Model validation (as defined in section 5.4) reporting should look in detail at comparisons between calibrated model results and existing conditions. The model developer should detail the validation process, from on-site surveys through to adjustments made within the model. Any decisions made by the model developer should be captured especially where model inputs have been adjusted in order to achieve validation.

Validated model results should be tabulated and compared with the surveyed on-street values for all modelled periods. If there are discrepancies between the model outputs and the on-street conditions then these should be identified, investigated and explained. Specific items that could be included in the validation reporting are:

- Details of traffic flows used, when they were recorded, who recorded them and how the peak hour was chosen.
- Validation data, such as vehicle journey times.
- Relevant site observations not already included in the calibration report such as give-way behaviour, exit-blocking, parking/loading and bottleneck details.
- Evidence of validation comparing modelled results to on-street observations and measurements.
- Any discrepancies should be analysed and discussed with model weaknesses identified and discussed.
- The stated purpose of the model.

The base model reporting is intended to provide RMS with an understanding of how the model has been developed and to demonstrate that it is fit for purpose to be used in the study. There are a number of key areas that must be included in the reporting and these are as follows:

- Outline of techniques used to develop network.
- Justification for changes to default parameters.

5.7.2 Reporting structure

RMS does not provide a mandatory report structure as each model will be different and may have been developed using a methodology that varies from any other model. It is therefore incumbent upon the modeller to develop a report that provides the most logical and accurate outline of the development and calibration/validation process in each case.

The structure set out below therefore simply provides a guide to assist inexperienced practitioners who wish to develop a basic Base Model Development Report (BMDR):

- Introduction – study objectives, network extents, core area extents, software package (and version), time periods etc.
- Data collection – description of data collected including type, date, location, time periods, etc.
- Network development – outline of coding used for links, intersections, signals etc.
- Demand development – description of methodology used to develop demand.
- Model stability – provide details of seed runs and model outputs showing stability (If the Statistical Toolkit is used then refer to section 11.8.3).
- Model calibration – statistical comparison of observed and modelled outputs.
- Model validation – statistical comparison of observed and modelled outputs.
- Summary – brief summary outlining data that demonstrates model is fit for purpose.

5.7.3 Option Assessment Report

The Options Assessment Report (OAR) can vary in its scope depending on the project brief requirements but would normally include:

- Description of options tested.
- Summary of key results obtained.
- Interpretation of model results.
- Conclusions about the adequacy of the options tested.

The reporting of model application results may vary widely depending on the objectives of the study being undertaken. Often the modelling reporting is part of a larger study report (eg environmental impact statement). The report may be a standalone report or a chapter in a larger report. The content of scenario assessment reporting should include a description of the proposed scenario(s) scheme and any expected impacts.

The modifications made to the validated base model to develop the scenario model(s) should all be based on these key details. All changes made in order to develop the scenario model(s) should be documented, along with the reasoning behind them. Specific items that could therefore be included in the scenario assessment report are:

- Scenario summary.
- Scheme objectives/problem.
- Scenario assessment methodology.
- Evaluation of scenario results.
- Conclusions and recommendations.
- Model source data.
- Modelling assumptions.
- Electronic copies of model input file with descriptions of the data files.

5.8 Reviews and audits

Two types of review are available:

- Peer review – where the model is reviewed at key points throughout the project. This involves appointing the review at the same time as appointing the lead modeller.
- Audit – a review of the model and documentation once completed.

Generally a peer review is preferred. Using the peer review method, any modelling or process issues are discovered early in the modelling commission and can be rectified immediately. The drawback of this approach is the cost of reviewing models throughout the modelling process.

Audits can be cheaper; however there is a risk that a major model error will be found during the audit that may mean re-doing the entire model and documentation. This may result in significant time and cost overruns.

All models require a peer review or model audit and the type of project and its timeframes will assist in determining whether a peer review or audit is preferred.

5.9 Traffic modelling panel

For all levels of traffic modelling the key component to successful model development is the modeller. The NSW RMS has instigated a Traffic Modelling Panel to identify organisations that have the appropriate skill and expertise to undertake traffic modelling tasks. Even when using the Panel, the following questions should be asked of modelling personnel:

- Level of modelling experience with software.
- Level of understanding of road network, both physical and operational.
- Level of traffic engineering knowledge.

A service provider must be able to provide modellers with the appropriate skills prior to engagement.

Should you require any further information on the Traffic Modelling Panel please contact the Traffic and Transport Modelling Section in Traffic Management Branch.

6 Other factors

6.1 On-road public transport

The impact of on-road public transport is critical in traffic and transport modelling. The impacts include:

- Bus lanes (and their usage).
- Bus priority at traffic signals.
- Bus stops (and in particular buses while stopped at bus stops).
- Bus bunching.

Conversely, the traffic flow (and delays) can also impact bus operations. The impact of increased (or decreased) delays on the road network can significantly affect bus operations including timetabling, the need for layover space and fleet size.

On-road public transport should be included in all models where service is provided. Care should be taken to ensure all service types are included, many of which are not timetabled (for example, school buses or dead-runners).

Performance measures for on-road public transport should be included in the results of modelling projects where appropriate.

6.2 Pedestrians and cyclists

Increased traffic flows can impact the opportunity for pedestrians and cyclists to use road space, be it at pedestrian crossings or on road facilities.

Pedestrian and cyclist flows can also limit the capacity for other road users through increased delays (particularly at left turn movements). The frequency of pedestrian calls, their volume and crossing times all impact road user capacity and should ideally also be calibrated (or at least estimated from local knowledge or site visit).

Pedestrian and cyclists (or the effects of pedestrians and cyclists) must be included in all modelling where they interact with general traffic. Where appropriate, the delays to pedestrians and cyclists should also be included in model performance measures.

6.3 Environmental considerations

Traffic modelling plays an important role in determining the environmental impact of road schemes and all levels of traffic modelling can be used for environmental analysis.

RMS is developing guidelines for modelling the environmental effects of road projects in the various levels of modelling.

7 Guidelines key points

This section summarises the guidelines by pulling the key points from each section of the guidelines into one convenient place. This is intended as quick reference guide for more experienced modellers (and those more familiar with the contents of guidelines).

PART A: Modelling matters	
2.8	Project managers and modellers should understand which level of modelling is appropriate for their particular study and be aware of the problems in passing information from detailed models to high level strategic models. RMS SCATS portfolio products are likely to have an increasing role in model development and their inclusion should be balanced against the likely increased costs (and RMS resources) of the modelling study.
3.3	Is modelling necessary or can an analysis of traffic operations and simple hand calculations suffice? The level of modelling chosen for a project should be discussed with experienced modellers.
5.3.2	The warm up period should extend for long enough prior to the required model calibration period to demonstrate sufficient traffic densities/vehicle volumes exist on (and at the boundaries of) the network at the start of the calibration period. If inflated demands are used during the warm up period to shorten the length of time required to run the simulation prior to model calibration then adaptive control systems (ie SCATSIM) should be carefully monitored to ensure correct operation during the calibration period. The warm down period should ideally include the period when excess demand (from earlier in the peak period) completes their traversal of the network or traffic densities/vehicle volumes reduce to uncongested conditions.
5.3.3	To account for the difference between demand and flow, some attempt should be made to capture the extent of queues (representing the unmet demand on the network) adjacent to the study area during periods of congestion.
5.4	**Model verification** – comparison and adjustment of modelled network coding to provide consistency with observed network characteristics and constraints. **Model calibration** – adjustment of the parameters of the model in order to optimise the agreement between observed data and the model's predictions. **Model validation** – comparison of model outputs against independent, observed data which were not used during the calibration process to provide confidence in the accuracy of the model forecasts.
5.6	RMS Manager Traffic & Transport Modelling can provide modelling requirements advice for specific projects on base case, do nothing, do-minimum and option assessments.
PART B: Modelling guidelines	
9 – Demand modelling	
9.2.3	Mobility is the basic measure of demand and is expressed as the number of trips per household or person by specific mode or purpose of trip.
9.2.4	The trip is the basic unit of traffic demand. It is characterised by origin, destination, purpose, mode, duration and time of day.

9.2.5	The definition of trip chaining can include: • Trip chains that involve a series of individual trips taken throughout the day where the destination of one trip is also the origin of the next trip (with each trip having its own mode and purpose). • Person-linked trips that have multiple destinations and ignore the change in mode.
9.2.6	Trip purpose is the basic explanatory trip attribute. Since purposes are differently distributed through the day, their inclusion in modelling is vital for accurately recreating demand at different times of the day.
9.2.10	It is the modeller's responsibility to determine the extent of the area of relevance (ie the study area). The creation of traffic zones is important for all stages of transport modelling. Their proper creation has an impact on the quality and accuracy of demand modelling as well as the quality of network creation and overall modelling results. The level of zone detail is a matter of judgment.
9.2.11	Trip matrices are the end product of the demand modelling process and they are a direct input to network assignment.
9.3.1	It is the modeller's responsibility to choose the kind of modelling methodology. No matter what methodology is applied, it is essential that the model explains transport demand in the most accurate way possible.
9.4.2	Trip generation is based on collection and analysis of complex travel behaviour data.
9.4.3	Distribution models define spatial distribution of trips in the study area. They use trip ends from the trip generation model and they are calibrated using data from specific transport surveys.
9.12.2	To create adequate trip production models, planners and modellers need to take special care of the availability of the variables used in the future. Some variables present today are difficult to forecast in the future. So in the creation of trip production models (and analysis), it is crucial to accept methodology, which will match the level of forecasting of independent variables in future.
10 – Highway assignment modelling	
10.1	In undertaking highway assignment modelling, the modeller should understand which of the available software to apply to the problem being considered. Depending on the study brief requirements important aspects of this selection may include: • Level and need for accurate intersection representation. • Source and ease of coding signal timing data. • Representation of bus vehicle behaviour and restricted lane use.
10.2.1	If using strategic model demand matrices, screenline count comparisons can determine whether demand matrix or network assignment adjustments are needed. Discrepancies between Dynamic Traffic Assignment (DTA) models and observed counts may differ for three reasons (each may require further investigation): • Local network capacity and control timing parameters. • Local traffic demand due to the assignment process in the form of route flows. • Global demand as represented by the O-D matrix.
10.3	Table 10.3 Link and turn target calibration/validation criteria. Table 10.4 Travel time target calibration/validation criteria

10.4	It is important to identify both the primary and secondary changes within a scenario. Other levels of modelling may be required to determine the required changes that need to be made to the Highway assignment model; these may include: • Isolated intersection optimisation using SIDRA. • Coordinated signal optimisation using LinSig. • An assessment of the induced traffic demand elasticity or strategic model runs used to obtain increases in through-traffic.
11 – Microsimulation modelling	
11.2	The core area should be agreed with RMS at an inception meeting and a list of included intersections should be presented in the Base Model Development Report (BMDR) with this being the focus of more rigorous calibration and validation effort.
11.3.2	It is mandatory that any adjustments to speed distributions are documented in the Base Model Development Report (BMDR) together with a justification for the changes and any evidence supporting this. Reducing speed distributions on isolated links in order to match modelled travel times with observed datasets is not acceptable to RMS. The location of blocking behaviour and the method with which it has been simulated should be described in the base model reporting as often cooperation between drivers allows for minor road turns to take precedence over slow-moving major movements. The technique used to simulate each signalised intersection should be agreed with RMS at the inception of the study and tabulated in the BMDR. The source of all signal data and layout plans should also be indicated. Guidance on appropriate criteria to use when reporting the calibration of signalised intersections is provided in this document. Assessment of key intersections against the provided guidelines is a useful indication of the level of calibration for each approach at any given location. The accurate modelling of signal timings and control at an intersection will significantly assist in any subsequent calibration of queue lengths and delays at each location. While RMS does not currently consider it mandatory to report saturation flow comparisons for all signalised stop lines, modellers should report values for key locations where data and model outputs are available. Guidelines for reporting are provided in this document. In all cases links and intersections must be coded to represent their operation on site. This may differ from aerial photography and survey information which may not adequately reflect localised vehicle behaviour or simply be out of date. Modellers should include any changes made during the calibration process as a result of field observations in the BMDR. The source of public transport data together with the dwell times assumed in the modelling should be documented in the BMDR.
11.3.3	If a significant amount of matrix adjustment is required then this should be detailed in the Base Model Development Report (BMDR). The trip totals for both the original demand and the adjusted demand should be reported for each vehicle type and for each modelled hour period. This will provide RMS with an indication of the scale of trip volume change incurred by the process. Further, graphs showing the changes in trip length distribution between the original and adjusted demands provide a useful indication of which types of trips have been in-filled or altered as a result of the adjustment. A statistical comparison of modelled and observed turning movements and link flows must be presented in the BMDR. For models with larger networks it may also be necessary to develop screenlines and/or cordons to evaluate the accuracy of the demand. Specific guidelines relating to the statistical comparison of observed and modelled volumes are provided later in this section.

	RMS suggests that models initially be developed using default values. However, it is considered appropriate to adjust the value of parameters to replicate local driver behaviour in some cases. If changes are made they should be documented in the BMDR together with a justification of why they were changed, what values were chosen and any evidence that can be provided to substantiate the change.
11.3.4	The level of detail to which the vehicle type demand should be developed must be agreed with RMS at the inception stage of the study and documented in the Base Model Development Report (BMDR). RMS suggests that models initially be developed using default values. However, it is considered appropriate to adjust the value of parameters to replicate local driver behaviour in some cases. If changes are made they should be documented in the Base Model Report together with a justification of why they were changed, what values were chosen and any evidence that can be provided to substantiate the change. The values of time and distance (and any additional toll or cost factors) should be documented in the BMDR Justification should be provided within the BMDR describing the location of any localised cost adjustments, the cause of the issue and why this could not be resolved through standard network coding.
11.5.2	Table 11.1 Link and turn target calibration/validation criteria (**network wide**) Table 11.2 Link and turn target calibration/validation criteria (**core area**) Table 11.3 Microsimulation signal time target validation criteria Table 11.4 Microsimulation stop line saturation flow target validation criteria Table 11. 5 Microsimulation travel time target validation criteria Table 11.6 Microsimulation time volume scatter plot target validation criteria Table 11.7 Microsimulation queue length target validation criteria
11.7.3	Table 11.8 Random Seed Values
11.7.4	When the comparison of results between base and/or option models shows only slight differences then the statistical toolkit should be applied to determine actual model results.
11.8.1	The statistical toolkit assumes that model calibration and validation has already been implemented successfully and models are not prone to unrealistic lock-ups. The modeller is advised to print the Easy Reference Toolkit Checklist and populate it while progressing through the Statistical Toolkit document. Table 11.9 provides overview of the components of the statistical toolkit.
11.8.2	It is important to remember that precision and confidence are dependent upon model inputs and their variability. The toolkit uses the model inputs as supplied and the modeller should try to remove unrealistic outliers. Hence from this initial simulation set of a minimum of 20 runs, obtain the sample statistics x and s of VHT required and enter into the checklist. The initial number of runs chosen is denoted as ni.
11.8.3	Scatter plots are useful to check for independence between runs – results should show random variation and no correlation. Observations beyond the whiskers are classified as “extreme point” or “outliers” and are shown as asterisks Box plots are useful to screen for extreme points Histograms are used to examine location, variation, shape and unusual features of models

	The larger the sample size, the narrower the confidence interval, and so the more precise the VHT estimate is. Extreme points can be used to assess model performance and detect model errors and thus need to be investigated. If there are any unreleased vehicles then use adjusted dVHT in all analyses, not the VHT given by the models' output. To compare the means from two scenarios: • Calculate and plot their differences • Run a Unpaired Two-sample t-test using a statistical software package or the Data Analysis ToolPak from Excel • Look at the "p-value" and if it is less than your chosen significance level α (usually 0.05) then you can state a statistically significant difference between the means from the two models. • Calculate the value of the mean difference between the scenarios and its CI. The conclusion of scenario comparison results should include: • Mean difference • Minimum and maximum of differences • CI for mean difference • Statement of statistical power of comparison test and effect size • Final comparison statement
11.8.4	The model stability outputs should be reported and commented upon in the Base Model Development Report. Any significant discrepancies from the average should be explained in detail.
12 – SCATSIM modelling	
12.2	Is the application of SCATSIM appropriate – refer to Table 12.1
12.6.1	SCATSIM methodology process – refer to Figure 12.2
12.11.1	Validation of the signal operation to be undertaken by graphical comparison of observed/modelled IDM data to the satisfaction of RMS Network Operations staff.
13 – Corridor modelling	
13.1.2	The guidance presented in this document relates to LinSig version 3.0
13.2.3	In LinSig it is possible to specify traffic flows in vehicles per hour. In this case care needs to be taken that saturation flows are also specified in vehicles per hour. If using vehicles it should be noted that all LinSig output tables will be wrongly headed using the unit PCU – these headings need changing manually. Conversion of queue lengths in vehicles to queue length in meters will require an approach traffic composition to identify the average vehicle length. If SCATS Maximum Flow (MF) data is used to provide model saturation flows it should be noted that this is specified in vehicles per hour.
13.2.5	Collection of classified traffic volumes is important due to the differing performance characteristics and road space occupied by the various vehicle types. As a minimum the classifications should include light and heavy vehicles, but improved model accuracy can be achieved with a greater range of vehicle classifications. Saturation flow surveys may be required if SCATS Maximum Flow data is unavailable.
13.3.5	The minimum clearance time is made up of the clearance 1 and clearance 2 intervals as defined in the controller personality.

13.3.8	Proposed intersection designs should not incorporate adjustments for yellow light running. The design must work satisfactorily without the need for the additional capacity such an adjustment provides.
13.3.9	Under this methodology, pedestrian delays cannot be extracted directly from the model. It is therefore recommended that if pedestrian delay times are required they be calculated using an external tool or spreadsheet.
13.3.13	Example. At a three phase intersection, due to low demand, Phase B only runs in 50 per cent of the cycles during the AM peak hour. When Phase B fails to run, Phase A receives all additional green time. In a cycle that completes the full three phase sequence, phase times are: Phase A = 80 s Phase B = 20 s Cycle time = 80 + 20 + 30 = 130 seconds Phase C = 30 s The LinSig modelled phase times should be as follows: Phase A = 80 + (0.5 x 20) = 90 s Phase B = 20 x 0.5 = 10 s Cycle time = 90 + 10 + 30 = 130 seconds Phase C = 30 s The modeller should be aware that where a phase is rarely demanded, it is possible for the hourly average phase time to violate the phase minimum. If this occurs the appropriate LinSig signal group minimums should be reduced to allow this phase time to run, as the key concern is accurately modelling existing intersection capacity for the main movements. The modeller must be careful in applying the same assumption to future year scenarios as it may no longer be valid if side road demand has increased. In the case of SCATS controlled intersections the average percentage values of phase length from the IDM data will correctly account for infrequent phase demand.
13.3.17	Should the green time for the movement be less than or equal to the queue clear time for the shortest lane, then the effective saturation flow is equal to TBs1+TBs2
13.3.21	A modeller using their local knowledge of the network to correct count discrepancies before entering these as junction turn counts will always result in a higher quality estimation than leaving LinSig to produce an estimation based on inconsistent data.
13.3.23	TIP: Connect weave connectors to an unconstrained lane (such as an intersection exit arm) as this prevents the model incorrectly reporting the build up of sliver queues on the downstream link (see Section 13.3.25 on Sliver Queues for further information). TIP: When building your network, start with the bare minimum of connectors required to get all the “actual” network demands and junction turn counts to match the “desired” values. Then begin adding weave connectors to balance lane delays as necessary. Remember to rerun the assignment after each change and once satisfied with the lane connector structure run the matrix estimation a final time to ensure all the new routes are taken into consideration.
13.3.24	TIP: If a u-turn manoeuvre at a roundabout or intersection is permitted, but very few vehicles are observed to use it and those that do have no impact on overall intersection capacity, consider removing the u-turn connector and ignoring those u-turning vehicles
13.3.25	LinSig is primarily a tool focused on traffic signal operations. It cannot accurately model the midblock delay caused by merges and side friction behaviour such as parking or stopping buses. These effects can be accounted for through longer connector mean cruise times to ensure signal offsets are accurate, but this requires collection of cruise times on street. If detailed assessment of midblock capacity constraints is required, microsimulation is better suited to this task.

13.4.1	The potential exists to make use of the SCATS Maximum Flow (MF) parameter, which provides a good estimation of lane saturation flow. To calculate a lane saturation flow from SCATS MF use the following equation: $$\textit{Lane saturation flow (veh/hr)} = \frac{\textit{Total phase time} \times \textit{SCATS lane MF}}{\textit{Phase green}}$$ SCATS MF Data may be made available by RMS. Contact the Manager, Traffic and Transport Modelling if MF Data is required.
13.4.3	The use of site measured turning vehicle delay due to the presence of pedestrians is particularly important in areas of high pedestrian activity as it is the only method that will capture these delay effects to traffic. As pedestrians can continue to commence crossing during the flashing red man the variability of this delay can be significant.
13.4.4	Be aware that both of the above methods for accounting for underutilised green time need to be removed before carrying out any signal optimisation. The calibration measures are dependent upon the signal timings in operation and as such calibration adjustments to saturation flows or green times are not likely to be valid for ant future set of signal timings.
13.5.2	It should be noted that for new intersection designs a DoS of no higher than 90 per cent should be aimed for. This is what is known as the practical operating capacity, above this threshold (due to random traffic arrival patterns and driver inattentiveness) queues and delays can become excessive. Where this is not possible due to existing traffic congestion the project should aim to improve upon the base case DoS.
13.5.3	Development of future year scenario models should only commence following satisfactory validation of the base models. Using a copy of these models as the starting point, the future year network can then be coded, leaving all parts of the model that are unaffected by the future year scenarios unchanged from the base model. In this way the calibration and validation can be retained with only the relevant changes re-coded in the model.
13.5.5	Timings obtained from a calibrated model of existing conditions should be compared with those obtained from the LinSig optimised timings. Differences can be compared and an explanation provided as to why they may exist. Table 13.5 provides a summary of the steps required to distinguish optimiser effects when undertaking any analysis involving LinSig optimisation. When calculating future option assessment signal timings, the LinSig optimisation process should generally be constrained to the RMS standard signal diagrams (see section 14.2.9 for examples) with appropriate pedestrian behaviour also reflected.
14 – Single intersection modelling	
14.2.2	Saturation flow measurements should be undertaken whenever possible on approaches that are heavily congested or forecasted to be heavily congested. Friction due to the presence of bus stops, short lanes and on-street parking should be correctly accounted for as part of model calibration.
14.2.6	Adjust default values for gap-acceptance parameters (ie critical gap and follow up headway) to local site conditions and provide justification.
14.2.8	The phase sequence and timings should be obtained from the site visit or directly from RMS as IDM data. Cycle time, offset and phase sequence to be in accordance with RMS advice.
14.2.9	Use RMS' Standard Traffic Signal Phasing diagrams

14.2.10	Values associated with model settings dialogue should be updated if possible using the *RTA Economic Analysis Manual*.
14.4	All changes required in order to calibrate the model should be documented. Table 13.5 provides a summary of the steps to be taken if any future scenarios require the optimisation of signal timings.

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PART B – Modelling guidelines

8 Strategic modelling

Strategic modelling is primarily used for estimating the effects on the transport network of:

- Major infrastructure changes.
- Different population/employment growth and distribution scenarios.
- Evaluation of travel demand management scenarios such as the introduction of alternative public transport, parking and pricing policies.

The primary source for strategic modelling in NSW is the Sydney Strategic Travel Model (STM) that is maintained by the Bureau of Transport Statistics (BTS) in Transport for NSW.

The STM produces forecasts for:

The Greater Metropolitan Area (covering Sydney, Newcastle and the Illawarra)

- Five yearly intervals from 2006 to 2036.
- Nine travel models (car driver, car passenger, rail, bus, light rail, ferry, bike, walk and taxi).
- Seven purposes (work, business, primary, secondary, tertiary education, shopping, other).
- 24 hour average workday.
- AM peak, PM peak and inter-peak travel (factored from 24 hour travel).

The STM is a series of models and processes that attempts to replicate, in a simplified manner, people's travel choices and behaviour under a given scenario. Inputs to the STM include:

- Population – using current demographics and population projections.
- Employment – using census journey to work data and employment projections.
- Household Travel Survey (HTS) – providing information to inform behavioural models such as amount of trip making, mode choice, destination choice, licensing and car ownership, trip length distributions and time of day factors.
- Journey to Work (JTW) – providing origins and destinations for travel to work.
- Freight Movement Model (FMM) – covering freight movements that are not in scope of the HTS.
- Road Network – providing a representation of the current and future road networks.
- Rail Network – representing the rail network and service patterns for current and future conditions.
- Bus Network – covering routes, stops and frequency of bus services.

8.1 Bureau of Transport Statistics (BTS)

Technical documentation for the STM is found on the BTS website www.bts.nsw.gov.au.

Outputs from a strategic model mean they are suitable for examination of the impact of significant proposed changes to land use or transport. Strategic models should not be used for detailed examinations. Furthermore detailed modelling (as outlined in the remainder of this document) should be used for detailed analysis.

Travel demand from strategic modelling is often used as an input to highway assignment modelling. In most instances the travel demand cannot be directly input to the highway assignment model and requires a level of demand adjustment.

If demand adjustment is to be undertaken prior to highway assignment modelling, the modeller must ensure that the integrity of the strategic model demand matrix is not compromised by the demand adjustment process. A detailed summary of the changes made to the matrix during the demand adjustment process is required. This process is discussed in the following section on demand modelling.

9 Demand modelling[3]

9.1 Introduction

Urban transportation planning is the process that informs decisions on transportation policies and infrastructure programs. In the transport planning process, planners develop information about the impacts of the provision of alternative transportation facilities, such as new highways, changes in public transport or parking restrictions.

The strategic transport planning process relies on travel demand forecasting, which involves predicting the impacts that various policies and programs will have on travel in the urban area. The forecasting process also supports analysis at a more detailed level for use by engineers and planners in preparation of detailed designs by providing information such as traffic volumes or bus patronage.

Demand modelling is the core activity in the transportation planning process and can be considered as lying between network modelling and traffic assignment modelling and is a crucial part of all strategic transportation models. While transport network modelling (roads and public transport – including rail, air and ferries) includes the creation of models that replicate physical characteristics of the road and/or the public transport networks, inputs into demand modelling deals more closely with human behaviour.

The diversity and unpredictability of individual human behaviour ensures that traffic behavioural data is not universal. Behavioural characteristics vary widely between different cities (and even different areas within those cities) and while there are some general similarities that can be found in comparisons of cities, there are many different factors that influence human travel behaviour, including: the size of the city, its urban density, its layout, the demographic and cultural properties of its population, economic conditions and the type and quality of the transport networks. These factors all play a vital role in influencing transport demand.

Because of the variability of human behaviour, to forecast transport demand with confidence it is always necessary to collect and analyse data that will reflect the makeup of the study area.

These guidelines provide general recommendations for demand modelling. Modellers need to ensure that demand models they develop are appropriate for the area and period for which they are forecasting. They will need to use their own expertise and professional judgement to infill gaps that these general guidelines do not address.

9.2 Basic Demand Definitions

9.2.1 Travel Time Periods

Depending on the size of the study area, peak periods and daily transport demand profiles, it is common practice to model demand periods that are longer than the peak hour to capture the full demand associated with peak periods (typically two–three hours are used to capture this). The modeller will need to define the periods for which demand will be analysed and forecast.

9.2.2 Travel demand

Travel demand is a secondary demand, arising from the spatial separation of home and basic human social activities such as work, education, shopping and recreation. Individuals travel from one point to another with trips of different purposes by various modes and durations and at various times of the day.

In everyday life, each individual makes a large number of trips, from micro-trips (kitchen to garden) to mega-trips (long interstate or international trips). Generally, micro-trips are made more frequently and mega-trips are very seldom. However, micro trips have correspondingly smaller impact on transport facilities and the environment.

Two types of demands are generally created:

- Analysis of existing travel demand patterns.

[3] SMEC Australia Pty Ltd has prepared this section of the guidelines dealing with Demand Modelling.

- Forecast of future demand using estimates of future values for independent variables such as population, employment and income.

Travel demand modelling is part of the overall transportation planning process and the form of a model depends on the methodology and computation techniques devised. As part of the overall transport modelling process, the demand model needs to be compatible with preceding (network creation) and subsequent (traffic assignment) transport modelling steps. There are some common rules and definitions that will help with the important need for compatibility between the various components of the various modelling steps.

9.2.3 Mobility (trip rates)

The usual most basic measure of transport demand is called mobility or trip generation rate. Mobility is expressed as number of trips per unit, where a unit might be a person, a household, or a unit area of a specific land use type. Mobility can be disaggregated into the number of trips per specific purpose or mode. Some trip rates are fairly stable over time (work related trip rates are steady) while other trip rates are growing (recreation, leisure and shopping, for example). In general, trends in overall mobility appear to be growing over time and this needs to be explained and taken into consideration in forecasting transport demand.

9.2.3	Mobility is the basic measure of demand and is expressed as the number of trips per household or person by specific mode or purpose of trip.

9.2.4 Trip (definition)

A clear definition of a trip is essential in transportation planning and modelling. For obvious reasons, not every trip can, or should be modelled (micro-trips have no impact and international trips have little meaning for a metropolitan area model). Careful definition of a trip helps to establish the line between what is included in the model and what is left out.

A common definition of trip is a movement longer than 100 m from one point (the origin) to another point (the destination) made by a person older than 6 years (children over two years pay something).

This is not a firm definition and needs to be refined to suit each individual study. In general, a trip should be defined taking the following into account:

- The start point and end point of a trip.
- The purpose for which the trip is made.
- The mode by which a trip is made.
- The length of a trip.
- The times that a trip starts and ends and its duration.

The purpose of a trip reflects the need to make that particular trip. Typical purposes are work, education and shopping trips. Mode defines the part of the transport network that the trip will use. The start and end times of a trip are useful in separating peak period trips from others, though peak periods are not always the focus of transport models.

The general measurement of a transport network's physical characteristics and performance may be summarised and measured by its capacity. This may be defined as number of trips a transport network could carry in a specified period (usually, but not always, an hour). Depending on the type of network, capacity can be expressed as:

- The number of vehicles/hour.
- The number of public transport passengers/hour.

9.2.4	The trip is the basic unit of traffic demand. It is characterised by origin, destination, purpose, mode, duration and time of day.

9.2.5 Trip Chaining

The point where one trip ends is often the start point of a new trip, depending on the definition of a trip. A series of trips throughout the day can be regarded as a chain of individual trips, with destinations of some trips coinciding with the origins of others. This perspective assumes that every trip is separate, each with a specific purpose and made on a specific mode. Distinctions can be made between primary destinations and intervening stops as well as direct and chained trips. The concept of tours defines the total travel between two primary destinations (which can also be the same place, ie home-to-home or work-to-work).

An alternative perspective is to regard the person-trip as made up of a series of destinations, where individual trips are linked. Linked trips describe travel from one activity to another ignoring change of mode but keeping trip purpose. In this case it is necessary to create a model hierarchy and mode priority to account for changes in mode. Linking trips could be defined in different ways to suit the overall modelling methodology and specific study needs.

9.2.5	The definition of trip chaining can include: • Trip chains that involve a series of individual trips taken throughout the day where the destination of one trip is also the origin of the next trip (with each trip having its own mode and purpose). • Person-linked trips that have multiple destinations and ignore the change in mode.

9.2.6 Trip purpose

There are a many possible trip purposes. The land use at the origin and destination of trips may be used to define the purpose of the trip and so, for example, a trip from a residential area to a commercial centre would be a home-based-work trip.

In a more detailed example, if the land use at the trips origin is home (residential x0,y0,z0) and its destination is the local swimming pool (recreational centre x1,y1,z1) then the purpose of this trip is “going to swim” or home-based-recreation. The next trip might include a stop at a shopping centre on the way home. Its origin is at x1, y1, z1, the location of the swimming pool and its destination is the shopping centre (retail x2, y2, z2). This trip has its purpose defined as recreation-to-shopping.

The total of all trips for all purposes creates actual total transport demand. Since the main purpose of models is to replicate real transport conditions, it is important to model as many trip purposes as possible to arrive at a complete view of demand. This is important because the validation of model reliability is commonly performed by comparing model results with actual traffic counts (which includes all purposes).

In general there two major group of trips:

- Home-based trips.
- Non-home based trips.

Home-based trips have at one end, a declared “home”. Trip rates, mode choices and other characteristics of these trips are typically related to the household trip making characteristics.

Non-home based trips are generally more difficult to model. Their number could be related to household trip making characteristics but their distribution is a function of the specific land use characteristics at both trip ends. Figure 9.1 shows magnitude and hourly distribution of home-based and non-home based trips for car drivers in Sydney.

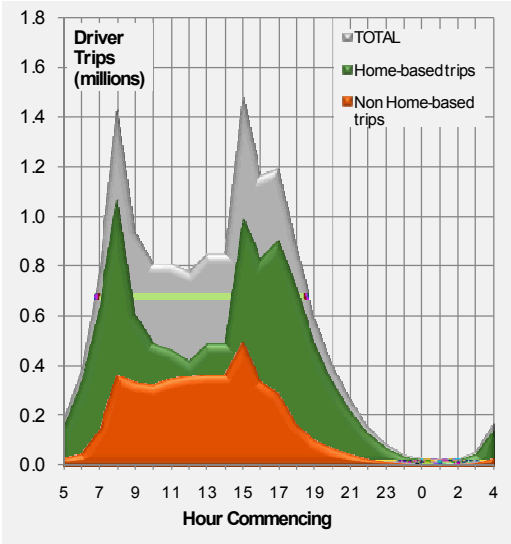


Figure 9.1 Distributions of home-based and non-home based car driver trips (Sydney GMS HTS 2007)

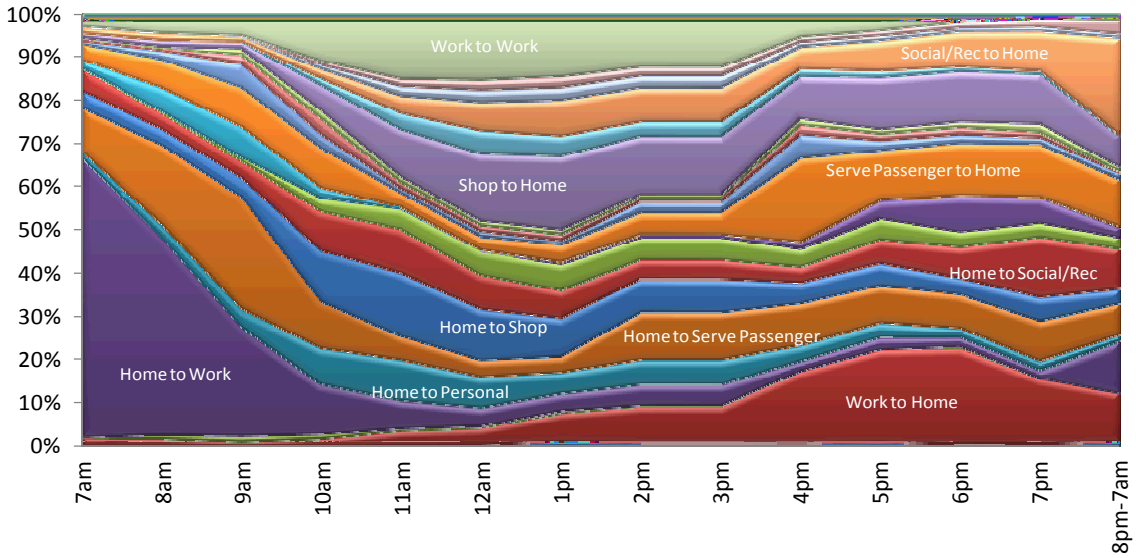


Figure 9.2 Hourly distributions of major trip purposes (Sydney GMA HTS 2007)

However in reality, the total number of trips is made up of trips with a large number of different purposes. These trips have different origins and destinations and they occur during different periods of the day. Figure 9.2 shows more detailed daily distribution of trips by purpose during the day and their share of all trips over a 24 hour period. This chart clearly illustrates the importance of analysis of trips by their purpose.

9.2.6	Trip purpose is the basic explanatory trip attribute. Since purposes are differently distributed through the day, their inclusion in modelling is vital for accurately recreating demand at different times of the day.

9.2.7 Trip mode

There are several common modes of transport – walking, cycling, driving, bus, train and other public transport modes. They each transport a share of the total number of trips and are dependent on the basic trip characteristics of travel by each mode (i.e. duration, purpose and cost) and their specific suitability to specific types of trips.

9.2.8 Trip time and duration

Start and end times of trips are used to define the quantum of trips in a specified period of the day. Duration is calculated as a difference between the start and end times of the trip.

9.2.9 Study area (modelling area)

Prior to the start of any transportation study it is important to define a study area that is relevant for the scope of planning being undertaken.

The Study area could be defined by the client's brief or by the modeller. For strategic models this area usually covers a continuous urban area of the city or region. This area could be extended to the areas where expected future growth will occur (as defined by Land Use Master Plans or other relevant documents).

9.2.10 Traffic zones (TAZ)

The basic data unit in transportation modelling is the traffic zone (TAZ). TAZs represent an area of homogeneous land use that produces and attracts trips. The traffic zoning system should be devised to coincide with (include as a whole number) the Census Collector Districts (CDs), or the recently introduced Australian Census Mesh Blocks.

Traffic zones comprise shape and position in the study area and are associated with all data relevant for modelling. TAZ cover the entire study area and create boundaries of the study area. They are called the "internal zone system". It is also necessary to develop an external zone system representing areas outside the study area. These zones usually do not have area since they represent large regions and remote cities connected on the border of the study area. They are usually represented by a regional road or transport link.

The development of the zoning system is one of the first steps in the development of a model and needs to be carefully designed. Once the zone system is created it is difficult to change later. There are many competing issues to be accounted for in developing a zone system. When zones are too large, local transport demand tends to be omitted. When zones are too small, there is often too few data to adequately represent transport demand patterns in each zone and computation times become prohibitive.

Number of zones depends on the size of the study area and sometime software limitations. The current zone system for the Sydney Greater Metropolitan Area model has 2690 internal zones and 25 external zones. The model created for the city of Orange has 187 internal zones and 10 external ones. However, the zone system for Orange is more detailed than the Sydney zone system because the population of Orange is around 40,000 and the population of Sydney GMA is 6.5 million. It is generally expected that models for smaller study areas will include a more refined zone system than large metropolitan models.

Computation time expands exponentially depending on the number of zones (Sydney matrices each include more than 7 million cells). Consequently, there is a premium in time to be paid for models that are too detailed in their zone system.

Sometimes the software licence size (number of zones that model can handle) dictates the size and shape of zones. In this case, it is worth considering software upgrades to allow for a more detailed zone creation.

Model results and robustness are largely dependent on the quality and suitability of the internal zone system. If zones cross physical barriers (eg rail line, creek, major arterial road) and are not homogenous in land use, the modelling process will be compromised. It is difficult to connect zones to the road and public transport networks and therefore, trip generation, distribution models and assignment models become less reliable as a result.

In creating a zone system, planners need to consider potential future land use changes in the remote future. Areas of future development need to be recognised and an appropriate zone system created for these developments that require a comparable level of detail as existing zones.

Figure 9.3 shows an example of a complete zone system created for the transportation study for the City of Orange.

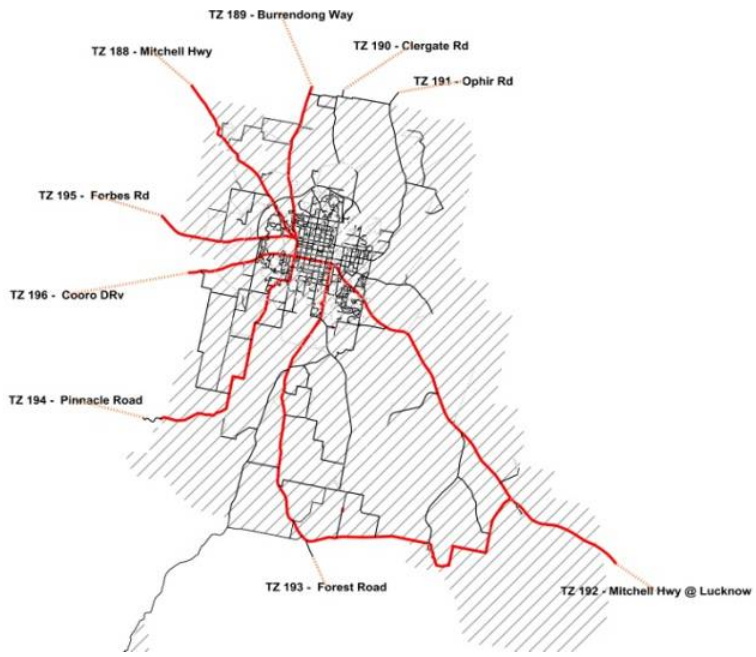


Figure 9.3 Internal and external zone system for the study area of Orange (NSW)

9.2.10	It is the modeller's responsibility to determine the extent of the area of relevance (ie the study area). The creation of traffic zones is important for all stages of transport modelling. Their proper creation has an impact on the quality and accuracy of demand modelling as well as the quality of network creation and overall modelling results. The level of zone detail is a matter of judgment.

9.2.11 Trip matrices

Transport demand is described in trip matrices. These matrices could be created for specific modes (car, commercial vehicles, public transport), for a specific time of the day (Peak, Off Peak) and for trip purpose (home based work or work to shopping trips). Trip matrices are the end product of transport demand modelling. They represent trips based on the systematic analysis of complex human behaviour. If trip matrices do not properly replicate travel behaviour, the transport model cannot be used with any confidence.

Trip matrices are square matrices with equal number of rows (origins) and columns (destinations). They could be created by mode, vehicle type, trip purpose and the period of the day. There would generally be several matrices representing the trip purposes in a model. The sum of all modelled purpose matrices represents the total trip matrix. To create hourly demand for the traffic distribution, each purpose needs to be factored appropriately to estimate the number of trips in a peak hour.

The size of the matrices is related to the square of the number of zones in the model and represents a spatial distribution of trips. These matrices are assigned to the corresponding network during the assignment process, which results in the loading of trips onto routes through the network.

Current traffic modelling tools are GIS based and allow for an easy graphical representation of results. Using aerial photography as a background, analysis of desire lines are useful to check if the modelled demand is logical and in accordance with the land use in the study area.

A graphic representation of the trip distribution described by the trip matrices is called desire lines plot. Figure 9.4 is the example of desire lines for home-to-shopping trips.

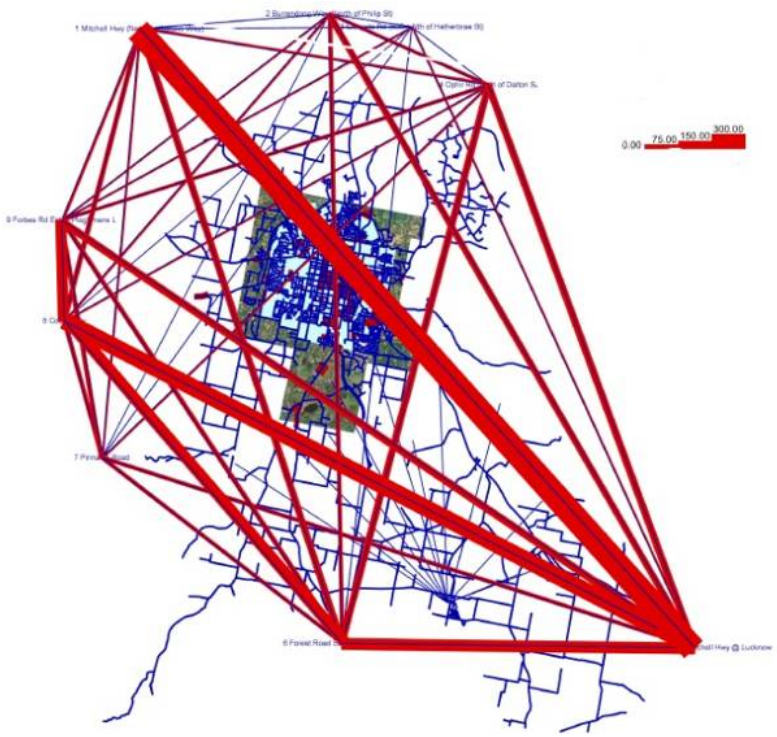


Figure 9.4 Home to shopping desire line plots – City of Orange

9.2.11	Trip matrices are the end product of the demand modelling process and they are a direct input to network assignment.

9.3 Appropriate use of demand

9.3.1 Demand Estimation in the Transportation Planning/Modelling Process

Demand modelling is the core of the classical four-step modelling process.

The four steps (also shown in Figure 2.5) of the classical urban transportation planning model are:

- 1st step – Trip generation, which determines the number of trips in each purpose arising at origins and ending at destinations in each zone, calculated as a function of land use, demographics and other socio-economic factors.
- 2nd – Trip distribution which matches trips associated with each origin to each destination, often using a gravity model function.
- 3rd – Mode choice computes the proportion of trips between each origin and destination that uses a particular transportation mode.
- 4th – transportation system route assignment allocates trips between an origin and destination by a particular mode to a route.

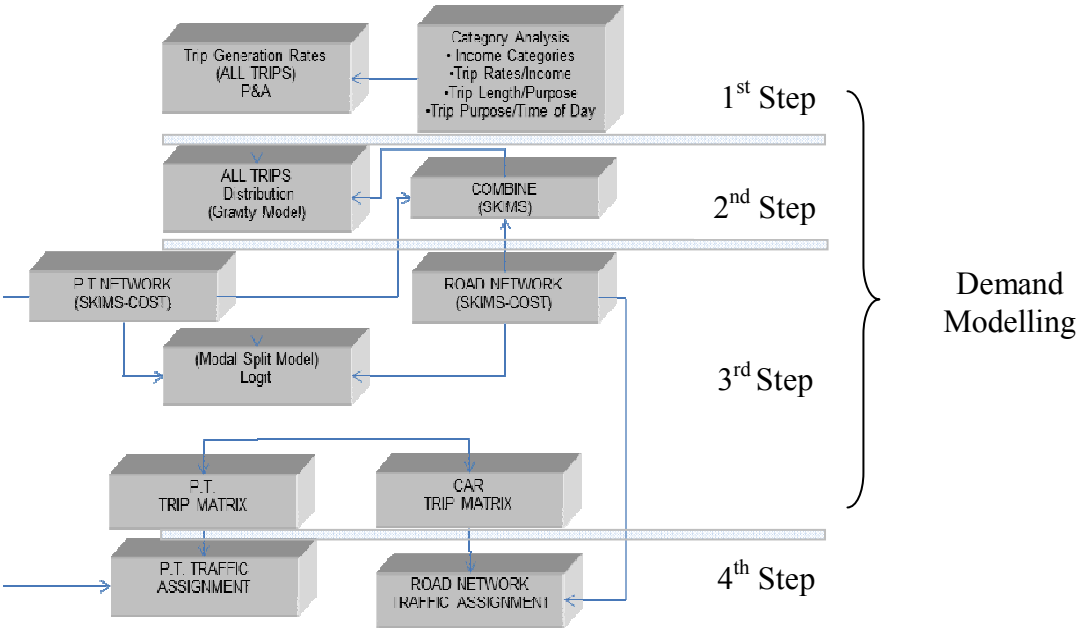


Figure 9.5 Typical 4-Step modelling process

Demand modelling is the subject of the first, second and third steps of the four step modelling process. Some strategic studies are created as three step models where only car trips are modelled and therefore the third step (mode choice) is omitted. Also, as a variation to this, models can be designed to split trips into modes before the second step (distribution).

There have been some recent developments in transport modelling that attempt to enhance trip distribution or replace it by other methods. One of these developments is activity-based models. They are a class of models that forecast individual trip movements rather than mass numbers travelling between zones. Many of these advanced modelling practices have been implemented only recently and there is not yet consensus that they should be widely adopted. More recent studies have not implemented activity-based or tour-based models since there is no actual evidence of their advantage over classic four step modelling. Instead more practitioners focus their resources on further refinement of the traditional four-step model, particularly to more detailed transport system analysis and improved trip generation and distribution techniques.

9.3.1	It is the modeller's responsibility to choose the kind of modelling methodology. No matter what methodology is applied, it is essential that the model explains transport demand in the most accurate way possible.

9.3.2 Transport modelling hierarchy and use of demand

Transport models have various levels of detail and coverage from large areas like the Greater Metropolitan Area (that includes Sydney, Newcastle and the Illawarra) to a single road intersection each of which relies on transport demand as a critical input.

Strategic models are the highest level in the modelling hierarchy and are used in the category of Macroscopic studies. They create land-use/transport interaction models and use forecasts of land-use derived from changes in land-use policies and accessibility brought about by conditions on the transport system to forecast transport demand.

The models are used to assess land use changes and to define appropriate impacts of these changes on transportation systems and vice versa. Strategic models are mostly used by government or city organisations in charge of Land Use Master Planning. The primary input into strategic models is the land use changes in incremental forecast periods usually five years with ultimate horizons of 20 or 30 years.

They are often used to optimise spatial distribution of activities and to prioritise land development or for planning the provision of transport facilities by assessing the impact of different land development options on the transportation system. They tend to minimise traffic impact by optimising distribution of urban activities by minimising trip length and therefore the need for mechanised travel (through active travel such as walking and cycling) and, as a result, reduce traffic demand.

By their nature, strategic models are detailed enough to assess land use changes but are not always detailed enough to define all the necessary parameters of transport networks. Their main output is transport demand, typically measured in trips by vehicle or total person trips. The difference of modelling person trips by vehicle and total person trips (besides the difference in terms) is in the modelling approach, which is fundamentally different. Modelling vehicle car trips only requires a three-step modelling approach while modelling total person trips requires the full four step modelling process.

The main output of strategic models is transport demand. Trip tables produced by these studies are developed from first principles using trip generation, trip distribution and modal split procedures. In four step models the mechanised person trip matrix is input to the complex modal split process to produce vehicle (car) and public transport passenger trips in the form of matrices. The vehicle trip matrix is a direct input to the traffic assignment step (for three-step models).

Transportation System Studies (Highway Assignment Model or Public Transport Model) belong to the macro-analytical or mesoscopic levels of modelling. They use inputs of land-use which have been forecast exogenously. They are similar to strategic studies but they have a different methodological background, different inputs and different application.

Their aim is to optimise development of transportation systems, which will satisfy given demand in the most beneficial way. Mode choice is not explicitly modelled but the effect of mode choice can be replicated at this level by using outputs derived from higher level strategic models.

They are used to forecast the need for refinement of the road or public transport networks through infrastructure upgrades and pricing impacts and can also be used as a basis for even more detailed analysis that incorporates some elements of network assignment (such as Microsimulation and Corridor Modelling). These models are used to assess different options and to determine subsequent transportation system development. They are suitable for corridor analysis and optional evaluation of different road layouts. Depending on the software platform used they can be refined to include intersection delays, signal timings and complex public transport interchange behaviours.

9.4 Demand development process

9.4.1 Demand creation steps

In the four step modelling process there are three equally important steps in the strategic demand modelling process:

- Trip generation.
- Trip distribution.
- Mode split.

Demand modelling in the three step modelling process has only two parts (trip generation and trip distribution).

9.4.2 Trip generation

Trip generation assumes that trip rates depend on the type and intensity of land use. The basic assumption of the trip generation step of the 4-step modelling process is that the number of trips produced by, or attracted to, each zone can be estimated by analysing specific transport data. The implicit assumption is that accurate land use forecasts can be used to forecast the number of trips accurately.

In undertaking the trip generation step it is necessary to collect data to explain complex human behaviour and the relationship of this behaviour with respect to land use. In transport modelling practice, this data is collected by undertaking specific surveys designed to suit the needs of transport modelling. They need to collect (at a statistically reliable level) all data necessary to explain basic trip

characteristics like mode of travel, purpose of trip, duration of trip, start/end time of trip as well as relevant socio-economic data of trip makers (like car ownership, income, employment status and education).

In addition, regular Census data can be used to check and validate data collected by traffic surveys. The Australian Bureau of Statistics (ABS) collects data in relation to journey to work (JTW) trips. Since ABS data can be collected for different spatial levels (mesh blocks, collector districts or destination zones), this comparison requires some additional work to adjust the various levels of geographic coverage if two or more separate data sets are used. To make this adjustment easier it is advisable, in the development of traffic zones, to establish spatial consistency with ABS land units (see 2.2.9).

In forecasting, depending on the methodology adopted, any possible changes in future trip rates needs to be modelled and forecast. Planners need to analyse historic data and develop a forecasting methodology appropriate to model future time horizons. It has been found that levels of mobility have increased over time and this growth differs from purpose to purpose (which is a critical consideration in achieving reasonably accurate forecasts).

9.4.2	Trip generation is based on collection and analysis of complex travel behaviour data.

9.4.3 Trip distribution

Trip distribution is based on simple mathematical processes and basic assumptions that relate traffic patterns across the road network to the number of trips generated at the traffic zones. Having said that, the application of trip distribution methods has historically been the least developed step of the 4-step modelling process with calibration to road network observations forming a vital (and resource intensive) element of the distribution process.

The larger the origin parameters (eg number of households per travel zone) and destination parameters (eg number of employees per travel zone), the higher the tendency to make a trip between this pair of zones. Conversely, the further apart an origin and destination are, the lower the tendency to make a trip between this pair of zones. This means that, in modelling terms, travellers try to minimise distance, time or cost when travelling from point A to point B. This impact of this assumption varies from purpose to purpose. Some trip purposes are less sensitive to the distance/time/cost component and some of them are more sensitive.

The distribution step of the 4-step modelling process is based on these data collected by specific traffic surveys of the road network. They use the trip ends produced by the trip generation step and employ mathematical formulas to explain complex human choice behaviour. The models need an extensive calibration exercise and have to be calibrated in such a way that model outputs meet observed relationships between the spatial distribution and numbers of trips. As a result distribution models produce “trip matrices” representing expected distribution of trips in the study area.

For forecasting, the assumption is made that the calibration constants will not change over time. This means that we assume that travellers will choose a destination in the same way in the future as they do now.

9.4.3	Distribution models define spatial distribution of trips in the study area. They use trip ends from the trip generation model and they are calibrated using data from specific transport surveys.

9.4.4 Mode split

Mode split aims to split a single trip matrix into several trip matrices representing trips on different modes of travel. It distributes total demand (usually only mechanised trips) to the appropriate transportation network (roads or public transport).

Mode Split uses physical characteristics of the transport networks to derive a share of the trips allocated to particular network. It assumes that the probability of choosing a particular mode is proportional to the probability that the perceived utility of that mode is greater than the perceived utility of other modes. As a result, this model creates demand matrices for each network to be used for evaluation and testing each of the networks.

In general, there are two ways of applying the mode split step in the 4-step process:

- Pre-distribution mode split (Trip End Modal Split) is less complicated and is based on the up-front definition (based on the survey data) of productions and attractions (trip rates). While it may be possible to find some relationships between physical characteristics of the networks (number of stops, public transport services, parking availability, network density) and surveyed mode split, this approach does not include variables related to the general network characteristics. For this reason, pre-distribution models are not commonly used.
- Post-distribution modal split (Trip Interchange) estimates the number of trips between two zones following the trip generation phase. The most used approach is a disaggregated behavioural logit model. This approach calculates the choice for each individual zonal pair based on the utility optimisation between competing networks.

Some steps are required before applying modal split. One is to define only mechanised trips (excluding walking and other non-mechanised trips). Another is to define so called “captive” trips – the proportion of households with limited choice (households with no cars, or persons with no driver’s licence).

The calibration process of a choice model consists of estimating parameter values evaluating the statistical significance of the estimates, and then validating the model by comparing its prediction with the observed behaviour. Giving large number of parameters modal split calibration could be time consuming and could require iterative refinements and adjustments of parameters.

9.5 Other demand factors

Special generators are land uses that generate trips at a significantly different rate and in a different way to normal zones. Since the attraction variables are mostly quantified in zones as employment (by type) or enrolment (primary, secondary, TAFE etc) there are some zones where this is not a primary trip making variable.

Quite often these special generators are not appropriately handled in a traditional model. These generators include ports, airports, intermodal nodes, hospitals etc. Some part of the attraction may be modelled using employment data but due to their nature their attraction rates are driven by more than just employment.

These zones are usually connected to major arterials or public transport services and underestimating demand can impact negatively on model reliability. To obtain data for modelling, specific surveys need to be undertaken to “adjust” trip generation for such trip generators. Data collected for this additional traffic generation need to be further compared with independent data variables, like departures and arrivals at an airport or adjusted to reflect throughput tonnage at a port. With forecasts of these variables, it is possible to adjust the demand that is calculated using standard procedures applied to the whole model.

Induced demand suggests additional traffic and an increase in traffic volumes as a consequence of increased infrastructure capacity. Demand forecasts in urban transportation planning have been based on exogenous variables such as land use, population, employment and income. The relationship between trip generation and these factors is assumed to be constant over time, an assumption that may not be accurate.

There is much debate about the effect of additional capacity on demand. One view is based on the premise that “build it and they will come”. This approach assumes the presence of latent demand (ie demand for travel that is not realised because the existing level of service is not high enough). Major sources of potential induced traffic are:

- Shifts from other modes, which may or may not have used the facility before, including changes in occupancy.
- Shifts of destination brought about by improved accessibility to areas resulting from the provision of the new facility.
- Additional travel due to improved accessibility.

At the strategic modelling level, induced traffic would be a small share of total traffic growth because only trips diverted from other zones, plus substitutions make up the induced share. New facilities will attract more trips to the specific mode and will be assessed in the modal split model assuming that total demand will remain the same. To do otherwise would require changes in trip rates.

9.6 Development of demands based on outputs from the Sydney Strategic Travel Model (STM)

9.6.1 STM demand

The STM is a strategic multi-modal modelling tool incorporating the latest population and employment forecasts. The STM has been successfully used to inform evidence-based policy development and decision-making in strategic, metropolitan scale land use and transport scenario modelling projects.

The model covers the entire Sydney Greater Metropolitan Area in 2,690 travel zones in the 2006 zoning system. It models seven travel purposes (work, business, primary school, high school, tertiary, shopping and other); seven transport modes (car driver, car passenger, train, bus, walk, cycling and taxi) and four times of day (AM, Inter-Peak, PM and Evening). The model years are 2011, 2016, 2021, 2026, 2031 and 2036, and will include 2041 and 2046 in near future.

9.6.2 STM demand data & use

The key data set generated from the STM forecasting for road traffic assignment is the car driver demand matrices. Bureau of Transport Statistics (BTS) also operates the Freight Mode Model (FMM) to derive commercial vehicle demand matrices. Both car driver demand and commercial vehicle demand are needed in road traffic assignment.

The other data sets relevant to road traffic assignment are the skim matrices in time, distance and toll.

9.6.3 STM demand limitations

The current STM is estimated on the Household Travel Survey data up to and including 2008 and Journey to Work data up to and including 2006 Census. It assumes that the travel behaviour responses to times, costs and modes within synthetic household classes do not vary over time, although the number of people within each household class will vary along with demographic change and socio-economic change.

The STM models an average work day, adopts the equilibrium assignment method for road traffic and does not apply a capacity constraint on public transport use. Whilst the STM has been validated to ensure that it reproduces reasonable estimates of current travel behaviour, it has not been calibrated to match base year travel in this implementation.

The existing zoning system is relatively coarse and the STM relies on the land use forecasts as one of key inputs.

Therefore, for specific projects, the STM results should be used as a starting point to produce estimates of overall demand in response to alternative land use and/or transport supply scenarios.

9.6.4 ABS data

Journey to Work (JTW) data are derived from the five-yearly Census of Population and Housing conducted by the Australian Bureau of Statistics (ABS). Data on employment by industry and occupation, and method of travel to work at a fine geographical level known as the travel zone is included. This information is a valuable resource for the analysis and forecasting of employment, commuting patterns and land use changes.

Each JTW table has a different combination of variables and is for a specific geographic scope, either for the Greater Metropolitan Area (GMA), for the “Rest of New South Wales” or for “All of New South Wales”. A table may be based on the place of usual residence (or trip origin end) only, the workplace (or trip destination end) only, or have both origin and destination ends, therefore providing a JTW trip matrix.

BTS JTW data may produce slightly different counts to those obtained directly from the Australian Bureau of Statistics (ABS) for the same geographic level due to:

- ABS confidentialising process (randomisation of small cells).
- Further validation and adjustment of these data by BTS.
- BTS imputation of records of incomplete addresses to eliminate locality “dump” codes.

9.7 Development of demands using the first three steps of the four step modelling process

Demand development is very similar in both the four or three steps modelling process. The following diagram below explains basic building blocks in the four step modelling process.

As shown in Figure 9.5 above, demand modelling is part of the second step in the three or four step modelling process.

In the four (three) step model, all steps are interrelated and results of previous steps are inputs for the next step.

As a predecessor of the modelling process, data collection and basic survey analysis are located in the first modelling stage. Trip generation is usually performed in the first step while trip distribution makes up the second modelling step.

In three step modelling, the third step is omitted. Estimation of the demand is finished in the second stage and the usual fourth stage, traffic assignment, becomes the third and final modelling stage.

9.8 Demand modelling data collection

9.8.1 Relevant Traffic

Different types of trips make up the total trip matrix. Figure 9.6 below explains four of these types. These types of trips determine the methods and sources of data collection used in demand modelling.

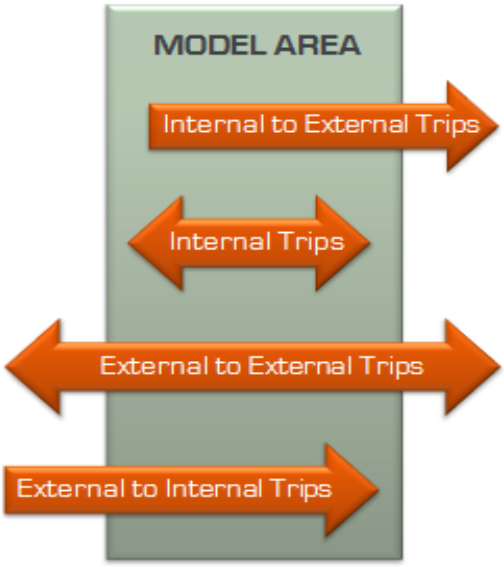


Figure 9.6 Study area traffic and trip matrix

All trips wholly within the study area are called internal trips. Trips to and from the study area and to and from outside of the study area are called internal-external (or external-internal) trips. Finally, trips that start and end outside the study area are called external-external or through trips.

The classification of trips into three classes ie internal, external-internal and through trips is unique to each study (meso scale and metropolitan level, small area studies) because all traffic related studies

must have a defined study area. To be able to define relevant traffic data properly, data related to all of these trips must be collected. The nature of these trips is different; while through trips may travel on a by-pass, external-internal trips need to be identified before they reach a heavily congested CBD area.

The following points are some ways of collecting data for strategic demand modelling:

- Household Travel Surveys (to collect data related to internal trips).
- External trips (road side surveys – RSS) to explain and collect data related to external trips.
- Special Generators Surveys.
- On-board transit survey (for mode choice model estimation).
- Depending on the character of study, some additional surveys may be needed such as:
  - Park-and-ride lot surveys.
  - Taxi survey.
  - Hotel guest survey.

For cordon studies, a sub-area is created as part of the larger Strategic model area. Most of the transport planning software is capable of creating a cordon model automatically. In this case, all trips within the study cordon area become internal trips and all outside the cordon area becomes external trips.

These guidelines focus on the first two most important data collection techniques and their use (HTS and RSS).

9.9 Household Travel Surveys (HTS)

The HTS is the centre point of any strategic transportation model. It is usually the major source of information used to develop a set of models for estimating travel behaviour in a study area.

The aim of the survey is to collect all relevant data for strategic transport modelling, in regards to trips (and their characteristics) as well as data related to the household's characteristics.

There are no differences in HTS for three and four step models. An HTS usually collects universal data and the choice of the type of model may then be a matter of the modeller's choice.

9.9.1 HTS area

Household travel survey area must coincide with the study area. This area usually covers a continuous urban area with the addition of areas expected to develop in the future. It must have a clear boundary including a full number of traffic zones. All zones within this boundary make up the internal zone system.

9.9.2 HTS methodology – Sampling

Almost always, this type of survey involves sampling, because it is practically impossible to survey every household. Opinions of an appropriate sample size differ widely. One view suggests that a smaller sample size is acceptable for large populations. However, it is usual to choose a sample size that is appropriate with the chosen model methodology.

For example, if a cross-classification trip generation model is chosen, the practical guideline for determining the appropriate number of samples suggests a minimum of 30 samples (or households) for each cross-classification stratum so that adjacent strata may be compared for statistical significance.

If the proposed demand modelling methodology analyses four income categories, cross-classified by five household size and four worker categories, a minimum of 2400 correct observations would be required.

9.9.3 HTS methodology – data gathering

Organising HTS requires strict rules, staff mobilisation and discipline. Depending on the area size and overall cost, different survey methods have been utilised in the past, including:

- In-home interview.
- Mail out-telephone interview retrieval.
- Mail out/mail back (or self administered).
- Recently more sophisticated GPS based method has been introduced.

For Sydney GMA, the BTS collects data on a year-to-year basis in over 5000 households. For example, HTS were created for the Transportation Studies for Great Lakes and Orange, such as home interview surveys were conducted to gather travel behaviour data and the mail out/mail back method was also used, as it was the most appropriate, given the size and nature of the area.

9.9.4 HTS methodology – creation of questionnaire

Each HTS consist of two questionnaires, collecting:

- Household data.
- Trip data.

Household data and trip data need to be linked together to analyse relationships between them. Household data take a snapshot of the household, defined by relevant traffic characteristics such as household size, income, car ownership and type of dwelling (are basic general data). In addition to this, information regarding the individuals within a household need to also be collected, including age, education, employment status, and driver's licence .

In general there are two methods of collecting home travel survey information:

- Traditional trip based survey method.
- Activity based survey method.

The information obtained from a trip-based survey is limited to the traveller's interpretation of trip purpose based upon a set of predefined trip purposes listed in the questionnaire.

An activity-based survey recognises that activities are the fundamental descriptors of trip making. The information reported about each activity, including the type of activity and the corresponding name of the establishment (or activity), is an important key in describing or defining a set of trip purposes. Linking an origin and destination activity combination could more accurately refine and describe trip purpose in comparison to predefined trip purposes.

A questionnaire from the BTS survey is available on the BTS website.

9.9.5 HTS methodology – data coding and data debugging)

Collected data generally need to be transferred from one media (paper) to electronic form. To do so, a set of rules (codes) are required. To facilitate processing for each collected item, an appropriate numbering system needs to be established. As an example, household income could be grouped in several numbered categories starting from 1 to N. Trip mode could be coded as 1-walk, 2-car driver, 3-car passenger etc. It is important to keep record of these codes.

The start and end locations of trips need to be coded to the zone system created for the study area. Using a GIS database, a list of house numbers and street names could be allocated in each TAZ. This will facilitate coding of origin and destination trips.

To get maximum benefit from the survey, it is important to get as many correct questionnaires as possible. Each interview sheet must pass a routine edit check process before being included in the final data set.

Usual errors are caused by:

- Poor response of respondent.
- Illegible hand writing.
- Typing errors or poor reading of the person entering data.

Once data entry occurs, they can be validated by defining rules, often called logical control (eg destination of one trip needs to be the same as origin of the next trip, start time needs to be earlier than end time, etc).

Modeller and designer of questionnaires will define the level of logical control. Better and more comprehensive logical control will yield better results.

9.9.6 HTS methodology – data expansion

Once the HTS database is finally checked and created, it is necessary to expand data collected by sampling to the full numbers. Since all data are collected by households, it is obvious that the number of selected households needs to be expanded to the total number of households.

The simplest way of data expansion is to multiply by the ratio of actual number of households in TAZ to number of surveyed households in the zone. For example, if 8 per cent of households in a zone are sampled, results of each record for that zone should be multiplied by 12.5.

When allocating data to TAZ, the resulting sample is not always equal. To correct this, it is useful to further disaggregate the sample. For example, comparison of the number of low income households (collected in ABS Census) with low income households surveyed (HTS) will produce an expansion factor for “low income category” households in each zone.

9.10 External trips (road side surveys – RSS)

To complete traffic data for modelling it is necessary to add traffic generated outside the study area to the HTS collected data (internal trips). A system of external zones needs to be established before the data collection process starts.

The aim of this survey is to collect the following data, origin and destination trips, time of day, purpose trip, car occupancy, and trip duration.

The external survey should include a simultaneous external station count so the surveyed vehicles may be expanded properly to the regional total of external trips. Two methods of performing an external survey are:

- License plate survey.
- Personal intercept.

The license plate survey is more economical but is not always detailed enough for strategic demand modelling.

The personal intercept survey is more costly because surveyors must stop and interview participating drivers, but the quality of these data is much higher because a wide variety of questions may be asked about the trip being made and the quality of information can be carefully controlled.

The nature of this survey is limited in the amount of data collected. This survey is conducted on the open road by stopping vehicles and interviewing drivers and passengers. To minimise disturbance and frustration of drivers it is necessary to reduce interview time.

Also, to minimise impact on the traffic operation this survey could be also conducted on a sample (such as all red cars). Organisation of these types of surveys requires coordination and involvement of police, authorised traffic controllers and an authorised survey company. It also requires adequate measures in regards to safety. A traffic management exercise needs to be put together for each RSS. Special attention to paid choice of interview sites is chosen to assure minimum traffic interruption and maximum safety.

Coding and logical control is similar to the coding of HTS.

It is important to avoid double counting of trips such as internal-external and vice versa as these trips are already collected in HTS. Based on the nature of these trips, they could already be recorded on the border of the study area. Simple questions like “where do you live?” will avoid double counted trips.

It is also sometimes necessary to collect data for commercial vehicles as part of the RSS.

The most common data required for each CV type (using Austroads classification) includes origin and destination, capacity (tonnes), load (tonnes) and predominant type of goods carried. It is advisable to have a uniform sample by CV type.

9.11 Trip Generation

9.11.1 Model

Trip ends are considered to be either productions (typically starting from home or from the beginning point of a non-home-based trip) or attractions (to the point where an out-of-home activity will be undertaken).

This is why a trip generation model comprises of two basic models – a production model and an attraction model. They are both part of the trip generation model and a necessary input into the next demand modelling step (Trip Distribution).

The trip production model focuses on residences, assuming that the number of generated trips is thought of as a function of the social and economic attributes of households.

At the level of the traffic analysis zone, it means that land uses produce or generate trips.

The trip attraction model focuses on zones as destination of trips, ie the trip attraction of one zone depends on the land use activity for the specific purpose of the trip. Zones concentrated with jobs will, as a consequence, attract trips with work related purposes.

If detail classification of employment is available, zones where retail employment is located will be a work related attraction variable in addition to a shopping trip attraction variable etc.

It is possible that the same attribute is used in both models (productions and attractions. As an example, the number of households in one zone is the attribute used in the production model (for all home-based trips). At the same time for all trips with purpose “home” (return to home) the attribute for attraction is, again, number of households in this zone.

9.11.2 Data sources

Basic data source for modelling trip generation such as traffic surveys are provided by corresponding government or city agencies (ABS census, Department of planning, Department of education, etc) as well as data from specific studies (eg demographic forecast, economic forecast etc) prepared for the study area.

9.11.3 Basic definition

Mobility is one of the major planning measures that characterises an area of modelling. It is expressed as the number of trips per person or per household.

This number is a ratio of total trips divided by total population or total number of households. As a rule, this number multiplied by the number of households (or population) gives total number of trips in the study area.

Trip rates represent mobility per mode or purpose. They are related to the trip production model defining the total quantum of trips from one TAZ and whole study area. Sum of rates by purpose or mode is equal to the overall mobility per zone or study area.

For low income households, the majority of trips are related to basic human needs (work and education) while for other purposes there is not enough surplus income to make additional trips. As income grows, the income surplus grows too, producing more non-basic trips.

Table 9.1 Common variables and their use in trip distribution modelling

Variable	HH Model	Production	Attraction	Mode choice	Need forecast?
Population (res)	✓	✓	✓	✓	Y
Employed (res)		✓		✓	Y
Average income	✓				Y
Household size	✓	✓		✓	N
Income level	✓	✓			N
Car ownership	✓	✓			N
Total employment			✓	✓	Y
Employment by type 1			✓		Y
Employment by type i			✓		Y
School enrolment (primary, secondary)			✓		Y
University Enrolment			✓		Y
Zonal area		✓	✓	✓	Y
Recreational space			✓		Y

In forecasting planners need to model those changes. The number of future trips will grow according to growth of population and additionally anticipated growth in mobility.

9.12 Trip production and attraction models

9.12.1 Trip production modelling approach

The trip production model calculates the total number of trips produced by the household or person. This model needs to be disaggregated, depending on the overall modelling methodology, to the number of trips for each purpose.

Two general approaches to trip generation are commonly used and applicable to the production model:

- Cross-classification analysis.
- Regression models.
- Cross-classification analysis is the most common method in current practice.

This approach groups individual households together according to common socio-economic characteristics (auto ownership, income, household size, etc.) to create relatively homogeneous groups. Average trip production (trip rates) is then computed for each group from observed data. This analysis similarly can be performed for trip attraction models. (eg total number of primary school trips versus total employment in primary education).

Among the advantages of cross-classification are that it is simple to apply, it captures correlations among the independent variables well and it imposes no prior assumptions about functional relationships among the variables.

Regression models were once a common technique for trip generation analysis, although today they are used less frequently than cross-classification.

They are mostly based on linear regression. A major pitfall is that they could give acceptable statistical results even if explanatory variables are not relevant.

In addition, the nature of trip generation is not always linear and therefore introduces a number of problems in modelling. The use of a linear form in such circumstances would be a misrepresentation of trip travel.

9.12.2 Software built-ins

Most of the commercially available software has built in routines to calculate trip generation:

EMME/2 can implement trip-generation using regression, cross-classification or trip rates. These methods can be implemented using a matrix calculator.

CUBE can perform trip generation using regression, cross-classification or trip rates. Activity, discrete choice record based processing can also be implemented in CUBE.

TransCAD can perform trip generation using regression, cross-classification or trip rates. It can also use Institute of Transportation Engineers (ITE) trip generation rates, logit, user defined macros and user written programs.

VISUM can generate trips using regression, cross-classification, and trip rate daily activity schedules and time of day generation methods.

It is equally efficient and frequently used by modellers to use custom built spreadsheets and mathematical programs (mat-cad or similar) to perform trip generation analysis.

9.12.2	To create adequate trip production models, planners and modellers need to take special care of the availability of the variables used in the future. Some variables present today are difficult to forecast in the future. So in the creation of trip production models (and analysis), it is crucial to accept methodology, which will match the level of forecasting of independent variables in future.

9.12.3 Trip production analysis

Common household characteristics collected with HTS to be used in production analysis are:

- Household size.
- Number of employees (jobs).
- Household income.
- Car ownership.

They vary from zone to zone. Some zones are only residential and they have no employment data. Other zones are strictly job related and they don't have any data related to households.

Residential zones may have different car ownership as a result of household density, proximity to the CBD etc. Additionally, the distribution of average income varies around the study area and employment density and structure of employment differs from zone to zone.

9.12.4 Household size

There is strong dependence between household size and numbers of trips, ie bigger households are generally expected to produce more trips. Use of this parameter is limited due to the following difficulties to forecast household size in the future:

- Forecasting household size usually requires detail demographic studies but is generally not detailed enough to suit the specific requests of transportation planning studies (level of TAZ).
- Household size shrinks or expands over time. This occurs even for the zones without any relevant changes in land use (no changes in number of dwellings, no major reconstructions or new development).
- It is difficult to forecast household size for new (empty at present) zones where new development will occur.

Figure 9.7 shows change of household size in Australia. In 1911, the average number of persons per household is 4.5 with as recent as the last 10 years (from 1996 to 2006) the average has dropped to 2.6. (Current household size for Sydney GMA is 2.4 persons per household.

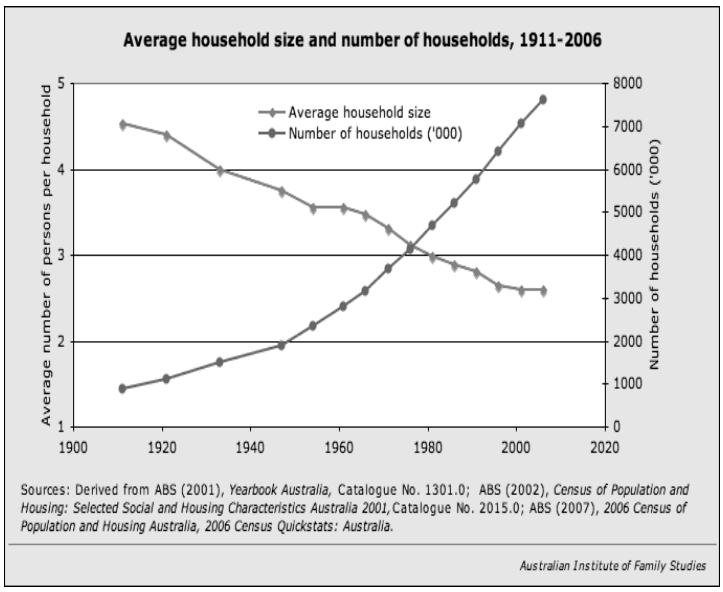


Figure 9.7 Historic data of household size changes over time in Australia

The Australian Bureau of Statistics collects data related to the household size on a detailed mesh block level and for each study area it is possible to get very detailed data in relation to the household size.

9.12.5 Number of employees

The number of employees per household collected through the HTS helps define work related trips. Since trip data and household data are related, it is possible to correlate the number of work related trips to the relative number of workers in a household. Usually, the number of work related trips is marginally lower (around two–five per cent) than number of employed in the household. The reason for this is absence from work due to annual leave, sick days, business trips etc.

Another characteristic relevant to a work related trip is the type of employment. Different “professions” have different characteristics and frequency of trips.

It is possible to analyse this information in detail, however, it is very difficult to forecast these parameters in the future. The number of employees is considered production variable trips where the origin is a work zone (work–home, work–shop trips etc).

9.12.6 Household income

Household income is a reliable base for trip production modelling. Income is strongly related to the GDP (Gross Domestic Product) and forecasts of this parameter are very reliable and relatively easy to make.

Household income is related to other parameters as well, including household size, number of employees, members of household, ownership etc. Household income shows strong correlation with total number of trips, as higher household incomes indicate more trips per household. Reason for that lies in the “surplus” of income to be spent on the non-essential trips – recreation, leisure, culture etc.

Figure 9.8 illustrates dependence of trip rates and income categories.

The use of this parameter has the following implications:

- This approach is based on the assumption that behaviour (trip rates) of households within the specific income group will not vary in the future.
- There is no good reason why low income households today will not behave in the same manner as in the future.

Australian Bureau of Statistics provides estimates of economic activity for each state on an annual basis.

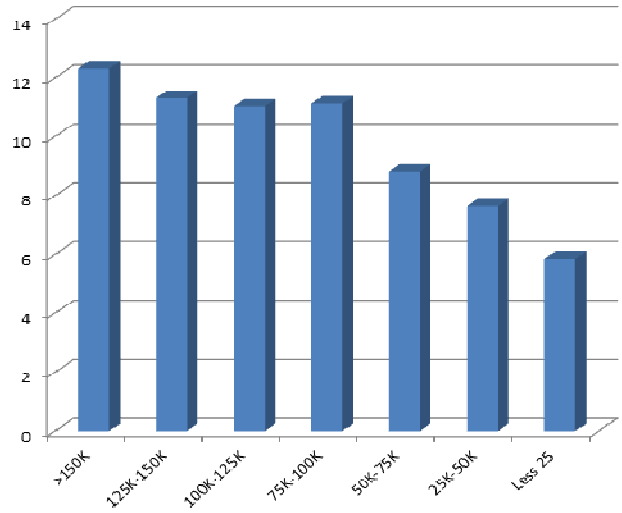


Figure 9.8 Income and number of total trips / household, Orange HTS 2008

The statistics provide insights into the relative economic performance of each of Australia's major capital cities over the past 20 years. Instead of GDP it is better to use ABS measures of Australia's progress. Australia's real national net worth per capita rose at an average annual rate of 0.9 per cent from 1995 to 2005. This growth will change income structure – the share of the low income households will decline over time and share of the high income household will grow. This will explain why the current mobility per trip rate of each group will remain the same while forecasting a rate of change in the future.

9.12.7 Car ownership

Auto ownership is important in four step modelling to define captive public transport trips and households with limited mode choice options. This is also an important parameter for mode split modelling.

Census data (shown in Table 9.2) is showing a decline of households in NSW without vehicles from 14 per cent to 11.2 per cent (from 1996 to 2006).

For modelling different areas in NSW, planners need to take into account characteristics of the car ownership for the specific area.

Australia's low density urban form influences large dependence on individual transport. This is more evident in smaller cities where public transport is not developed enough to completely replace the need for individual transport and ownership of a car. It is the planner's choice to decide the extent of the role of car ownership in trip making. Giving the fact that 90 per cent of households possess a car, it seems that relevance of car ownership, as a sole base to trip generation would not be confidently defined.

Table 9.2 Car ownership in Australia

Car ownership (vehicles per household)	New South Wales						
	2006			1996			
Enumerated data	number	%	Sydney Statistical Division %	number	%	Sydney Statistical Division %	Change 1996 to 2006
No vehicles	276,745	11.2	12.6	303,596	14.0	15.4	-26,851
1 vehicle	907,166	36.7	36.4	915,807	42.1	40.9	-8,641
2 vehicles	775,918	31.4	30.2	633,292	29.1	28.4	142,626
3 vehicles or more	304,609	12.3	11.5	202,341	9.3	9.3	102,268
Not stated	206,015	8.3	9.3	119,881	5.5	6.0	86,134
Total	2,470,453	100.0	100.0	2,174,917	100.0	100.0	295,536

Source: Australian Bureau of Statistics, Census of Population and Housing, 2006, 2001, 1996, and 1991.

9.12.8 Trip attraction analysis

While the trip production model forecasts the number of trips generated by each of the zones in the study area, the trip attraction model has the role of estimating the quantum of these trips that will be attracted to zones in total and by specific purpose.

Trip attraction of each zone for each purpose should be defined by the model. Zones where jobs are located will mostly attract work related trips; school (education) trips will be attracted to the zones where schools are located.

In reality, zones are not uniform by land use and are often a combination of many land uses. For each purpose, it is necessary to define an adequate attraction model. For some, they could have a single parameter (eg shopping trips are defined by number of employees in trade or commercial GFA) and for some purposes, attraction could be a combination of several parameters (eg school related trips such as primary, secondary and tertiary enrolment data)

All attraction parameters need to be explained and documented (using either cross classification or regression models) and, as a rule, total attraction trips are approximately the total number of production trips.

9.12.9 Trip generation model outputs and reasonable checks

Trip generation models produce a series of productions and attractions for all purpose trips. Production and attraction by zone is commonly shown as P's and A's. They are used as input into the distribution model.

Reasonable checks need to be performed when trip generation modelling is finished:

- Are the production rate models sensitive to base for modelling (household size, household income, and household automobile availability)?
- Depending on the method used (cross classification or regression model) a check that the attraction rate models are sensitive to the total employment and the number of households.
- What trips purposes were used? How are non-home based (NHB) trips divided into additional trip purposes?
- How were external-external and external-internal trips accommodated in the travel model?
- What was the Production and Attraction balance by trip purpose? Also explain balancing scaling.
- Were special generators used in the travel model? If yes, how are the special generators rates included in trip rates and balancing?

9.13 Trip distribution model

9.13.1 Model inputs and outputs

Outputs from each step of traditional transport models are inputs for the next. As a result of the first step, trip generation – productions and attractions are derived for each of the zones in the study area and they are inputs for the next model.

The trip distribution model connects trip ends estimated in the trip generation model to determine trip interchanges between each zonal pair. This model considers the effects of impedance or accessibility on destination choice.

The most common rule in traffic behaviour is that travellers tend to minimise the travel distance or time of their travel. This rule is incorporated in the trip distribution model and in the traffic assignment model. While in the assignment model this is relatively simple and depends on network characteristics, it is complex in principle and function for the distribution model.

Some of the trip purposes are more sensitive to distance and travel time and others are less so:

- For home to work trips, place of resident is mostly fixed and it is not always possible to choose work place closer to the residence (or vice versa).

- For shopping or recreation trips, there is relatively free choice based on the proximity and/or magnitude of the zone where attraction for those trips are located.

For this reason, the trip distribution model needs to be able to replicate different distance/time functions for each of the modelled purpose.

9.13.2 Models

There is a large family of distribution models. Some of them are based on the probability theory (Intervening Opportunity model, Competing Opportunities model), some are based on the logit form of distribution models but the most commonly used model is the Gravity model.

It is a matter of the planner's preference to choose the type of distribution model. No matter what kind of model is used, emphasis on the credibility of the entire modelling process and its results depends of the quality of this model.

In these guidelines, only the application of the Gravity Model will be discussed.

9.13.3 Gravity model

The Gravity model is based on the simple Newton astronomical gravitation model.

In essence, the Gravity model states that the number of trips between an origin and destination pair is directly proportional to the number of productions at the origin and the number of attractions at the destination and inversely proportional to the spatial separation between zones. This function of spatial separation adjusts the relative attraction of each zone for the ability, desire, or necessity of the trip maker to overcome the spatial separation involved.

The general formulation of the model can be described as follows:

$$T_{i,j} = P_i * \frac{A_j * F_{i,j} * K_{i,j}}{\Sigma_j^1 (A_j * F_{i,j} * K_{i,j})}$$

Where:

Ti,j = the number of trips between zone i and zone j

Pi = the trip productions for zone i

Aj = the trip attractions for zone j

Fi,j = is an accessibility factor associated with the measure of travel impedance from zone i to zone j (Friction Factor)

Ki,j = is the socio-economic or physically related factor for all movements between zone i and zone j

9.13.4 Model calibration

All distribution models require an extensive calibration process. This process is essential for model validity. Calibration of the gravity model is based on comparison of observed trip length by purpose and resulting trip length after model application. This is an iterative process that is repeated until reasonable compliance is achieved.

Each modelled purpose has its own specific trip length characteristics and this depends on the size of the study area and distribution of relevant activities for the specific purpose.

Figure 9.9 shows trip distribution for home-to-work trips for Sydney GMA car trips and TLD by income category (C1 lowest).

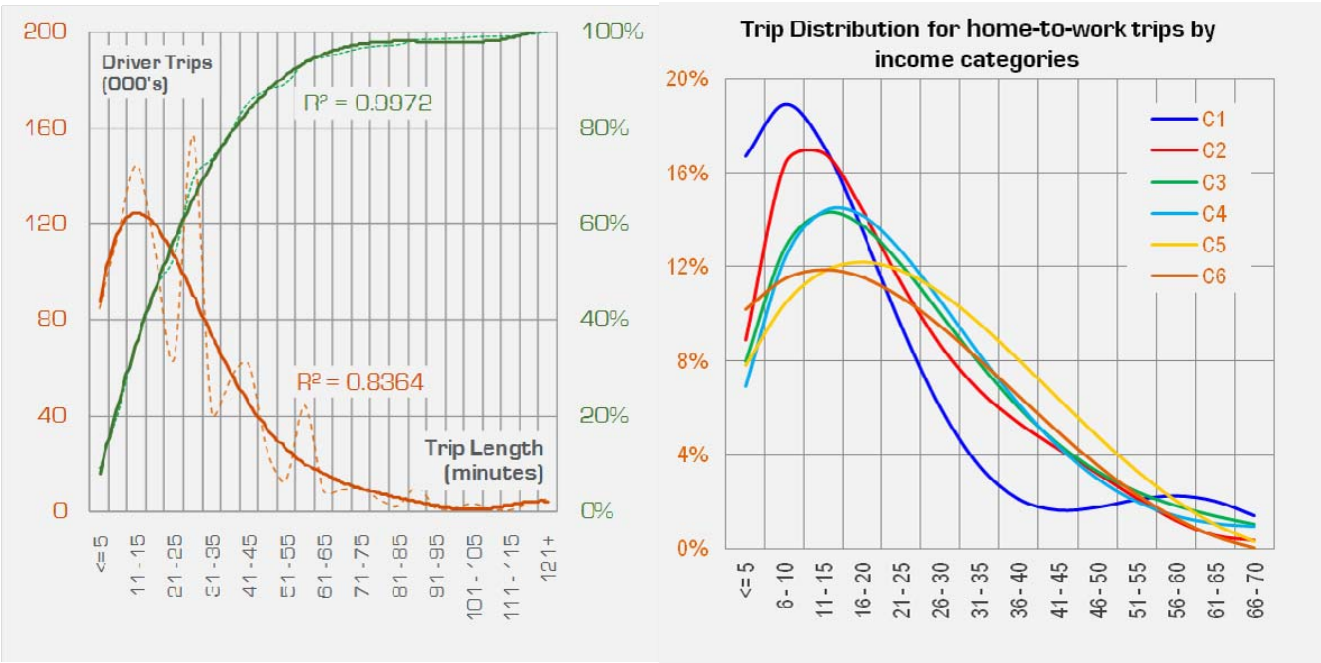


Figure 9.9 HTS trip distribution (TLD) for home-to-work trips for Sydney GMA car trips

After a first run of the gravity model, the TLD curve is compared with the actual results. The calibration process involves matching the modelled TLD with the one from HTS for each purpose or category of modelled trips.

9.13.5 Calibration process

Gravity model input data include:

- Production and attraction vectors obtained from the trip generation step.
- Zone-zone travel time (skims).
- Friction factors vector.

The household survey data is used to develop mathematical relationships (or functions), that correlate observed travel behaviour to variables that can be more easily and directly forecast. In general, the model parameters that rely on travel survey information are assumed to remain constant between the base year and the forecast year.

The process of the calibration Gravity model assumes iterative changes of initial friction factor values until achievement of statistically valid compliance between modelled and observed spatial distribution. Figure 9.10 below shows the iterative procedure for Gravity model calibration.

A comparison of observed and modelled trip length frequency is used to adjust the initial friction factor. For the next iterations, the friction factors are obtained by the fraction between the numbers of trips calculated in the last two iterations. When statistical compliance is achieved, the resulting final calibrated trip matrix is created. The friction factors obtained represent the network's behaviour for each trip purpose and they become the default for every other gravity model that is to be calculated from the model.

Irrespective of the type of model used for the trip distribution process, it is necessary to document the calibration process and to perform logical checks of the model results. New generations of transportation planning software allow for different kinds of useful numeric and visual checks.

Major checks are based on the comparison of spatial distribution resulting from the model and independent information (traffic count data; land used data, aerial photography etc).

Usual checks are:

- Screen lines comparison.
- Desire Lines plots.

- Trip end analysis;
- JTW census data TLD comparison.
- Reasonable checks of TLD.
- Reasonable checks of intra-zonal trips.

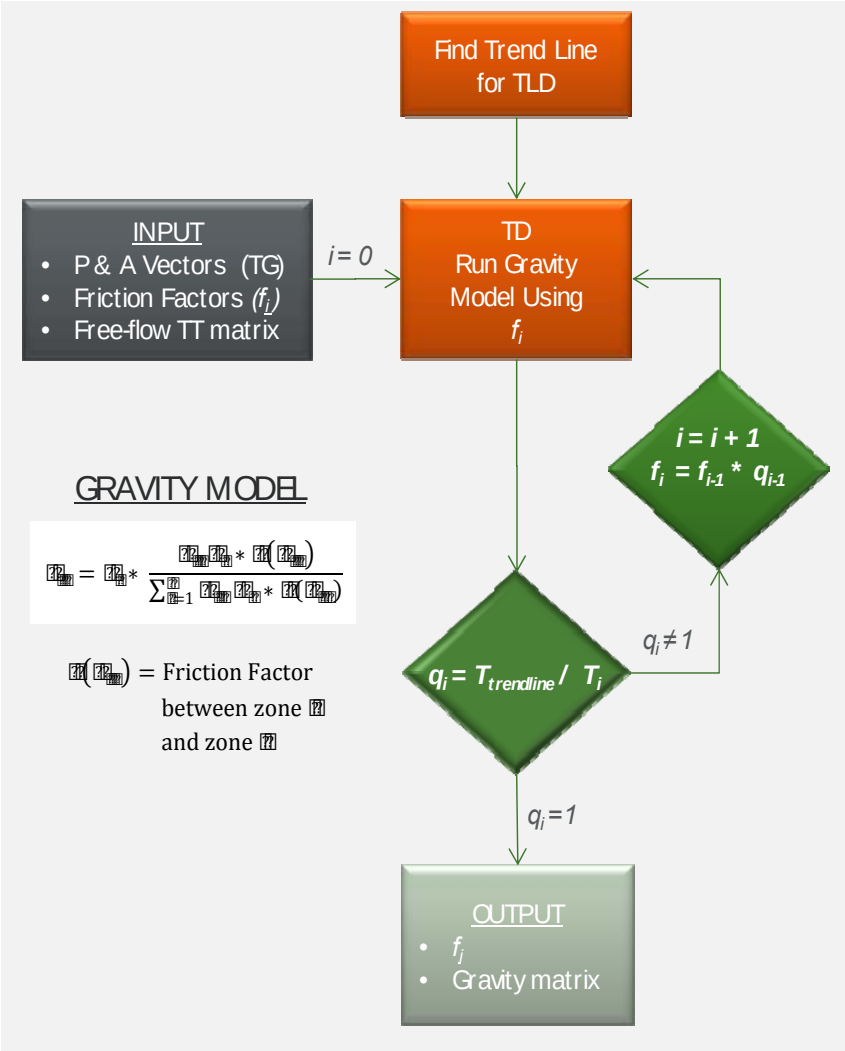


Figure 9.10 Example of Gravity model calibration process

It is advisable to perform these checks for all modelled purposes. For screen line comparison, total daily or hourly trip distribution need to be compared with appropriate screen line traffic data.

Even a well calibrated model can produce unexpected results and therefore the modeller should consider applying a K factor to correctly analyse logical errors. The use of K factors needs to be documented and an analysis of pre- and post- distribution results need to be reported. Figure 9.11 shows likely use of K-factor.

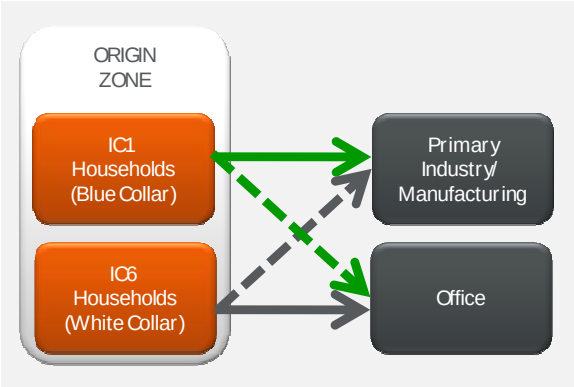


Figure 9.11 Meaning of K-factor use

9.14 Mode Split Model

9.14.1 Modelling approach

The mode split model is the third step in the four step modelling process. This model produces matrices for a modelled transportation sub-system. Usually it produces car and public transport matrices.

Mode split is used to assess expected shifts from one network to another due to improvements in one or both of them. It predicts changes in public transport patronage due to changes in a network, like new services, increased frequency etc.

The Four Step modelling methodology is often applied in the large cities with well developed public transport networks. Small percentage public transport shares of total daily trips (8–10 per cent) are a result of the characteristics of the urban form in Australian cities (low residential densities, high and concentrated employment densities). However, this share is much higher in the CBD, showing increasing importance for suitable mode split modelling.

Basic model philosophy is based on the user's choice between two competing sub-systems. This is a complex behavioural mode, created as either binary logit models, multinominal logit models or different models based on probability theory. There are two basic approaches in mode split modelling:

Pre-Distribution (Trip End Mode Split). This approach follows trip generation and is based on the different characteristics of the individual household. This approach could be very accurate in the short term where changes in the public transport sub-system will be steady without big qualitative and quantitative changes (shown in Figure 9.12);

This can be applied for smaller cities, where public transport tends to be a supportive, rather than competitive, sub-system.

Trip Interchange Mode Split. This is the most widely adopted approach by the practitioners for strategic modelling of large cities. Figure 9.13 shows the simplified trip interchange model flow (phase III of IV step modelling process). This model is applied after the distribution phase and is more sensitive to the travel attributes that influence individual choice of mode.

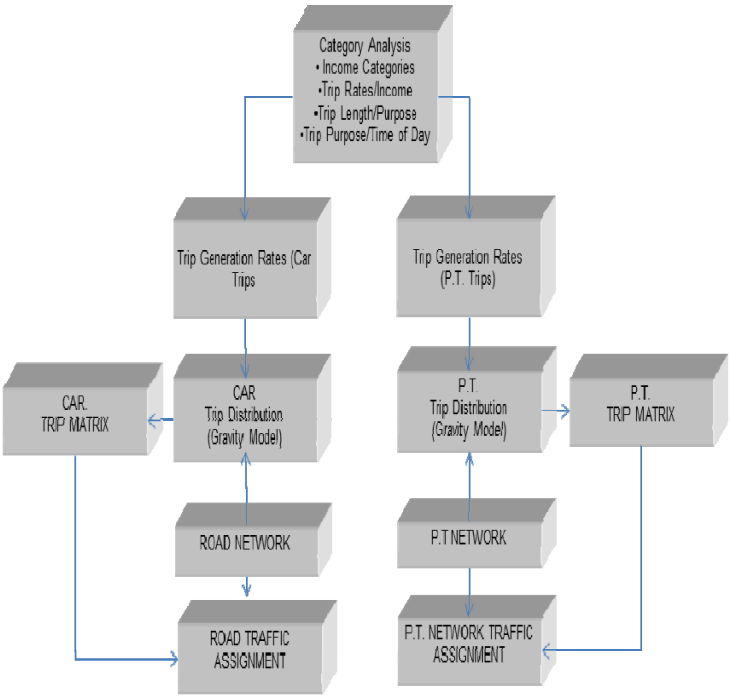


Figure 9.12 Pre-Distribution Mode Split

Three major factors influencing modal choice:

- Character of the trip maker (car availability, income etc).
- Character of trip (purpose, time of the day).
- Characteristics of the competing transportation networks.

Common inputs to the model are:

- Trip and traveller characteristics analysed based on the HTS data.
- Mechanised trip matrix (by purpose and time of the day).
- Road Network Model and network skims.
- Public Transport Network Model and network skims.

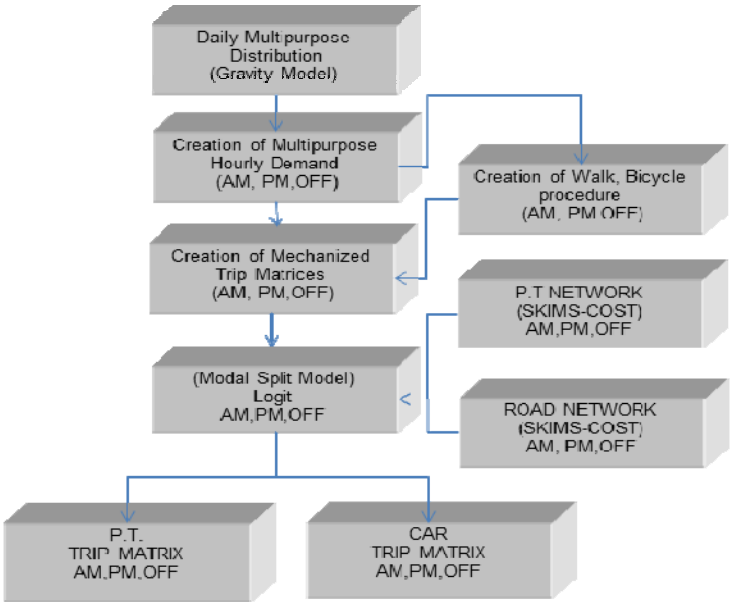


Figure 9.13 Trip interchange mode split

Before applying mode split, it is important to define mechanised trips or motorised trips. This definition excludes modelled trips that do not use public transport or the road network (car trips) such as short trips, usually walk trips – and some proportion of bicycle trips. Analysis of HTS by mode and distance/time could be used to document and create an appropriate model for excluding non-mechanised trips.

Mode Choice models are complex models used to analyse and predict the choices that individuals or groups of individuals (eg same income group) make in selecting the transportation modes that are used for particular purposes of trips.

In these guidelines, the form and type of the mathematical mode choice model will be left to the modellers/planners. Any type of model is acceptable if it is well documented and calibrated.

The focus will be more on the model inputs, the calibration process and model sensitivity.

9.14.2 Major inputs

The choice of mode of travel depends on many factors. Some of them could be accurately modelled and some of them are subject to the model imperfections and simplification (eg comfort).

The major inputs into the model are the attributes of two competing networks – public transport and urban road network. It is crucial for model robustness and validity that both sub-systems are described at a similar level of detail. It is not desirable to have a very detailed road network model and a coarse public transport model.

Basic parameters emerging from sub-system models are shown in Table 9.3.

The decision of what transportation network will be used for a trip mostly depends on the comparison of time or cost to travel from one zone to another zone (logit curve). In the process of model calibration there are calibration parameters used to force a model to produce a desired output.

There is a fundamental difference of time component in competing networks (road and public transport). While travel time on the road network could be considered mostly as real time, for the public transport network, only a part could be consider as real time. Other components of the travel time are usually regarded as perceived time. The implication of this is that individuals measure walk time, waiting time and transfer time differently. Some studies have shown that for the same trip, travel times of 47 minutes by car have a perceived travel time of 100 minutes by public transport. Comparison of actual public transport time versus perceived time has a ratio of 1.5 meaning that perception of time in public transport is 50 per cent longer than actual time.

Table 9.3 Major Mode Split Inputs

Modal Split Parameters	Public transport	Car
Walk time (access time)	✓	
Waiting time	✓	
In-vehicle time	✓	✓
Transfer time	✓	
Terminal time	✓	✓
Fare	✓	
Parking cost		✓
Toll cost		✓
Time cost (person)	✓	✓
Vehicle operation cost		✓

In creating competing travel times or costs for public transport to be used in mode split models, real-time outputs need to be adjusted to replicate perceived time. It is common to factor travel time skim outputs to create travel time in public transport comparable to travel time in cars.

Usually 1.0–1.1 is used to factor walk time, 2.0-2.5 to factor wait time and transfer time is factored by 1.1–1.2, while in-vehicle time is used as it is (real time).

Usually for large strategic modelling studies, value of time is defined by conducting specific studies – stated preference studies. If such investigation is not available, use of analogy with similar models could be used.

Another vital issue in the whole process of strategic modelling and in particular for mode split modelling is the cost of time. Cost of time varies from purpose to purpose and could be provided by stated preference studies. In the absence of these types of studies, analogy with similar studies could be used (it is a fair assumption that the cost of time is uniform around Australia). Additionally, results from other stated preference surveys could be used if the economic parameters (GDP, income etc) are similar to the local conditions.

To make models simpler it is advisable to define the time cost component for JTW trips and apply same cost for all other purposes.

The primary use of mode split models are to assess the impact of changes in two networks to the potential shift from one mode to another based on the physical changes in them (like new services, changes in frequency, new motorway). For this reason it is important that relevant outputs from networks are equally accurate. This will assure that all important input parameters are at the same level of detail.

9.14.3 Mode split calibration

The calibration process for mode choice models consists of estimating parameter values, evaluating the statistical significance of the estimates, and then validating the model by comparing its prediction with observed behaviour. Observed values may be obtained from HTS but some of them need to be collected from the public transport agencies that provide public transport service. These include data related to passenger corridor loads, station loads and other patronage statistics.

In general, the model needs to produce similar number of trips as in the base year. Analysis of the mode choice at the zonal level and/or large districts (group of zones) is more common. For the comparison of HTS data and modelled data the following need to be taken into account:

- Both network models have some usual approximation in their creations. Zone connectors representing intrazonal network are straight lines with speed around 10kph. Pedestrian connectors are the same with lower speed (usually 5 kph). For this reason travel times from models and from surveys cannot be the same.
- Depending on the modelling software used, intersection delay is not always included in network models and public transport stations are not properly represented, resulting in differently computed travel times from zone to zone.

A common way to calibrate a model is to compare modelled travel times (by network) with collected surveyed (HTS) travel times (using travel diaries/questionnaires) for all modes, purpose and time of the day.

When building paths for both networks, computation procedures involve calculating travel times based on the model data available that embraces previously explained deficiencies.

It is essential to compare surveyed data with data produced by the model being aware that it is not likely that complete compliance will be achieved.

Reasonable checks for mode split need to be documented:

- Are the calculations of non-mechanised trips logical? What is the impact of connectors representing internal network?
- Are the variables in the utility function, logical? How do these variables coincide with alternate models?

- Are the coefficients in the utility function, logical?
- Are terminal times, parking costs, fares etc. correctly modelled and is their impact logical?
- Are total trips (by mode) equal to the HTS data?
- Is mode split logical in relation to position of zones and attributes of sub-systems?
- How does mode share compare with other cities with similar size and similar urban form?

In addition to standard statistical tests, it is necessary to conduct sensitivity tests. These tests could be used with stated preference data to compare sensitivity of model to parameter changes. With limited fundamental studies these tests will require common logic or comparison with some historic data if available (change in mode split due to change in parking cost, impact increase or decrease of transit fare etc).

9.15 Modelling multiple class purposes

9.15.1 Creation of AADT using multi-purpose approach

The total of all trip purposes equals the total number of daily trips (AADT) for the study area. All purposes have different origins and destinations. As an example, education trips go only to the zones where education facilities are located (schools, TAFE's, Universities). These trips use allowed networks to travel to destinations (road network or public transport system) resulting in the modelled volumes on the network links.

The number of analysed purposes depends on the number defined in the HTS. As many purposes are modelled, the results will more accurately replicate traffic counts therefore it is advisable to model as many purposes as possible.

In the early modelling history, planners only used work trips (JTW). There are still some examples of the JTW created models. These models use JTW data to simulate the peak hour expanding these to represent the whole peak period. For example, to create a PM peak hour the JTW matrix is transposed to represent afternoon traffic conditions.

To assess existing and future transport network performance, it is vital to define conditions in the peak hour as closely as possible. This will enable planners to define characteristics of the system which will give maximum socio-economic benefits assuming that in these periods most important trip purposes will occur.

To define relevant demand properly, it is important to add "all" other trips (non-modelled) since they could have, at some time, an impact in the comparison of demand and supply (volume/capacity).

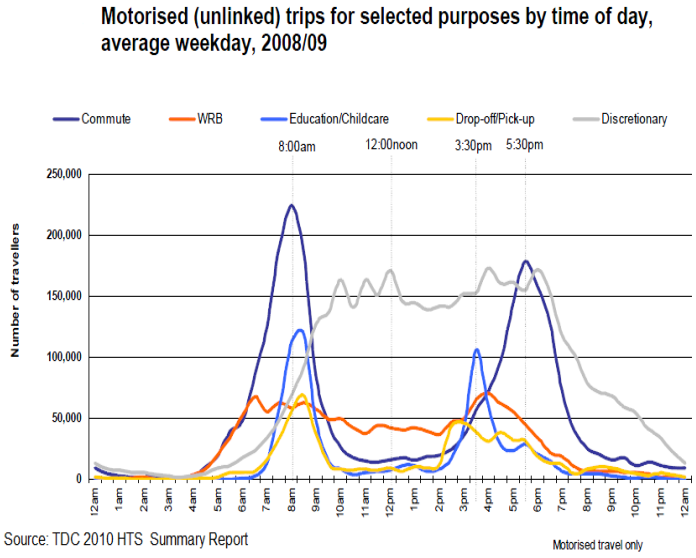


Figure 9.14 Traffic profiles by purpose

Figure 9.14 clearly shows the importance of that. The hourly trip distribution defines relevant demand matrices to help generate required outputs for model runs. Typically a peak hour matrix is required, although daily traffic or midday traffic volumes are sometimes required (depending on the scope of investigation).

In general, peak hour is assumed to be around 10 per cent of AADT. This varies from city to city depending on the magnitude of the study area, spatial distribution of activities, network congestion (peak spreading) etc.

The HTS for Orange (2008) for the AM and PM peak (one hour) show 20 per cent and 16 per cent of the respective peak hour share in relation to all AADT trips. In Sydney, this is different with the one hour peak share of all trips being much lower (6–7 per cent).

9.15.2 Hourly trip distribution (multi-purpose approach)

Traffic patterns, trip purpose, vehicle type proportions, traffic flows and congestion vary by time of day. It is conventional to define peak periods, and inter-peak periods, as combination of hours rather than as single hour. This depends of the size of the modelling area and for smaller modelling areas using one hour is acceptable.

Analysis of peak hour HTS data is the base for the creation of parameters used in creating hourly matrices. In addition, investigation of the traffic count data could also be undertaken to further explain peak hours.

Care needs to be taken in comparing HTS and traffic count data. Traffic counts on the sites (links or intersections) where volumes are close to capacity may have lower peak hour factors compared to less congested links or intersections.

Additionally, in cases where older than base year data are used (for calibration) applying a growth rate to these old volumes should be done with care. In congested cities, absolute values of peak traffic may not change over time due to capacity limits.

Most transportation planning software can perform multi-class assignments with classes such as vehicle type (cars, LGVs or HGVs) or trip purpose (home-to-work, home-to-shop etc). Depending on the aim of the modelling, planners could also create demand splits by income categories when tolling and charging options are to be assessed.

The ideal approach is to create a series of daily demand matrices (by purpose) and further develop peak hour matrices using share of every modelled purpose.

Analysis of the HTS data could be used to find relevant proportions for modelled purposes in the hourly distribution of trips. Aggregating hourly distribution in multiple hours (two, three hours) is then a simple matrix operation process.

It is the modeller's choice on how to define the purpose of the model and to define the number of relevant trip purposes for overall modelling as well as for modelling peak hours.

There is no simple formula to define this. As a rule, more trip purposes imply less non-modelled purposes and less need for adjustments.

There are obviously some imperfections in modelling a large number of purposes (eg how to define attractions for home-to-other trips). Some of the purposes are difficult to describe. This is especially related to the definition of attraction, or for non-home based trips for both production and attraction.

On the other hand, knowledge of trip distribution characteristics for these "difficult to model" purposes makes it possible to calibrate the distribution model more accurately. It is up to the modellers' analytical skills to define multi-purpose methodology. This will require additional analysis to define relevant and allowable land-use parameters to create production and attraction variables in the model.

For large strategic network models, it is advisable to combine hours of the day into larger (two to three hours) peak periods. The main reason for this is to avoid the impact of congestion on traffic counts (queuing, upstream bottlenecks etc) and peak spreading in a heavily congested network.

9.16 Freight demand

The share of commercial vehicles in urban traffic has not been a significant part of modelling in the past. Typically, commercial vehicles make up around 2 per cent of total city traffic. Because this proportion is low, freight demand modelling were not often included in transportation models. However, quick response techniques were developed to estimate freight matrices. These techniques were fairly approximate.

Even with a small share of overall traffic, the proportion of commercial vehicles on some busy corridors (near industrial zones, ports and airports, for example) may be significant. Additionally, some commercial vehicles are banned from some routes (like B-Doubles) and their relatively small volumes are more concentrated on a limited number of routes.

The small proportion of commercial traffic was not the only reason why commercial vehicles were excluded from models in the past. Another reason is that modelling demand for commercial vehicles is more complex than modelling of daily person movements. A large number of commodity types and various modes of transport create that complexity. However, in general, the principles behind the demand for person transport and freight transport are similar. Demand for transport of goods is generated at an origin, and attracted to a destination. These can be modelled by production and attraction models using different inputs. There is also a need to estimate the way the goods are distributed between origins and destinations, for which a trip distribution of a similar form to those used for person transport can be used. And finally there is a need for a mode split model to proportion demand to various available competing modes (rail, road, sea, air).

An additional issue to be addressed is that of sub-modes. For example, commodities that are to be transported by road could be transported by different vehicle types (small trucks, articulated vehicles or B-Doubles).

It is possible in modelling freight, to devise a four step modelling process. In this approach, demand and choice models would be similar to person demand modelling. The steps could include:

- Commodity generation model.
- Gravity model for distribution.
- Logit models for mode choice.

The commodity generation model would need to define trip rates by commodity. Those rates would need to define annual or daily production and attraction of commodities for use in estimating total productions and attractions in each TAZ. They could also, as a basic default, use population or employment data and other available and relevant activity data as proxies for freight productions and attractions.

Special generators such as intermodal terminals need to be defined in production and attraction models.

Gravity distribution models estimate the spatial distribution of specific (modelled) commodities. Commodity groups are equivalent to purpose of trips in the commuter travel models and calibration would be required for each commodity group. This would need some form of friction factor to be derived for use in the calibration process. Additionally, estimates of observed trip length frequency distributions would be required for each of the commodity types, in order to complete a satisfactory calibration. State statistics (ABS) or other sources of data could be used for this estimate.

Mode choice would define multimodal trip tables. The mode choice model could take the form of a Logit model that estimates the probability transport by a particular transport network (air, rail, sea and air) based on the comparative advantages/disadvantages of transport by each mode.

This process would produce an output of trip matrices in terms of tonnes of a commodity per day or year.

Forecasting freight demand is more complex than passenger trip forecasting. Production of commodities is more erratic than population changes and new commodities enter the market every year. Only 20 years ago, for example, there was little demand for transport goods such as personal computers and mobile phones. Also, the fundamental attributes of commodities like bulk, value and

shelf life are also important in forecasting mode choice. As a result, models for forecasting freight demand would need to forecast the type of freight and its growth, which is a difficult pair of tasks.

In urban networks, freight transport would be predominantly by road for trucks and a four step model would be a consistent and applicable approach to modelling. However, in general, distribution of goods is not a simple single vehicle trip. There would be a large number of chained trips, so that some form of tour-based model would be more appropriate for the inclusion of person-based travel models.

Most urban transportation models have relied only on modelling of trucks. Modelling of trucks is simpler but still complex, and is usually based on analysis of trip diaries, warehouses and terminals surveys, or road intercept surveys.

Trip diaries can produce trip attraction and production rates per land-use for different truck types, as well as data of trip length distribution used for calibration of the distribution model.

For the Sydney GMA, the Bureau of Transport Statistics developed a freight demand model and produced separate trip matrices for light commercial vehicles, rigid and articulated trucks.

For other study areas, because of the complexity of modelling, it is advisable to use simple methods based on road side interview data. Fratar or Furness, or other simple growth factor models, should be used to forecast future volumes of commercial vehicles. Where there is a lack of specific freight data, it may be acceptable to use classified traffic counts data to factor up forecast total vehicle trip demand on urban networks.

9.17 Demand for models based solely on O-D traffic surveys

Development of demand based solely on the traffic surveys is not acceptable for forecasting of demand in strategic models because traffic counts do not collect data related to the socio-economic parameters of users and their connection to each particular trip. Additionally, they do not have a clear relationship to land use.

Number Plate surveys are used to create origin-destination matrix for corridor study or small area modelling. The methodology for these surveys requires definition of the survey station where number plates will be recorded and definition of a zone system. They are, because of cost, usually based on sampling techniques (red cars, white cars etc). They require mathematical manipulation to balance them and to produce acceptable O-D matrices (different samples at different stations and directions).

New technologies such as license plate readers could increase accuracy and the quantity of data collected. This, of course, will not change overall deficiencies inherent in the use of this data in the estimation of demand.

The major difficulty, besides the lack of socio-economic data, is the difficulty of identifying origins and destinations of trips starting or ending within the cordon. This limits the use of number plate surveys used to create demand in strategic modelling.

Matrices created from this type of survey need to be carefully analysed before being used as an input to traffic assignment.

A combination of these matrices and turn counts could be used to create synthetic trip matrices. All transportation software is capable of producing matrices based on the traffic counts and O-D number plate surveys. Matrix estimation procedures could generally reproduce new synthetic matrices using an assumed prior matrix, especially for small area models.

To assure some level of confidence and to be able to use this matrix for short term forecasting, a set of logical checks need to be undertaken to link origins and destination to the land use (it is the modeller's choice how to undertake these checks and document them):

- Check origins and destination of internal zones in a synthetic matrix against allowable land-use data (use of Google Earth could be of use if numeric data are not available).
- Check whether a synthetic matrix has artificially created traffic in empty zones.
- Check if origins and destinations of internal trips are symmetrical in the morning and afternoon peak.

- Check that the synthetic trip matrix agrees comprehensively with observed data from the number plate O-D survey data and data produced by synthetics matrix (difference +/- 5 per cent).
- Check ratios of trips/person/employees to be in accordance with generation rates from other sources (eg Guide to Traffic Generation Developments) to check for extremes and compliance.

In forecasting, use of a type of growth modelling technique may be acceptable if the relation between allowable land use data and synthetic matrices are found. A major pitfall in this approach is that all trips are within one category, without the possibility of forecasting by trip purpose.

9.18 Method of matrix estimation/manipulation

The main purpose of matrix estimation is for adjusting model results to fit the observed data (traffic counts). These counts are usually located at screen lines and only on some major links in the network model. The nature of matrix estimation techniques often cause adjustments in cells that are far removed from counts and that are already accurate.

Matrix estimation procedure is applied to the original or prior matrix and it alters all non-zero O-D pairs to fit assignment results to the observed data (traffic counts).

If the proportion of zero trips is large, some modellers often “fill” zero cells with fraction of trips (eg 0.0001 trips). This method should be used with caution as it can significantly change the size of the original matrix.

Assigned model volumes seldom replicate traffic counts accurately because:

- Queuing, bottleneck and congestion in reality contribute to lower traffic volumes compared to the volumes produced by assignment of modelled matrices. Modelled volumes represent demand rather than actual volumes.
- Numbers of modelled trips limited by the number of purposes are compared with traffic counts that include “all” trip purposes.
- Commonly used adjustments to expand the modelled matrix to fit all trips may also contribute to inaccuracies because non-modelled purposes may have different spatial and temporal distributions.
- Traffic counts, depending on the counting method (automatic or manual) may have errors of up to 5–10 per cent.

Before matrix estimation is carried out, it is vital to adjust the prior demand matrices to get the total number of reported trips from the HTS by time of the day. This procedure may involve a range of factors because the mix of non-modelled purposes varies through the day.

Prior matrices should be validated by comparing screen line and cordon modelled flows by time period and vehicle type, especially if commercial vehicles are included in the modelling.

Matrix estimation may adjust non-zero O-D values in the prior matrix in the attempt to fit the matrix to traffic counts at the specific location in the network model. Matrix estimation is an iterative procedure involving repeated assignments and comparison of the output traffic volumes to counts.

Because the procedure changes the prior (initial) matrix, it is important that these changes are minimised. That is, matrix estimation should look for a maximum fit of the trip matrix with the minimum adjustment of the cells in the matrix. Large adjustments may result in a loss of linkage with the original demand modelling process.

All sophisticated transportation planning software (EMME, TransCAD, VISUM etc) has its own procedure for matrix estimation. They are generally based on specific mathematical procedures (such as linear programming and Bayesian estimation). They usually provide options to limit the level of acceptable changes of prior matrices. These options should be used to minimise the impact of adjustments as far as possible ie adjustments less than 5 per cent of the trip end change. It is important to maintain the same convergence criteria used during the matrix estimation and creation used for prior assignment.

Alterations of the trip matrix by matrix estimation need to be evaluated by comparing prior matrix and resulting matrix. While matrix estimation (ME) may adjust the origin and destination of non-zero cells, as a result, changes in trip ends, O-D zonal cell values and overall trip distribution are to be expected.

The following are suggested checks for the results of ME:

- Analyse differences in desire lines of prior and ME matrix (at a zone or group of zones level).
- Analyse differences in a plot of prior and ME matrix assignment.
- Check scatter plots of matrix zonal trip values of prior and ME output matrix. The slope of the linear regression line should be within +/-2 per cent of 1.0 and correlation coefficient should be higher than 0.90–0.95 with intercept at 0.
- Check scatter plots of trip ends of prior and ME output matrix. The slope of the linear regression line should be within 1 per cent of 1 and the correlation coefficient should be higher than 0.95 with the intercept at 0).
- Standard deviation of the trip length distribution should change by less than 5 per cent.

Prior matrices used in the matrix estimation procedure are based on the analysis of the trip making characteristics and are the result of the trip generation and trip distribution modelling. It is important to achieve these standards to assure that the relationship between initial demand modelling and ME adjusted demand is still strong. If these criteria are not met, additional model adjustments and checks would be required. Recalibration of the trip distribution model should be considered. Figure 9.15 shows example of the matrix comparison analysis.

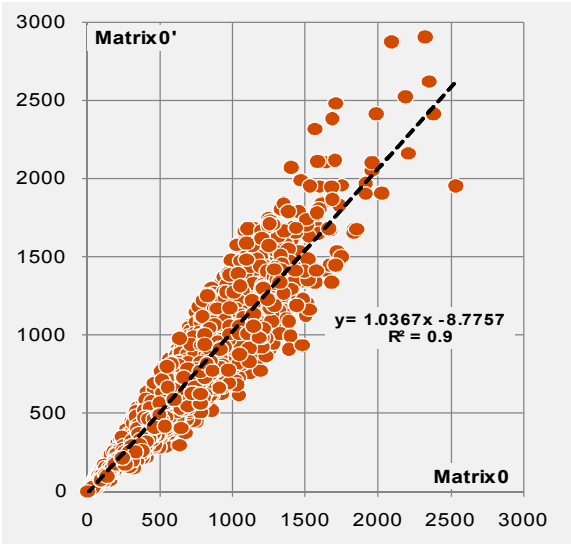


Figure 9.15 Prior and ME matrix comparison

In forecasting future demand it is assumed that current behaviour will not change significantly in the future. Low income households will produce the same number of trips as today (only their proportion of all households will change) and the basic trip distribution parameters will remain constant. Consequently future matrices will depend solely on the expected land use and socio-economic changes in the future.

The matrix estimation procedure when used to adjust modelled demand, changes the prior matrix. Assuming that these changes have improved the modelling, it is necessary to fix those changes in the future too. This is important in order to maintain the connection between demand modelling for the base and future years. To do this, planners should establish some functional relationship between the prior and ME output matrix.

There are different ways to use matrix estimation results for modelling of forecasting years:

- Create difference matrices (new matrix minus prior matrix) and to add these values to the appropriate cells of the forecasted matrix.

- Create a simple factor matrix of the ratio between prior and output matrix. This matrix should have ratios around value of 1.0 for all existing non-zero O-D pairs. This factor matrix will be further used to correct forecast matrices and to derive a new adjusted matrix.

Both of these methods have their pros and cons. However, the two methods can result in significantly different results. For example, if the matrix estimation process resulted in a change in trips of an O-D pair from one to two trips, the first method generates an adjustment factor of +1, the second method generates a multiplier of 2.0. In an extreme example where future land use growth generates 1000 additional trips between the O-D pair, the first adjustment factors results in 1001 trips, the second method results in 2000 trips.

Care should be exercised when using matrix estimation. O-D Pair adjustments should be limited, where possible, to avoid extreme adjustments and damage to the overall trip patterns.

Future matrices may have more non-zero cells than the base year because of land use changes, and therefore it is the planner's choice what factor to apply in those cases. A possible approach is to apply similar factors to those used for existing neighbouring zones.

The matrix estimation procedure and the creation of factor matrices are shown at Figure 9.16.

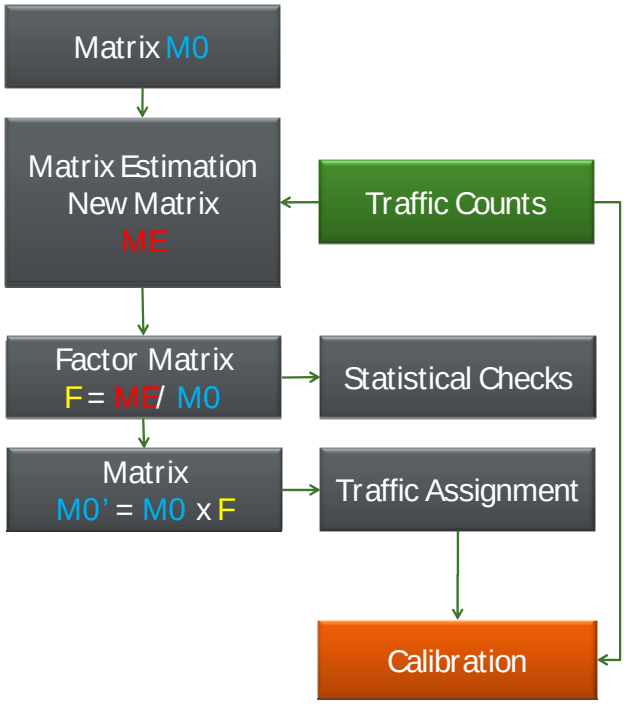


Figure 9.16 Basic matrix estimation process

9.19 Method of using outputs from different level of modelling

Demand modelling is a costly and time-consuming process. Apart from actual modelling the costs are made up of comprehensive data collection and processing. If the strategic model is already developed for part of the study area, it can be expected that it will be used for other transportation studies as input. However, it is possible to develop a parallel demand model if the magnitude of model and budget allows.

In practice it is common to use demand developed in other models. Contemporary software could "communicate" to each other. There are interfaces between different software (EMME, VISUM, TransCAD) that allow the transfer of information from one package to another.

The only requirement for use of demand information from other models is that the two studies (models) use the same zone system.

Use of pre-modelled traffic demand is often used by:

- Mesoscopic transportation models (transportation studies of transportation sub-systems).
- Highway assignment models.
- Multi-intersection and corridor models.
- Microsimulation studies and local area modelling.

All of these use more detailed network representations than strategic models.

Direct use of pre-modelled demand is more commonly used for transportation studies and highway assignment modelling.

The major difference is that in transportation studies only demand is used as input, while in sub area-modelling, demand and transport networks are required from pre-modelled information.

It is often the case that use of the pre-modelled demand is assumed as data and in reality it is considered variable data. Checks are required and sometimes adjustments are necessary in relation to use. If demand is used for testing significant improvement to the network (eg new rail corridor) then a planner needs to assess the likely impact to the use of pre-modelled demand.

A major limitation of pre-modelled demand is that it represents a “black box” imbedded in the new model. Modellers are not aware of the vagaries of the basic inputs, the model methodology and the assumptions involved in production of the model. This often creates difficulties for model calibration. Since the demand effectively comes from a “black box”, it is difficult to distinguish where the sources of calibration problems lie. To avoid these problems, detailed checks of the demand need to be made to assist when calibration difficulties may arise.

Another problem arising from the use of external demand is the lack of ability to measure changes in demand caused by network changes, mode split changes or to account for induced traffic. This is acceptable if the transportation study examines only different options of a facility that has already been modelled in the strategic model being the source of the demand data.

Often transportation studies have to test and evaluate new transport facilities. Fixed demand matrices in such cases need to be used with great caution. A new road corridor or new public transport service will, in reality, impact on demand and this impact will not be replicated with a fixed demand matrix. It could be assumed that network changes will not impact significantly on option testing. In this case, it is desirable to test the options in the strategic model and to produce appropriate new demand. New demand matrices produced in this way may be used with confidence and further fine tuning will have improve methodological background. This approach will require a minimum repetition of trip distribution model and mode split however is seen as costly and not likely to happen.

In other cases it is the modeller’s choice how to assess possible impact that the network changes may have on the demand. Sensitivity tests to test the impact of inputs on demand should be performed to create alternative scenarios and to better evaluate options.

A sub-area analysis is used in transport network planning and operation in situations that may not require a complete network. In some cases, sub-area modelling is used to better define the local network or refine land use. This requires zone refinement and additional connections on the network. It is not likely that this will impact significantly on demand. However, modellers need to adjust previous intra-zonal trips appropriately and carefully as some adjustments of the demand may occur.

Advantages of sub-area modelling, besides more detail network modelling, include shorter run time and better model convergence.

Special care needs to be taken of the logic connection of external networks to the study area network. Use of automatic procedures imbedded in software packages need to be checked for reasonableness.

It should be noted that because sub-area models use a pre-defined demand, it is not possible to use them for assessment of larger land use changes without adjusting pre-modelled demand. These adjustment need to be well documented.

9.20 Growth factors techniques

9.20.1 Growth factor modelling

There are various techniques to calculate trip distribution based on the factoring of growth. Following are the most common:

- Uniform factor method.
- Average factor method.
- Fratar method.
- Furness method.

A common characteristic of these methods is that they do not account for changes in the transportation system and influence the travel time distribution. They all extrapolate base year trip tables to the future year base on the defined growth factor.

Use of these techniques in strategic modelling is limited to the short term horizons where land use changes are minimal (maximum of five years). Additionally, these techniques could not be applied to the empty zones in the base year because zero cells will not grow.

Growth factor methods can be useful for forecasting external trips (intrastate/interstate). Applying growth factors to the external matrix where changes in exogenous factors over time is not significant is acceptable. Based on long term horizons, demographic forecast could be used successfully to forecast external trip growth. However, these exercises should be undertaken with caution and results should be checked carefully.

The major characteristics of growth factor modelling are:

- They are limited to forecast horizons.
- They require base year O-D trips tables.
- They need estimates of future trip ends.

Uniform and average factor methods are no longer used by practitioners. It is the modeller's choice to decide what technique will be used and for what part of the modelling unless directed by RMS.

Advantages of growth modelling techniques lie in their relative simplicity however, major pitfalls are:

- Lack of interaction with transportation network changes.
- The potential for magnifying errors in some zone-to-zone movements.

They can be used for studies of small areas and for updating stable and uniform data. Using growth factor techniques to change externally derived matrices to forecast the impact of changes in land use should only be used for updating base year matrices. They could be used for short forecast horizons where changes in transportation networks are minimal and their impacts on distribution are negligible. In both cases growth factor techniques require caution, thorough documentation that includes the type of growth factor used and some calibration.

Growth factor techniques are more suited to sub-area modelling. Sub-area models are extracts of an area where impact of the changes over time and network changes are included. This technique could be effectively used for small study area modelling projects and for preparing inputs for microsimulation.

For corridor studies, refinement of the zones growth factors could be applied. In strategic modelling, a growth model could be used mostly for external trips where the changes over time have a minimal impact on the trip distribution.

Applying the Fratar model for internal trips should be used only for short forecast horizons where land use changes are minimal.

10 Highway Assignment Modelling[4]

In preparing the highway assignment techniques to be adopted for macroanalytical and mesoscopic models, this first version of the guidelines utilises existing sources drawn from other Australian and international authorities. Some tailoring has been undertaken to fit the local NSW context and input from NSW government stakeholders has also been reflected in these guidelines.

10.1 Model development guidance

This section draws heavily on the *Traffic Modelling Guidelines, TfL Traffic Manager and Network Performance Best Practice* [5] as this document is a recent, practical and succinct summary of traffic modelling best practice. Some modification has been made in this NSW guideline to suit the local context.

10.1.1 Passenger car units

Traffic is composed of various classes of vehicles, the range and relative composition of which can vary from location to location. Traffic modelling software frequently utilises a common unit, known as the Passenger Car Unit (PCU), to represent traffic flow and capacity. Conversions are applied to weight the traffic based on the relative effect each class has on capacity or road space. Typical PCU factors are given in Table 10.1.

The use of PCUs to represent demand and network capacities is recommended. Local effects such as steep grades can be accounted for using this method. While the PCU is preferred for assignment, traffic flows in vehicles (classed by at least lights and heavies) is the preferred output. Appropriate multi-class assignment is recommended to achieve a PCU assignment and a vehicle output.

Table 10.1 Passenger car units (example equivalencies)

Vehicle type	PCU factor
Passenger car	1.0
Light commercial vehicle (LCV)	1.0
Rigid heavy	2.0
Bus	2.0
Articulated heavy	4.0

10.1.2 Zones and connectors

The size and number of zones within a traffic model varies based on the type of model, the overall study area and practical run-time or data considerations.

Macroanalytical models typically have a large coverage and the assignment model is usually only part of the overall model structure. The number of zones is therefore more a function of the demand estimation process and data source resolution. As an example, the Sydney Strategic Traffic Model (STM) has in the order of 2700 zones (based on the 2006 zoning system) covering the Sydney Greater Metropolitan Area. This is expected to change in future zoning system.

Where a macroanalytical model is to be used for scenario assessment, it is common practice to provide more detailed model zoning and network in the area surrounding the scheme. The aim is to correct any traffic access issues and provide a uniformly distributed access to the network for local traffic. Traffic zones should cover homogenous geographical areas that have similar access points onto the network. Zones can have more than one connector and zone sizes should generally be adjusted to deliver no more than 300 to 500 vehicles per hour. Zone connections to the network should be at nodes on lower

[4] Sinclair Knight Merz (SKM) prepared this subset of the guidelines dealing with the highway assignment techniques for macroanalytical and mesoscopic models of road vehicle traffic.

hierarchy links in the network and never directly to nodes representing intersections that are significant with respect to network delays.

For mesoscopic models, zone sizes will be smaller and likely represent vehicle trip origin/destination (as opposed to person origin/destination). Connection to the network may be along a link (eg SATURN) or at minor network nodes and should be coded to represent street or car park catchments as appropriate. Zone sizes should be restricted to limit each connector demand to 150 vehicles per hour.

Additional zones will be required for external traffic. The size and location of these zones will be governed by the location of the study area cordon.

10.1.3 Nodes and links

Development of the coded road network should begin with GIS mapping information to provide accurate distance and link length information. If available, driver navigator databases might represent a convenient source of information for lanes, hierarchy and link posted speeds. It is more often the case that this information must be added to the link and node databases after being initially developed from the basic topology data.

Aerial photography can be a useful reference source, particularly if GIS software can be used to view this information simultaneously. The use of a GIS database to store network information also gives an excellent data auditing capability using theme plotting to show coded base information.

Link data should also include information of lane restrictions and periodic lanes due to kerbside parking, bus/transit lanes or tidal lanes. This information may vary by time of day. Accurate coding of mid-block restrictions may be important for modelling bottlenecks. For tidal lane coding in particular, use of a common dataset for all time periods with a time dependent lane allocation is the recommended method for time of day networks. This will improve model consistency between time periods.

10.1.4 Intersection coding

Intersections are the dominant source of delay in congested urban networks. It is therefore critical that intersections are coded accurately, and that modelling software correctly simulates the operation and capacity of flows through intersections.

Macroanalytical models can (and perhaps should) be fashioned to include intersection delays, either as link based intersection approach delays or as turn delays. However, if intersection delays are the main determinant in route choice and capacity then a mesoscopic model (or micro-simulation model) should be used to correctly account for vehicle interaction and time dependant capacity constraints. Stop line capacities are an important input when including a level of intersection delay into models.

When coding intersection characteristics, the methodology for delay calculations used by the software should be taken into account. Both the coding approach (eg single or multiple nodes) and the parameters often differ between software.

Information about signalised intersections should be extracted from SCATS to give accurate phasing, phase times and offset information. Some phasing plans contain demand dependant optional phases. The frequency these are called during on the modelled average day may also need to be obtained.

10.1.5 Signal phasing and timing data

Observation can be used to provide the basic phasing and green splits although information from RMS SCATS databases is preferred as this would also include plan, typical offset and demand dependant phasing information. Signal timings should be included in highway assignment models where appropriate.

10.1.6 Bus vehicle and bus lane usage

In the context of a vehicle assignment model, public transport vehicles (in NSW restricted to buses) may or may not be significant depending on the number of bus services in the corridor and the level to which they affect traffic flow and the detail at which the assignment modelling is to be carried out.

Bus flows can be easily obtained by time period from route maps and timetables. Significant flows can be assigned separately in both macroanalytical and mesoscopic models. In the case of mesoscopic

models, it may be important to obtain survey information on stopping patterns, dwell times and any capacity obstructions the buses cause. However, it is important to note that bus timetables do not include “dead” (empty) running, generally appearing in the contra-peak direction flows.

Modelling packages generally include the ability to simulate the impact of vehicle congestion on bus times where buses share road space with private vehicles. Bus dwell times and dedicated bus lanes can also usually be simulated to assist in representing the interaction of buses and general traffic flows. The use of bus lanes by the various bus routes/operators should also be observed through survey. Use by other vehicle types, whether legal (eg taxis) or illegal, may also be useful to collect depending on the significance of the flows and detail possible within the model.

10.1.7 Model software

Selection of software can influence the success or failure of a modelling exercise as each software package has particular strengths or weaknesses. An objective assessment of the relative strengths of each package should be undertaken as part of the specification development. As a guide, RMS considers the following macroanalytical and mesoscopic modelling packages, listed in Table 10.2 below, suitable for use in NSW for modelling.

Table 10.2 Macroanalytical and mesoscopic network modelling packages in NSW

Macroanalytical modelling packages	Mesoscopic modelling packages
CUBE Voyager	AIMSUN (1)
EMME	CUBE Avenue (1)
TransCAD	DYNAMEQ (1)
VISUM	SATURN
	TRACKS

Notes: (1) RMS is currently assessing mesoscopic model software. Note that the AIMSUN mesoscopic capabilities are only available in the advanced version of the software.

The version of software used should also be selected carefully. Newer versions are not necessarily better than the older versions. The same version of the software should be used throughout the project (base and option testing models) to avoid invalidating the calibration or causing inconsistencies in scenario evaluation.

10.1.8 Scale of study area and network

The traffic model should assess the full impact of a scheme on all road users over the impacted area. In general, the model boundary should encompass the area within which traffic flows, journey times or delays will be significantly affected by the implementation of the scheme or proposed intervention. The scale of the model network can usually be determined by considering the following issues:

- Routes being affected by the proposal.
- Opportunities for re-routing leading to changes in origin and/or destination of trips.
- Decision-making context relating to the nature of trips being made (ie long or short distance trips, whether they are mandatory or optional, etc).
- Areas where significant benefits or dis-benefits may be provided by the proposal.
- Changes in traffic levels on both existing and new/improved roads in the areas affected by a proposal.
- The area over which economic benefits are to be assessed.

The *Design Manual for Roads and Bridges (DMRB)* [6] suggests that the traffic engineer will need to take account of:

- The location of the scheme and whether it is isolated or part of a comprehensive route improvement. In the latter case (eg a series of local bypasses on a long distance route) it is likely

to be more efficient to construct a single model to examine major reassignment due to the improvement(s) as a whole, and to isolate a local cordon from this model to evaluate each individual scheme.

- The density of the existing trunk and principal road network and the location of any competing routes.
- The conflicting requirements of the small increase in information available from a wider study area with the high costs of collecting additional survey data for that area, and the subsequent increase in running costs for the study itself.
- The existing and any known future land use patterns and changes which will have an influence upon the scheme, along with the influence of any Local Authority road proposals adjacent to the proposed trunk road scheme.

The overriding consideration when defining a study area is that the boundary should be drawn as close to the scheme as possible consistent with the need to provide the information necessary to make robust decisions. Some judgement may be required to trade-off the costs associated with the development of large models and the need to assess distant impacts.

10.1.9 Representation of tolls

Modelling route toll road patronage requires specialist approaches that vary depending on the toll road(s) to be assessed and the level of accuracy required. Toll roads are a feature of the road network in Sydney and as such some treatment of tolls is required where toll roads feature in the study area network.

Where evaluation of toll road patronage is a key objective of a modelling project, a separate toll assignment traffic model will be built with specific vehicle classes and advanced assessment of drivers' willingness to pay tolls. This can often require significant network skimming, matrix manipulation and tight controls on route selection. Two general methods exist:

- Logit toll choice models.
- Multi-class equilibrium assignment.

Both methods rely on value of travel time savings obtained from stated and revealed preference surveys. Much of these data from surveys conducted in NSW in the past is held as commercial in confidence by toll road bid teams.

As a minimum, tolls should be used in the assignment approach with cash values stored on the links representing the toll plazas. A value of travel time saving (VTTS) value should then be used to convert the tolls to an equivalent time penalty. This approach would be applied separately to different toll classes, at least cars and truck should be separated as the tolls and VTTS vary significantly between these two classes. It is important to note that VTTS is not the same as vehicle operating cost or the values used in economic analysis.

10.1.10 Demand matrices

Vehicle movements are generally stored in origin to destination table format for models. The source of the information varies; some might be sourced from another model, some from origin-destination survey information. The fine tuning of the demand matrices is often an important model calibration step.

This adjustment can be done using a matrix estimation process provided by the modelling package. However, it is important to check the validity of the output by reviewing model outputs against observed or anticipated data in terms of trip productions/attractions and trip length distribution. Some distortion of travel patterns can result if matrix estimation techniques are used without suitable monitoring and control of the process.

The demands may be divided into separate vehicle classes to allow different treatment for network access, demand loading, vehicle parameters, route cost characteristics and output statistics. A common segmentation is light (eg motorcycles, cars, light goods vehicles) and heavy vehicles (ie rigid and articulated trucks). Taxis may be loaded separately if sufficient information is available as they can have different network access (eg bus lanes). Buses are not generally loaded using demand matrices but are loaded on fixed routes with defined frequencies.

10.1.11 Assignment

For a macroanalytical model, the total demand for the modelled period is stored in single demand matrices for each vehicle class. This demand for each origin-destination (O-D) is assumed to load for relatively long periods as a single group and appear simultaneously along the chosen path through the network. The congestion properties of each link are described by a volume-delay function (VDF) or link time/performance function that expresses the average or steady state travel-time on a link as a function of the volume of traffic on the link. This “static” assignment method is time invariant and while the algorithms generally strive to reach an equilibrium state, this approach has difficulty representing the delays and capacity constraints evident in congested urban networks.

In static assignment models, congestion affects travel time or speeds and is often represented using speed–flow or flow–delay functions in static assignment models. Graphical representations of these are given in Figure 10.1, sourced from Akcelik [4]. The functions used generally calculate monotonically reducing speeds (or increasing delays/times) with increasing flows and as such include the oversaturated “tails” on the curves depicted in Figure 10.1.

Inflow to a link in static assignments is always equal to the outflow, and the travel time increases as the flow (“volume”) increases. This means that all the traffic demands get through from origin to destination, even if all route options contain links with volumes over capacity (v/c > 1.0) and result in very low simulated speeds. This is not a traffic modelling error, as the theory of equilibrium assignment is independent of time. A problem occurs for the modeller when an assignment result is interpreted to represent volumes within a given time period (eg the peak hour), because those over-saturated network elements should act as bottlenecks. These oversaturated network elements will in reality produce queues that block back upstream and meter downstream traffic volumes. The effects of oversaturated conditions and the impacts of blocking back should be discussed in the modelling report where significant to the outcomes of the modelling.

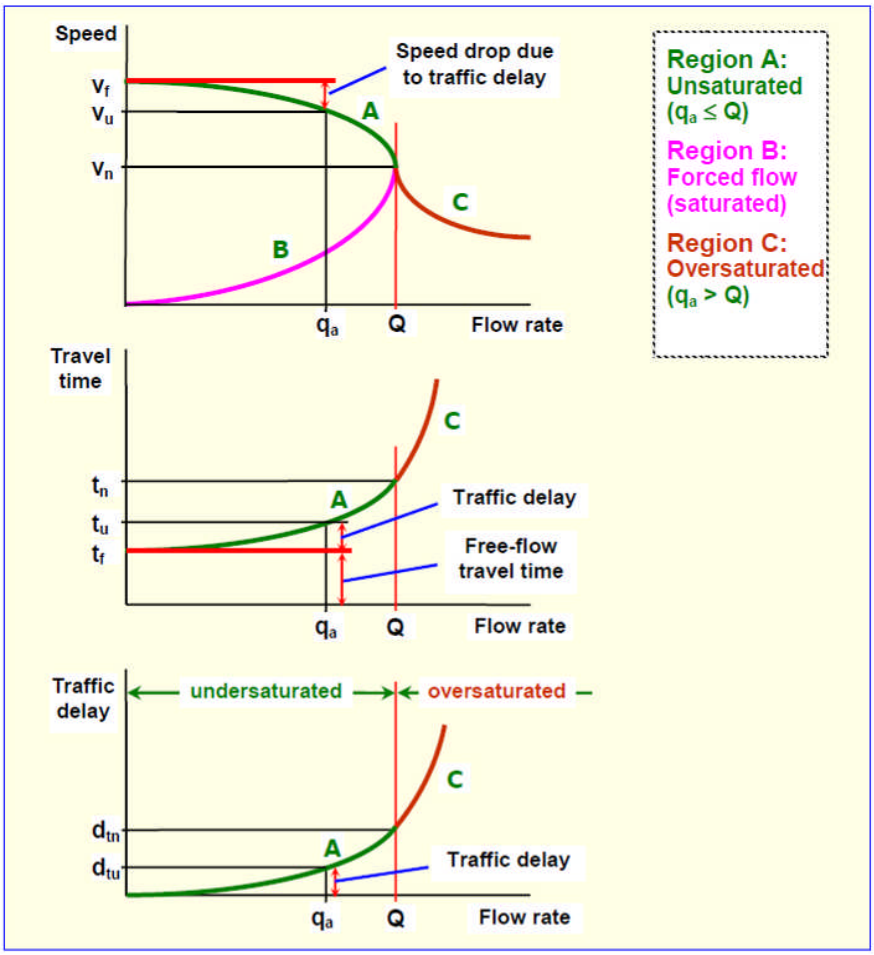


Figure 10.1 Examples of Speed, Travel Time and Delays as a Function of Flow Rate

Mesoscopic models employ time dependant assignment methods. The vehicle demand matrices are not loaded as a single group but released in discrete time dependant portions for each O-D movement and vehicle class, sometimes as individual vehicles as in micro-simulation models. The assignment algorithm tracks each discrete group of vehicles. The interaction for the various vehicle groups at conflict points that gives rise to a more realistic calculation of delay and the temporal effects of congestion. The effects of congestion on delays and flow are modelled more directly in these models and demands beyond saturated flow conditions result in queued vehicles as opposed to flows increasing into the oversaturated section of the figures above.

Assignment algorithms vary and while an equilibrium assignment is normally recommended (particularly for most peak-period urban networks), other approaches may be useful:

- Incremental assignment is a technique where small successive components of the demands are assigned to the network and delays reassessed. This has largely been replaced by equilibrium assignment but may still be useful where equilibrium assignment is stubbornly refusing to converge. Some care should be used to ensure that the reason for the convergence problems do not affect the accuracy of the incremental approach as well.
- Stochastic algorithms assume a variation in perceived user costs around a mean value and are useful in situations where drivers are unfamiliar with the network or the assignment of traffic across route alternatives is not necessarily on the lowest cost path.
- All-or-nothing assignment allocates all flows to the shortest cost path in one pass without re-evaluation of the resultant congestion cost effects. This can be a useful assignment technique to assess the impact of congestion effects on route choice.

10.1.12 Blocking back

In addition to more realistic delay calculation in mesoscopic models, over-saturated elements of the network will produce realistic queuing effects. Propagation of queues may affect upstream intersections and delivery of traffic downstream from a pinch-point will be metered. It is for this reason that only mesoscopic and microsimulation models are considered capable of modelling congestion effects in urban networks.

10.1.13 Convergence

High levels of convergence should be achieved in traffic modelling. This is important because if link flows and their corresponding flow-delay curves are not reasonably consistent then there can be little confidence in modelled outputs, such as link flows, costs, etc. Convergence also provides confidence that any differences in traffic flow between converged base and proposed networks can be ascribed to the effects of the scheme being tested rather than random assignment “noise”.

Macroanalytical and mesoscopic software all tend to offer an equilibrium assignment and some alternative assignment algorithms. These algorithms differ and offer varying performance although with all a greater number of iterations generally results in a more stable result closer to the balance between traffic flow and congestion delays. As the assignment approaches equilibrium, fewer trips change route to seek shorter travel times and this assignment “noise” becomes negligible. Assignment convergence parameters should be set to achieve this outcome.

The convergence of total road user costs in the 2004 STM model network [11] is shown as an example in Figure 10.2 and Figure 10.3 below.

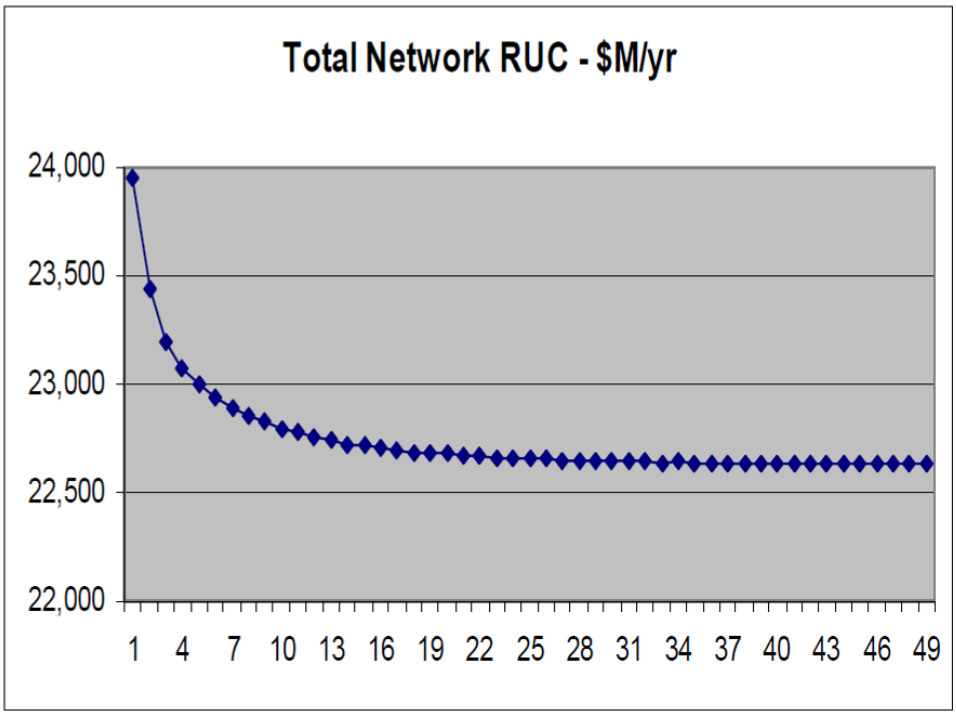


Figure 10.2 Convergence of total road user cost

Some transport modelling packages have provided improved algorithms or traffic assignment that offer reduced run-times to achieve satisfactory convergence (eg the projected gradient method in EMME provides significant time advantages over the previous linear approximation method). Sensitivity testing of new assignment methods on convergence statistics and volume results should be undertaken before switching the assignment method in an existing model.

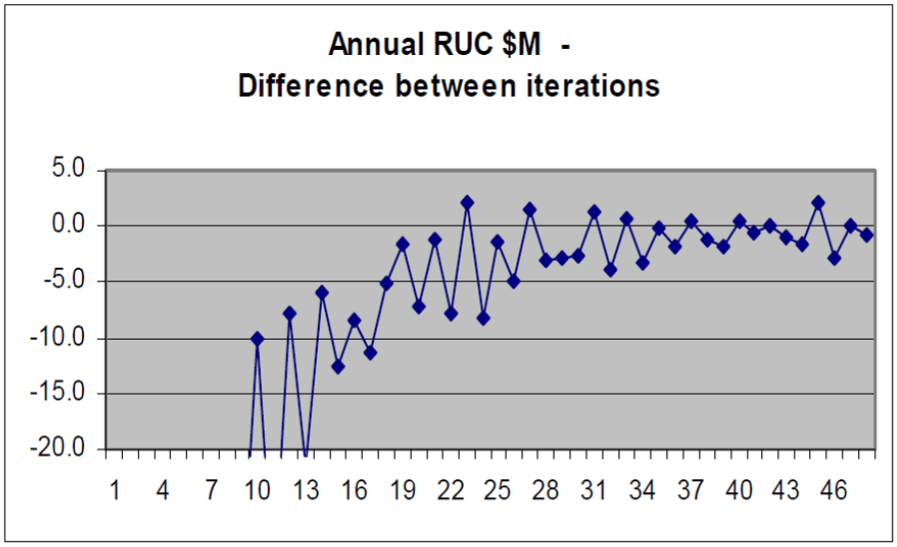


Figure 10.3 Difference between iterations

The DMRB [6] gives advice on convergence although the most important convergence measure for user equilibrium assignment is the percentage change of traffic flow on the individual links. The recommendations within *New Zealand Economic Evaluation Manual* [8] provide a useful summary of model assignment convergence criteria consistent with the DMRB. As a general guideline, the degree of assignment convergence should be such that the difference in activity benefits computed from successive iterations is only a small fraction of the total activity benefit. The following measures are suggested:

- The proportion of links in the entire network with flows changing less than five per cent from the previous iteration.
- For stability there should be consecutive iterations with proportion greater than 95 per cent.
- Where available, the “normalised gap”, δ, which expresses the flow–weighted difference between current total costs and the costs incurred if all traffic could use minimum cost routes, should be less than one per cent for convergence.

Other measures of stability and convergence provided by transportation modelling packages may also be included.

Generally assignment iteration exit criteria can be set to achieve these convergence measures, although the following points should be noted:

- More assignment algorithm iterations should achieve more stable results, closer to the equilibrium solution, but some networks converge better than others, and some iterative methods converge better than others. The modeller should choose the appropriate method and convergence procedures.
- The aim is to get convergence to a point where the remaining "noise" is not great enough to affect the conclusions of the study. Assessment of any assignment noise effects on the project is advised.
- It is relatively easy to get the model to converge far enough to get stable estimates of link volumes and travel speeds although it may be more difficult to get the model to converge far enough to get stable estimates of project benefits, especially if a large model is being used to evaluate a small project. In this case, it may be necessary to take average results from a number of iterations, or to use a sub-area model extracted from the larger model.

10.1	In undertaking highway assignment modelling, the modeller should understand which of the available software to apply to the problem being considered. Depending on the study brief requirements important aspects of this selection may include: • Level and need for accurate intersection representation. • Source and ease of coding signal timing data. • Representation of bus vehicle behaviour and restricted lane use.

10.2 Base model calibration and validation

10.2.1 Highway assignment model calibration

Traffic models are only potentially as accurate as the calibration process undertaken during development. Modellers should consider the most appropriate techniques, as accurately validated models form the basis for proposed scheme modelling.

Calibration describes the process of placing verifiable data into a traffic model to replicate observed street conditions. All input data for calibration should be auditable, such as signal timings and on-street measurements (eg lane distance, cruise speeds, saturation flows, PCU factors). It is usual for this information to have been collected from on-street measurements. Calibration may require the adjustment of model parameters to re-create observed behaviour, for this reason the calibration process should be undertaken for each time period being modelled.

In the instance where macroanalytical assignment model demand matrices have been developed from a forecasting model, count comparisons across screenlines can determine if demand matrix adjustments are required or if the network assignment might require adjustment. If total screenline flows are high or low compared to total screenline counts, the process generating the demand matrix is likely to require adjustment. If the comparison shows screenline crossings are quite close in total, any local difference between count and model flow along the screenline is likely to be as a result of an assignment or network issue. These adjustments to network or demand matrices in mesoscopic can generally be made independently due to the static nature of the assignment (noting, of course, that in a four step model some major network changes may also influence the demand matrices).

Making adjustments within mesoscopic models to improve flows, however, must be carried out in line with delay adjustments and demand adjustments due to the dynamic nature of the assignment. The US Transport Research Board (TRB) has discussed this in a primer for dynamic traffic assignment [9] and suggests that a discrepancy between model volumes and counts at a particular observation location (the plural here is used to refer to time-varying data) is essentially due to an imbalance in the model between capacity and demand. There are three basic factors that contribute to this imbalance:

- Local network capacity and control timing parameters.
- Local traffic demand as a result of the assignment process, in the form of route flows.
- Global demand as represented by the O-D matrix.

Each of these three influences can be a possible source of error. Their respective contributions to a specific outlier can be determined by following a process of investigation and elimination.

10.2.1	If using strategic model demand matrices, screenline count comparisons can determine whether demand matrix or network assignment adjustments are needed. Discrepancies between Dynamic Traffic Assignment (DTA) models and observed counts may differ for three reasons (each may require further investigation): • Local network capacity and control timing parameters. • Local traffic demand due to the assignment process in the form of route flows. • Global demand as represented by the O-D matrix.

10.2.2 Highway assignment model validation

The information used to calibrate the model should be independent to that used for the validation checks. This data independence ensures that validation statistics are a true measure of validation. It is not appropriate to supplement these data used for calibration with validation data in order to improve the quality of model validation. It is acceptable to supplement calibration data with validation data to improve the calibration however, another set of validation data are then required to undertake validation in this case.

10.3 Calibration and validation criteria

The validity of a traffic assignment model should be assessed by comparing the model volumes, travel times and queue lengths against field observations.

10.3.1 Traffic counts

Calibration for traffic models can involve adjustment of the demand matrices to match traffic counts (matrix estimation). In this instance, separate and independent counts should be used for calibration and validation. The TfL guide [5] suggests using counts on screenlines across multiple boundaries (say) running north-south and east-west for validation and using counts between the screenline “cells” for calibration.

Useful measures of “goodness-of-fit” generally used to compare model flows against observed counts are GEH and RMSE. These are defined as:

“The GEH statistic is a formula to compare two sets of traffic volumes and gets its name from Geoffrey E. Havers, who invented it in the 1970s while working as a transport planner in Greater London Council. The formula is a form of Chi-squared statistic that is designed to be tolerant of larger errors in low flows. The reason for introducing such a statistic is the inability of either the absolute difference or the relative difference to cope over a wide range of flows.”

The Florida Department of Transportation Systems Planning Office reviewed US model calibration and validation standards [10] and produced various validation criteria that recognised that higher level of statistical validity is generally recommended for higher order facilities. The GEH validation statistic provides a convenient validation measure in line with this approach. The formula for the GEH statistic as found in the UK DMRB [6] and NZ EEM [8] is:

$$GEH = \sqrt{\frac{(V_o - V_m)^2}{0.5\,(V_o + V_m)}}$$

Where:

V_o is the observed flow in vehicles per hour

V_m is the modelled flow in vehicles per hour

The Root Mean Square Error (RMSE) and R-Square (R^2) are statistical measures of the correlation between the entire count data set and the predicted model volumes. Unlike the GEH statistic (which applies to individual flows and screenlines), the RMSE applies to the entire comparison data set and is expressed as a single value. The formula for RMSE is:

$$RMSE = \frac{\sqrt{\dfrac{\sum (V_o - V_m)^2}{C - 1}}}{\dfrac{\sum V_o}{C}} \times 100$$

Where:

Vo is the observed flow in vehicles per hour

Vm is the modelled flow in vehicles per hour

C is the number of count locations in set

In the first instance, obtaining sound counts for comparison is paramount. TfL [5] suggest that the accuracy of observed counts must be within ±50 PCU/hour or within a GEH of two. Obtaining multiple counts to assess the accuracy of the counts is often impractical although where the information has come from automated collection sources (eg long term count sites or SCATS data) inspection of the variation of counts is recommended. In the case of SCATS counts, verification that the detector loops are functioning is recommended, if possible by comparing to an independent count survey or other adjacent upstream or downstream SCATS counts.

Target validation criteria have been combined from various sources for use in NSW and are shown in Table 10.3.

Table 10.3 Highway assignment modelling link and turn target calibration/validation criteria

Topic	Criteria
Link and Turn	Results to be tabulated in appendices and summarised in main report
	Tolerance limits for network-wide area:
	95 per cent of individual link volumes to have a GEH ≤ 5.0
	85 per cent of individual turn volumes to have a GEH ≤ 5.0
	All individual link and turn volumes should have GEH ≤ 10
	Plots of observed vs. modelled hourly flows required for all observations
	Plots to include lines showing GEH = 5 tolerance limits
	R^2 value to be included with plots and to be > 0.9
	Slope equation to be included with plots (intercept to be set to zero)
	All counts RMSE should be 30.0 or lower
Screenline or Cordon	Tolerance limits for network-wide area:
	Each directional screenline or cordon total to have GEH < 4.0

Figure 10.4 demonstrates the flow difference implied by a GEH statistics of 5.0 and 10.0 compared to a simple 5 per cent difference criteria.

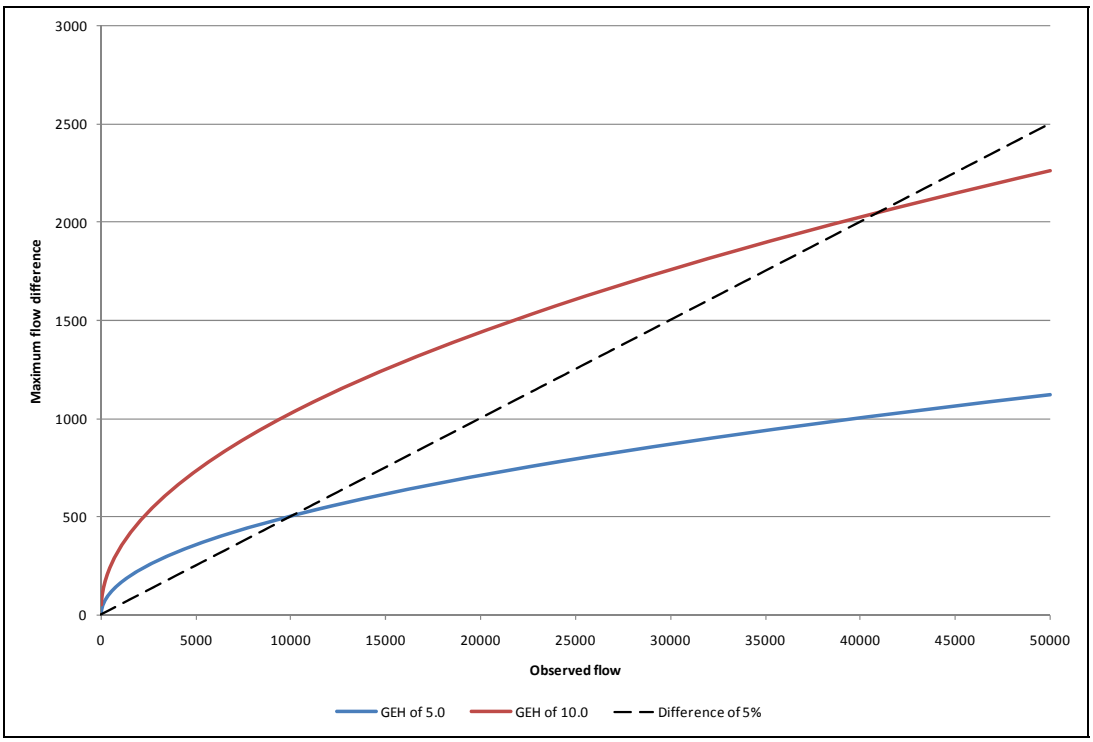


Figure 10.4 GEH statistics compared to volume difference

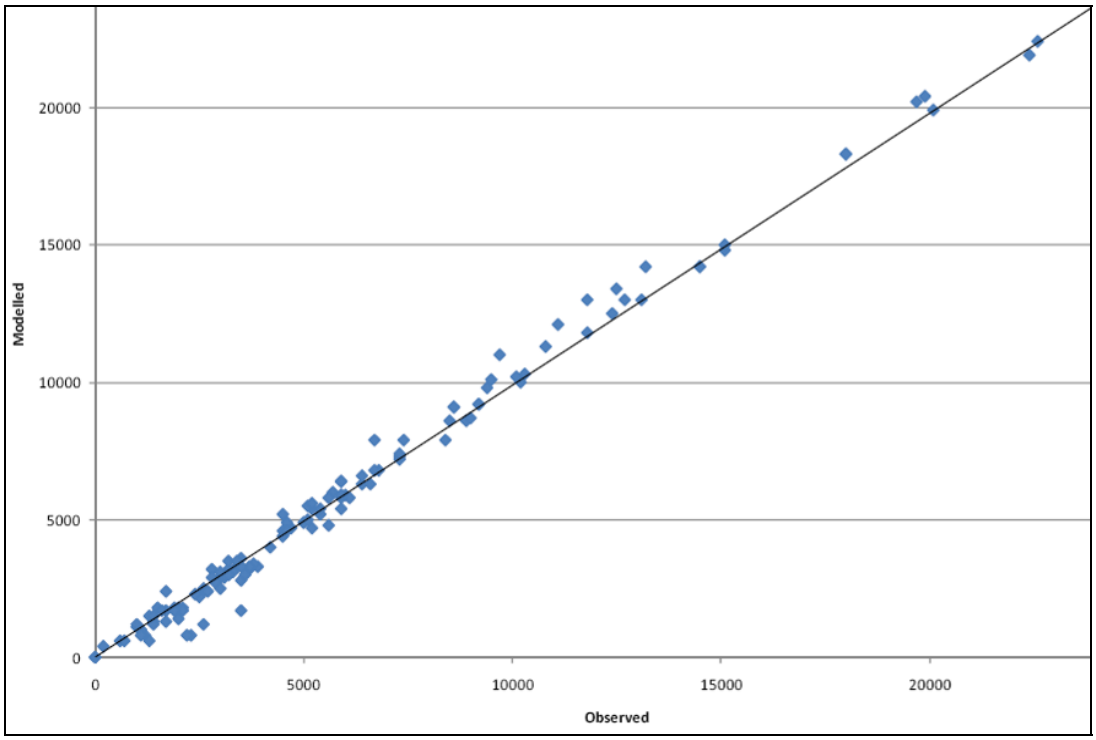


Figure 10.5 Example count versus modelled flow scatter plot

Performance of the models against travel times is important for both economic evaluation and route choice accuracy. Journey times collected for validation of model performance should be collected by undertaking multiple travel time runs to establish a statistically sound data set of comparison. Transport for London [5] recommends journey times be within ±10 per cent before validation checks are conducted. These survey data accuracies should also reflect the actual period (eg workday, PM peak) that is being modelled, noting the variation that can occur in different average conditions suggested by BTS [7].

Target validation criteria have been combined from various sources for use in NSW and are shown in Table 10.4.

Table 10.4 Highway assignment modelling travel time target calibration/validation criteria

Topic	Criteria
Journey time average	Average modelled journey time to be within 15 per cent or one minute (whichever is greater) of average observed journey time for full length of route for 95 per cent of observed travel time routes. Travel times on each route should be cumulatively graphed by sector

TfL guide [5] and NZ EEM [8]

Checks should also be made to verify that the route choice within the model is logical. This can be done using visual checking against expected paths against shortest path plots produced by the software. This should be carried out for all time periods and vehicle classes.

10.3	Table 10.3 Link and turn target calibration/validation criteria. Table 10.4 Travel time target calibration/validation criteria

10.4 Scenario model application

Following calibration and validation of the base model, the model can be used for scenario testing. This can vary widely although essentially involves (a) the alteration of the base model to reflect a defined set of proposed or anticipated changes and (b) comparison of the scenario test model against the base model to determine impacts of the scenario. A scenario may involve changes to one or more of the following:

- Additional road links.
- Physical road layout, geometry and line marking.
- Driver behaviour and system characteristics.
- Intersection control, including changes to traffic signal operation.
- Increased or changing demands.
- Traffic compositions.
- Road user charges.

It is important to identify both the primary and secondary changes within a scenario. Changes in demand (eg new development) may require alteration of traffic signal phasing and timing or the physical layout of downstream intersections. An upgrade project may reduce delays along a corridor to the degree that induced traffic may need to be assessed by increasing demands for particular origin-destination combinations.

In many cases, other analysis methods may be required to determine the changes required to the scenario model. Optimisation of signal phasing or intersection layout may require assessment in SIDRA. Optimisation of signals may be possible directly in the mesoscopic model although in some cases the offset settings may require TRANSYT or LINSIG analysis. Changes in the demand may require an induced demand elasticity approach or potentially reassessment of through traffic demands from a strategic model.

Consideration of the scale of the scenario tests should be included in the initial scoping and specifications exercise to ensure that the models developed are capable of assessing the scenarios. The scenario testing may involve progressive application of model changes to separate the various effects and to account for positive and negative impacts for economic analysis.

Models can generate a wide range of outputs that provide an indication of the performance of the network. Performance statistics that could be provided include:

- Macroanalytical models
  - Traffic volume changes on links.
  - Traffic delay changes on links.
  - Link capacity ratios (volume/capacity).
  - Global statistics – study area or on link sub-sets – (eg VHT, VKT, vehicle emissions).
- Mesoscopic models (additional to macroanalytical list).
  - Degrees of saturation.
  - Junction practical reserve capacity.
  - Maximum average queue lengths.
  - Cyclic flow profiles (CFP) for critical links (short/highly saturated).
  - Location and impact of queuing.
  - Average delay per vehicle per link.
  - Average delay per bus per link.
  - Percentage of vehicles per route waiting more than one cycle to clear intersections.
  - Variation in private and public transport along pre-defined routes.

There may be occasions when it might be necessary for modellers to present the impact of a proposed scheme using a selection of these performance indicators depending on the objectives of the scheme. The selection of performance indicators should be agreed along with the scenario coding method within the model specifications before scenario resting and reporting is undertaken.

10.4	It is important to identify both the primary and secondary changes within a scenario. Other levels of modelling may be required to determine the required changes that need to be made to the Highway assignment model; these may include: • Isolated intersection optimisation using SIDRA. • Coordinated signal optimisation using LinSig. • An assessment of the induced traffic demand elasticity or strategic model runs used to obtain increases in through-traffic.

10.5 Reporting

Refer to general reporting requirements, section 5.7.

The Base Model Development Report (BMDR) and Option Assessment Report (OAR) for highway assignment models will generally focus on queue propagation due to control delays (ie at intersections, merge and weave areas) and travel times on competing routes through the network.

11 Microsimulation modelling[5]

11.1 Background

The preparation of the microsimulation modelling advice in these guidelines is the result of a literature review of existing guidelines and published documents from other jurisdictions from around the world. To ensure that only practical and relevant advice is provided in these guidelines, a summary of these documents was developed as a working paper and presented to RMS staff for review. Workshops were then conducted to determine the most appropriate measures to include in this guideline document.

11.2 Core area of model

One of the key aims of these guidelines is to ensure that the significant time and resources that practitioners spend calibrating and validating microsimulation models are channelled in the most appropriate and efficient manner in order to achieve models that can provide accurate outputs that minimise risk in the forecasting process. RMS has therefore developed the concept of the "core area" which aims to improve the accuracy of models in those parts of the network that are of critical significance to the study.

Microsimulation models can range in size and complexity from single intersections, road corridors and up to entire towns/activity centres or even freeway networks. It is therefore important to recognise that every model is different and that the form and function of the core area for any given model will vary. Intersections and links within the core area will be subject to more rigorous calibration and validation targets in order to ensure that these areas of the model provide the best possible representation of surface transport conditions.

The extents of the core area should be agreed between RMS and the service provider at an inception meeting prior to the commencement of modelling. In some cases (such as corridor models with no route choice) the entire model may be deemed to be within the core area and therefore subject to more stringent criteria. In other cases (such as larger, more strategic models) the core area may be a relatively small portion.

The inclusion of an intersection within the core area will be affected by a number of issues including the study objectives, the location of the intersection within the study area and the importance of the intersection to local traffic movements, signal control and route choice.

11.2	The core area should be agreed with RMS at an inception meeting and a list of included intersections should be presented in the Base Model Development Report (BMDR) with this being the focus of more rigorous calibration and validation effort.

11.3 Model calibration

11.3.1 Overview

Calibration is a term that describes a wide range of adjustments that can be made to model coding, parameters and demand in order to assist in the development of an accurate simulation of on-street conditions. Calibration can generally be split into three core areas:

- Network verification – refinement of network inputs.
- Demand calibration – refinement of trip volumes, patterns and driving behaviour.
- Route choice calibration – refinement of parameters that influence a driver's routing decisions.
- Each of these core areas should be investigated and addressed as a part of the overall model calibration and each is discussed in more detail in subsequent sections of this document.

[5] GHD has prepared this subset of the guidelines dealing with Microsimulation Modelling. The section on Model Stability is based on work undertaken by the Australian Centre for Commercial Mathematics (ACCM) at the University of NSW.

It should be noted that the accurate calibration of a microsimulation model is a complex and time-consuming task. The calibration of a parameter in one area of the model may have subsequent and unexpected impacts in other areas of the model (these “butterfly effect” phenomena have been observed in a number of software packages and usually are most conspicuous in unstable network conditions). It is therefore important to develop a calibration strategy and to approach each step in a logical and disciplined manner. Generally it is advisable to adjust a single parameter at a time so that the impacts of the change can be isolated and understood when the simulation is run. Adjustments should be logical, reasonable and appropriate for their purpose.

It is unlikely that a single iteration of calibration addressing each of the core areas outlined above will achieve a sufficiently accurate model at the first attempt. A number of iterations are usually required before the base model is refined to a level of detail that is fit for the purpose of the study and that will provide reliable forecasts going forward.

Figure 11.1 below provides a simplified understanding of the broad issues that affect the model calibration process. Each is described in detail in subsequent sections of this document.

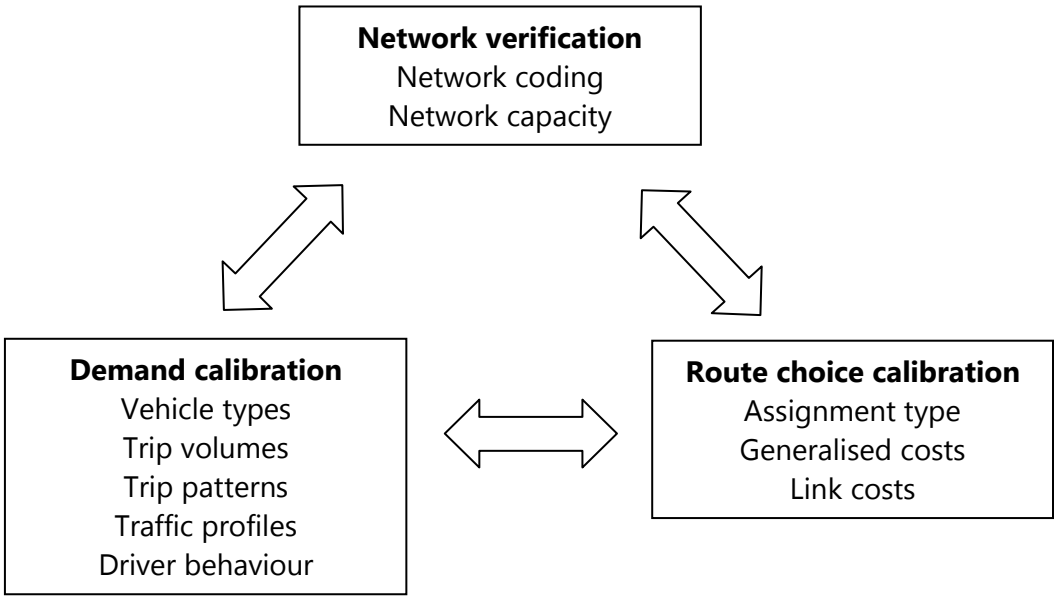


Figure 11.1 Model verification and calibration process

11.3.2 Network verification

Basic network coding

The initial network coding phase represents an important stage in the overall model development. The creation of a basic network that is of a consistent and accurate standard can significantly reduce the duration of the subsequent model calibration process.

Each area of the network should be verified over the course of the calibration process to ensure that it is accurately representing the observed capacity and driver behaviour for that location. However, it is likely that many links and intersections will exhibit similar characteristics, and the initial development of a consistent approach to coding therefore provides a stable platform from which to undertake subsequent calibration adjustments.

Each software package represents road networks in a slightly different manner. Some packages use a link and node structure whilst others use a link and connector structure. Regardless of the technique employed there are a number of key parameters that must be coded when developing a basic network:

- Number of lanes.
- Lane widths.
- Lane closures / restrictions.
- Z-height / gradient.
- Basic geometry (based on a correctly scaled background).

Ensuring that each of these areas has been coded correctly and consistently will assist in the calibration process that follows the initial model development.

Vehicle speeds

Posted speed limits should be assessed for the full extents of the study area and should be coded during the initial model build. This will provide a starting point from which any further localised adjustments can be made as required. The method by which the posted speed limits are applied also varies between packages since some apply speed distributions to entire links whilst others use explicit locations to inform drivers of speed changes.

Each software package provides default speed distribution categories that can be used during this initial stage. However, in some cases the distributions may not be appropriate for the localised area and it may be necessary to make adjustments.

In some studies (particularly those assessing freeway operations) it is possible to acquire point-speed data from detector loops or other sources. The analysis of these data for periods of low traffic flow can provide an excellent indication of appropriate speed distribution data for vehicles under free flow conditions. These speed data can replace the default software values that represent desired speeds and is a useful calibration tool to ensure that localised driver behaviour is more accurately simulated within the model. In areas of the network that experience congested conditions it is not appropriate to adjust speed distributions in the model to match observed values since these observed values are a consequence of the congestion (and therefore can be used as a validation parameter of model outputs but not as a calibration parameter of model input).

For locations where speed data is not available it may still be acceptable to adjust speed distributions from the default values. In specific and rare cases it may be necessary to adjust the speed distribution on isolated links. This might be as a result of activities that cannot be accurately otherwise represented within the model. Examples of this might include side friction from pedestrian activity, narrow lanes, parking activity or visibility issues. However, it should be noted that the manual adjustment of speeds on individual links should be a last resort and should only be used if other network coding cannot adequately simulate the actual cause of the issue.

Priority intersections

Priority intersections often account for a large proportion of all the intersections to be coded in a microsimulation model due to their prevalence across the entire road network. They form an important constraint on network capacity in many study areas and can therefore cause significant delays and rerouting in some models. Correctly modelling the parameters associated with these intersections is therefore an important part of the wider calibration process. A number of relevant parameters are discussed below.

Gap acceptance

Gap acceptance is one of the critical parameters affecting the capacity of approaches to priority controlled intersections. Many software packages provide default gap acceptance values and care should be taken to ensure that these values are appropriate for each modelled conflict location. It is not acceptable to assume that the default parameters are suitable at all locations throughout the network without assessing the intersection performance and calibrating values where necessary.

There are many factors that influence the value of gap acceptance and these should be assessed and taken into account on an individual location basis (where a particular model allows). Key factors that might affect gap acceptance include:

- Visibility.
- Geometry.
- Vehicle type.
- Level of congestion.

In locations where visibility is poor or the angle of approach or exit is acute an increased gap acceptance may be required. Conversely in some urban areas where congestion is severe and drivers

are prepared to take more risks (or are more familiar with the local network) the gap acceptance may be reduced.

An additional issue is the need to specify different gap acceptance values for various user classes within the model. Heavy vehicles often require larger gaps than light vehicles to join fast moving streams of traffic from side roads or to make right turns across oncoming traffic. Therefore if the modelled network has a significant volume of heavy vehicles it may be necessary to explicitly code different gap acceptance values for each vehicle type where possible.

The *Highway Capacity Manual* (HCM) a publication of the Transportation Research Board (TRB) in the United States provides some useful guidance on the development of appropriate gap acceptance values and modellers are encouraged to familiarise themselves with these values. However, these values are to be used as a guide and should not be simply used in place of site observation and calibration.

Blocking

In dense urban networks it is possible for intersections to become blocked by vehicles queuing through an intersection. Blocking can decrease the capacity of some movements at priority intersections and roundabouts and is therefore an important calibration tool in defining the capacity and efficiency of the local road network.

The nature of this behaviour should be observed on site and replicated in the model where possible. Most software packages offer a direct or indirect method of achieving different levels of blocking. This is achieved, either through specific blocking parameters, or via the use of a number of other network coding tools (that can be applied through workarounds).

Turning lanes

Turning lanes allow traffic wishing to undertake a particular turning movement to queue without blocking traffic on other turning movements. They can play an important role in local road capacity since congestion can quickly develop when a turning lane becomes full and begins to block other movements on the same approach. It is therefore essential to ensure that turning lanes are defined correctly both in length, entry location and upstream driver awareness.

The correct calibration of turning lanes in the base model also has implications for any future year scenarios to be assessed. This is important since many intersections in the network may operate at or below capacity in the base year but subsequently operate over capacity in future year scenarios. Correct calibration of turning lane parameters in the base year will therefore ensure that the behaviour of vehicles within future year models is realistic and that the model will be able to provide an accurate assessment of intersection performance.

Further, if a carriageway is wide enough to accommodate passing vehicles (but only line marked as a single lane) it is reasonable for the model to be coded using two lanes to allow for the passing. Care must be taken that the passing lane is available and not blocked by parking, bus stops or local driver behaviour.

Signalised intersections

Signalised intersections have a significant impact upon the capacity of modelled traffic networks as they are the focus of (often) high volume conflicting traffic movements that are only allocated a portion of available green time to undertake their manoeuvre. The adjustment of signal timings, and associated parameters that affect stop line saturation flows, directly control the throughput of each approach in the model and often dictate capacity.

Since most microsimulation model applications are of congested urban areas, with many signalised intersections, the accurate calibration of these parameters is often critical in the development of a robust base model.

The development of an accurate simulation of on-street signal operation has further benefits beyond the calibration stage of the study. One of the key benefits of microsimulation over other modelling techniques is the ability to simulate signalised intersections operating as part of an integrated wider adaptive control network or as vehicle actuated. It is therefore important that base models are

developed to a sufficiently high level of accuracy to realise these benefits during the scenario testing stage.

In order to accurately code a signalised intersection, the layout plan should be obtained from RMS together with the relevant SCATS and IDM data for the modelled time periods. The intersection coding should reflect the detail in the layout plan and should be confirmed during a site visit. The length of turning lanes should be assessed from plans or from scaled aerial photography and should be accurately coded into the model to reflect actual vehicle behaviour during the most congested periods. If a turn movement has a dedicated lane then it is acceptable for this to be coded as a separate link to improve lane discipline upon approach to the intersection. However, care should be taken to ensure that the entry point to the turning lane is accurately positioned as observed vehicle behaviour may not correspond with on the ground lane markings.

Signalised intersections can be modelled using a number of different techniques in microsimulation packages. RMS may recommend the technique that they wish to apply for signal control within the study brief. If the brief does not provide guidance relating to signal control then the modeller should assess the technique that is most appropriate for each site taking into account the significance of each site to both the study area and to the operation of the network. This should then be discussed and agreed with RMS for each location prior to the commencement of modelling.

Generally, four techniques are commonly used when coding signalised intersections in microsimulation models:

- Fixed time signals.
- Vehicle Actuated (VA) signal coding.
- SCATS operation through the SCATSIM interface.
- SCATS historical operation through the SCATS History Reader.

Fixed signal timings

Average signal timings can be derived from SCATS data provided by RMS, site visits or ideally a combination of both. In locations where signal timings show significant variability over the modelled period it may be necessary to operate a number of fixed time plans throughout the modelled period if the software package being used offers this functionality.

Signal timings should be verified against the provided SCATS data and site visits during the calibration stage to ensure that they provide as accurate a representation of on-street conditions as is possible. Limited adjustment from the observed hourly average is allowable to account for variability across the hour period.

Signal offsets must also be included in the coding of fixed time signals.

Vehicle actuated signal timings

In more complex situations signals may be coded using vehicle actuated signals. These signals operate under a dynamic plan that can respond to calls from detectors or other controller logic to provide variable green times, phase calls and cycle times. Vehicle actuated signals therefore provide an excellent representation of intersections that respond to demand from detector loops in the road or for intersections that include public transport priority phases or similar. Vehicle actuation can also be used to simulate ramp-metering operations, part-time signals and many other logic-controlled situations.

Signal timing settings, detector locations and control logic should be sourced from RMS for each site when undertaking vehicle actuated signal development. This will allow an accurate simulation of the on-site control to be developed.

Signal offsets must also be included in the coding of vehicle actuated signals.

SCATS signal timings

In some cases it may be necessary to simulate the SCATS system of signal control within the model. In these cases it will be necessary to use the SCATSIM interface and to obtain data from RMS pertaining to the current operational setup. The use of SCATSIM is not a requirement for all projects and will be

requested by RMS only where it is considered to be of critical significance to the study. As this method requires significant RMS resources, the Network Operations section should be contacted and their agreement sought prior to specifying this method of signal control.

Since both SCATS and VA timings are dynamic by their nature it is also useful to compare the modelled operation of the simulated intersections against real-world data. This can provide confidence to both the modeller and RMS that the model is adequately replicating the on-street intersection control over the modelled time period.

Saturation flow at signalised stop lines

The saturation flow modelled at signalised stop lines has a significant impact on the throughput of any approach. There are a number of factors which may affect the stop line saturation flow on-site and these must be replicated as closely as possible in the model. A number of these factors are listed below:

- Geometry.
- Gradient.
- Visibility.
- Gap acceptance for turning traffic.
- Lane width[6].

The method by which these factors can be controlled is dependent upon the software package used. Most packages allow for the use of gradient on individual links and this should be coded as appropriate for each approach.

Some packages automatically assess the geometry of any turning movement and reduce vehicle speeds accordingly whilst others require a manually applied reduction in speed. Care should be taken in these cases to ensure that appropriate account is taken of the geometry for each movement. It may be necessary to undertake a basic site survey of saturation flow in order to assess the calibration of some key approaches.

Visibility and lane width also have an impact upon the saturation flow and should be assessed on-site. Some packages allow for a visibility parameter to be coded directly into the model but if this feature is not available then account should be taken of visibility issues using other parameters (eg adjustments to approach speed or gap acceptance). Lane widths generally have no impact upon modelled saturation flow and therefore the implications of a reduced lane width should again be taken into account through the use of other available parameters if appropriate.

A well calibrated signalised intersection incorporating accurate signal timings and realistic saturation flows at stop lines will provide a robust base from which to validate a model. It is therefore strongly recommended that modellers review the operation of signalised intersections at an early stage during model calibration.

Lane utilisation

Lane utilisation can have an important impact upon network capacity and network operation in a congested study area and should be calibrated against observed site conditions. The use of practitioners with significant local knowledge is therefore critical during this process.

A number of different parameters can affect lane utilisation and these should be checked and adjusted as appropriate throughout the network. Modellers should undertake site visits during peak time periods in order to observe lane discipline and utilisation at all major intersections and other areas of significant congestion. This will allow the development of driving behaviour within the model that is consistent with observations made on-site.

A key parameter affecting lane utilisation is the upstream distance at which a driver will become aware that they are required to change lane for a downstream turn movement. In practice, drivers can be influenced by a number of factors including:

[6] Although microsimulation models do not use this directly – opportunities for passing on wide lanes or added friction on narrow lanes need to be considered.

- Drivers who are unfamiliar with the local network may react to signposting or lane markings that indicate the correct lane with observed behaviour occurring a short distance in advance of necessary turn manoeuvre.
- Drivers who are more familiar with the network may make the necessary lane choice earlier in order to affect an easier lane changing manoeuvre (sometimes this can be multiple intersections in advance of the turn manoeuvre).

Each software package will provide a method of informing drivers of an upcoming lane change through the use of an upstream awareness distance value. It is appropriate to adjust these distance values throughout the model as they will vary significantly between approaches and turn movements. A useful technique is to initially code these distances to reflect the on-street signage and lane marking strategy and subsequently adjust any that require further calibration due to other factors such as driver familiarity.

In some cases it may be necessary to split approaches into separate links in order to improve lane discipline. This is a technique that is acceptable to RMS when used for this purpose, however, if this is applied too far in advance of the stop line then insufficient weaving distance or insufficient friction due to lane changes may result.

If possible, observations of the lane utilisation for different vehicle types should be undertaken as some sites demonstrate clear segregation for various reasons (including that some lanes may be more attractive to heavy vehicles or buses due to lane width or turning geometry). In addition, high occupancy vehicle (HOV) lanes and bus lanes may operate at certain times of day.

A further issue associated with lane utilisation can occur on links that feed traffic from zones into the model. It is important to ensure that these links are sufficiently long to allow vehicles to make lane changing manoeuvres prior to the first turn movement. This is particularly important for freeway links where unrealistic congestion can occur if the fully signposted distance (as a minimum) is not modelled.

Impact of pedestrians

Pedestrian activity can impact upon traffic movement and road capacity in some networks and therefore should generally be modelled in some form. Modelling packages provide a variety of ways to account for pedestrian activity and the modeller should choose the most accurate and relevant method on a case by case basis.

Pedestrians at signalised intersections

Signalised intersections are one of the key locations that accommodate pedestrian and vehicular interaction. In some cases pedestrian usage of these facilities can have significant impacts upon the network capacity since pedestrians can affect the capacity of left, right and (in the case of shared lanes) through movements on some approaches. This occurs for a number of possible reasons:

- A dedicated pedestrian phase is called, thereby increasing delay for traffic waiting at the stop line and possibly reducing the green time available in subsequent phases.
- Pedestrians crossing during a traffic phase (with or without full pedestrian protection) have priority over left or right turning traffic and reduce the capacity of those movements by blocking the exit for a proportion of the allocated green-time (this is particularly significant for left turning traffic).
- Traffic phase durations may be altered when pedestrian phases are called due to the requirement for longer clearance times for pedestrians.

The modeller should assess the impact of pedestrians upon traffic movements during site visits to develop an understanding of which locations are subject to any significant capacity constraint. RMS does not expect that every signalised intersection will be modelled to include the impact of pedestrians. However, where the impact is significant then attempts should be made to simulate this as this will improve the model calibration and provide a more realistic outcome.

RMS is able to provide SCATS data for many signalised sites. This can provide an indication of the number of times that pedestrian phases are called during signal operation and allows the coding of VA signals to simulate the call of pedestrian phases on an appropriate basis for any given time period.

While this provides useful information relating to the call frequency of the phase it will not provide an indication of the actual volume of pedestrians (and hence disruption for left or right turning vehicles).

The use of dummy signals or phases to simulate pedestrians blocking turning traffic during appropriate phases is also considered acceptable, although the coding of actual pedestrian movements (where software permits) is considered the optimum approach.

Pedestrians at zebra crossings

Heavily utilised zebra crossings can cause delays to traffic, and since this can restrict the capacity of the local road network, it can be important to code zebra crossings and calibrate the associated level of disruption (distribution of times that vehicles are stopped) to replicate observed conditions.

The modeller should assess locations where zebra crossings are likely to have a significant impact upon vehicle travel times or where they are likely to discourage drivers from using a route (either due to the delay or the perceived delay that they cause). Some attempt should then be made to replicate the level of delay observed on site. This can be achieved by coding a set of dummy signals or explicitly coding pedestrian movements across the zebra crossing if the software being used provides that capability.

Pedestrians at Mid-block Signal Crossings

Apart from the primary effect of delaying traffic during the pedestrian invitation and clearance time at mid block signalised crossings the secondary effects are also apparent in microsimulation models – as platooning of vehicles increases this can have significant effects on downstream intersection operations. Flashing yellow periods associated with pelican crossings are dealt with differently by each software package but most have sufficient capability to adequately represent this behaviour either directly, or by adjusting other parameters to arrive at an appropriate workaround that increases delay to vehicles dependant on the incidence of pedestrians crossing after the green man (ie during the flashing red man period).

Public transport

The level of detail to which public transport should be represented within a microsimulation model is dependent upon the objectives of the study and the impact that public transport may have upon the overall operation of the network. The development and calibration of public transport elements within a model therefore varies on a case by case basis, however, for the majority of arterial roads, under congested conditions, there would be a requirement to model bus operations directly.

The modeller should assess the likely implications that public transport movements may have upon traffic flow in the study area. This will provide an indication of how public transport movements may be interacting with other vehicles in the current network and in any future scenarios. Typical issues might be:

- Buses/trams stopping at on-street stops.
- Buses merging with general traffic from indented bus stops.
- Bus/tram lanes for full or part links.
- Public Transport (PT) phases in signal operation altering available green time for general traffic movements.

Modellers should identify if these issues are likely to have a significant impact upon the network area to be modelled and should code these accordingly. Site visits can assist in identifying the impacts of public transport operations and can provide insight into driver behaviour where relevant. This behaviour and subsequent adjustment to local capacity can then be calibrated within the model to be consistent with the observations.

Public transport services and headways should be coded into the model based on data sourced from the relevant public transport authority. Dwell times at stops should be coded for PT services using any available datasets. Where the dwell time is likely to have a significant impact upon road capacity and congestion it is preferable to undertake dwell time surveys to establish a distribution that can be applied within the model. RMS may be able to supply practitioners with dwell time data for public transport services from the PTIPS GPS system which can provide a robust observed dataset.

In addition to the dwell time at each stop, account should be taken of the means by which PT vehicles leave and rejoin the main flow of traffic. This is particularly the case with indented stops as the interaction of the PT vehicle with traffic in the main flow can have implications upon travel times for both the PT service itself and also general traffic.

In some areas non-scheduled bus services (school buses, dead running etc) constitute a large proportion of on road public transport use. In these areas it may be necessary for modellers to contact the public transport service providers to ensure the full impact of on-road public transport is taken into account.

Other issues that may require attention are the operation of other PT services such as light rail and the operation of signalised level crossings. The operation of signals at level crossings may be linked to adjacent signalised sites and this should be investigated prior to coding.

11.3.2	It is mandatory that any adjustments to speed distributions are documented in the Base Model Development Report (BMDR) together with a justification for the changes and any evidence supporting this. Reducing speed distributions on isolated links in order to match modelled travel times with observed datasets is not acceptable to RMS. The location of blocking behaviour and the method with which it has been simulated should be described in the base model reporting as often cooperation between drivers allows for minor road turns to take precedence over slow-moving major movements. The technique used to simulate each signalised intersection should be agreed with RMS at the inception of the study and tabulated in the BMDR. The source of all signal data and layout plans should also be indicated. Guidance on appropriate criteria to use when reporting the calibration of signalised intersections is provided in this document. Assessment of key intersections against the provided guidelines is a useful indication of the level of calibration for each approach at any given location. The accurate modelling of signal timings and control at an intersection will significantly assist in any subsequent calibration of queue lengths and delays at each location. While RMS does not currently consider it mandatory to report saturation flow comparisons for all signalised stop lines, modellers should report values for key locations where data and model outputs are available. Guidelines for reporting are provided in this document. In all cases links and intersections must be coded to represent their operation on site. This may differ from aerial photography and survey information which may not adequately reflect localised vehicle behaviour or simply be out of date. Modellers should include any changes made during the calibration process as a result of field observations in the BMDR. The source of public transport data together with the dwell times assumed in the modelling should be documented in the BMDR.

11.3.3 Demand calibration

Demand refers to the trips that drivers wish to make from any given origin to any given destination within the modelled study area. The demand must be calibrated to ensure that the vehicle movements within the model are an accurate representation of the observed vehicle movements that exist on site.

The demand calibration process comprises adjustments to the definition of different vehicle types, the development of trip volumes for each origin-destination (O-D) pair and the profiling of the demand over the total modelled time period.

Defining vehicle types

All software packages offer the ability to segment travel demand into a range of vehicle types. The differing characteristics of each vehicle type can affect both route choice through the network and also the localised network capacity. This is due to parameters such as acceleration rates, gap acceptance and vehicle length differing greatly between vehicle types. It is therefore relevant to ensure that a sufficiently accurate trip demand is defined for each of the vehicle types to be modelled and that these demands are later calibrated to an acceptable level for the purpose of the study.

The necessity to develop detailed demand for each type of vehicle is dependent upon the nature of the study network and the project objectives. In some networks the influence of different vehicle types may be minimal and it may be sufficient to simply split the total demand based upon a global factor sourced from count data. However, more complex studies will require detailed demands to be developed for each different type of vehicle. This will ensure that the resultant model will be able to accurately replicate the impact of the varying characteristics of these vehicles throughout the model.

As a minimum, RMS would expect demands to be developed for both light vehicles and heavy vehicles. Other vehicle types could include (but are not limited to) taxis, HOV or T2/T3 vehicles, light commercial vehicles and B-doubles. Buses are generally defined as an independent vehicle type within the model but are assigned separately as a public transport line with headway rather than as a genuine demand segment. The inclusion and operation of public transport will be provided in further detail later in this section.

Demand development

The development of demand for a microsimulation model can be undertaken using a number of different methodologies. RMS accepts that each study may require a different approach and is therefore open to a variety of techniques to develop accurate trip demands for models. Whatever the methodology chosen, the process should be documented in the base model reporting and trip totals for each matrix should be reported by vehicle type and for each time period.

Guidance in the use of several commonly used techniques for developing trip demand is outlined below. This is not an exhaustive list and other methods may be used or these methods may be combined as considered appropriate. The ultimate aim of demand development is to use the best available data to provide an accurate simulation of trip patterns and volumes throughout the study area.

Strategic model sub-area cordon

A typical approach to developing matrices for microsimulation models is to extract travel demands for the study area from an existing strategic model of the wider area. A well-calibrated strategic model can be cordoned to provide an origin-destination (O-D) matrix for each vehicle type and for each time period consistent with the microsimulation model.

Before proceeding with this approach it is important to understand the level to which the strategic model has previously been calibrated. This is particularly the case for the area to be cordoned since data for this area will be imported directly into the microsimulation. Strategic models are generally calibrated using screenlines (rather than individual turning volumes) and as such it is common to find that the demand from a calibrated strategic model is not sufficiently accurate to immediately calibrate within a microsimulation model. It may therefore be necessary to make further adjustments to the demand to ensure that the microsimulation model is fit for purpose.

Care should be taken to ensure that any further adjustments that are made to the demand are documented and reported. If the strategic model is to be used at a later stage to provide demand for option testing or future year scenarios then these adjustments will need to be applied to the extracted matrices in some form to ensure consistency with the base model.

Balancing intersection counts

Another common method for developing demand for microsimulation models is to collate network-wide turning movement data from recent surveys or from SCATS detector outputs. This data can be input into a spreadsheet to show the expected turning movements at each key location throughout the network. It should be noted that survey data is preferable to SCATS data since surveys can often provide data disaggregated by vehicle type. In addition SCATS data does not distinguish between movements for shared lanes and may not provide information for left turn slip lanes.

The use of this technique can provide accurate turning volumes for each individual intersection but does not provide robust data relating to trip origins and destinations. It is therefore often necessary to undertake an O-D survey for key locations within the study area to gain an understanding of the distribution of trips through the network.

Any discrepancies between total arrivals and departures at adjacent count sites must be assessed and some minor adjustments may be required in order to provide balanced volumes at each location.

Generally the larger figure should be assumed in this process where possible. Further, if major discrepancies are noted then it will be necessary to investigate the cause of these rather than simply make large adjustments to the observed values.

Demand adjustment

The demand development stage outlined above provides an initial estimate of trip demand through the study network. RMS accepts that this demand may require further manual calibration in order to ensure that the model accurately reflects turning movement counts and other link and screenline data. The purpose of microsimulation is often to provide a detailed assessment of intersection performance and it is therefore preferable for the base model to provide the most accurate possible representation of turning volumes at key locations.

There are a number of methods available to the modeller in order to undertake this additional demand adjustment and each should be used with a degree of caution and in a manner that can be audited independently should this be required at a later stage.

Matrix furnessing

Matrix furnessing is a procedure that factors rows and columns within a demand matrix to attempt to match a number of user-specified observed values. The main advantage of furnessing over other techniques is that the proportional distribution of trip origins and destinations for each zone remains consistent with the original demand matrix. The process simply uniformly uplifts or reduces the rows and columns until the best match is found with the observed data for each origin or destination zone.

Matrix estimation

Matrix estimation is a more complex technique that requires both the original demand matrix (termed a “prior” matrix) and a reasonably calibrated network of the study area (with particular attention to well calibrated route choice). The process assigns the original trip demand to the model network and then factors individual O-D cells until the modelled turn volumes are sufficiently close to the observed values.

This technique requires vigilance as it can significantly distort the trip pattern and distribution of the original demand. Detailed checking of changes to the demands is required and the process should be constrained as far as is possible to ensure that only a limited number of cells are adjusted where absolutely required. The factor by which cells can be adjusted should also be constrained to an appropriate value. A common issue with this process is the over-estimation of short trips in order to in-fill the matrix to fit the observed values.

Manual adjustment

The trip demand can also be manually adjusted by the modeller if no other option is available. Major changes should be documented and should again be constrained so as not to significantly alter the pattern and distribution of the original demand.

The graph below shows an example that compares the changes to trip length as a result of a matrix estimation process. In this case it can be seen that the distribution of trip length remains relatively similar throughout the process and this provides some confidence that the process has been sufficiently constrained so as to avoid major structural changes.

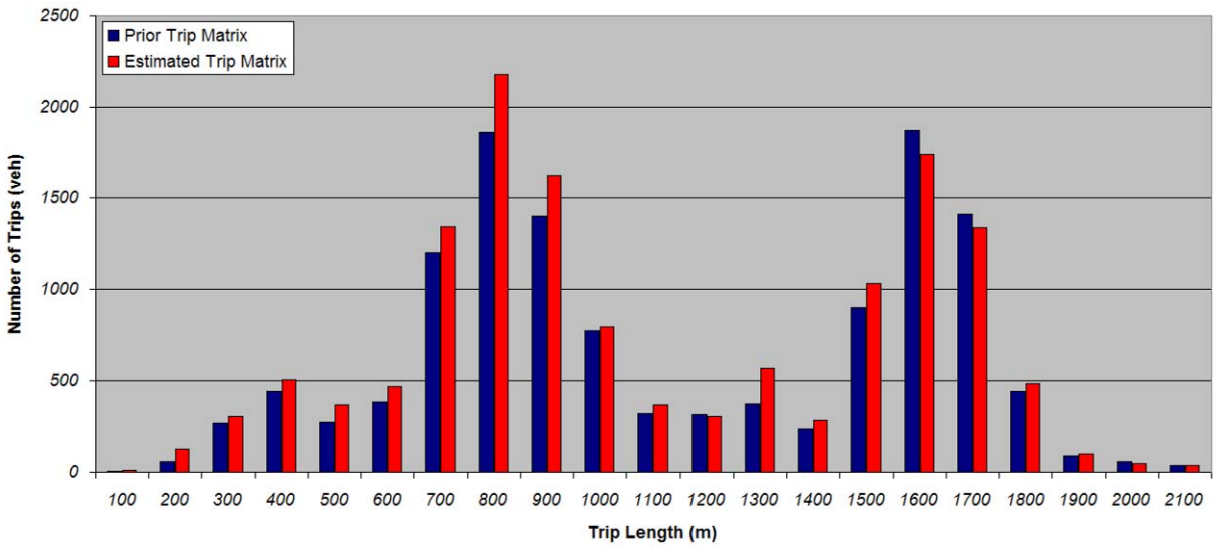


Figure 11.2 Trip length distribution comparison

Demand profiling

The calibration of link flows and turning movements provides confidence that the model demand is accurate over each hourly period. However, since microsimulation models assess the performance of the network at every time step it is also necessary to ensure that the model adequately represents the “peakiness” of travel demand within each hour. This is often referred to as profiling of demand.

The profiling of demand at major entry points into the model can have a significant impact upon the development of congestion and queue lengths throughout the network. In some locations such as those near schools or areas where shift work is prevalent there may be a short and very defined peak whereby queues at nearby intersections quickly develop at a specific time of day and then dissipate quickly as the demand drops. Other areas where traffic is fed by more mixed use zoning may have a flatter profile with queue lengths sustained over the entire period.

An assessment of the study area should be made to understand the likely implications of the local demand profile. This can include analysis of count data throughout the network and site observations from key locations. It is beneficial to attempt to source survey data that is disaggregated into five minute intervals as this provides a good level of detail for the development of a profile. However, 15-minute intervals are acceptable if data is only available in this format.

It is preferable to develop profiles for as many zones as possible and for each vehicle type where possible. However, in some cases a single adjusted profile over the entire study area may be acceptable. It is not acceptable for models to be developed with a flat profile without justification being provided.

Behavioural parameters

There are a wide range of behavioural parameters that may affect the calibration of a microsimulation model. Each software package will use some or all of these parameters to simulate driver behaviour in the model. However, since each package uses the parameters differently it is not possible to specify here the appropriate values for each.

Some packages allow the user to adjust high-level parameters which influence or determine lower-level parameters (eg aggressiveness, awareness). Modellers should ensure that they are familiar with the effects of the high-level parameters before making adjustments to these as the use of these parameters may have unintended impacts throughout the network.

Typical behavioural parameters used by majority of the software packages include:

- Headway.
- Lane changing gap acceptance.
- Reaction time.

- Awareness of other vehicles.
- Vehicle performance characteristics (ie acceleration, braking etc).
- Distance between vehicles at standstill.

11.3.3	If a significant amount of matrix adjustment is required then this should be detailed in the Base Model Development Report (BMDR). The trip totals for both the original demand and the adjusted demand should be reported for each vehicle type and for each modelled hour period. This will provide RMS with an indication of the scale of trip volume change incurred by the process. Further, graphs showing the changes in trip length distribution between the original and adjusted demands provide a useful indication of which types of trips have been in-filled or altered as a result of the adjustment. A statistical comparison of modelled and observed turning movements and link flows must be presented in the BMDR. For models with larger networks it may also be necessary to develop screenlines and/or cordons to evaluate the accuracy of the demand. Specific guidelines relating to the statistical comparison of observed and modelled volumes are provided later in this section. RMS suggests that models initially be developed using default values. However, it is considered appropriate to adjust the value of parameters to replicate local driver behaviour in some cases. If changes are made they should be documented in the BMDR together with a justification of why they were changed, what values were chosen and any evidence that can be provided to substantiate the change.

11.3.4 Route Choice Calibration

Models that involve route choice must undergo an additional process of route choice calibration. This process relates to the refinement and analysis of the manner in which drivers choose their paths through the network and ensures that the modelled paths are logical and realistic.

Route choice calibration is focused upon a number of model parameters that affect a driver's perception of the attractiveness of any given path through the network. These can be broken down into global parameters and local parameters which is discussed below.

Assignment type

Each modelling package provides a variety of different assignment methods. RMS accepts that each study may require a different approach and it is incumbent upon the modeller to select the appropriate assignment technique in each case. The chosen technique should be outlined in the Base Model Report together with an indication of the reason for its selection and any relevant parameters that are used.

Generalised costs

Every route choice model (regardless of software package) relies upon a generalised cost equation to calculate a driver's most attractive route or routes through the model. The concept of the equation is that a driver perceives each route to have a total cost and can therefore rank each route from most attractive to least attractive. The equation initially takes factors of time and distance into account for each route and has an additional cost added to account for tolls or other manually included impediments. The basic equation is shown below:

$$\textit{Generalised cost} = (A \times \textit{time}) + (B \times \textit{distance}) + (C \times \textit{additional cost})$$

significantly affect a driver's choice of route. It is therefore important that appropriate values be used in order to ensure that drivers take logical routes through the network. It is also important to note that different vehicle types will often have different values of time and distance (i.e. a truck driver may have a different value of time to a car driver). RMS does not provide default values for the generalised cost equation and it is therefore incumbent upon the modeller to assess the values that are appropriate for their study. Strategic models that incorporate the study area may provide relevant cost factors and may be used for this purpose.

Link hierarchy

Some software packages provide default link types that allow the stratification of links into major and minor routes. This is generally achieved by automatically applying a link cost or a link cost factor to each link of that type. For software packages that do not provide this functionality this can often be undertaken by manually applying a categorised cost or cost factor to each link.

This is a useful technique for refining the assignment of traffic through the network as it can be used to deter or attract drivers from using certain routes (eg rat-runs or signposted routes) by adjusting their perception of the route cost. The stratification of link type costs is considered an appropriate form of assignment calibration and is preferred to the isolated adjustment of individual link costs.

Localised cost adjustments

In some isolated cases it may be necessary to adjust the costs of individual links. Care should be taken to ensure that all other techniques that might resolve the issue have been attempted before cost factors are applied to isolated links.

Route assignment

During the calibration exercise it is essential to undertake logic checking to ensure that the route choices available to drivers are sensible and realistic. Most packages allow the modeller to select individual O-D pairs and assess the available routes and the proportion of drivers using them.

It is unlikely that routing survey data will be available and it can therefore be a relatively subjective exercise to assess the route choices that drivers make through the model. However, the primary purpose of the exercise is to ensure that drivers have been deterred from using any illogical routes through the network. The use of illogical routes is likely impact upon model performance and therefore remains an important step in the calibration process.

11.3.4	The level of detail to which the vehicle type demand should be developed must be agreed with RMS at the inception stage of the study and documented in the Base Model Development Report (BMDR). RMS suggests that models initially be developed using default values. However, it is considered appropriate to adjust the value of parameters to replicate local driver behaviour in some cases. If changes are made they should be documented in the Base Model Report together with a justification of why they were changed, what values were chosen and any evidence that can be provided to substantiate the change. The values of time and distance (and any additional toll or cost factors) should be documented in the BMDR Justification should be provided within the BMDR describing the location of any localised cost adjustments, the cause of the issue and why this could not be resolved through standard network coding.

11.4 Model validation

Model validation is the term used to describe the independent verification process used to demonstrate that a model has been calibrated to a sufficient extent to accurately reproduce on-street conditions.

The process is far simpler than model calibration since it does not require any adjustment to parameters or inputs. The modeller simply runs the simulation and compares a set of model outputs with an equivalent set of observed site data (this must be data that has not been used during the calibration process). A statistical comparison of these datasets using the validation guidelines provided in Section 11.5 of this document then provides two key areas of feedback. Firstly, it will indicate if the model is sufficiently calibrated to be fit for purpose. Secondly, if the model is not sufficiently calibrated it will provide an understanding of which areas of the model need further attention.

Should the validation process imply that the model is not yet at a sufficient level of accuracy then the specific areas of concern should be identified and analysed. The model therefore returns to the calibration stage such that the relevant parameters can be adjusted to address the relevant issues.

The calibration and validation processes are therefore part of an iterative cycle that continues until the validation can confirm that the model has reached a level of accuracy that is acceptable. The diagram below outlines this process.

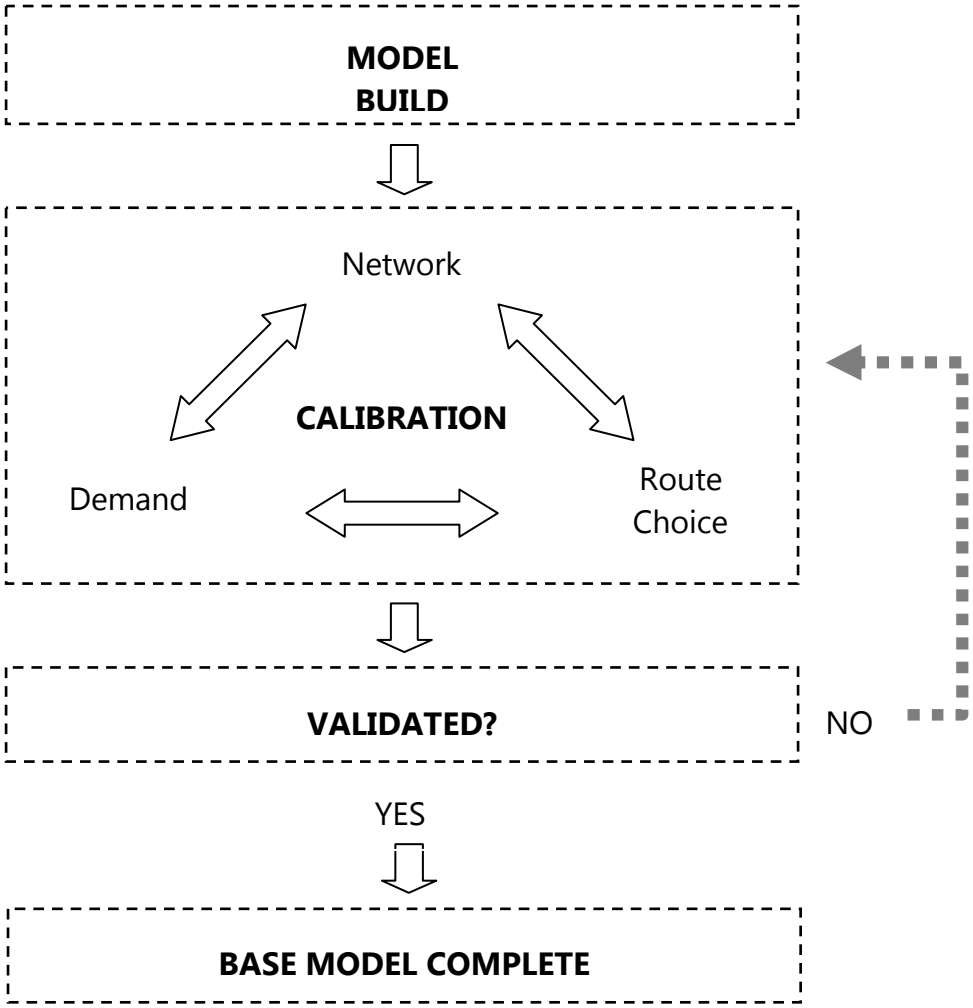


Figure 11.3 Model calibration and validation process

11.5 Suggested calibration and validation criteria

11.5.1 Overview

Many of the adjustments made to parameters during the model development process are simply documented in the base model report to provide a record of the changes. However, in addition to this record it is also necessary to provide some statistical comparison of model performance with on-street observations. This produces a quantifiable record of the level to which the model has been calibrated and subsequently validated.

The base model report includes separate sections for the reporting of calibration and validation and the modeller must assess which of the observed datasets have been used for each process (remembering that validation data must be independent and cannot have been used during the calibration stage). A common example might be the use of flow volume and queue length data during model calibration followed by the use of journey time data for model validation.

A comparison of each of the observed datasets against modelled outputs is then presented in either the calibration or validation sections of the report. The statistical criteria used for comparison of observed and modelled output do not change regardless of whether a dataset is used for calibration or validation; it is simply the location of the reporting that varies.

The guidelines below provide statistical criteria that will help to indicate if a model is performing adequately. The following data types are addressed:

- Traffic volumes.
- Signal timings.
- Saturation flows.
- Journey time routes.
- Queue lengths.

It should be noted that there will be occasions where models may not meet these criteria but are still considered fit for purpose. Likewise, some models may meet the criteria but require further attention in areas of critical significance to the study. The extents, structure and objectives of every modelling exercise are different and these will all have a bearing upon the level of importance that might be placed upon successfully achieving each of the targets.

The decision to accept or reject a model lies with RMS and it is therefore incumbent upon the modeller to explain any shortcomings or failures in the modelling that might prevent the model from successfully achieving the guideline calibration and validation criteria.

11.5.2 Guideline criteria

Traffic volumes

Traffic volumes are often used as a key statistical indicator that the model is sufficiently calibrated as they provide an easily measurable dataset both in the model and on site. Traffic volumes can be in the form of link flows or turning movement flows. These can also be aggregated to provide screenlines or cordons.

Traffic volumes can also be used in the validation process (rather than the calibration process) but this can only occur where independent volume data that has not been used during calibration exists. This is unusual since most modellers will use all of the available traffic volume data during the calibration process in an attempt to provide the most accurate distribution of demands possible.

Generally RMS requires demand to be calibrated for each one hour period within the model and for each major vehicle type. Results should be extracted from the “median seed run” (see Section 11.7.3) in order to provide a stable, repeatable dataset that can be re-run for visual presentation.

The presentation of traffic volume data should be undertaken in two distinct steps as follows:

- Step 1 – present results for all observations within the study area against standard target criteria.
- Step 2 – present results for core area observations against core target criteria.

The core area is described in detail in Section 11.2 of these guidelines and should include intersections and links that are of critical significance to the study.

Table 11.1 and Table 11.2 apply where the models are to be matched to a single data set. Should the modeller have additional data available that shows variations in observed demand then it is adequate for the model to be shown to be within the tolerances of the observed data set (provided the observed data set is considered to be representative).

Table 11.1 Microsimulation link and turn target calibration/validation criteria (network wide)

NETWORK-WIDE	
Topic	**Criteria**
Link or turn	Results to be tabulated in appendices and summarised in main report Tolerance limits for network-wide area: *GEH < 5 Minimum 85 per cent of observations to be within tolerance limits* *Turn or link flows with GEH > 10 require explanation in reporting* Plots of observed vs modelled hourly flows required for all observations *Plots to include lines showing GEH = 5 tolerance limits* *R^2 value to be included with plots and to be > 0.9* *Slope equation to be included with plots (intercept to be set to zero)*
Screenline or cordon	Tolerance limits for network-wide area: *Each directional screenline or cordon total to have GEH < 3* *Individual links in screenlines / cordons to have GEH < 5 for 85 per cent of observations*

Table 11.2 Microsimulation link and turn target calibration/validation criteria (core area)

CORE AREA	
Topic	**Criteria**
Link or Turn	Results to be tabulated in appendices and summarised in main report Tolerance limits for core area: *Flows < 99 – to be within 10 vehicles of observed value* *Flows 100 to 999 – to be within 10 per cent of observed value* *Flows 1000 to 1999 – to be within 100 vehicles of observed value* *Flows > 2000 – to be within 5 per cent of observed value* *100 per cent of observations to be within tolerance limits* Plots of observed vs modelled hourly flows required for all observations *Plots to include lines showing core tolerance limits* *R^2 value to be included with plots and to be > 0.95* *Slope equation to be included with plots (intercept to be set to zero)*

Figure 11.4 below shows an example of a plot for the core area of a microsimulation model.

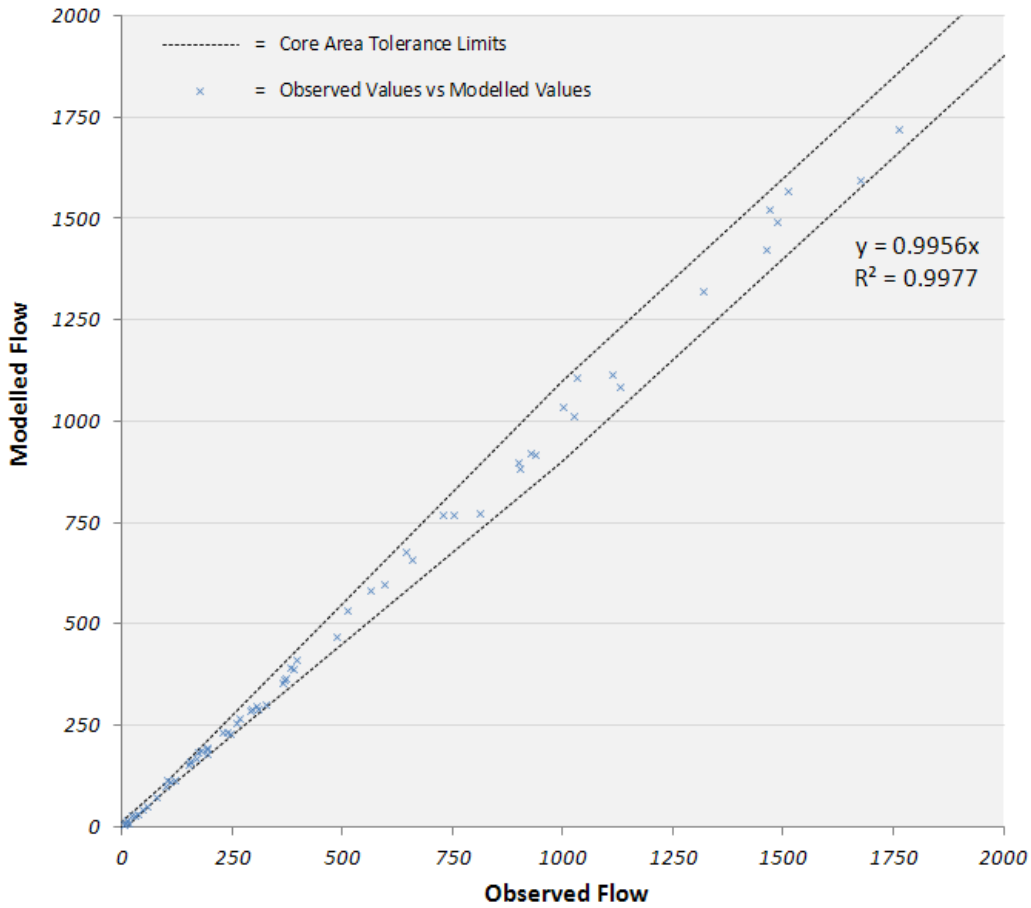


Figure 11.4 Core area traffic volume comparison

Signal timings

A comparison of model output and observed data will provide confidence that the operation of the signal cycles and timings are similar in the model to the recorded on-street operation. The guideline criteria outlined below should be presented for all signalised intersections within the core area of the model as agreed at the inception of the study. Results for non-core signalised intersections must also be presented if requested by RMS.

RMS will provide an “observed dataset” in the form of relevant SCATS output for each intersection and time period. This data should be used in the comparisons below.

Table 11.3 Microsimulation signal time target validation criteria

Topic	Criteria
Cycle time	Average modelled cycle time for each one hour period to be within 10 per cent of observed average cycle time for same one hour period.
Green time	Total of green time over each one hour period to be within 10 per cent of observed equivalent for each phase (since this has a direct impact upon hourly stop line capacity).
Call frequency	Call frequency of demand-dependent phases (including pedestrian phase calls) to be compared with observed data to ensure phase activation occurs to a similar level over each hour period. Frequency to be to modeller and client satisfaction.

Saturation flows

Some microsimulation modelling packages provide outputs that allow the calculation of saturation flows for signalised stop lines within the model. Where specified in the project brief, RMS may require modellers to provide a comparison of observed and modelled saturation flows at signalised stop lines in the core area of the network.

Observed datasets may come from a number of sources:

- Surveys can be manually undertaken at key stop lines to determine the saturation flow.
- RMS may provide information from SCATS relevant to maximum traffic flow rate and density data for signalised stop lines (although some adjustments may be required as directed by RMS).

The observed values should be compared with modelled outputs against the criteria set out below.

Table 11.4 Microsimulation stop line saturation flow target validation criteria

Topic	Criteria
Stop line saturation flow	Modelled saturation flows should be within 10 per cent of the recorded on-site survey data.

Journey time routes

A common technique used to assess the accuracy of a model is to compare surveyed and modelled journey times along key routes in the study area. This is an important comparison since journey times can affect driver route choice through the model and therefore have a significant impact on traffic volumes and the development of delays and congestion.

It is important to ensure that a sufficient number of journey time surveys have been undertaken during the data collection stage of the study. This will provide an accurate understanding in two key areas required for any subsequent statistical comparison:

- Average[7] journey time for each route.
- Variability in journey time for each route.

When collecting data it is also a requirement to disaggregate the route into smaller sections such that the location of key delays within the overall journey time can be easily identified. RMS defines a section as being the distance between intersection stop lines in an urban area and journey time surveys should be undertaken on this basis unless alternative approaches are discussed and agreed with RMS.

RMS collects significant volumes of journey time data and may be able to provide service providers with access to this information for relevant routes. Where used, this data should also be disaggregated into sections. The use of sections allows a cumulative graph of travel time along the route to be developed. This type of graph can provide an accurate analysis that demonstrates how the model is performing in each key section, rather than simply providing a total travel time.

Figure 11.5 below, provides an example of this type of comparison. In the example it can be seen that for the fifth section of the route the model does not generate the same level of delay that was noted during the surveys. This causes the final modelled average to fall outside of the tolerance limit. This implies that the model requires further calibration in the fifth section area before it can be considered to be sufficiently validated.

This method of assessing model performance provides confidence to both the modeller and RMS that the model is adequately representing on-street operation and is therefore considered an important part of the journey time validation process.

[7] It is recognised that average travel time can be sensitive to the impacts of outliers and that median travel time is actually a more useful and stable statistic. However as this is more difficult to obtain from some software, averages are used in this version of the guidelines.

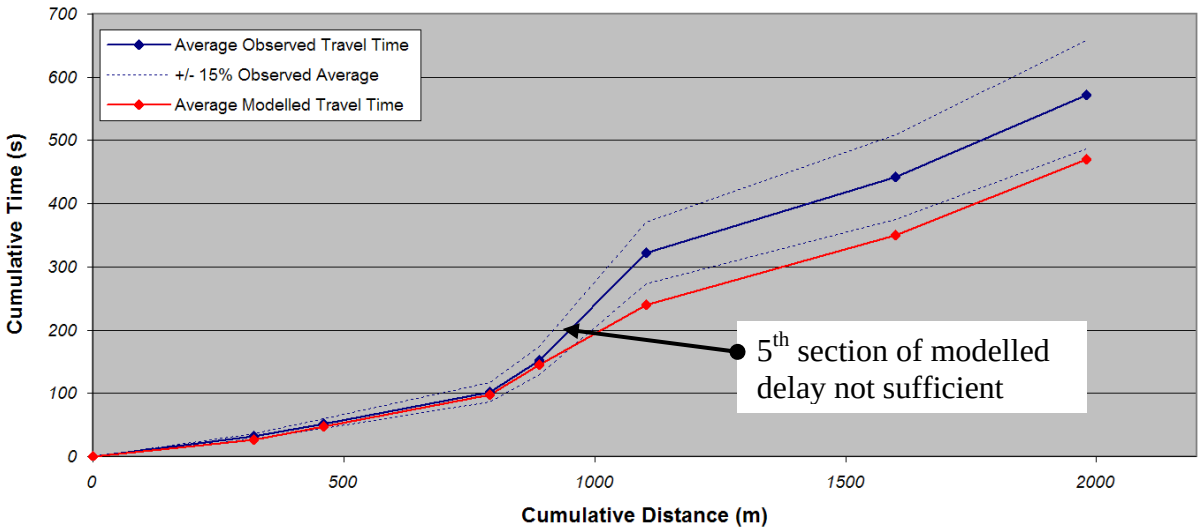


Figure 11.5 Travel time comparison

The cumulative graphing of journey times by section provides a good assessment of average travel times for each route. However it is also important to ensure that the model is accurately representing the variability of journey times noted during the surveys. In order to provide a comparison of observed and modelled variability it is common to provide a graph plotting the average travel time and a 95 per cent confidence interval for both the observed and modelled datasets. This demonstrates the level of variability within each dataset and provides a clear indication of how closely the model is reflecting the observed values.

An example plot showing this data for a number of journey time routes is shown below. It should be noted that the purpose of the plot is not to achieve a numerical target for model calibration/validation. Rather it is intended to provide RMS with a visual indication of how accurately the model is performing in regard to observed and modelled journey time variability.

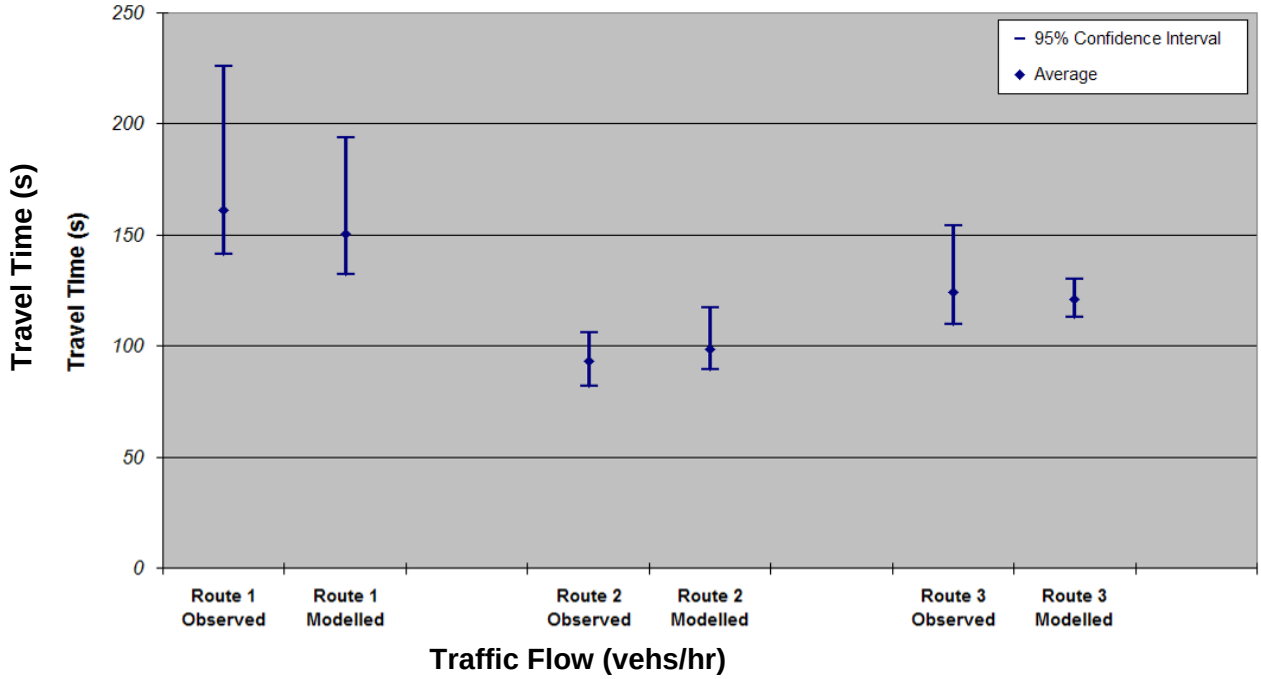


Figure 11.6 Travel time comparison in bands

Table 11. 5 Microsimulation travel time target validation criteria

Topic	Criteria
Journey time average	Average modelled journey time to be within 15 per cent or one minute (whichever is greater) of average observed journey time for full length of route. Each route should be cumulatively graphed by section as shown above
Section time average	Average modelled journey time to be within 15 per cent of average observed journey time for individual sections
Journey time variability	Average and 95 per cent confidence intervals to be plotted for observed and modelled travel times for each journey time route. Comparison to be to modeller and RMS satisfaction.

In specific cases RMS may request that a more detailed assessment be made for isolated sections of journey time routes that are of critical significance to the study area. This assessment requires an analysis of the relationship between travel time and traffic volume for both the observed and modelled datasets for that section.

The modeller should plot a scatter graph where data points correspond to section traffic volume on the x-axis and section travel time on the y-axis. This is done for all observations of that section travel time regardless of time period or traffic conditions. Likewise, modelled travel times from all time periods can be plotted against the modelled hourly flow volume. The graph can include datasets collected at any time of day and under any flow conditions since the greater the variety of data that can be incorporated, the greater value the graph will have.

The plot shows the relationship between traffic flow rate and travel time over a wide range of conditions in both observed and modelled situations. This provides an indication of how closely the model is replicating the operation of the links and intersections at different levels of congestion (rather than simply the average peak hour observation). The graph below shows an example of the scatter plot.

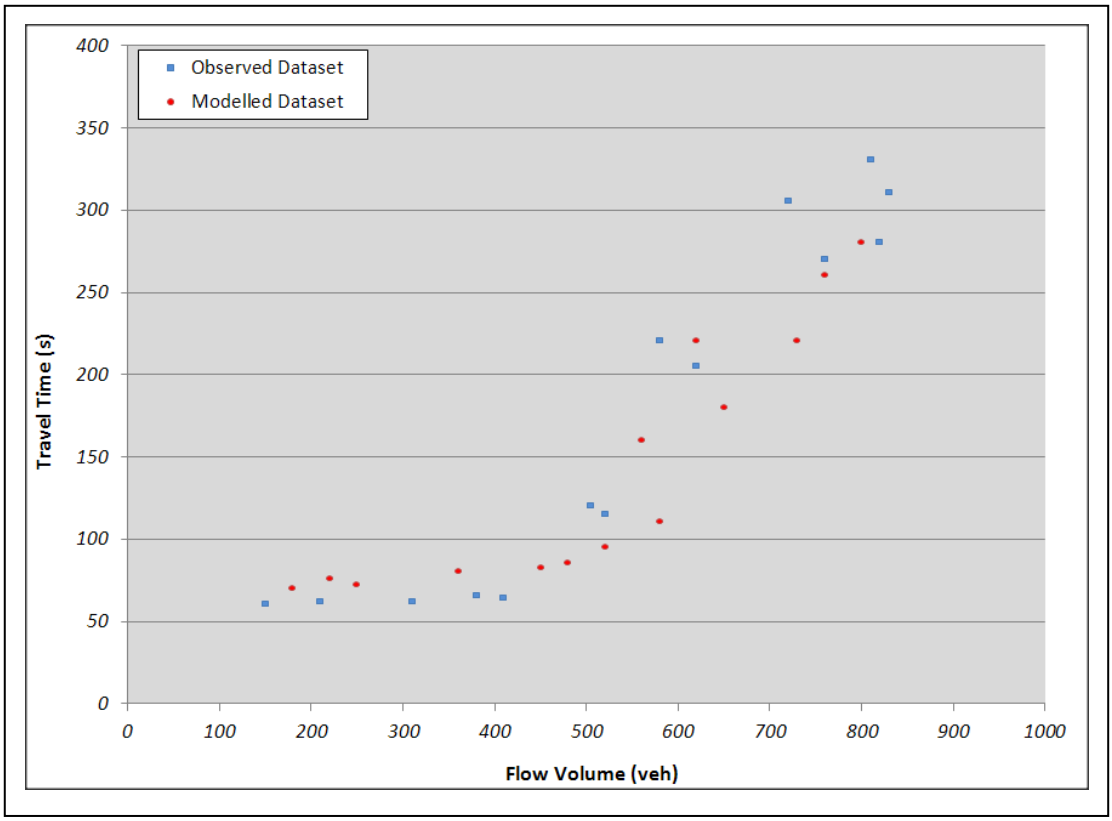


Figure 11.7 Travel time comparison scatter plot

Table 11.6 Microsimulation time volume scatter plot target validation criteria

Topic	Suggested criteria
Flow/Time relationship	Observed and modelled datasets for flow and travel time to be plotted for specific sections of journey time route as requested by RMS

Queue lengths

Queue length data can be collected on site and compared with modelled outputs to provide an indication of how accurately the model is replicating congestion on approaches to key intersections in the model.

Counting or calculating queue lengths is a subjective exercise since queued vehicles will often still be moving slowly and it will not always be clear what criteria should be used to constitute a queue. Also, since data is likely to be collected by a number of surveyors it is unlikely that consistent and accurate reporting will be possible across the study area. Additionally, software packages will each calculate queue lengths using different criteria and methodologies which add a further level of complexity.

For this reason RMS does not have mandatory statistical guideline criteria for queue length comparison. If no measured data is available RMS will consider that queue lengths are appropriately validated when the modeller can demonstrate to an appropriate Network Operations staff member that modelled queue lengths are representative this can be achieved by presentation of calibrated models to RMS staff for approval.

If queue length data is to be collected for calibration/validation purposes it is useful to develop an understanding of the key approaches within the study area that may have a significant impact upon delays within either the base model or any future year model. Ideally a survey should then be undertaken on each approach providing the maximum queue length for each signal cycle (or within a specified time period for an unsignalised intersection i.e. every five minutes, 10 minutes, 15 minutes etc).

This type of survey will allow for the calculation of a 95th percentile queue length that can then be directly compared with model outputs. This is a useful statistic since it can partially remove the influence of any unusual outlying results in the dataset. However it should be noted that some software packages may not be able to provide data that allows the calculation of this statistic and in this case a comparison of the model outputs that are available will suffice.

Table 11.7 Microsimulation queue length target validation criteria

Topic	Suggested criteria
Queue length	Modelled and observed queue lengths to be compared at key locations within the study area (95th percentile to be used if possible). Comparison to be to both the modeller and RMS satisfaction.

THE HCM 2010 provides some guidance on the measurement of queues for the purposes of model validation (see section 5.3.4).

11.5.2	Table 11.1 Link and turn target calibration/validation criteria (**network wide**) Table 11.2 Link and turn target calibration/validation criteria (**core area**) Table 11.3 Microsimulation signal time target validation criteria Table 11.4 Microsimulation stop line saturation flow target validation criteria Table 11. 5 Microsimulation travel time target validation criteria Table 11.6 Microsimulation time volume scatter plot target validation criteria Table 11.7 Microsimulation queue length target validation criteria

11.6 Sensitivity analysis

Sensitivity analysis can be considered for either base or future option models if there is some uncertainty around the input model parameters or model assumptions. It should not be used as a replacement for data collection but more as a targeted assessment of how variations in the input parameters vary the model results. Typically these uncertainties include:

- Future demands.
- Network improvements outside the model study area.
- Any input parameters the modeller has some uncertainty about.

11.7 Model stability

11.7.1 Overview

Microsimulation packages dynamically model traffic interaction and driver behaviour for the duration of the modelled time period in a stochastic way much like real world traffic behaviour. Small changes on a network can therefore have significant cumulative impacts upon congestion and delays over the course of the simulation. For this reason microsimulation models tend to show more instability than more traditional forms of modelling as they utilise ranges and distributions (of input, control and behaviour) parameters rather than single value averages.

If a model is considered unstable then it cannot be reliably used to forecast future scenarios. Demonstrating that the model is both stable and developed to an appropriate degree of accuracy is therefore of high importance for option assessment.

11.7.2 Time steps

As the microsimulation models rely on algorithms to incrementally determine the state and positions of vehicles on the network the set intervals that these incremental calculations are called time steps. Increasing the number of time steps in each simulation second will improve the accuracy of the model (subject to theoretical and software limitations, ie many car following models are not considered valid beyond five time steps second time step resolution which reflects human reaction time) but will also increase the run-time. Since some complex models will have extremely long run-times a compromise between accuracy and simulation duration may have to be achieved.

RMS therefore recommends that the default time-step values be used for each software package, but these can be increased within the limits recommended by software developers if time and resources allow. Since time step resolution affects model results all models have to be undertaken at the same time step resolution for entire simulation period.

11.7.3 Seed values

Microsimulation models use random number sequences to produce a small level of variability (stochasticity) within each simulation to reflect the range of behaviours that are exhibited in the real world. These range of behaviours capture the variability in release times of vehicles onto the network, the individual driving style allocated to a particular vehicle as well as the total demand loaded onto the network (typically 3 per cent variability in demand is used by the simulation software packages). It is therefore important to ensure that the model is run a sufficient number of times to capture the full extent of this variability. The running of a simulation model over a number of times also allows for an assessment to be made of the stability of the model.

Every software package allows the modeller to provide an initial “seed" value for each model run. The seed value affects the generation of the random numbers that influence the model operation and variability. Therefore each time the model is run with a different seed value, a slightly different set of outputs will be generated. It would generally be expected that these outputs would be very similar, but not identical, and it is an analysis of the variability between these results that indicates the stability of the model.

The level of variability within models will be considerably different for networks of varying size and complexity, however, for the majority of cases a total of five seed values should be run in the order detailed in Table 11.8.

Table 11.8 Random seed values

Normal		Extended	
Seed Run no.	**Seed Value**	**Seed Run no.**	**Seed Value**
1	560	6	5321
2	28	7	137
3	7771	8	98812
4	86524	9	601027
5	2849	10*	559

*RMS can provide additional seed values if more than 10 runs are required.

It is not acceptable to change the order or omit numbers from this sequence without providing justification within the base model reporting. The reason for sequential seed numbers is to ensure model results can be replicated for individual seed values if required.

Although multiple seed runs are required to demonstrate model stability, the results presented for the calibration and validation exercises should be output from a single modelled seed run. The selection of the appropriate seed run for reporting purposes is calculated by assessing the vehicle hours travelled (VHT) for each of the simulated seed runs and identifying the median value from this dataset. All calibration and validation outputs should be drawn from this median seed run.

Congested networks, SCATSIM models or more generally when a comparison of base and option models is inconclusive then it may be necessary to extend the number of seed runs beyond five.

To assist in determining the appropriate number of runs required, RMS has undertaken a significant amount of research in this area. In partnership with ACCM, RMS has developed a methodology for calculating the required number of seed runs required to achieve a specified level of precision expressed as a confidence interval on a chosen summary output (for example, mean vehicle hours travelled) for any given model. This is described below in Section 11.8 “Statistical Toolkit for Model Confidence and Stability”.

11.7.3	Table 11.8 Random seed values

11.7.4 The importance of variability comparison

As RMS continues to expand its traffic detection and monitoring systems[8] to move towards network wide monitoring in real time, there is a corresponding increase in available data that can be used for model calibration, validation and results interpretation. In order to fully utilise these data and to be able to undertake robust analysis of network variability, a comparison of distributions (rather than averages) is possible. Analysing ranges of values for model input and output parameters leads to better insight about network performance especially when observed real word data is also available. These data and analysis of distributions enables statistically meaningful conclusions to be drawn about network performance improvements.

One of the issues that has arisen in the past when comparing microsimulation results against observed average values is that traffic flow, road user behaviour and network conditions can be highly variable on a day-day basis. This inherent system variability can affect model results interpretation as the magnitude of this variability can be much greater than the expected difference of the option performance under test. This is more likely true for an adaptive traffic system where performance

[8] These systems include SCATS, PTIPS, Etag reader, Bluetooth and detector loops on motorways

improvements could be expected to be “on the margin” especially if only portions of the network are under consideration.

To assist with the proper identification of differences between two alternative model options that show only slight differences then their network performance should be compared using the statistical toolkit described in section 11.8.

11.7.4	When the comparison of results between base and/or option models shows only slight differences then the statistical toolkit should be applied to determine actual model results.

11.8 Statistical toolkit for model confidence and stability[9]

11.8.1 Introduction

The model confidence toolkit for RMS Traffic Modelling Guidelines is designed as a user-friendly guide to assess model stability and to demonstrate to decision-makers the level of confidence in the model results obtained. This version of the toolkit is primarily intended to provide statistical rigour to the comparison of model results (once they are calibrated and validated) to assist the modeller in interpreting whether the results obtained are representative.

The statistical toolkit can be used for:

- Comparing means between two models to determine if they are significantly different (this is useful for comparing marginal improvements in scheme options over the base situation).
- Comparing difference in variability between two scenarios.
- Test for bias due to incomplete and unreleased vehicles.
- Actual difference in results between two models exhibiting similar network performance statistics (i.e. when results of option testing are inconclusive).
- Number of runs required for a given level of confidence.
- Level of confidence for given number of runs.
- Understand salient features of model results.
- Identify outliers in the results for further examination or exclusion.

(The concepts introduced as part of the statistical toolkit can also be used to assist modellers with complex model calibration and validation but this is outside the scope of these guidelines and ACCM can be contacted directly for project specific advice).

The toolkit is divided into two parts:

- Part 1: Planning the statistical analysis.
- Part 2: Model output analysis.

11.8.1	The statistical toolkit assumes that model calibration and validation has already been implemented successfully and models are not prone to unrealistic lock-ups. The modeller is advised to print the Easy Reference Toolkit Checklist and populate it while progressing through the Statistical Toolkit document. Table 11.9 provides overview of the components of the statistical toolkit.

As all simulation is really a “computer-based statistical sampling experiment" then if the results of a simulation are to have any meaning, appropriate statistical techniques must be used to design and analyse the “experiments”.[10]

Table 11.9 provides an overview of the components in the statistical toolkit.

[9] The Toolkit has been developed by Australian Centre for Commercial Mathematics, UNSW (ACCM). It is a by-product of the comprehensive 3-stage report entitled ‘Development of a statistical framework for analysing traffic micro-simulations’ prepared for RMS by the ACCM & MASCOS.

[10] Extracted from “Simulation Modelling & Analysis”, 4th ed., A M Law, 2007

Table 11.9 Components of the Statistical Toolkit

Part 1: Planning the statistical analysis

Before running 20+ simulation runs

Task	Task Name	Description
1.1.1	Choose summary measure for network performance	VHT is a useful measure as it includes total network performance and effects of delay
1.1.2	Generate descriptive statistics	Generate: mean, median, mode, std dev, 95 percentile, range, interquartile range, min, max sample size, Confidence Interval (CI)
1.1.3	Choose precision and confidence levels required	Precision level required (per cent of summary measure; or Abs. value of summary measure)
1.2	Confirm Number of Runs Required	Choose initial no. of runs, n_i (20+)

Part 2: Model output analysis

Describe, analyse and compare outputs

Task	Task Name	Description
2.1	Describe outputs	Describe patterns and salient features: Check Independence between results, Scatter Plots, Screen for Outliers, Assess Model Variability, Check Descriptive Statistics
2.2.1	Complete required no. of runs	Based on Task 1C (and results from initial no of runs undertaken as part of that task) calculate CI half-width and sample size (no. of runs) required
2.2.2	Calculate no. of runs for previously chosen confidence level	Calculate n_1 for precision defined in task 1.1.3
2.3	Assess model stability	Use Boxplots to Identify Outliers due to model error or sensitivity to congestion
2.4	Incomplete & unreleased vehicles – test for bias	If excluded from VHT calculations the effects of this traffic is considered with an “add back” of the summary measure
2.5	Comparing scenarios	Is there a significant difference between scenarios? How large is this difference? Apply “Unpaired Two-sample t-test”
2.5.2	Comparing variability between scenarios	F-test (consider specialist statistical assistance)

11.8.2 Part 1: Before running the model

This section involves planning the statistical analyses. Please enter results into the Checklist.

Task 1.1 Simulation models and population parameters

Statistical analysis recognises that *sample statistics* are distinguished from *true population parameters* and that there are risks in inferring samples are representative. For example, a certain quantity will have a *true population mean*. From a sample of the population we can obtain a *sample mean* which is an estimate of the true population mean. In stochastic simulation modelling, we can perform multiple runs of a model to obtain sample estimates of the true population parameters.

Task 1.1.1 Choose the summary measure

This is the summary measure from the model to be analysed and reported and is a proxy for overall model network performance. It assumes that modellers have first calibrated and validated their models to avoid unrealistic lock-ups. An example is VHT (Vehicle hours travelled) as it is a single figure summary of the total (global) network performance and includes, by definition, the effect of delays. VHT is used as an example throughout this guide.

Task 1.1.2 Choose statistics for the summary measure

These are sample statistics of the summary measure that summarise:

- The model's total set of runs.
- How the summary measure is distributed.

It is recommended to start with the standard measures called "descriptive statistics" (see Glossary for definitions), which may include:

1. Mean (x)
2. Median (med)
3. Mode
4. Standard deviation (s)
5. 95 per cent percentile
6. Range
7. Interquartile range
8. Minimum
9. Maximum
10. Sample size (n)
11. Confidence Intervals (CIs)

Task 1.1.3 Choose levels of precision and confidence for the summary measure

Precision level – this involves choosing precision measures and has two options:

- As a percentage of the statistics (eg VHT to be within +/-1 per cent, 2 per cent or 5 per cent of the mean – typically used).
- As an absolute value of VHT (hours).

Confidence level: It is also necessary to set an acceptable confidence level (for a significance level, α), as a percentage for future confidence intervals (CI), usually chosen as one of 90 per cent, 95 per cent or 99 per cent. Examples throughout the Toolkit use a 95 per cent CI.

Task 1.2 Choose Initial Number of Runs

At step 2.2 it is necessary to obtain a sample mean (x) and sample standard deviation (s) in order to calculate the number of repetitions required for the precision level set at 1.1.3. This will achieve stable and more robust results. An initial number of runs are required to obtain these estimates.

It is recommended to start initially with a minimum of 20, but preferably 25 or more. Statistical theory proves that the estimates x (mean) and s (standard deviation) are more robust for larger number of runs (we will have greater confidence in the results' stability if a larger, >20, number of runs is used, regardless of how the output is distributed).

11.8.2	It is important to remember that precision and confidence are dependent upon model inputs and their variability. The toolkit uses the model inputs as supplied and the modeller should try to remove unrealistic outliers. Hence from this initial simulation set of a minimum of 20 runs, obtain the sample statistics x and s of VHT required and enter into the checklist. The initial number of runs chosen is denoted as ni.

11.8.3 Part 2: Model Output Analysis

This section explains how to describe, analyse and compare model outputs.

Task 2.1 Describe outputs

Describing outputs is essentially about identifying patterns in them in order to detect salient features. "Salient" refers to those features that help understand what effects the confidence in outputs and what has most effect on the general behaviour of the simulation.

Statistical graphing tools are very useful for identifying patterns, and include: scatter plots, box plots, and histograms. Descriptive statistics (as mentioned earlier) such as mean, median, range and standard deviation are also needed to identify structures in the outputs.

The Toolkit suggests using graphical tools to describe the outputs. This is in preparation for analysing model outputs as explained in Sections 2.3–2.5. Any statistical or spreadsheet package can be used. Once they are created they can be marked off on the Checklist provided.

As an example, if VHT is the summary measure chosen at 1.1.1 then create:

- A scatter plot of VHT by run.
- A box plot of VHT.
- A (frequency) histogram of VHT.
- Descriptive statistics as chosen at 1.1.2.

Describing the outputs means understanding their "salient features"; and also understanding extreme points (called "outliers"). During this process, the toolkit suggests to perform these checks:

- Task 2.1.1 – Check for independence between results.
- Task 2.1.2 – Screen for extreme points.
- Task 2.1.3 – Assess model variability.
- Task 2.1.4 – Check sensibility of results.

Task 2.1.1 Check for independence between results

Each model must satisfy the necessary assumption of statistical independence across simulation runs in order to apply statistical tests. The following criteria ensure this occurs:

- Use a different random number seed for each simulation run so that each run is independent of the next one. This is the most critical assumption to be checked by practitioners.
- Each run uses the same initial conditions.
- The simulation starts empty at the start of each run.
- Each run has the same duration.
- Each simulation run ends at some pre-determined end time.
- Simulation runs employ warm-up periods as described in section 5.3.2.

Scatter plots are useful to check for independence across simulations and should display all of the following independence validations (otherwise the model should be checked for error before the analysis stage):

- No evidence of correlation.
- Random variation only between simulations.
- No sudden or large shifts in value due to a special or non-random event (as implied by random variation).

Figure 11.8 displays a scatter plot of independent runs as they are vary randomly and show no correlation.

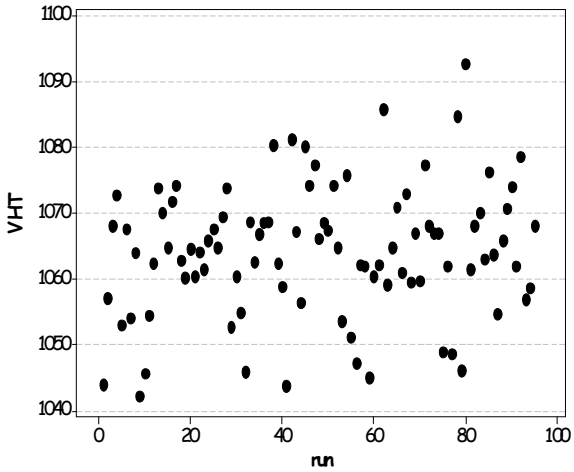


Figure 11.8 Scatter plot of a model with 100 runs showing random variation and no correlation for VHT

Figure 11.9 strongly suggests an error in the model.

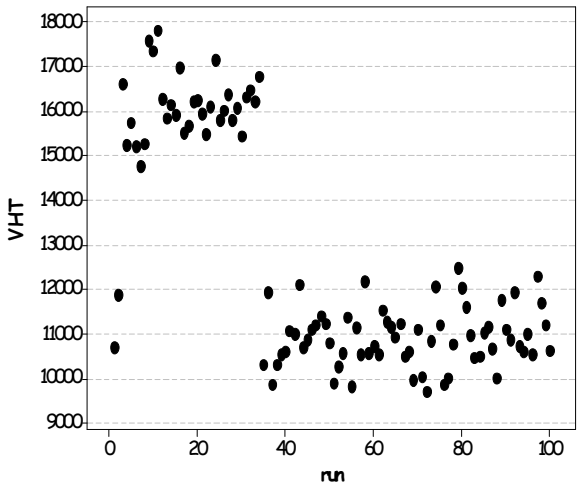


Figure 11.9 Scatter plot of a model with 100 runs showing non-Random variation and clustering of VHT

Task 2.1.2 Screen for extreme points or "outliers"

In analysing simulation outputs we need to estimate the mean of a summary measure (eg VHT) and calculate the confidence interval of that estimate. However the mean may be heavily influenced by extreme values, so it may be necessary to exclude extreme points from the mean and confidence interval calculations. It is not advisable to blindly remove observations, but consider whether they represent true variation one might expect in a network.

Box plots are a useful graphical tool to screen for extreme points to be excluded. A box plot displays the middle 50 per cent of these data as a box and the median as a vertical line inside the shaded box. The left and right endpoints of the box are known as the 1st and 3rd quartiles, and are the values for which 25 per cent and 75 per cent of these data are less than, respectively. The width of the box is known as the interquartile range. “Whiskers” extend either side of the box to maximum of 1.5 times the interquartile range, or to the maximum and minimum values.

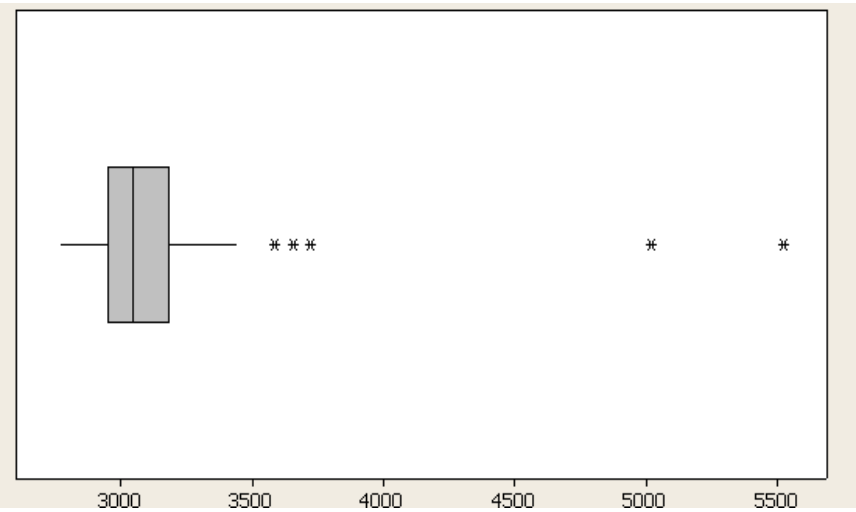


Figure 11.10 Box plot of VHT showing median, inter-quartile range and extreme points (outliers)

It is important to investigate possible extreme points and not simply ignore them. Extreme points may actually be representative of the outputs. However, not filtering for extreme points can lead to an analysis that is unrepresentative of the majority of the outputs. Figure 11.10 shows an example box plot with some potential extreme points for exclusion. In this case it may be reasonable to exclude the two points with values greater than 5000, but retain the three points between 3500 and 4000. Outlier classification and elimination as addressed further in the following sections.

Task 2.1.3 Assess model variability

Histograms are useful for understanding the variability of a model. Important factors to consider when investigating histograms to get a feel of the outputs are: location, variation, shape and unusual features.

Location – The location of the histograms on the x-axis needs to be acknowledged. For example, two distributions may appear identical with the same range and standard deviation however they may have different mean values. A common example would be the distributions of male and female heights as illustrated in Figure 11.11.

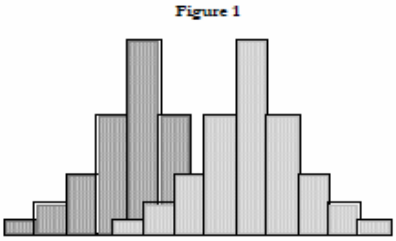


Figure 11.11 Male and Female Height Distributions

Variation – The best measure to consult for variation is the inter-quartile range since the range and standard deviation are both affected by the extreme points (outliers). It is critical to measure variation between simulation runs of say VHT or VKT, as variability directly affects the level of confidence in the

estimate of the Mean, Median or 95th percentile. Figure 11.12 illustrates two distributions of differing variability but with the same mean – their ranges are very different.

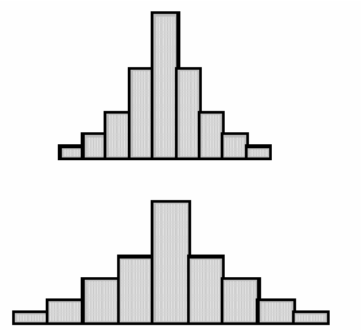


Figure 11.12 Two Distributions of Differing Variations

Shape – Data distributions are not always symmetric. Figure 11.13 displays “skewed” distributions where there is a greater weight on one side of the mean. The first is skewed to the right and the second is skewed to the left. It should be noted that for the symmetrical distributions seen so far, the mean and median values would have been the same. For skewed distributions the mean no longer lies in the centre of the outputs and so the median should be used as a measure of “centre”.

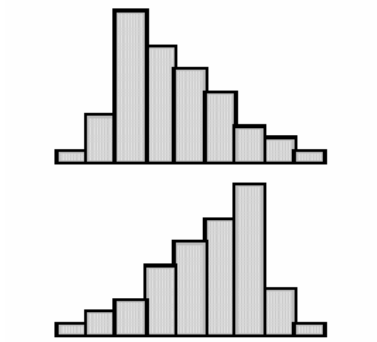


Figure 11.13 Skewed Distributions

The histogram of VHT in Figure 11.14 shows a right (or positively) skewed distribution. The network model was comprised of 100 runs in the morning peak period with 522 nodes, 31 signalized intersections, 1162 links and 89 zones. Positive skewness is caused by the fact that there is a lower bound on VHT (max possible speed) but no upper bound due to congestion

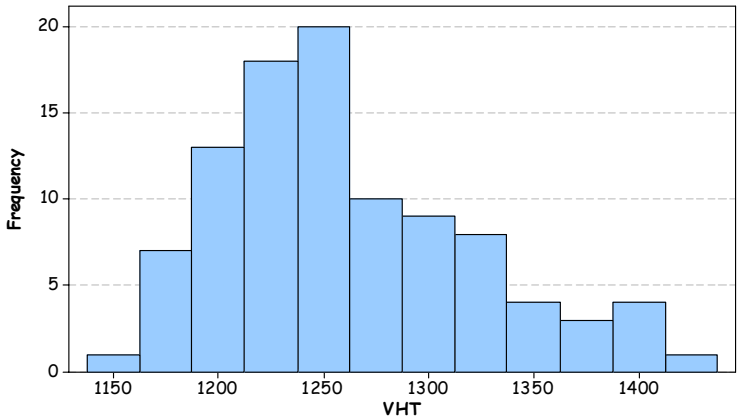


Figure 11.14 Model showing skewed distribution

Bimodal Histogram – When there are two peaks (or modes) it is called bimodal – as in Figure 11.15. Models with bimodal distributions need to be examined as they may indicate sampling from two

populations in the same model due to something causing a “bifurcation” or split into two parts of the outputs.

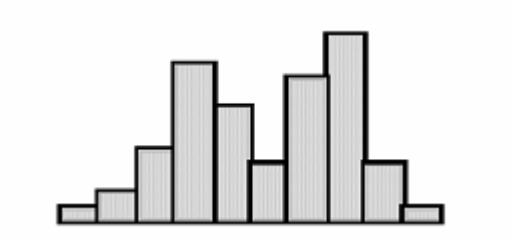


Figure 11.15 Bimodal distribution

Task 2.1.4 Check descriptive statistics

“Sensibility checks” of the descriptive statistics chosen previously need to be completed. This means ensuring the figures “make sense” in terms of reality. For example is a mean of 3118 hrs of VHT possible for the network being analysed? Table 11.10 presents some descriptive statistics output in Excel for a mode of 100 runs of network in the a.m. peak with 522 nodes, 31 signalized intersections, 1162 links and 89 zones (see Appendix D for how to obtain this output in one step).

Table 11.10 Descriptive statistics example

VHT	
Mean	4349
Standard deviation	502
Range	2264
Minimum	3671
Maximum	5935
Count (= no. of runs)	100
95 per cent Confidence interval on mean	(4249,4448)

Descriptive statistics and graphs can easily be obtained in one step using statistical software packages. Figure 11.16 illustrates Minitab’s version of this for raw VHT of a Model, whose results are shown in Table 11.10 above. It contains a histogram with an overlaid “normal curve”, a box plot of 95 per cent Confidence intervals for the mean and median of VHT and other useful descriptive statistics. Notice the extreme or “outlier” runs from the box plot shown as asterisks.

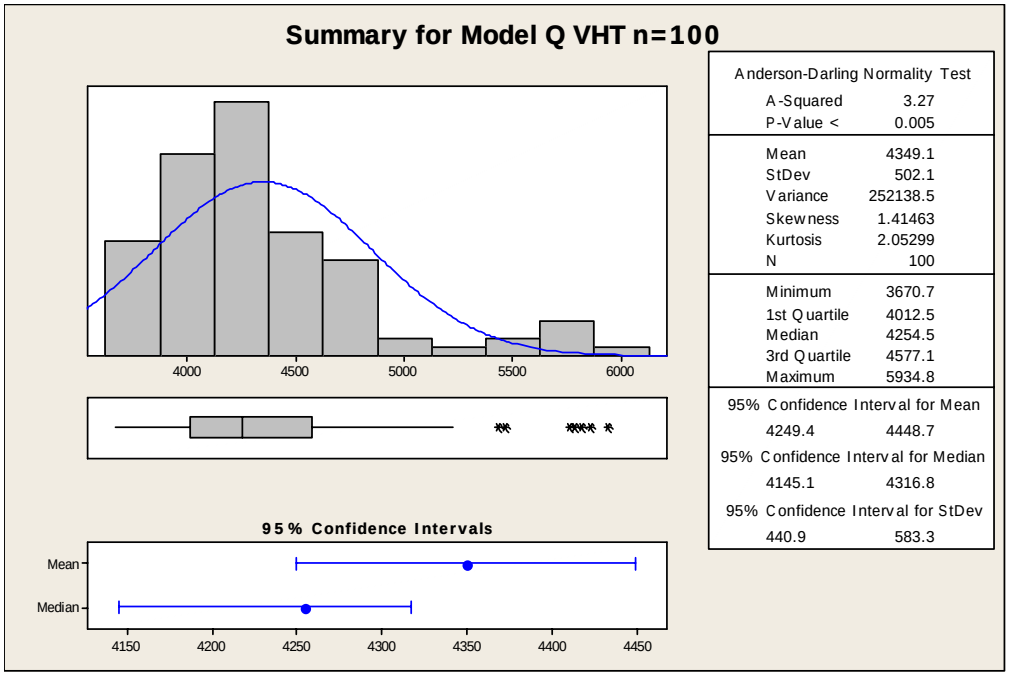


Figure 11.16 Descriptive statistics for raw VHT results

Figure 11.17 is this same model but with the outlier runs excluded. Removing the outliers eliminated most of the right skewness and decreased the standard deviation from 502.1hours to 338.8hours (i.e. reducing variability of the model results). The width of the confidence interval (CI) of the mean VHT has also been reduced from 200 hours to 140 hrs (see actual figures in tables for this).

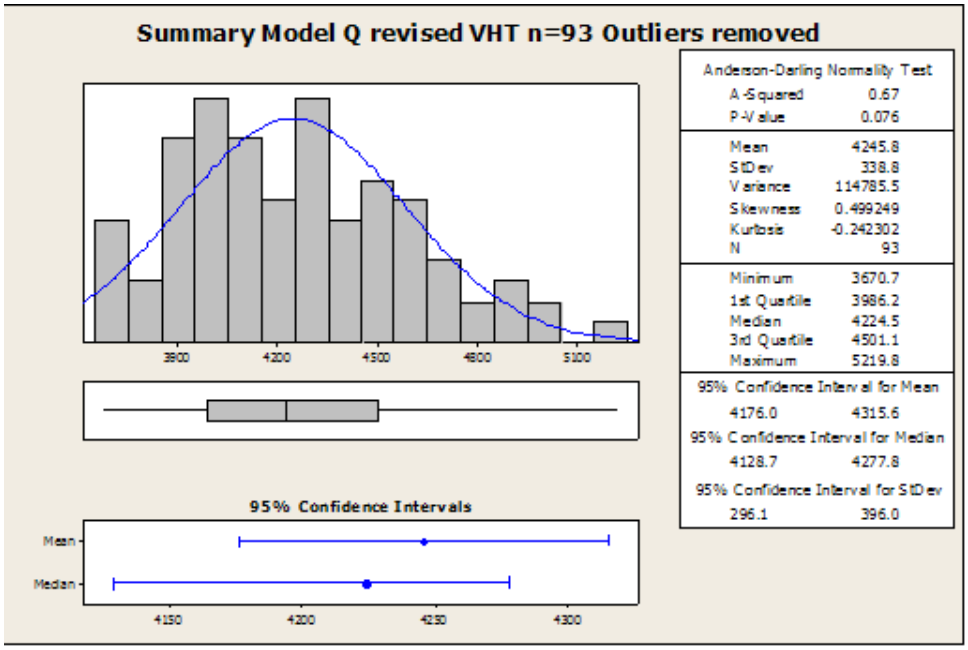


Figure 11.17 Description statistics for raw VHT results (extreme points removed)

Task 2.2 Complete required number of runs

Earlier levels of precision and confidence were chosen and the initial number of runs, ni, were completed. The precision level determines the width of the confidence interval (CI). The more precise the estimate, the narrower the CI. We increase the precision of our estimate by increasing the number of simulation runs, ie by increasing the sample size (n).

Figure 11.18 illustrates this graphically. It is a plot of CIs for mean VHT of a microsimulation model at four sample sizes. As can be seen, the larger the sample size, the more “precise” or narrower is the CI.

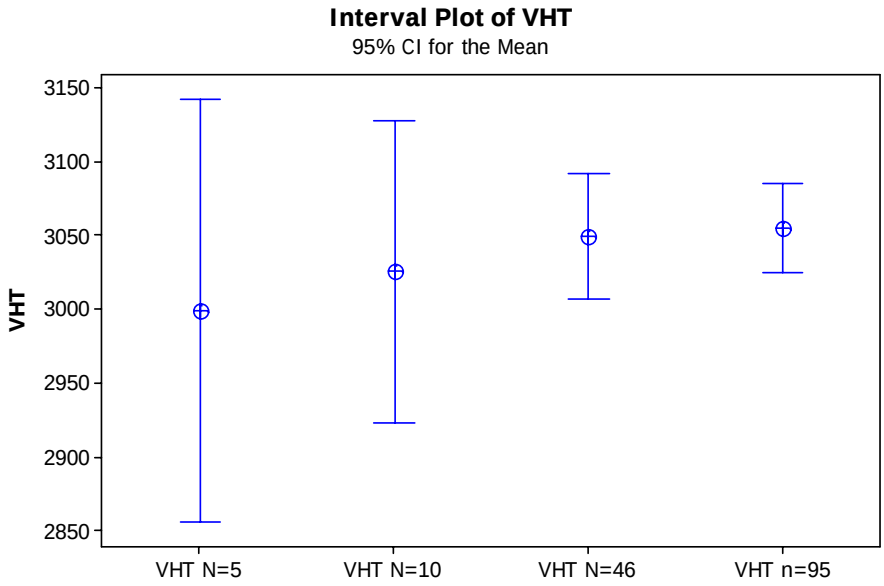


Figure 11.18 Confidence Intervals for Mean VHT of a Model at Four Sample Sizes

Figure 11.19 shows how confidence interval half-width decreases – or precision increases as the sample size increases (scaled for sample standard deviation of 1). This shows that there is a large improvement in precision going from five to 20 runs, with diminishing returns in the improvement of precision after 25 runs.

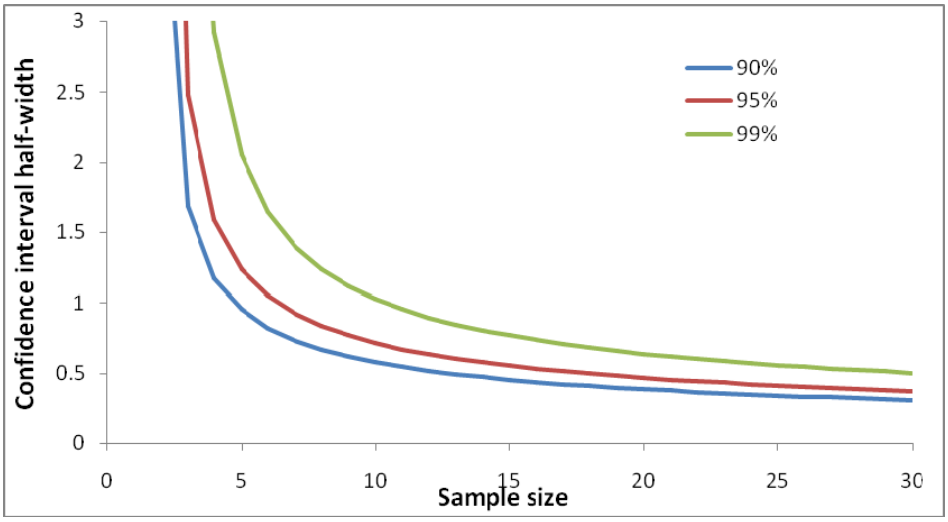


Figure 11.19 Relationship between confidence interval and sample size

This means we have to perform the simulation with the number of runs required to obtain the confidence level and precision level chosen earlier.

Task 2.2.1 Calculate number of runs for previously chosen confidence level

To obtain the number of runs consult the toolKit checklist to obtain:

- The confidence level.
- The initial number of runs, ni.
- The sample standard deviation, s.

When commencing a simulation, the iterative procedure is in steps 1–9 below:

1. Set Initial number of runs, ni =10 or 15 and run ni simulations.
2. Calculate s.
3. Set precision as a percentage of the mean.
4. Set confidence level at 95 per cent.

5. Calculate n1 runs required to meet precision based on s in step 2.
6. Compare n1 to ni and run additional n1-ni simulations.
7. Recalculate s based on additional simulations and calculate n* (the required runs to meet precision based on the new s).
8. Go to Task 2.2.2 compare n* to n1 and run n*- n1 additional simulations.
9. Go to Task 2.2.3 calculate the CI for the Mean.

Steps 1 to 4 above should already be completed. The number of simulation runs n1 required for the chosen confidence level is calculated by:

$$n_1 = (t \times s/w)^2$$

Here t is the "t statistic" obtained for the given confidence level and initial number of runs ni. This value is easily obtained from Excel using the "TINV" function. Recall that s is the already calculated sample standard deviation. Finally, w is the desired confidence interval half-width. If the precision level was specified as an "absolute" value then w is simply equal to the precision. If the precision was specified as a "percentage" then w is:

w = Precision (per cent) x Sample mean (x).

Excel formulas for the automatic calculation of n_1 are included in the toolKit checklist spreadsheet. An example calculation is also included.

It should be noted that n_1 should always be rounded up to the nearest integer. Remember to add value for n1 to the toolkit checklist. If n_1 is greater than ni then n_1-n_i additional runs should be performed.

Task 2.2.2 Calculate new n based on results of additional runs*

After the additional runs are performed, new values for x and s should be obtained (which are calculated using results of both the initial and additional runs). A new number of runs required n* is then calculated using the updated values of x and s, by the same formula that was used to calculate n_1.

Formulas for the automatic calculation of n* have been included in the toolKit checklist spreadsheet, as well as a numerical example.

Remember to add n* to the toolkit checklist. Again n* should be rounded up to the nearest integer. If n* is greater than n1 then n*-n_1 additional runs should be performed.

Task 2.2.3 Calculate the actual CI

After any further additional runs are performed, new values for x and s should again be obtained (which are calculated using results of the initial runs and both sets of additional runs). We now calculate the actual confidence interval. The upper and lower bounds of the confidence interval are:

$$\text{Upper CI} = x + t^*(s/\sqrt{n_1})$$

$$\text{Lower CI} = x - t^*(s/\sqrt{n_1})$$

Here t is the t statistic based on Student's t distribution and the required confidence level. An example Excel formula for automatic calculation of the confidence interval is included in the ToolKit checklist.

Remember to add the upper and lower CIs to the Toolkit checklist.

Task 2.2.4 Calculate current precision level based on results from initial no. of runs

To calculate the current precision level we need to determine what percentage of the mean the width of the confidence interval is:

Width = (upper CI – lower CI)/2

Precision = (width/mean) per cent

This calculation can be performed automatically in the ToolKit checklist. Remember to add this current precision level to the toolkit checklist.

Task 2.3 Assess model stability

Extreme points or "outliers" as a tool for model diagnostics

Earlier, extreme points were screened using box plots. The extreme points detected need to be classified appropriately since they can either truly represent the outputs or skew the outputs

unnecessarily thereby impacting the standard deviation and lead to a wider CI and result in a less precise estimate of the mean.

Examples of extreme points

Simulation running error (aborted run) – Figure 11.20 illustrates a low value extreme point for VHT for a model. The inter-quartile range shows that 50 per cent of the outputs are between 8506 hrs VHT and 9081 hrs VHT (the width of the grey box zone). Thus the extreme points at 5500 hrs VHT can be used as a diagnostic that strongly suggests simulation error for the run(s) that produced it – warranting further investigation of the runs themselves in order to check the model.

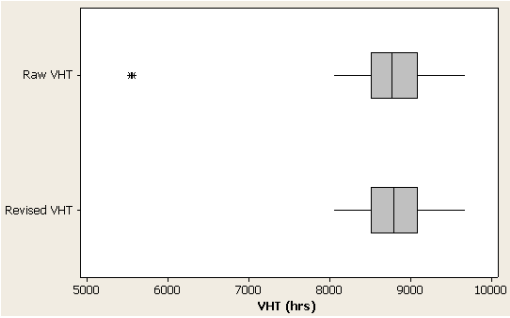


Figure 11.20 Box plot of model showing low extreme points

If the subsequent investigation of the suspect run(s) shows it was stopped before the end of the simulation period and hence not truly representative of results, the run(s) should be discarded and/or repeated.

Model Error – Figure 11.21 illustrates how the model's extremely high variability and unreasonable descriptive statistics proved to be a result of a fundamental error of the model itself.

The interquartile range displayed in Figure 11.21 is the best indicator of extreme variability. The VHT results for 40 runs of the model spans an unrealistic 7000 hrs to 12000 hrs.

The descriptive statistics in Figure 11.22 show large variability in these data, a very wide confidence interval on the mean estimate (9321 hrs to 10090 hrs) as well as bi-modality displayed in the histogram – all reflect unreasonable summary statistics and as such are not dependable results.

Further investigation revealed that the model had not been calibrated properly. Hence analysis was suspended until the calibration was corrected and the model could be re–run.

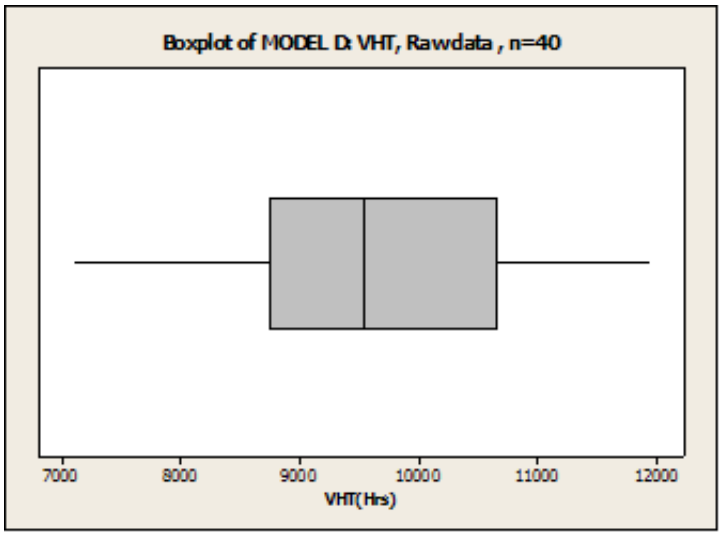


Figure 11.21 Boxplot of model showing very wide range on results

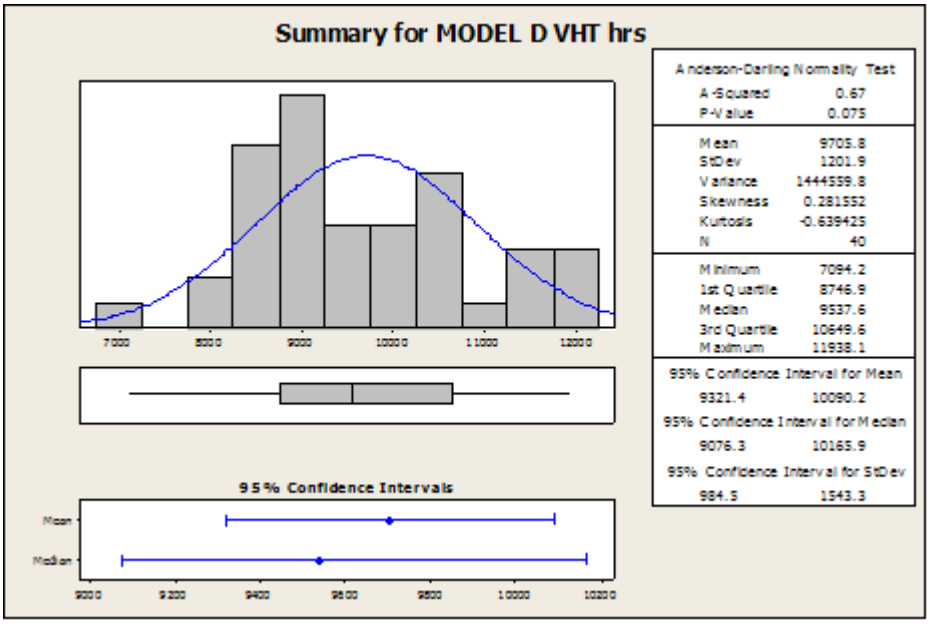


Figure 11.22 Boxplot of model showing possible bimodal results

<u>Extreme sensitivity due to congestion</u> – The simulated network may be very sensitive to small changes in input values – eg demand. This sensitivity is shown by a large and sudden increase in total vehicle delay in the network, resulting in an extremely high value of VHT that may be classified as an outlier. Figure 11.23 illustrates high extreme points for VHT for a model.

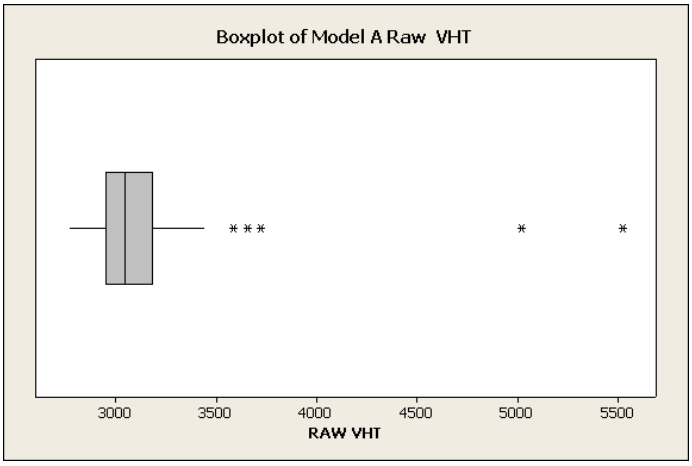


Figure 11.23 BoxPlot of model showing possible bimodal results

Steps for dealing with extreme points:

- Identify the run number of the extreme point run.
- Using the same random number seed for the run, repeat the simulation.
- Focus on the time and location of the outlier run event to diagnose the cause.
- Drill down into the time of the extreme point event and its location in the network.
- Consider whether effect is due to unreleased vehicles or incomplete trips (see following version for method to deal with this).

Task 2.4 Test for bias due to incomplete and unreleased vehicles

In this step, we quantify and correct the likely effect of the bias resulting from incomplete and unreleased vehicles. This refers to vehicles that were not loaded onto the network due to a queue build

up to the entry zones ("unreleased vehicles"), as well as vehicles that could not exit the network as the simulation terminated before they could exit ("incomplete trips").

Unreleased vehicles and the unfinished sections of incomplete trips are not counted automatically in the vehicle counts that contribute to VHT.

Not counting unreleased vehicles and the time they are queued will result in a misleading reduction in VHT. In order to adjust for this in the assessment of network congestion it is necessary to add back the hours that vehicles spent queuing to enter the network.

To solve the problem an appropriate "add back" of hours of VHT is added to the initial VHT (here known as delayed VHT or "dVHT"). As the time that vehicles spent queuing is only available in blocks for each time interval, the total time to be added to the initial VHT is given as:

dVHT = Mean of vehicles blocked per time interval (hrs) x quantity of time intervals

To be expressed as per cent of original VHT:

$$\text{Vehicle add back (per cent)} = \frac{dVHt \times 100}{\text{Original VHT}}$$

A major characteristic of the models with a very high ratio of delayed VHT or "addback" is the high demand level used in the model. In these cases, the modelled demand has clearly exceeded the effective modelled road capacity, leaving a large number of vehicles unable to enter the network, ie "unreleased".

It is recommended to use the total adjusted VHT (that includes the added delay figure dVHT) in all cases where there are any unreleased vehicles. Using the adjusted VHT will also change the sample standard deviation "s" of the VHT over all runs and hence change the confidence interval of the Mean estimate of VHT.

Task 2.5 Comparing Scenarios

When analysing the comparative performance of two traffic scenarios using simulation, we need to answer two questions:

- Is there a significant difference between the two scenarios?
- If so, how large is the difference?

The scenarios are compared by forming a CI for the difference in the means of the same measure from each scenario. The statistical technique used to achieve this is the Unpaired Two-sample t-test (other techniques such as the Modified Two-sample t confidence interval can also be applied but are not as appropriate to the traffic simulation context).

A hypothesis test is used for testing if the scenario difference is significant (or not), and answers question 1: "Is there a significant difference?"

The confidence interval is used to quantify the difference between scenarios and answer Question 2: How large is the difference?

Scale of the difference to be detected (or "power")

For most scenarios, the parameter estimate and the confidence interval for that parameter are of primary interest. The dedication of resources, especially computing resources, will therefore be based on the required precision for the outcome of interest.
However, sometimes the objective is determining whether two scenarios are significantly different; that is, whether the observed differences between two scenarios are likely to be genuine not just due to chance. The sample size calculation is then not a question of precision but statistical power.

The statistical background and motivation behind power analysis are based on the two kinds of errors that occur in hypothesis testing, as well as their probability of occurring which needs to be quantified.

Significance level, denoted by α is the probability of making a type I error. This is when the null hypothesis we are testing for says there is no difference in the mean VHT between two scenarios is actually true but our statistical test incorrectly rejected that hypothesis.

A type II error is when the alternative to the hypothesis we are testing is actually true but our statistical test accepted the null hypothesis. The conclusion would be that there was no difference in the mean VHT between two scenarios. The probability of making a Type II error is denoted as β.

The power of a test is defined as the probability of not making a Type II error:

- Power = probability of accepting the alternate hypothesis when it is in fact true (correctly rejecting the Null hypothesis) =1-β

When the objective is to determine whether the observed differences between two scenarios are likely to be genuine (significantly different) and not just due to chance, then the sample size calculation is not a question of precision but statistical power.

The ability to detect a statistically significant difference between two scenarios depends on the underlying mean difference between the groups, the standard deviations in the groups and the size of the sample n taken. The chance of detecting a difference for a test, when there actually is a difference of a given size, is also known as the power of the test and is usually set at 0.8 or 0.9 for a chosen scale of difference.

Power in this case then may be defined as the probability of correctly detecting a difference between two scenarios (rejecting the null hypothesis that states there is no difference). It is commonly chosen to be 80 per cent or 90 per cent

When wishing to detect a statistical significant difference between two scenarios, the ability to do so depends on the underlying mean difference between the groups we want to be able to detect, the standard deviations in the groups and the size of the sample taken n. The chance of detecting a difference for a test is also known as the power of the test and is usually set at 0.8 or 0.9.

There are some approximate formulae to calculate sample sizes for set mean difference, standard deviation and power but more accurate calculations involve iterative processes, available in statistical software.

Using statistical power in practice (example)

To compare VHT in two Models “A” and “Q” where the difference is in the demand only (Model A had the observed level of demand, whereas Model Q had this demand increased by 5 per cent) it is appropriate to use a paired t-test. The following plot (Figure 11.24 below) gives an indication of the power of such a test (the y axis) for a variety of different underlying mean differences (the x axis) and sample sizes (different lines).

Recall power is the probability of correctly detecting a significant difference between two scenarios when there really is a significant difference to detect.

The power curves below show that the larger the sample size, the smaller the difference we are able to detect between the two scenarios. For a positive difference, as we move from the right-hand-side to the left at, say, the power value of 0.8, the difference that can be detected gets smaller, as the sample size required gets bigger.

For example, with a sample of n=5 we can only detect a difference of 750 hrs in VHT between the two scenarios, at 80 per cent power. With a sample size n=20 we can detect a difference of 250 hrs in VHT. This is based on a standard deviation of 500 which is similar to the standard deviation for the comparison of the real VHT data from these models.

The dots on the plot indicate the power to detect a difference of 1000 in VHT, similar to the actual VHT difference observed between Models A and Q, a large difference which can be detected with high power for even small sample sizes.

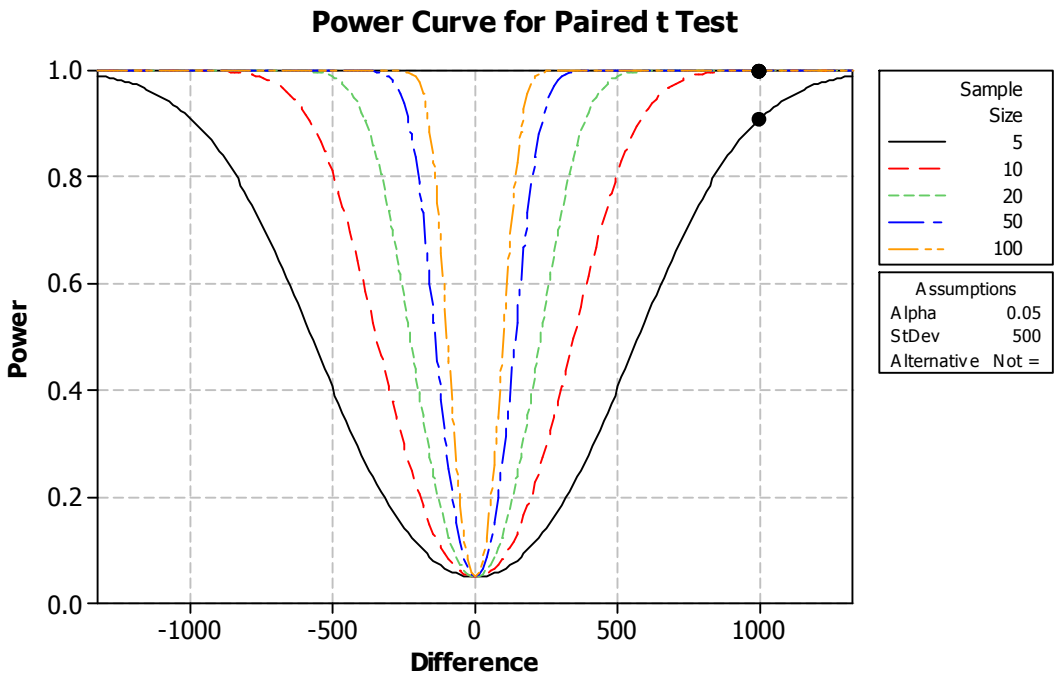


Figure 11.24 Power curves showing the power of such a test (the *y* axis) for a variety of different underlying mean differences (the *x* axis) and sample sizes (different coloured lines).

Guidelines for power and sample size calculations:

1. Determine the smallest effect size (the difference to be detected) that is of practical interest, noting that the smaller the effect size the greater number of observations will be required to detect that difference.
2. Choose the desired level of power to detect this difference (usually 80 or 90 per cent).
3. Choose the desired significance level (usually 5 per cent).
4. Determine the sample size required for this comparison.
5. Display power curves to assess the consequences of the choices in substeps 1–3.

Power analysis is standard in all statistical software packages. The formulas for automatic calculation of power are included in the toolkit checklist spreadsheet, with a numerical example.

Graphical example

The usefulness of statistical analysis when comparing two or more scenarios is shown in Figure 11.25 (Source: TEC, June 2006, Emily Seaman SIAS). A scenario comparison is shown that compares a base option with two alternatives (Options 1 and 2). Each option is simulated with 5, then 10 runs. By increasing runs from five to 10, the confidence intervals for the difference between Option 1 and 2 and the base option are narrowed.

The first graph is based on five runs and the second is based on 10 runs. When only five runs are used the confidence intervals for all three options overlap – so we cannot claim there is a statistically significant difference between the options. When 10 runs are used the confidence intervals do not overlap and are distinct from each other – so we can state there is a statistically significant difference between the options.

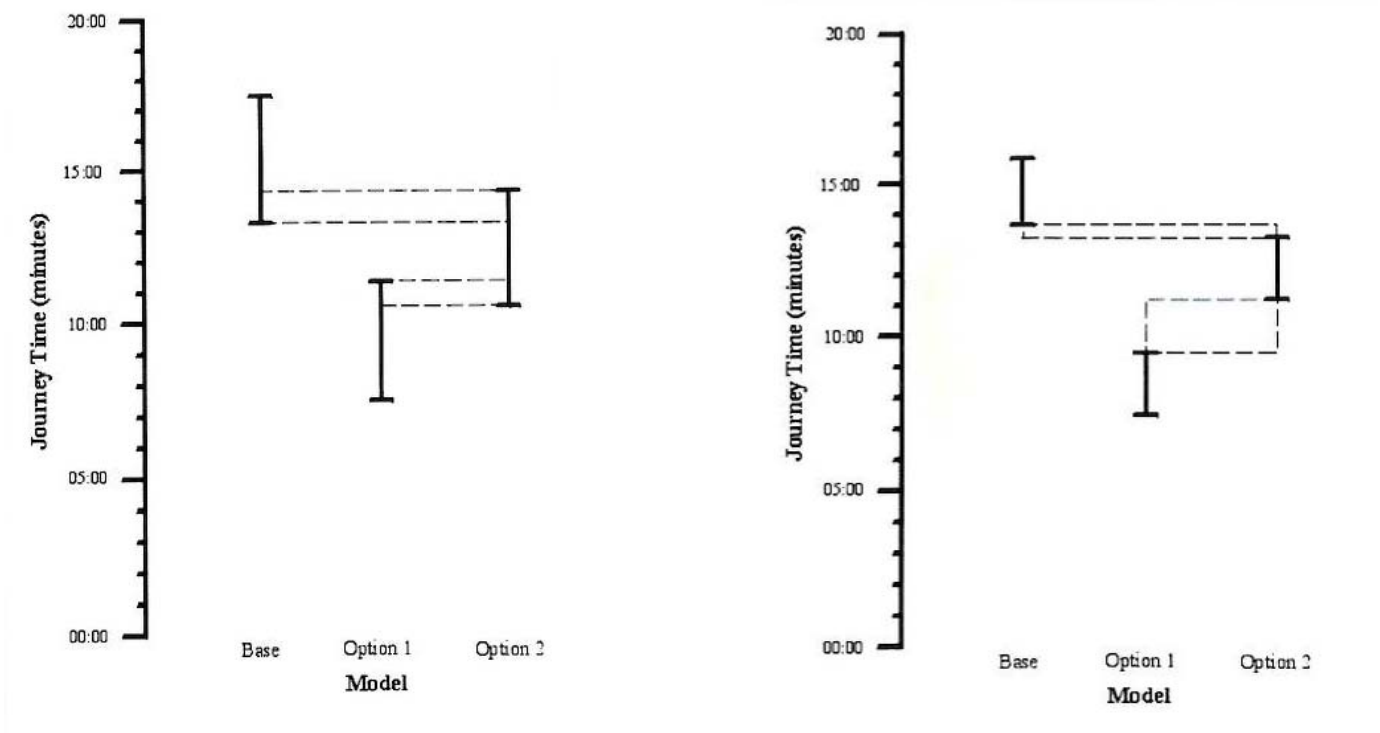


Figure 11.25 Comparing base and scenarios – effect of increased number of runs

Unpaired-two sample t-test Method

In comparing Scenarios 1 and 2 we measure the difference between them by calculating the difference in the means of a selected measure in both scenarios (eg mean VHT).

For two scenarios, we want to construct a confidence interval (CI) for the difference in mean responses. We assume that the different scenarios have the same sample size (n1 = n2 = n).

Note that in microsimulation, even with the use of a same random number seed for each scenario, the outputs of the simulation are not likely to be correlated as a micro-simulation is based on many random inputs. Hence it is a highly complex, unpredictable process that evolves over time.

The test “t” statistic to test whether the Means of Scenarios 1 and 2 are significantly different can be calculated as follows:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{s_{\overline{X}_1 - \overline{X}_2}}$$

Where,

$$s_{\overline{X}_1 - \overline{X}_2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}.$$

Where s2 is the unbiased estimator of the variance of the two samples (subscript 1 refers to model 1, subscript 2 refers to Model 2)

The two sample t-test is standard in all statistical software packages and Excel. The Excel formulas for automatic calculation of the confidence interval are included in the Toolkit checklist spreadsheet, with a numerical example.

The results of the two sample t-test will give a confidence interval for the difference in population means. For example, a 95 per cent confidence interval of two scenarios’ measure of VHT could be (80 hrs, 96 hrs) . As the confidence interval does not include zero, it suggests that there is a significant difference. Next is the hypothesis test result. The results will also give a “p” value. If the p value is less than 0.05, the commonly chosen significance level, it suggests there is evidence for a difference

between the two models. Conversely if the p value is greater than 0.05, it shows there is not a statistically significant difference between the two models.

In our example, the mean difference between two scenarios' measure of VHT could be 88 hours with a 95 per cent CI of (80 hrs, 96 hrs), so that the CI half-length is 8.0 hours.

Excel formulas for automatic calculation of the confidence interval are included in the Toolkit checklist spreadsheet, along with a numerical example.

Task 2.5.1 Comparing means between two models

Design considerations for a paired t-test require the two simulation models to be compared to:

- Only differ by the feature to be investigated.
- Be based on the same random seeds.

Note that your "null hypothesis" Ho, is that the mean difference is equal to 0 (i.e. that the scenarios are equal), and your "alternative hypothesis" H1, is that the mean difference is not equal to 0 (i.e. that they are not equal).

Example

To compare two scenarios based on the same network, which differ only by their demand level:

- Model 1 = observed demand VHT.
- Model 2 = 5 per cent increase of observed demand VHT of Model 1 (i.e. Model 1 + 5 per cent).

The mean differences (model 2–model 1) between the models are plotted in Figure 11.26 below.

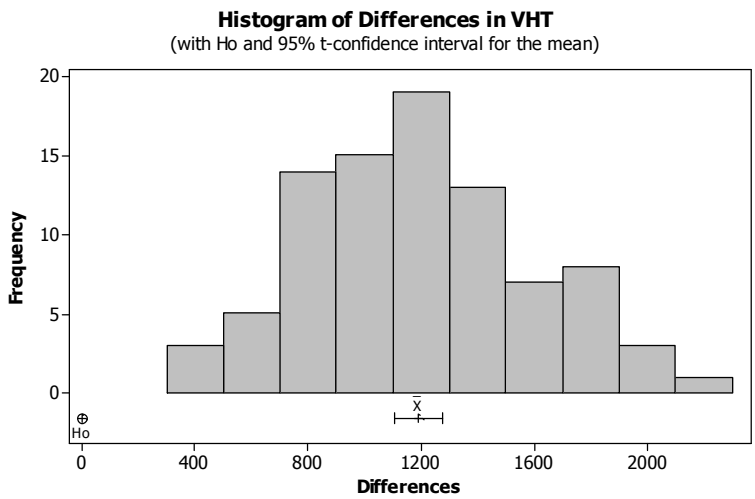


Figure 11.26 Histogram of differences between two models

As this demonstrates, the hypothesis of no difference in means between model 1 and 2 (H0) is highly inconsistent with the outputs. In every run there was an observed increase in VHT; the minimum increase was 373 while the maximum was 2244.

The estimated mean difference is 1190 hours and a 95 per cent confident interval for the sample mean difference is between 1107 hrs and 1273 hrs. This result indicates that vehicle hours travelled (VHT) is significantly longer for model 2 compared to model 1.

Statistical toolkit reporting

Having stepped through the process of undertaking the testing of model stability and demonstrating its statistical confidence it is worthwhile including diagnostics of stability and statistical confidence levels of results prepared for the summary statistic selected (eg VHT).

The descriptive statistics defined in section 11.8.2 should be reported together with graphical results that include:

- A scatter plot of VHT by run.
- A box plot of VHT, including Screen for Extreme Points Or “Outliers”.
- A (frequency) histogram of VHT.

The reporting of model stability should include the extreme points or “outliers” and these should be attributed to one of the following:

- Simulation running error (aborted run).
- Model Error.
- Extreme sensitivity due to Congestion.

The reporting should include the test for bias due to incomplete and unreleased vehicles together with how these were quantified and corrected.

Task 2.5.2 Comparing variability between two models

The paired t-test allows for comparison of the means between two scenarios. However to compare the difference in the spread or variability between two scenarios, the “F-test” is employed. Figure 11.27 illustrates how an increase in the demand for Model A by 5 per cent impacts its variability.

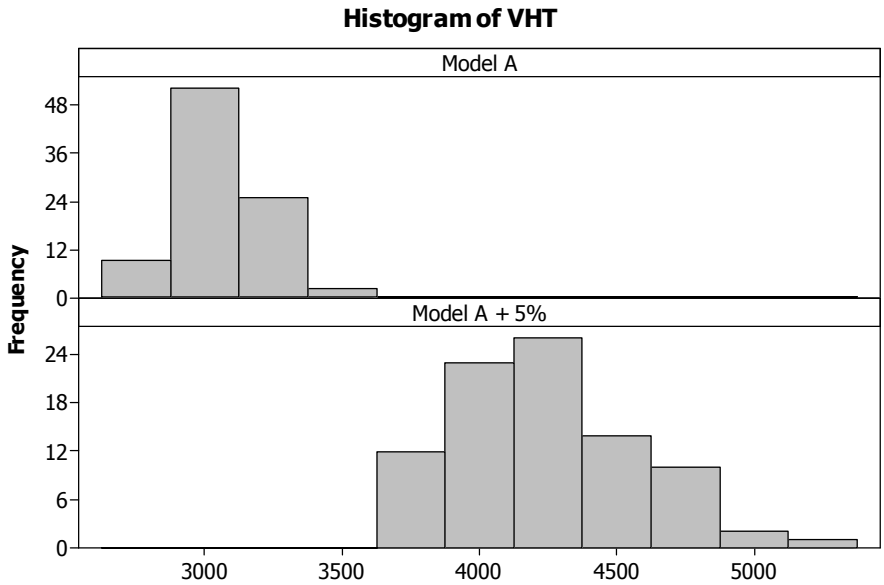


Figure 11.27 Histogram showing difference in variability

Further information on the F-test is out of scope for this toolkit. If this is necessary the user is advised to seek further statistical advice.

Reporting of model stability

There are a number of ways in which the stability of a model across a number of seed runs can be demonstrated. RMS suggests that at least one of the following techniques be graphically presented within the base model reporting:

- Number of vehicles in the network (for regular intervals over the modelled time period).
- Total travel time in network.
- Average vehicle speed in network.

Each software package generates model output data in a different format and therefore the modeller should assess which of the above measures of stability can be readily produced by the package.

Number of vehicles in the network

The presentation of the number of vehicles in the network for regular intervals throughout the simulation provides a good indication of model stability. Any incidents where congestion in one seed run is significantly different to congestion in the remaining runs are easily identified as a spike in the graph. In addition, should any of the seed runs become gridlocked then this will also be readily identified from the graph.

There are no set criteria for what is acceptable in terms of variability. Indeed it would be expected that some day-to-day variability be experienced in most models. However, by presenting the graph and a commentary explaining any significant variability the modeller will provide confidence that the simulation is stable and providing a consistent and accurate output.

The graph below shows an example where five seed runs have been simulated and the number of vehicles per minute has been plotted.

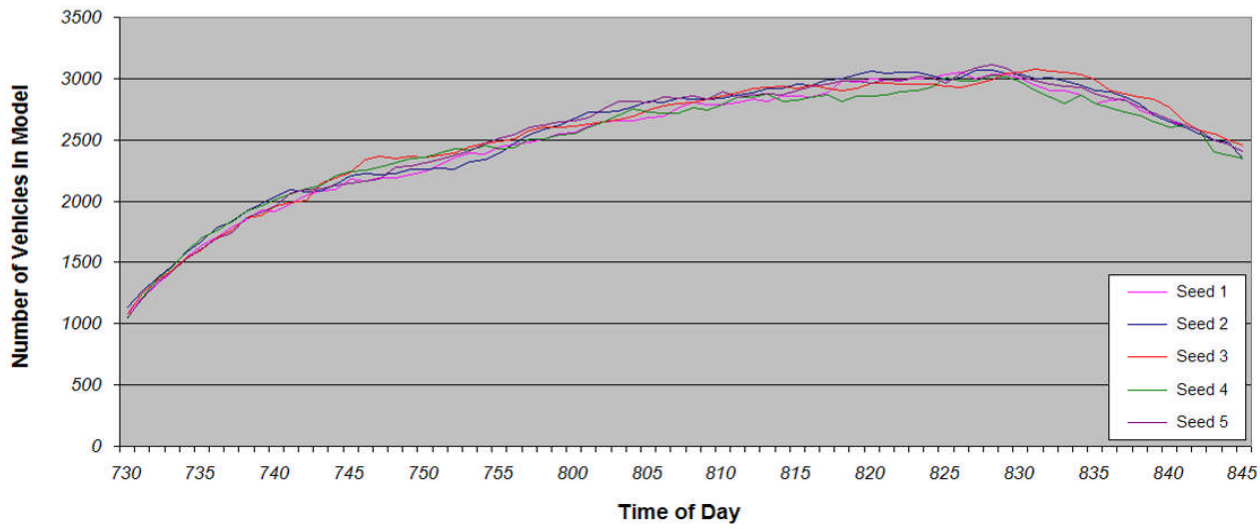


Figure 11.28 Plot of number of vehicles in network

Total travel time in network

The total travel time in the network provides another indication of model stability since a model that has become gridlocked or has developed a significantly higher level of delay due to an incident will generally show a greater total travel time. The travel times for each seed run should be presented either in a table or in a graph.

Average vehicle speed in network

The average vehicle speed in the network provides a similar indication of model stability as the total travel time. If any of the seed runs show a significant variability in average vehicle speed from the majority of the remaining seed runs then some explanation or justification may be required. A table or graph should be presented showing the average speed for each seed run.

11.8.3	Scatter plots are useful to check for independence between runs – results should show random variation and no correlation. Observations beyond the whiskers are classified as “extreme point” or “outliers” and are shown as asterisks Box plots are useful to screen for extreme points Histograms are used to examine location, variation, shape and unusual features of models The larger the sample size, the narrower the confidence interval, and so the more precise the VHT estimate is. Extreme points can be used to assess model performance and detect model errors and thus need to be investigated.

	If there are any unreleased vehicles then use adjusted dVHT in all analyses, not the VHT given by the models' output. To compare the means from two scenarios: • Calculate and plot their differences • Run a Unpaired Two-sample t-test using a statistical software package or the Data Analysis ToolPak from Excel • Look at the "p-value" and if it is less than your chosen significance level α (usually 0.05) then you can state a statistically significant difference between the means from the two models. • Calculate the value of the mean difference between the scenarios and its CI. The conclusion of scenario comparison results should include: • Mean difference • Minimum and maximum of differences • CI for mean difference • Statement of statistical power of comparison test and effect size • Final comparison statement

11.8.4 Summary

The use of the statistics outlined above will provide an indication of the level of stability within the model over a specified number of seed runs. It is not possible to provide a guideline statistic that accepts or rejects the model stability based upon these outputs. This is due to the inherent variability that can exist within some networks.

However, if the analysis of the outputs described above shows that the model performs significantly differently between runs then this should be investigated by the modeller in order to understand the cause. In many cases simple coding errors can be the cause of unrealistic congestion or gridlock situations. These should be rectified and the full set of seeds should be re-run and analysed. In other cases a small amount of instability may be caused by the natural variability within the network operation and this may be acceptable.

Ultimately the decision to accept or reject the model based upon the provided model outputs rests with RMS.

11.8.4	The model stability outputs should be reported and commented upon in the Base Model Development Report. Any significant discrepancies from the average should be explained in detail.

11.9 Forecast models

11.9.1 Network consistency

The approval by RMS of an accurate base year model that has been calibrated and validated to the guidelines within this document generally leads to the use of that model in forecasting mode. The development of a future year model (or option test) should follow similar principles to the development of the base model. This implies that where changes are made to existing infrastructure or where new infrastructure is added the modeller should attempt to remain consistent in the use of locally calibrated parameters wherever possible.

There are many areas where the use of locally calibrated parameters from the base modelling can be incorporated within the option testing models. These include (but are not limited to):

- Driver behaviour parameters.
- Gap acceptance parameters.
- Vehicle speeds.
- Lane utilisation.

- Saturation flows.
- Link type costs.

It is critical that areas of the network that are not expected to change between the base year and the forecast scenario are not adjusted in any way without agreement from RMS. This is because the model has been calibrated against on-street data and adjustments to these areas of the model may invalidate the calibration. In addition, these changes would make a like-for-like comparison between the base year model and the forecast scenario impossible.

A further area where models should remain consistent with current best practice is in the development or adjustment of signalised intersections. Care should be taken to ensure that minimum green times are adhered to and that pedestrian phases and clearance times are allowed for. It is not appropriate to assume that signalised intersections can be adjusted or developed without allowance for pedestrian facilities within any forecast modelling unless specifically agreed with RMS.

11.9.2 Demand consistency

Overview

The development of demand for future year scenarios is one of the most important aspects of using the model in forecast mode. It is not generally possible to calibrate future demand against a measurable dataset and it is therefore difficult to make accurate judgements regarding the validity of the demands. However, it is possible to manage the risk associated with this aspect of forecasting through:

- Use of a transparent methodology for future year demand development identifying the assumptions made, the processes used and undertaking a detailed comparison of the base demand with the forecast demand.
- Proper distinction between background traffic and development traffic to avoid double-counting in those scenario comparisons that involve traffic generation associated with specific developments.
- Undertaking sensitivity tests to show the impact of increases in demand beyond the initial forecast.

Following these guidelines will provide RMS with both an understanding of the level of detail to which the trip demand has been adjusted and an indication of the sensitivity of the results to minor changes in demand. This allows RMS to make informed judgements and assess the degree of confidence that can be placed in the forecasting.

There are a number of methods that can be used to develop future year demands and each has advantages and disadvantages in any given situation.

Strategic model inputs

If the base year demand was developed using a strategic model to provide information relating to the trip pattern and O-D volumes then this model may be used to update the forecast demand. There are a number of risks associated with this technique since it is highly likely that the base year strategic trip demand will have been significantly adjusted for use in the microsimulation base year model. This means that it is not acceptable to simply take forecast demands directly from the strategic model and assume that these are appropriate for the forecast microsimulation modelling.

The modeller should undertake a detailed analysis of the changes between the base demands from the strategic model and the forecast demands for the strategic model. These changes then need to be applied on an O-D cell-specific basis to the base year microsimulation demand and would require an understanding of the absolute/percentage change in demand for every O-D pair in the strategic model.

Assumptions will also need to be made regarding when it is appropriate to use the absolute change and when it is appropriate to use the percentage change. Each assumption should be recorded and the methodology should be provided to RMS along with an analysis of the impact of the changes to the microsimulation demands. Common problems include the impact of zero values in the trip matrices and the calculation of negative trip volumes when using absolute changes.

When applying growth factor techniques (as described in section 9.20 of these guidelines) the extent of the cordon area required will generally match the micro simulation model study area. However, where there is any doubt about the possible effects of traffic re-assignment or zone centroid connections on

the periphery of the study area (as a result of applying results from the future demand model) a “buffer” network around the study area may be required. If in any doubt the RMS Manager, Traffic and Transport Modelling should be consulted before specifying the extent of sub area required in the project brief.

The diagram below outlines the process for developing a calibrated base year demand and subsequently applying the changes drawn from the strategic model demand to the microsimulation demand.

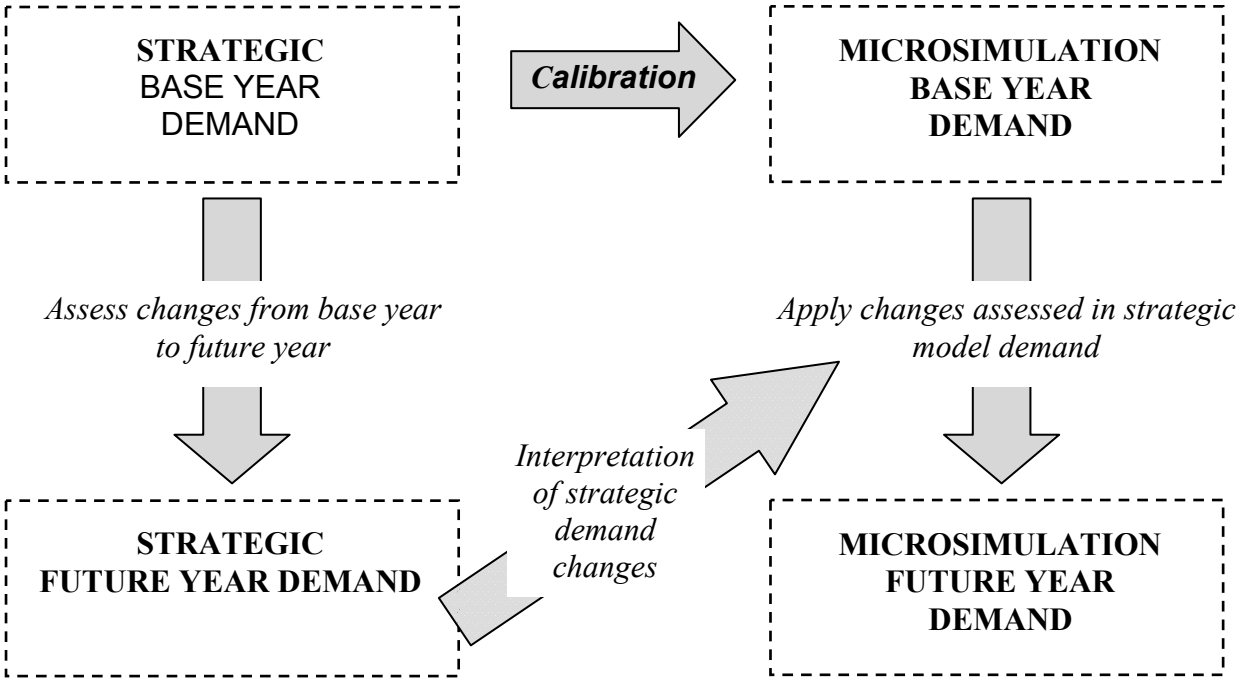


Figure 11.29 Development of future base models

Growth factors

A simpler method of updating trip demand is to use growth factors to adjust the trip demand. This can be done in a number of ways:

- Global factor that uplifts the entire matrix.
- Zone specific factors that uplift origin and destination demands.
- O-D specific factors that uplift individual movements.

This is a very transparent and simple approach to generating future year demands. However it is subject to a number of disadvantages since the agreement of growth factors must be based on assumptions relating to projected future land use, expected background traffic growth or a combination of both. This methodology takes no account of the influence of factors external to the localised study area (ie re-routing due to wider changes in network capacity or levels of congestion. The calculation of growth factors can be based on compound or basic annual growth rates that are normally provided by RMS or BTS.

Summary

The most important aspect of developing future year demands is to ensure that the methodology and assumptions used are documented such that RMS has an understanding of the confidence that can be attached to the process. This is of key significance since the microsimulation modelling may be used as justification for the development of infrastructure or other associated schemes and these decisions rely on the accuracy of the model outputs. Understanding the accuracy of the modelling can therefore play a major role in the ability of RMS to make informed decisions that affect the road network.

11.10 Reporting

Sections 4.8 and 5.7 of these guidelines provides general discussion on content to be provided as part of the model requirements The base model reporting is intended to provide RMS with an understanding of how the model has been developed and to demonstrate that it is fit for purpose to be used in the study. There are a number of key areas that must be included in the reporting and these are as follows:

- Purpose of the study.
- Model extents.
- Software package used.
- Modelled time periods.
- User class/vehicle type definition.
- Data collected.
- Outline of techniques used to develop network.
- Justification for changes to default parameters.
- Methodology used to develop demand.
- Calibration issues and statistical comparison.
- Validation statistics.

11.10.1 Suggested structure of base model development report

RMS does not provide a mandatory report structure as each model will be different and may have been developed using a methodology that varies from any other model. It is therefore incumbent upon the modeller to develop a report that provides the most logical and accurate outline of the development, verification, calibration and validation process in each case.

The structure set out below therefore simply provides a guide to assist inexperienced practitioners who wish to develop a basic Base Model Development Report:

1. Introduction – study objectives, network extents, core area extent, software package, time periods.
2. Data Collection – description of data collected including type, date, location etc.
3. Network Development – outline of coding used for links, intersections, signals etc.
4. Demand Development – description of methodology used to develop demand.
5. Model stability – provide details of seed runs and model outputs showing stability (If Statistical Toolkit used then refer to Section 11.8).
6. Model calibration – statistical comparison of observed and modelled outputs.
7. Model validation – graphical or statistical comparison of observed and modelled outputs.
8. Summary – brief summary outlining data that demonstrates model is fit for purpose.

12 SCATSIM Modelling[11]

12.1 Introduction

SCATS in **m**icroscopic simulation (SCATSIM) is a suite of software that allows offline versions of the Sydney Coordinated Adaptive Traffic System (SCATS) to be linked to micro simulation packages.

This guide has been written specifically for SCATSIM practice within NSW and elements of it may not be applicable in other jurisdictions. The purpose of this section of the guidelines is as an overview for project managers and model practitioners, to better understand the SCATSIM process. It does not provide detailed information of the installation, data and error checking process. In NSW, historically, the predominant micro simulation package linked to SCATSIM has been Quadstone (Q)Paramics however the linkages to other micro simulation packages including: Commuter, VISSIM, Aimsun and SIAS (S)Paramics have also been developed and are as equally valid as suitable platforms for SCATSIM modelling.

12.2 Project suitability and cost considerations

Before utilising SCATSIM for any project, reference should be made to Section 3 “Appropriate Use of Modelling” of this guide as well Section 2.7 “SCATS Portfolio Products”. An experienced modeller may be needed in assessing whether the project warrants the use of SCATSIM and the RMS Manager, Traffic and Transport Modelling should generally be consulted as to whether SCATSIM modelling is required. In deciding whether it is necessary to include SCATSIM functionality this will depend on:

- The project purpose (ie are signal operations critical to the objectives of the study brief)?
- Sensitivity of the model results (ie will the range of model results generated by the application of SCATSIM modelling be sensitive enough to the infrastructure changes being proposed?).

In assessing whether SCATSIM models are required consideration should be given as to whether the benefits of a SCATSIM model are outweighed by the costs of additional data calibration requirements and the availability of RMS network operations staff and resources. Often more basic signal representations in micro simulation models are sufficient for project purposes as worst case operations are sometimes all that is required to be investigated and the range of results that SCATSIM models produce can often make interpretation of the effects of infrastructure changes problematic. Consideration should be given to the three questions in Table 12.1 before utilising SCATSIM modelling in the project assessment.

Table 12.1 Is the application of SCATSIM appropriate?

Is the application of SCATSIM required? *(if project satisfies two or more of these criteria then SCATSIM may be appropriate)*	**Is the application of SCATSIM achievable?** *(if the answer to any one of these is “no” then SCATSIM cannot be applied)*
SCATS traffic signals are used or will be used.	Are network operations staff available to provide assistance?
There are concerns about existing or future SCATS operation.	Do the modellers have adequate training/experience in SCATSIM to setup correctly?
Complex signal co-ordination cannot be achieved otherwise.	Is there the ability to provide future intersection personality files (if not, can substitute personalities be used)?
Testing of SCATS settings and software is required before “on the ground” implementation.	**Are other methods of signal representation more appropriate?**
High profile or critical projects where greater confidence in the representation of signal operations is required.	Can the project be adequately modelled as a fixed time model or using the basic functionality of the micro simulation software package such as coding basic “gap out” logic?
SCATS operator training in the virtual world is preferred to training on the real world system.	Can signal cycle by cycle fixed time models with VA conditional phasing (such as SCATS History Reader with Paramics playback plugin) be used to closely represent SCATS operation?

[11] Halcrow has prepared this subset of the guidelines dealing with SCATSIM.

12.2	Is the application of SCATSIM appropriate – refer to Table 12.1

12.2.1 Coordination

In some instances the signal coordination can be complex, particularly in some grid network situations. SCATSIM is able to replicate the actual signal coordination because it uses the real world software and algorithms to model signal operation. As traffic increases on a network SCATS adapts a range of signal control parameters including: cycle time, phase sequence and green splits such that optimised signal coordination is generally achieved based on the predominant traffic flows. Linkages between subsystems can form and dissolve as part of this signal coordination optimisation.

12.2.2 SCATS operation

Some SCATS operations are difficult to replicate in fixed time micro simulation models. For instance the “gap out” functions on a diamond overlap. Although vehicle actuation can be coded in most of the available microsimulation software packages, these will not correctly replicate SCATS operations. SCATSIM can be used to test operation such as:

- Bus priority.
- Specific action plans.
- Emergency phases.
- Time of day routines.
- Changes to signal coordination.

12.2.3 Adding realism

As SCATSIM implicitly demonstrates how the real world SCATS system will respond to the modelled traffic flow conditions it provides additional realism to the modelling work. In this way the SCATS operation (that would be experienced in the real world application of the proposed infrastructure changes) can be established and assessed. This level of realism may be required where the project lies within a sensitive area that is prone to congestion or there is an identified need by RMS Network Operations.

12.2.4 Access to Network Operations staff

When considering whether a project is suitable for the application of SCATSIM it is important to have RMS Network Operations staff provide support to the project. Network Operation staff may be required to:

- Provide SCATS files and data for the models.
- Provide advice on signal operation.
- Confirm the model signal operation is representative of real SCATS operation.
- Help setup any future scenario that requires changes to SCATS files including signal personalities.
- Confirm peak hour queuing patterns across study network.

12.2.5 Future Signal Designs

As future signal designs may require the generation of a new signal personality file an extended notice period may be required to produce this. This is particularly true for future intersection designs with complex or non-standard signal configurations. As an alternative, it may be possible to select a personality file that has been developed for another signalised intersection site from the library of around 3000 SCATS controlled intersections in NSW. If there is some aspect of the intersection operation that is unique it will almost certainly require a specific personality file to be created and, as this can be time consuming, it should be started as soon as possible to avoid delays and additional costs to the project.

12.3 SCATSIM glossary

Batch file – A text file that contains a series of commands to open SCATSIM and to copy files.

Calibration – The process of adjusting model factors so that the model correlates to observed data.

Central manager – Central computer that coordinates between the SCATS region computers.

Checksum – A computer file identifier based on the number of characters in a file. Used to check that the personality file is compatible with the LX file in use.

Isolated – A state in SCATS where an intersection will run independently of the rest of the system.

Fallback – SCATS fail safe mode of operation that allows a set of traffic signals to continue operating in a safe manner with preset signal timings. This represents the first level of signal coordination in SCATS.

Fixed Time – Traffic signal timing that operates on a set of fixed phase and cycle times. Commonly used as the basic mode of signal operation in micro simulation software packages.

Flexi-link – SCATS mode of operation that represents the second level of signal coordination in SCATS where an intersection will run in coordination with adjacent and local intersections (within the sub system).

Plug-in – Additional software that increases the capability or functionality of the original software. In SCATSIM plug-ins are often used as an interface between the Micro simulation software and SCATS.

Links – Micro simulation software is often based on a Link or Link-node systems. Links are the equivalent of a street (with one or more lanes).

LX – The LX file is the data file that feeds into the region computer. It contains the data necessary for communications, signal timing, coordination and variation routines.

Masterlink – The third (and highest level) of SCATS coordination whereby an intersection is controlled by the external region computer.

Personality – Signal controller logic as defined on the PROM.

Ports – Can refer to either physical or virtual connection points. In SCATSIM these software ports are virtual connections that can be used by the various programs to exchange data directly. These virtual ports are assigned an identifying number and operate under TCP/IP protocols.

PROM – (Programmable Read Only Memory) is physical memory chip that stores signal controller personality

Region – An area in SCATS controlled by a single region computer due to historical limitations in hardware.

SCATS – Sydney Coordinated Adaptive Traffic System. The traffic signal system developed by RMS and operated in Sydney (as well as over 260 cities around the world). In its basic form SCATS is a suite of software comprising the SCATS Region, SCATS Central Manager and SCATS Access.

SCATS Access – GUI interface for the SCATS system.

SCATSIM – SCATS In Micro simulation is the suite of software that enables SCATS to operate alongside a microscopic simulation software package.

SFT/PROM/Personality – Is the data file that is used by a controller to control key signal operation parameters. It contains sufficient information to allow the traffic signals to operate safely and independently if required.

Signal Group – A set of lanterns with common electrical switching such that the aspects illuminated in each lantern are always identical.

TCS number – Identifying number for a controller normally associated with a signal controlled intersection in NSW.

WinTraff – Windows application that utilises RMS traffic software (TRAFF) and standard configuration data to emulate the operation of SCATS signal controllers.

12.4 Software

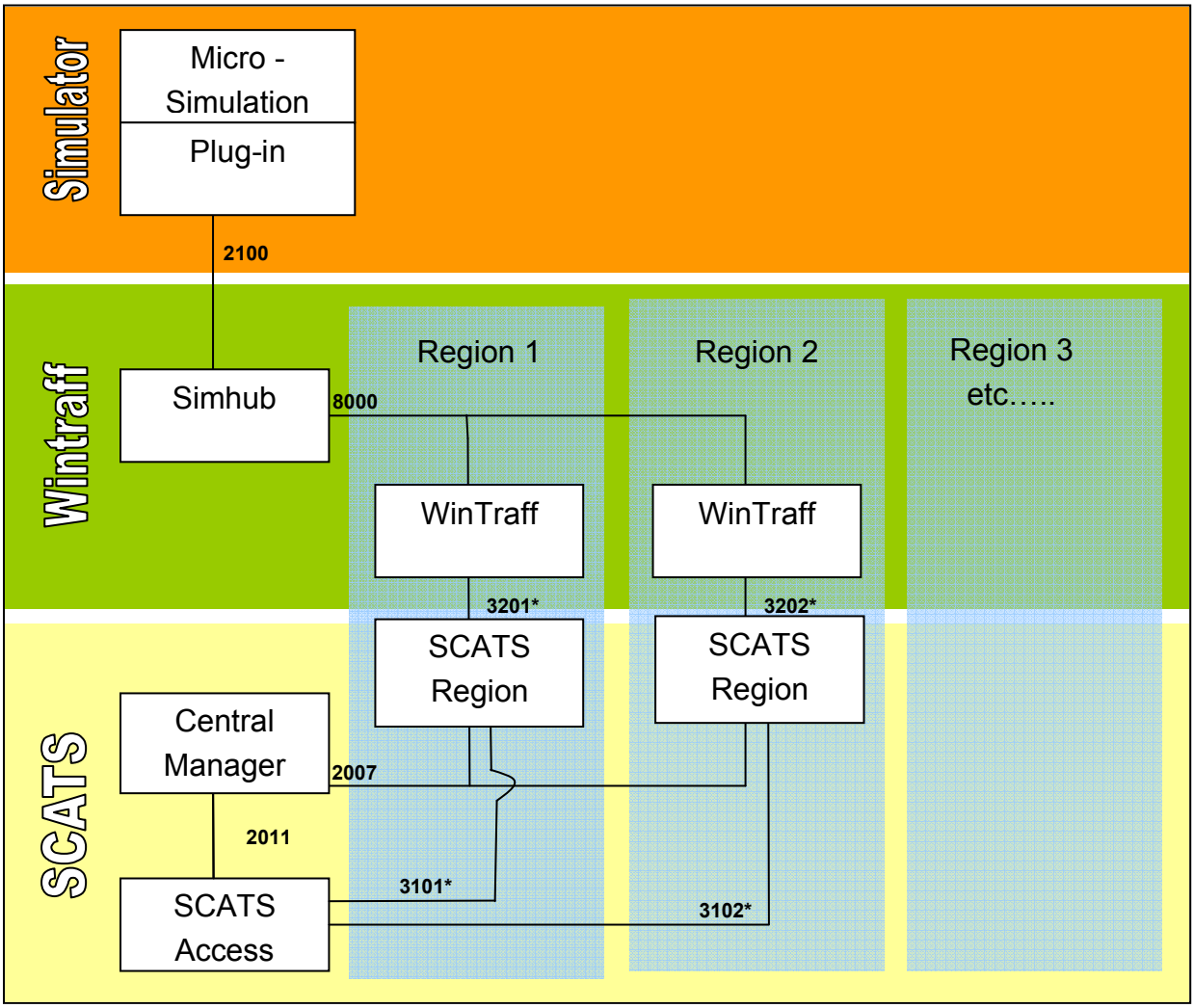
SCATSIM includes a number of software packages:

- Micro simulation (and interface with SCATSIM eg SCATSIM plugin).
- SimHub.
- WinTraff.
- SCATS Region.
- SCATS Central Manager.
- SCATS Access.

12.4.1 Software Packages

*These virtual port numbers increase consecutively as number of regions increase.

Figure 12.1 shows graphically how the SCATSIM software relates to each other. Each connection represents a virtual port (shown as 4 digit numbers) between the software applications.



*These virtual port numbers increase consecutively as number of regions increase.

Figure 12.1 SCATSIM structure

12.4.2 Microsimulation

There are various commercial microsimulation packages available. The packages that connect to SCATSIM include:

- Aimsum.
- Commuter.
- Q-Paramics.

- S-Paramics.
- VISSIM.

12.4.3 Plug-ins

Some of the microsimulation packages require an additional piece of code that extends the softwares' functionality to enable an interface between SCATSIM and the microsimulation software. The interface plug-in allows the microsimulation package to receive signal phase information from SCATS and to send detector data back to SCATS.

12.4.4 SimHub

Where more than one SCATS region is required, SimHub[12] manages the information and distributes data to/from the appropriate SCATS region via a single port connection.

12.4.5 WinTraff

WinTraff emulates controllers that are located on site. The controller's function is to:

- Receive data from the external SCATS system (region computer) and process these data.
- Receive data from the detectors, push buttons and switches pass actuation information to the SCATS region computer.
- Change the signal lantern aspects.

The signal controller is able to operate the intersection independent of the region computer in isolation or flexi-link mode. These states are used as fallback if there is a communication error or if the intersection does not require coordination.

12.5 Data and resource requirements

The following data are required in addition to the normal data required for a micro simulation model:

- SCMS.mdb file.
- LX Files.
- TC Files.
- SFT Files.
- Signal Layout Plans (TCS drawings).
- SCATS graphics (if new intersection required update).
- IDM Data.
- Ram Files.

12.5.1 SCATS

Table 12.2 lists the files required to runs SCATS in SCATSIM and a description of each data item.

Table 12.2 Data files required for SCATSIM

Software	Data Files	Description
Central Manager	SCMS.mdb	Database of all intersection in the system including graphics
SCATS Region	LX files	Contains information about Strategic Inputs, signal timings and signal coordination. One file required for every region in the model.
	TC files	Contains action lists for special time of day routines. 1 file for every model region.
	RAM files	Specifies the user-configurable settings in the controller eg Flexilink/local time settings
WinTraff	SFT files	Controller information. One file is required for every intersection. Personality /Prom
	WinTraff	Configuration file for WinTraff (*.cfg).

12.5.2 Network Operations staff

To ensure that SCATS is operating correctly it is a requirement to consult with RMS Network Operations staff. Network Operations staff can observe both the operation of the model as well as the

[12] Note that S-Paramics does not use SimHub as the FUSE software incorporates this per region message management.

SCATS response. In this way it is possible to determine whether the model reflects the real behaviour of SCATS under specific traffic conditions.

12.5.3 New intersections

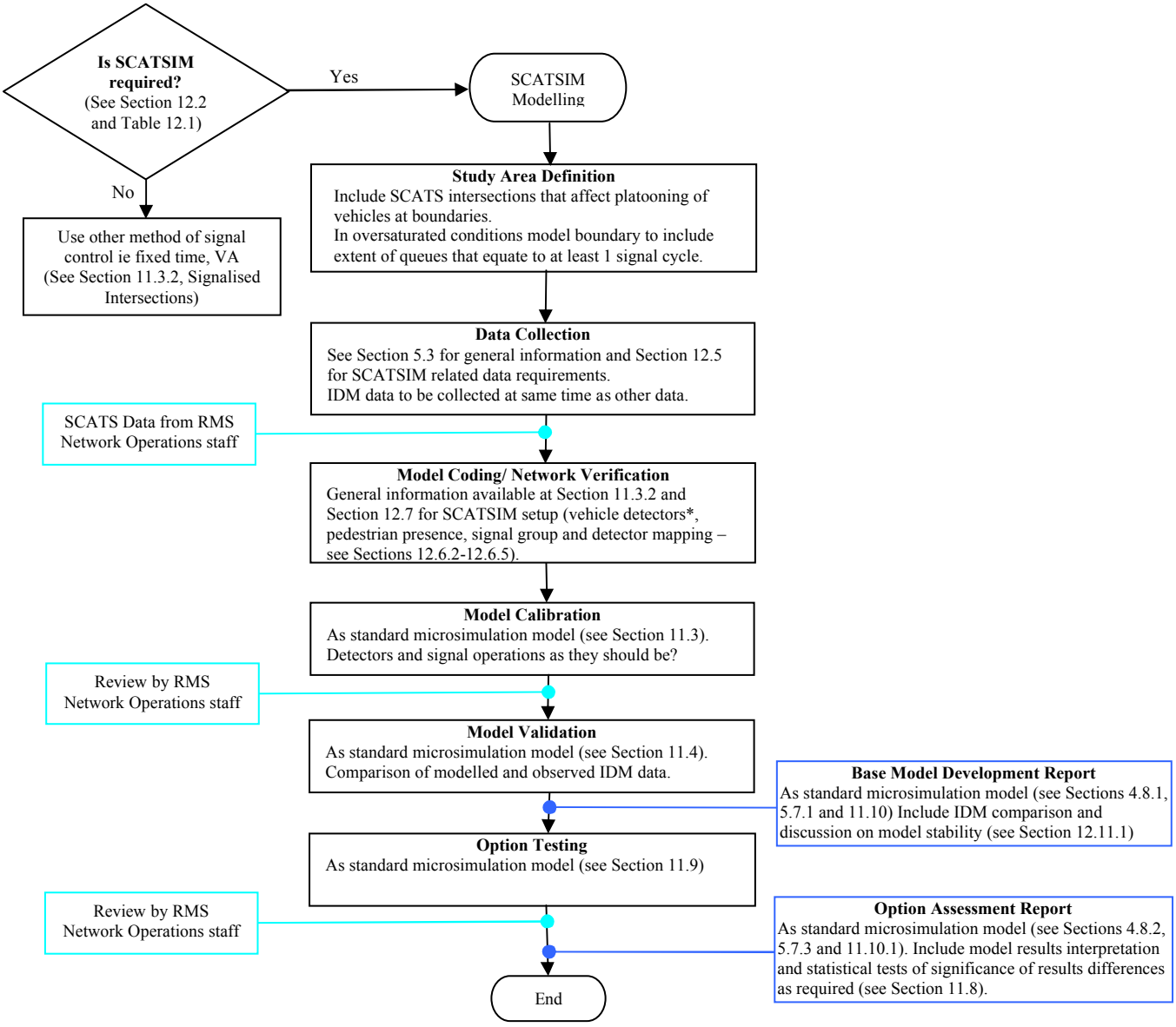
New intersection to be modelled will require a corresponding personality. This can take some time to produce (unless a suitable alternative personality can be found as a substitute) and should be considered at the beginning of the project to avoid delays.

12.5.4 IDM data

IDM data are used to validate the operation of the traffic signals in the model. IDM data needs to be pre-arranged with RMS to collect data and ideally should be collected on the same day as other traffic data. The data files contain a record of which phases and split plans were called, which link plans were used as well as phase times and cycle times throughout the monitored period. IDM data can be read with the RMS Intview software.

12.6 Model development and coding

12.6.1 SCATSIM methodology process



* (eg some known issues with detector placement in Paramics includes missed detections on curved links and on oblique angles formed by the skeleton network.) Note that workarounds are available for both these issues.

Figure 12.2 SCATSIM structure

12.6.1	SCATSIM methodology process – refer to Figure 12.2

12.6.2 Lane utilisation

In addition to the normal considerations given to the development of micro simulation models SCATSIM modelling also requires the accurate representation of traffic flow over the stopline detectors. It is important to ensure that vehicles arrive at an intersection in the correct lane and unrealistic lane changing in the vicinity of the stopline is eliminated. Although vehicle lane discipline is important in microsimulation models it is critical to the operation of SCATSIM models as a vehicle in the wrong lane may result in a phase not being called and the model locking up.

12.6.3 Coding vehicle detectors

Vehicle detectors should be coded to reflect the situation on the ground. The mapping of SCATS detector nomenclature to the simulation is critical for the correct operation of SCATSIM and detector numbering should generally match that provided in the SCATS graphic shown in SCATS Access. The following conventions should generally be followed.

TCS number _ detector number

(eg detector 3 on intersection 357 is 357_3).

There are various types of detectors used by SCATS.

Stop Line Detectors – Stop line detectors should be coded to match their position and size in the real world. In most cases it is not possible to measure these on site so the recommended approach is to assume that detectors have a default length of 4.5 m and set back 1.5 m from the stop (as shown in Figure 12.3).

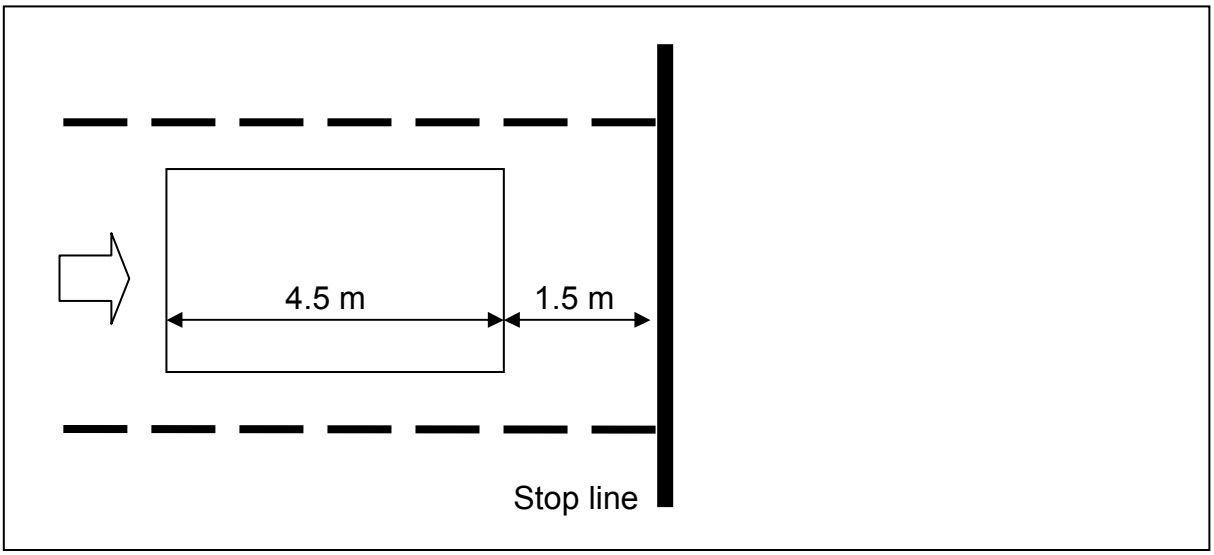


Figure 12.3 SCATSIM 4.5 m detectors

11 m Detectors – In reality SCATS doesn't use 11 m detectors but two connected 4.5 m detectors (one behind the stop line and one in front) however the 11 m detectors is used in microsimulation models to represent this arrangement with the addition of a 4.5 m detector behind the stopline. The 11 m detector then effectively sits on top of the 4.5 m detector and extends in front of the stopline. This represents the logic received in the real world SCATS since a vehicle sitting behind the stop line triggers both detectors but if a vehicle is in front of the stop line only one detector is triggered.

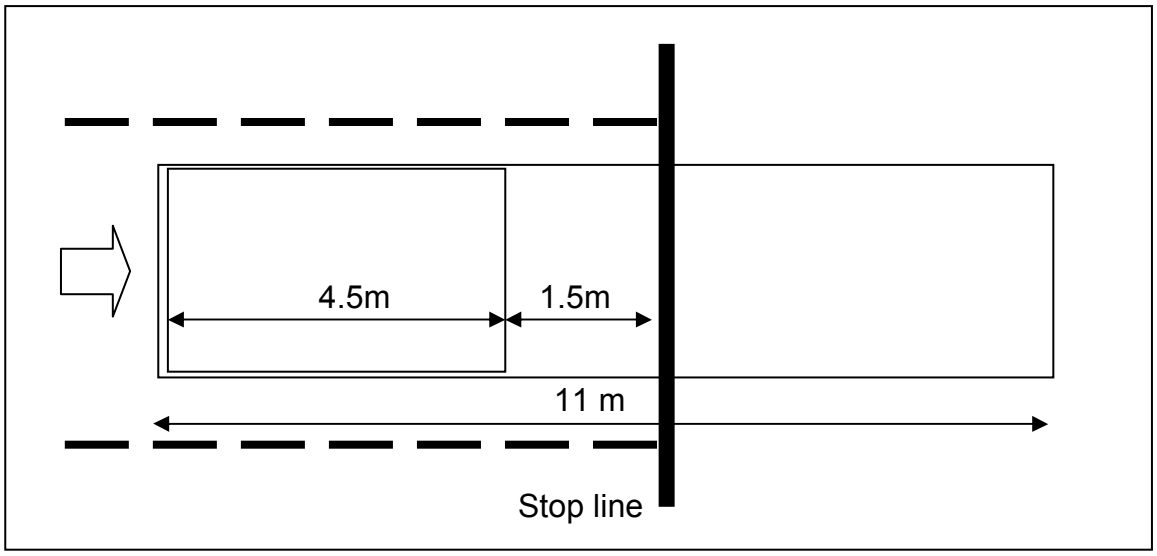


Figure 12.4 SCATSIM 11 m Detectors

Queue Detectors – Queue detectors measure the presence of vehicles. These detectors are often used to trigger variation routines to clear queues. They are coded as 4.5 m long detectors. The location of the queue detector is important to reflect the critical queue lengths. The locations are sometimes indicated on signal plans but may require additional advice from RMS to find the correct location.

Bus Detectors – For bus priority a series of four detectors is often used. These detectors are 2.5 m long. The model needs to be coded in such a way that the detectors are triggered in order by buses.

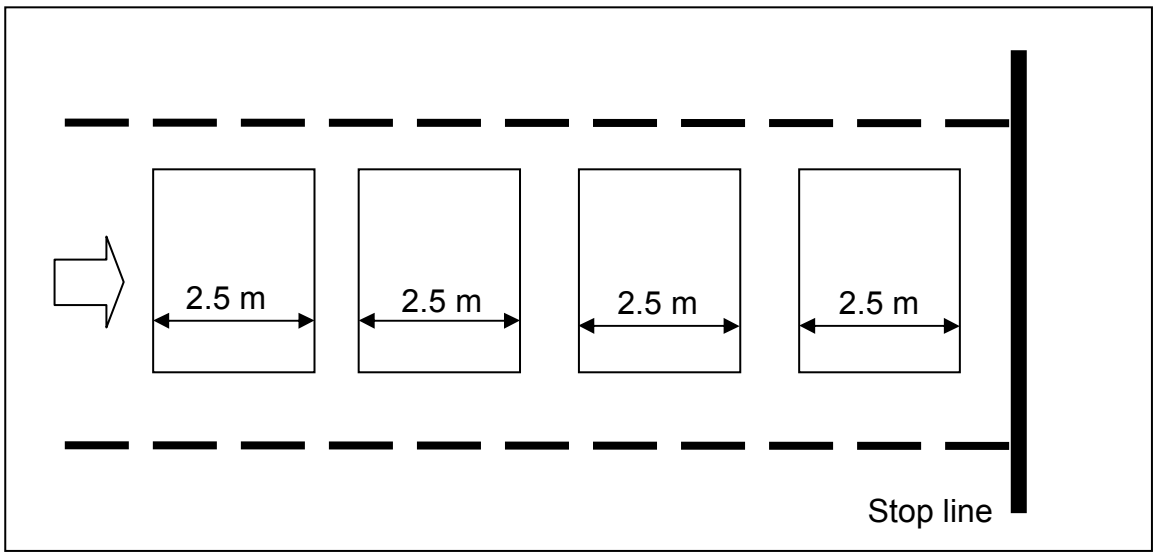


Figure 12.5 Bus Detectors

Special detectors – Occasionally there are instances where an unusual detection method is used for example bus height detectors in the CBD. RMS Network operations should be consulted if these issues arise.

12.6.4 Interface coding

The microsimulation package usually has a plug-in of some description that allows for the interface between SCATSIM and that particular microsimulation package.

Nodes – If the microsimulation package allows for the naming of nodes the convention is to name the node so that it matches the RMS TCS number.

Signal Groups – In SCATSIM, groups can be either green, yellow, red or off (note that SCATS allows for the additional states of flashing red and flashing amber but the SCATSIM interface only requires the Red, Amber, Green, Off states). As most microsimulation software only allows for green, yellow or red it is necessary to allow for the “off” state by introducing the concept of a “secondary group”.

Turns – Each turn should be mapped to the corresponding turn or turns. Note that a single group may control traffic for the left, through and right turn movements. For example, a simple signalised intersection with a split approach has a single group that may give priority to the left, through and right turn movements.

Secondary groups – Secondary groups account for the state when a group is turned off in SCATS and where vehicles are opposed by other vehicles (or crossing pedestrians) and must give-way. These are situations where two groups may control a single turn. This occurs for example when a left turn that has its own signal group but may turn off during another phase (see Figure 12.6). In this case the left turn is coded with the secondary group being the same as the through movement (ie the signal group that is green during phase B) and the primary group as the left turn group (ie the signal group that is green during Phase A). Similar situations occur when:

- Filter right turns are followed by green arrows.
- Left turns with red holds for pedestrian walk movement.

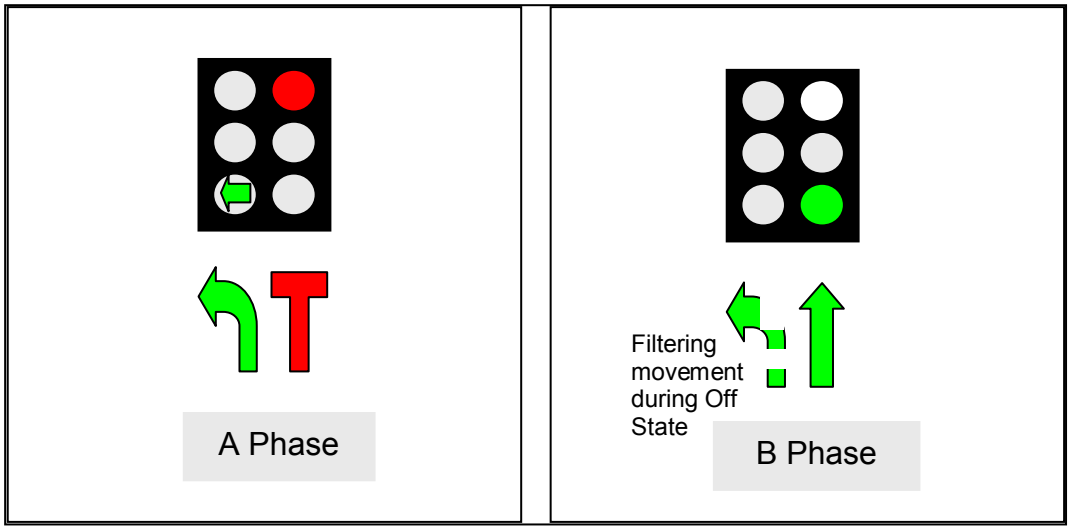


Figure 12.6 Example of where a secondary group is required for a left turn

Dummy groups – At simple two phase signalised intersections often the right turn movements have to filter through opposing traffic flow as they do not receive their own primary signal group. In these situations a “dummy” group is assigned that relates to the primary group of the through movement on that approach. The dummy group is assigned a number not used by other groups and set to be always “off” so that right turning vehicles will give-way to on-coming traffic. The convention is to assign dummy groups the same number as the primary group for the through movement on that approach proceeded by “10” (ie a number 10x where x is the primary group).

Auxiliary lanes – In the case of bus priority a separate group may be required to control a particular lane such as the “B” phase aspect associated with bus lanes.

12.6.5 Pedestrians

Due to the extended clearance times required for pedestrians at crossings the SCATSIM model is primarily affected by the delays to traffic and to phase calls due to their presence. The sources of delay include:

- Pedestrian protection holding red arrows on left and right turns during initial stages of pedestrian crossing phase which delays turning vehicles.
- Volume of pedestrians and their tendency to walk after flashing red man delays turning vehicles.
- Clearance timers for pedestrian crossings are directly related to their width and subsequent phases cannot be called until clearance times are met. This causes delays to traffic movement in subsequent phases.

If no pedestrian phases are called, SCATS may operate much shorter phase times. This should be taken into account where:

- The pedestrian crossing is long, has wide median or has six or more lanes.
- High to medium pedestrian volumes are present.

In areas with low pedestrian volumes the pedestrian calls may not be required to be modelled but this should be agreed with the RMS Manager, Traffic and Transport modelling before model calibration. In high pedestrian volume areas, consideration should also be given to delays to turning vehicles filtering through pedestrian movements either by directly modelling the pedestrian-vehicle interactions or by imposing a delay to turning vehicles (this requirement is not a restricted to SCATSIM modelling).

12.7 SCATS setup

12.7.1 Connections and ports (standard ports discussion)

As SCATSIM uses various ports to communicate between the software packages it is advantageous to the user to standardise which port numbers are used to manage SCATSIM configuration and to help understand and trace errors in the communication configuration.

Port numbers between 0 and 1023 are reserved for other applications and should be avoided. Generally ports between 3000 and 4000 have been found to avoid most port conflicts.

A standard port configuration is presented in Table 12.3.

Table 12.3 Standard port numbers

Connection	Port	Comment
Simulator – SimHub	2100	
SimHub – WinTraff	8000	
WinTraff – SCATS Region	32xx	“xx” is the region number from 1-64
SCATS Region – SCATS Central Manager	2007	
SCATS Access – SCATS Region	31xx	xx is the region number from 1-64
SCATS Central Manager – SCATS Access	2011	
SCATS Region – SCAT Terminal	30xx	Not used in SCATSIM

Note –This naming convention may not avoid conflicts for all computer systems.

12.7.2 WinTraff

WinTraff loads the logic for multiple SCATS controllers and runs these logic controls in a single application. If more than one SCATS region is modelled then multiple instances of WinTraff are required (one for each region).

A configuration file is used to specify which controller logic files (SFT files) are loaded and run from the WinTraff application. An example WinTraff configuration file is shown in Figure 12.7.

```
#cfg
! The first line needs to contain #cfg ie the config header
! Lines starting with a '!', space or tab are skipped
!
! simulator host
!
id=sWEN_2010_EX
!
simhost=localhost
!
! simulator port
simport=8000
!
! scats host
!
scatshost=localhost
!
! scats port
scatsport=3242
!
! to use list ids and not site ids or slot numbers
!listorderids=F
!
! The following data indicates the slot No and the sdata file for the intersection
! If necessary a full path can be specified for the files, all files following a path
! specification will be located in that path.
! The path specification can be changed as often as desired.
! An empty path specifictaion will result in the default directory being used
!
path=
!
21=S0206.SFT
18=S0502.SFT
19=S1248.SFT
20=S2270.SFT
60=S2693.SFT
61=S2773.SFT
27=S2883.SFT
73=S3706.SFT
88=S3995.SFT
64=S3676.SFT
```

Figure 12.7 Example of WinTraff configuration file

The configuration file allows you to name the WinTraff region:

id=sWEN_2010_EX

and set the port numbers:

scatsport=3242

simport=8000

There is an option to use the list order rather than the intersection name. In this case the “listorder” option is being ignored. This can be set to True “T” or false “F”

!listorderids=F

The path to the SFT file is listed and the corresponding slot number.

21=S0206.SFT

The version of WinTraff should be compatible with the dominant controller type. Typically this is controller type 5.

Figure 12.8 shows an example of WinTraff running. Note the “comms” column shows “c” for all entries indicating the intersections are communicating. Most intersections are operating in Masterlink (MLink) though some are operating Isolated (Isol).

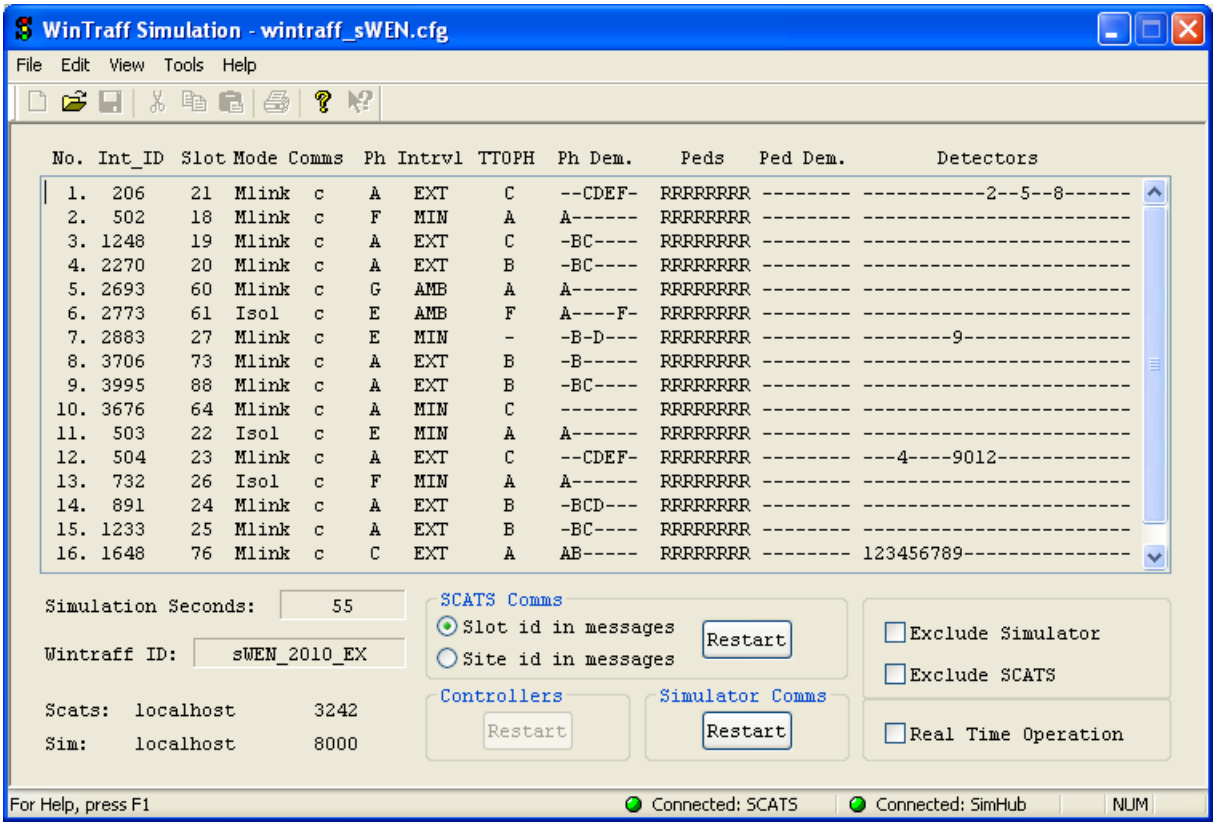


Figure 12.8 Example of WinTraff Instance

12.7.3 SCATS region (LX Files, TC Files)

SCATS LX files are used to configure the SCATS region. LX files need to be modified so that the “COM =” entries are set to “COM = NET”. RAM files can be modified by the user using SCATS Access to modify Flexilink and local time settings.

The slot numbers can be read from the LX file and are used in the WinTraff configuration file.

The region configuration in SCATS should use an “s” prefixing the region name. This protocol is used to avoid mixing a simulation region with a real region name, which can be of particular concern to network operations staff.

12.7.4 Central Manager

Central Manager should connect to both the region instances and SCATS Access.

The SCMS.mdb data base needs to be registered in the ODBC settings.

12.7.5 SCATS Access

Each region needs to be setup in the configuration settings in order to view the intersection operation.

12.7.6 Batch files / GUI

It is advantageous to use a Batch file to open the SCATSIM software. The batch file is used for two reasons:

- Assisting in the management of software versions, configuration files and the location of output files which limits the risk of mixing up SCATSIM configuration scenarios.
- Easier to open multiple regions and numerous applications especially for larger model areas.

For this reason if changes are made to the LX file while running the model the LX should be saved separately to avoid the changes being written over the next time a batch file is run.

12.8 Checklists – common errors

The following are checklists that may help eliminate errors. Further advice on SCATSIM installation and error checking can be found in the upcoming SCATSIM user guide anticipated in early 2013.

12.8.1 SCATS Checklist

SCATS setup checklist		
	Yes	**No**
Simulator		
Is the simulator connecting to SimHub		
SimHub		
Do all the modelled regions appear in SimHub?		
Does the Simulator appear in SimHub?		
WinTraff		
Have all the WinTraff Regions opened?		
Does the version of WinTraff correlate to the controller type used?		
Is WinTraff connected to SimHub?		
Is WinTraff connected to SCATS Region?		
Are all modelled intersection communicating “c” ?		
Are all intersections operating in Masterlink?*		
*Some intersection are set to run in flexilink or Isolated		
SCATS Regions		
Are the all SCATS regions connected?		
Central Manager		
Is Central Manager connected?		
SCATS Access		
Has the Central Manager connected?		
Have regions connected?		
Are there any intersection in Fallback mode		

Operation Check List (Model Observations)

Signal operation checklist

Each intersection should be observed in the model. The follow things should be considered when observing the intersection operation (one checklist is required for each intersection)

Intersection name…….

	Yes	No
Are the queues expected?		
Are the phases running consistent with SCATS?		
Are there any conflicting movements occurring?		
Have pedestrian been coded if required?		
Are the appropriate phases being called?		
Are all detectors triggering?		
Are all pedestrian calls being triggered?		
Are left turns running with the appropriate priorities?		
Have barred turns been coded correctly?		

12.9 SCATS (alarms)

SCATS alarms can occur when the data being received by SCATS are inconsistent with or missing from the SCATS configuration.

The most common alarms are caused by the controller type being inconsistent.

Wrong Controller Type (VC) – This occurs when the version of WinTraff is incompatible with the version of controller.

Checksum Error (CK) – This occurs when the SFT is inconsistent with the LX file being used. Commonly occurs if the VAX has not been updated properly or has a future file that is not in use.

Propagate fallback (FB) – As intersections outside the model area are not connected the system may propagate fallback into the model area.

Invalid Controller Ram (IR) – Check the version of SCATS and the personality file are compatible.

Communication error (ST) – Communication error somewhere between the simulation and the region computer. Check the slot numbers in WinTraff and whether the intersection has been coded correctly.

12.10 Known issues

12.10.1 Repeatability

Unlike fixed time models, SCATSIM models are not yet repeatable. This means that microsimulation models that are run multiple times with the same seed value will produce different results. This raises a number of potentially serious issues when comparing scheme options against base conditions as the repeatability issue creates a spread of results that can be difficult to differentiate scheme benefits over the “noise” inherent in the results. Section 11.8, “Statistical Toolkit for Model Stability and Confidence” has been developed to address this particular issue to assist project managers and modellers with model results interpretation.

12.10.2 Detectors

The detection of vehicles in the real world has imperfections; however the micro simulation models will theoretically model detectors perfectly, 100 per cent of the time. For instance in the real world it is inevitable that across a citywide area there will be a number of detectors that are faulty and unable to provide data to SCATS or require calibration to better reflect some aspect of the traffic flow in the vicinity but have not been calibrated correctly.

Conversely, microsimulation models can have their own peculiarities that do not exist in the real world, for example, (Q) Paramics detectors placed on curved links or at intersections with obtuse angles can occasionally miss the detection of vehicles properly. Viewing the detectors through the plug-in indicates that the detectors are placed differently than the Paramics core is showing. Stacking stop lines also cause detectors to move position.

12.10.3 XSF and SSF flags

Some intersections require a physical switch to be operated onsite before a particular mode of operation is invoked. These generally occur where there is a tidal flow arrangement. To work around this the corresponding switch needs to be triggered for the controller in WinTraff to change modes.

12.10.4 Level Crossings

Unresolved issues have been encountered with modelling level crossings. Additional details on train detectors and signals may be required.

12.11 Validation

12.11.1 Validation of signal operation (IDM)

Validation of the SCATS operation can be achieved by comparing to IDM from the model. IDM data should be collected during the model run and compared to the real IDM. Comparisons should be made of phase splits, cycle times and link plans. These comparisons can be graphically presented and inconsistencies highlighted. The validation process should be undertaken to the satisfaction of RMS Network Operations staff to ensure SCATS operations are being reflected in the SCATSIM modelling.

12.11.1	Validation of the signal operation to be undertaken by graphical comparison of observed/modelled IDM data to the satisfaction of RMS Network Operations staff.

12.12 SCATS user assistance

Trained SCATS users may be required to assist with SCATSIM setup for more complex applications described below.

12.12.1 New intersections

If new intersections are required for testing options then a new personality file will need to be found. This can be done by either finding a suitable substitute personality or alternatively having a new personality developed. Note that there may be conflicts if the substitute personality chosen is from the same region.

Once a suitable personality is sourced the LX file needs to be reconfigured to correspond with the new personality file. Offsets and strategic inputs need to be adjusted to suit the new intersection and a suitable slot number applied. If replacing an existing intersection then the same slot number may be used.

12.12.2 Action plans

SCATS has the ability to operate action plans that can be called upon when a particular network event is triggered. Network Operations staff may be able to set up action plans in a SCATSIM model to reflect dynamic operations. For instance you may want an action plan to clear out a queue to avoid vehicles queuing into a tunnel. These action plans invoke a predefined response to a particular set of traffic conditions by utilising the standard SCATS data.

12.12.3 SRMS

SCATS ramp metering is a system for metering traffic on motorway on ramps. SCATSIM has the ability to test ramp metering in microsimulation if the SRMS executable is made available by RMS.

(See Section 2.7.2 of these guidelines for more information on SRMS).

13 Corridor modelling[13]

13.1 Introduction

RMS adopted LinSig version 3.0 as its preferred software for the assessment of coordinated intersection operations and corridor modelling. This document aims to provide guidance on the appropriate application of the software and to promote best practice usage in New South Wales.

Other corridor modelling software (Transyt and SCATES) are used within NSW and guidelines for these software packages will be added to this guideline document at a later date.

13.1.1 LinSig version 3.0

At the time of writing the latest version of LinSig is version 3.0. All of the guidance in this document refers to this version of the software. Future versions of the software may differ, but the majority of the principles presented in this guidance will remain relevant.

13.1.2 LinSig version 3.0 development history

LinSig version 3.0 represents the latest version of a design and assessment tool for signalised intersections. This version of the modelling package was released in mid 2009 by the UK based, traffic software development firm, JCT Consultancy. Version 3.0 represents a major new upgrade in the software, which historically was only able to assess isolated intersections. The software now has the capability to model road networks including signalised intersections, non-signalled intersections and roundabouts. It should be noted that while there are no theoretical limitations to the number of modelled intersections, due to excessive runtimes associated with traffic assignment and signal optimisation larger networks should be approached with caution.

13.1.2	The guidance presented in this document relates to LinSig version 3.0

13.1.3 The LinSig traffic model

LinSig is a macro-simulation model capable of modelling isolated or coordinated networks of traffic intersections. It is able to assess performance at individual intersections and at network level for existing or future year design options.

To limit the level of complexity and to allow faster calculation of results, it uses a traffic flow model that considers platoons of vehicles rather than individual units. Provided all signalised intersections in a network operate on the same cycle time the pattern of traffic arrivals, departures and queues at an intersection stopline will be very similar during each cycle. LinSig is able to propagate these platoons of traffic through a road network to enable calculation of network performance statistics. LinSig is then able to optimise traffic signal timings for the network so that the level of delay is minimised or traffic capacity is maximised. A diagrammatic representation of the LinSig traffic model and how the platoon of traffic passes between two intersection stoplines is shown in Figure 13.1. For further information on the LinSig traffic and controller model please refer to the LinSig User Guide (Sections 4 and 5).

[13] AECOM has prepared this subset of the guidelines dealing with Corridor (LinSig) Modelling.

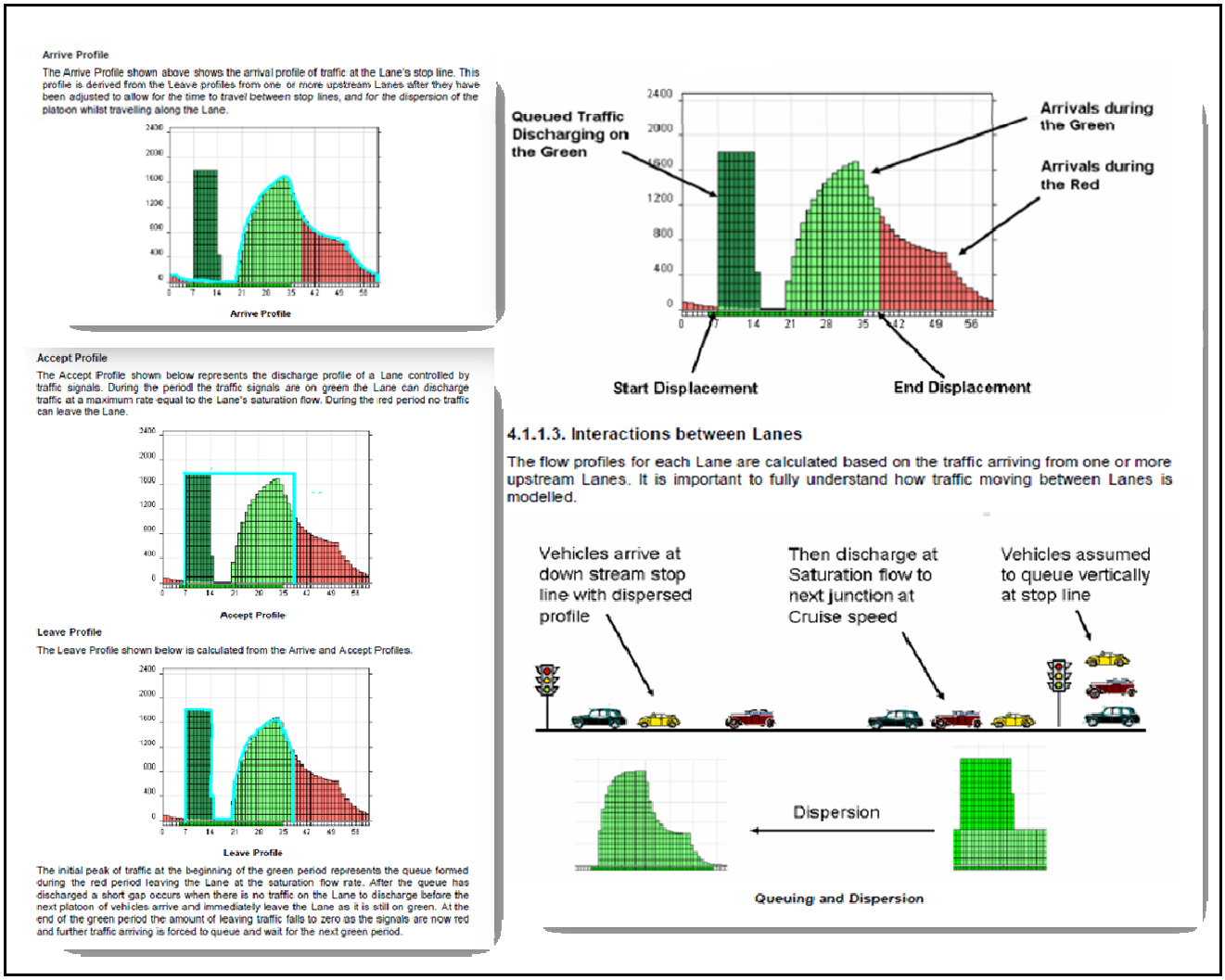


Figure 13.1 The LinSig traffic model

Source: LinSig User Guide & Reference, JCT Consultancy Ltd May 2010

13.1.4 Appropriate use of LinSig

As previously discussed LinSig is a macro-simulation traffic model capable of modelling isolated or coordinated networks of traffic intersections. The software has the ability to assess most intersection types and can optimise traffic signal timings for the modelled network.

LinSig should be used to assess the performance statistics for a group of intersections that have a shared interaction. In the case of urban traffic networks, where intersections are closely spaced, this is extremely common. It is usually not appropriate to assess an intersection in isolation as its performance is highly dependent upon the effects of the intersections which surround it. Historically in NSW the software package SCATES has been used for these types of assessment, but the software is no longer supported and LinSig represents a highly capable alternative.

LinSig is best suited to the assessment of smaller networks. Where the modelled corridor consists of a six lane two-way highway it is advisable to restrict the LinSig network to a maximum of 10 intersections. If a larger corridor requires assessment it can be split into separate LinSig models at no additional time or cost.

13.1.5 LinSig applications

LinSig is a flexible tool that can aid in the design and assessment of intersection or road upgrade projects. The ability to model signalised intersections in detail allows design options to be assessed and refined as the project progresses. LinSig should be considered in projects that include:

- Intersection design.

- Corridor design and assessment.
- Traffic signal optimisation and coordination.
- On-road public transport priority design and assessment.
- Assessment of pedestrian or cycling facilities.
- Assessment of development proposals.
- Development of traffic management plans.
- Cost benefit analysis.

The above is by no means an exhaustive list but serves to demonstrate LinSig's capabilities.

13.1.6 LinSig strengths and weaknesses

Like any traffic modelling package, LinSig has a number of inherent strengths and weaknesses as a result of the simplifications it makes in representing the network and traffic. An understanding of these is useful when considering the suitability of the software for use in a particular project. Table 13.1 highlights some of the key attributes of the software.

Table 13.1 Strengths and weaknesses of LinSig

Strength	Weakness
LinSig can model signalised intersections, priority controlled intersections and roundabouts and understand how they operate as a single network.	LinSig is not spatially aware of queue lengths between intersections and therefore cannot automatically identify when a queue blocks an upstream intersection (an experienced modeller can understand when it occurs and can account for it through manual adjustments as part of model calibration).
LinSig models are much cheaper to build than microsimulation models.	LinSig is not able to output a 95th percentile queue or an equivalent to the SIDRA effective stop rate
LinSig can optimise traffic signal timings for a network.	LinSig is not able to directly model dynamic signal control such as SCATS, Vehicle Actuation and bus pre-emption. Simplifications have to be made based on average timing data.
Public transport routes can be assessed separately to general traffic.	All signalised intersections in a LinSig model must run the same cycle time or a fraction thereof (ie half or third) to achieve network coordination.
Design changes can be coded and updated results produced very efficiently.	LinSig assumes a flat demand profile during the model period
Ability to assess local area traffic reassignment i.e. on routes within the LinSig model network.	LinSig cannot accurately model mid-block capacity restraints such as lane merges, bus stops and parked vehicles (although it can be accounted for in base models through manual adjustment).
Results can be presented in tables or graphically on a network diagram.	It is not practical to build large complex traffic networks in a single LinSig model.
Short lane overflow is taken into account when calculating intersection capacity.	

13.1.7 LinSig outputs

LinSig models aid in the assessment of proposed projects by providing network performance measures for comparison. A list of the main data outputs that can be extracted from LinSig are listed below:

- Journey times for user selected routes (seconds).
- Average stops per vehicle.

- Total number of stops.
- Average delay (seconds per vehicle).
- Total delay (vehicle hours).
- Queue lengths (vehicles).
- Mean maximum queue.
- Back of queue at end of red.
- Capacity (vehicles/hour).
- Degree of saturation (per cent).
- Demand flow (vehicles per hour).
- Actual flow (vehicles per hour).

13.2 LinSig model scope

Correct scoping of a LinSig model is critical to delivery of accurate model outputs that provide the appropriate information for assessment of the project. The specific requirements of each project will be unique, but the key principles and data inputs outlined below will apply to all LinSig projects.

13.2.1 Network familiarisation

To enable accurate modelling of an intersection or road network a site visit is required. This should be conducted by the model developer and is required to:

- Provide familiarisation of the existing traffic conditions and network geometry.
- Collect site specific data for the calibration and validation of the model.
- Confirm the accuracy of supplied drawings, traffic signals and survey data.

The site visit(s) should be conducted during the peak hour periods being modelled to capture the conditions that require replication in the model. Paper work recording the details and findings of the site visit should be included in an appendix to the modelling report. (See example at Appendix B.)

13.2.2 Model boundary

Careful consideration needs to be given to the model coverage. This decision needs to take into account the following factors:

- Where practical the model needs to capture the existing causes of congestion in the local network. If these are not contained within the proposed model boundary it can be difficult to capture the effects these critical bottlenecks have on the project and prevent testing of possible improvement options at those locations.
- The influence a proposed project has on the network will often extend beyond the area in which physical changes are being made. Local knowledge of the network is invaluable in identifying the extent of the likely impacts and as such it is recommended that advice be sought from RMS Network Operations staff when defining the model boundary.
- LinSig requires a consistent cycle time for all signalised intersections in the model. The model boundary can therefore be influenced by the existing groupings of coordinated signals. Advice should be sought from RMS on existing signal operations in the area.

13.2.3 The Passenger Car Unit (PCU)

The Passenger Car Unit (PCU) is the standard unit for specification of traffic volumes in LinSig. The PCU aims to account for the different performance and physical characteristics of vehicle types in the network. It does this by assigning a higher conversion factor to larger, slower vehicles. The PCU values used for specific vehicle classifications vary from location to location, but a suggested set of values is shown below in Table 13.2.

Table 13.2 Suggested PCU values for vehicle classifications

Vehicle Type	PCU Factor	Physical Length (approx)	Source
Pedal Cycle	0.2	2 m	UK, Transport for London
Motor Cycle	0.4	2 m	UK, Transport for London
Car	1	5.5 m	N/A
Rigid Truck	1.9	7 m-12.5 m	UK, Department of Transport
Bus	2.0	11 m-14.5 m	UK, Transport for London
Articulated truck	2.9	11.5 m-19 m	UK, Department of Transport
Articulated bus	3.2	18 m	UK, Transport for London
B-Double	3.6	19 m–25 m	Estimation

LinSig expresses model queue and lane lengths in PCUs. To take account of the space left between queuing vehicles one PCU should be assumed to equal 6.25 metres in length (ie a mean-max queue of 10 PCUs in LinSig is equivalent to 62.5 metres in length).

13.2.3	In LinSig it is possible to specify traffic flows in vehicles per hour. In this case care needs to be taken that saturation flows are also specified in vehicles per hour. If using vehicles it should be noted that all LinSig output tables will be wrongly headed using the unit PCU – these headings need changing manually. Conversion of queue lengths in vehicles to queue length in meters will require an approach traffic composition to identify the average vehicle length. If SCATS Maximum Flow (MF) data is used to provide model saturation flows it should be noted that this is specified in vehicles per hour.

13.2.4 Base case and scenario modelling

LinSig has the ability to combine signal control plans, network geometries and demand flows across multiple scenarios within the same project file. In defining these scenarios refer to Part A:

- Section 5.4 for the specification of base case modelling requirements.
- Section 5.5 for future model requirements.
- Section 5.6 for definition of option assessments.

13.2.5 Traffic survey requirements

In addition to the collection of standard survey data (see Section 5.3.4 Tables 5.1 and 5.2) additional surveys may be required for Corridor model calibration including:

- Extending the vehicle classification system in classified counts (beyond the usual lights, buses and heavies) so that vehicle length proportions and pcu values can be adequately identified for the vehicle fleet.
- Saturation flow surveys to reflect stop line capacities experienced during modelled periods (see 13.2.6 below).

13.2.5	Collection of classified traffic volumes is important due to the differing performance characteristics and road space occupied by the various vehicle types. As a minimum the classifications should include light and heavy vehicles, but improved model accuracy can be achieved with a greater range of vehicle classifications. Saturation flow surveys may be required if SCATS Maximum Flow data is unavailable.

13.2.6 Saturation flows

Saturation flows represent a critical input into analytical software like LinSig (including Transyt and SIDRA) as these packages all require estimates of saturation flow as an input to the model. This is in contrast to microscopic simulation models that output saturation flows as a result of the car-following behaviour that is modelled explicitly.

While all of these analytical software provide default values of saturation flow, based on key parameters derived from basic geometry and vehicle behaviour, there is also the opportunity to refine these to better match actual observed stop line behaviour. The collection of stop line saturation flow measurements is a key calibration input in developing all of these models and can be obtained in two ways:

- SCATS Maximum Flow (MF) data provide an excellent approximation to existing stopline saturation flows and should be acquired where applicable.
- If these data are not available then saturation flows need to be collected on street over a minimum of 10 cycles to provide a reliable average.

13.2.7 Traffic control signals (TCS) drawings and SCATS plots

TCS drawings provide details regarding the geometry and configuration of existing signalised intersections. They help to correctly define the traffic signal groups and phases and can provide useful geometry data such as number and length of lanes.

All SCATS intersections also have TCS plots that show the phasing data as it has been entered into the SCATS central computer. Either the TCS drawings or SCATS plots (ideally both) should be acquired for every signalised intersection that is to be modelled in LinSig.

13.2.8 Signal timings

A critical input for all traffic signals in a base LinSig model is the average phase timings for the peak hour being modelled. These average timings and their relationship with surrounding intersections will have a significant impact upon network capacity, delay and queuing. Without these actual operational timings it is not possible to develop an accurate base model. Phase timing data should include:

- Phase definitions.
- Phase sequence.
- Interphase times.
- Average phase times.
- Average cycle time.
- Number of times phase is demanded.
- Phase offsets to surrounding intersections.

The way in which the above data is acquired depends upon the type of control under which the intersection operates. The main types of intersection control and relevant method for signal timing data collection are given below.

13.2.9 Vehicle Actuated (VA) intersections

Phase timing data must be collected manually; average timings should be based on as many readings as possible, collected during the time period being modelled. Vehicle Actuated signals in a network are not linked and therefore are likely to be running inconsistent cycle times and phase offsets. The modeller must review these data collected on-site and produce a single cycle time for the entire modelled network. If an intersection has a phase that is demanded infrequently then the modelled signal timings (as they are averaged over the study time period) need adjusting to reflect this.

13.2.10 Fixed time coordinated intersections

This includes intersections that operate under cableless link control. These intersections run to a set of plans that are stored in the controller personality. These plans change by time of day and dictate the

phase splits, cycle times and offsets to surrounding intersections. If at least one intersection operates under fixed time coordinated control during the modelled period then the details of these controlling plans should be attained from RMS and used as an input to the model. The plans will identify the allocated phase times, cycle time and offsets to other intersections, but it will not identify the frequency of phase demands. If an intersection has a phase that is demanded infrequently then the modelled signal timings need adjusting to reflect this.

13.2.11 SCATS coordinated intersections

In the case of SCATS much of the timing data can be extracted from the Intersection Diagnostic Monitor (IDM). This provides average phase times averaged over a specified period of time. The average timings will vary throughout the day in response to predominant traffic movements, so IDM data should be requested from RMS for all SCATS intersections and for all time periods that are to be modelled.

IDM data do not provide information about how adjacent intersections are coordinated. The direction of coordination will usually favour the predominant traffic movement for a particular time of day. This data needs to be obtained from the SCATS Strategic Monitor for each time period being modelled. Please contact RMS Manager, Traffic and Transport Modelling for further advice on how this can be acquired.

13.2.12 Pedestrian facilities

Pedestrian movements play a major role in the definition of intersection capacity, particularly where there are heavy vehicle turning volumes or high numbers of pedestrians. It is important that the amount of delay pedestrians impart to turning traffic is captured in the model.

In the case of existing intersections this can be directly measured on street by timing the average delay (in seconds) between the turning movement receiving the green signal and vehicles being able to proceed through the intersection. The frequency of pedestrian demand as given in the SCATS IDM output can also be used to gain an understanding of whether pedestrian demand at the intersection is sufficient to warrant modelling of delay to turning vehicles. (Most locations in Inner Sydney require this delay to be quantified.)

13.2.13 Base model validation data

In addition to the collection of input data as covered previously, further data is required for the validation of the base LinSig model outputs. The purpose of this data is to provide a comparison of model outputs to real world data, based on this data the model can be adjusted to provide a more accurate representation of traffic conditions. Examples of appropriate validation data includes:

- Degree of saturation measurements.
- Queue lengths (although the manual warns against detailed comparisons with observed values).
- Network journey times.

13.2.14 Proposed models

Development of proposed design option models should only commence following satisfactory validation of the base models. A proposed model should be created from the validated base model. All aspects of the model unaffected by the future design options must remain unchanged from the base case. This improves the confidence levels in the proposed model forecasts and ensures comparison of base model against proposed model provides a clear assessment of design performance.

13.3 LinSig modelling approach

13.3.1 Default program settings

All LinSig models created for networks in NSW should be set to SCATS-based terminology. This ensures the traffic signal control data is specified in a way that is consistent with current AustRoads standards.

The default values for start and end displacements should both be set to three seconds. This accounts for the delay after the start of green before traffic reaches saturation flow and the additional time gained at the end of green by vehicles crossing the stopline during the yellow period. These defaults are

consistent with current SIDRA default settings and research presented in ARRB Research Report ARR 340[14].

13.3.2 File details

All LinSig files should have the following data specified in the Network Information Tab:

- Project Name – Clearly identifies the project the model has been produced for.
- Title – Network title that clearly shows the design, time period and year represented in this file.
- User details – Clearly identifies the originating modeller, internal reviewer, company name and address.

13.3.3 Junction (intersection) details

Junction Name – Should include the TCS number.

13.3.4 Controller details – TCS number, location

A separate controller should be specified for each junction in the model unless the junctions operate as separate streams on the same controller in reality. The controller details should include:

- SCN – TCS number as specified in TCS or SCATS plots.
- Allow non-standard UK Filter Arrows – Should be ticked to enable specification of left turn arrows.

13.3.5 Signal group definition

Controller signal groups should be defined as specified in the relevant TCS plot. The correct signal group type should be selected based on the type of movement it controls, eg traffic, LRT, pedestrian, green arrow. The default minimum green times for signal groups should be:

- Traffic Signal Group – five seconds.
- Non-UK Arrow Signal Group – five seconds.
- Pedestrian Signal Group – Equal to walk time + minimum clearance time – inter-phase time.

13.3.5	The minimum clearance time is made up of the clearance 1 and clearance 2 intervals as defined in the controller personality.

13.3.6 Dummy signal groups

Due to LinSig originally being developed to UK standards, the software is not able to automatically model situations where turning movements must give way to parallel pedestrian movements. For the same reasons it is also unable to model situations where a lane has shared movements that are controlled by different signal groups (ie red and green arrows). To accurately model these situations it becomes necessary to create additional “dummy” signal groups and/or short lanes that do not exist in reality. To prevent confusion, care should be taken to ensure that dummy signal groups do not share a signal group number with any of those that exist in the controller personality. The following sections provide guidance on these specific issues:

Green left turn arrows where there is a shared though and left turning lane – In this instance the left turn movement needs to be controlled independently of the through movement, but LinSig only allows a controlling signal group to be assigned on a lane basis. This can be overcome by creating a dummy short lane of one PCU in length for the left turning traffic which is controlled by the arrow signal group as shown in Figure 13.2.

[14] Fundamental relationships for traffic flows at signalised intersections AKÇELIK, R., BESLEY, M. and ROPER, R. (1999)

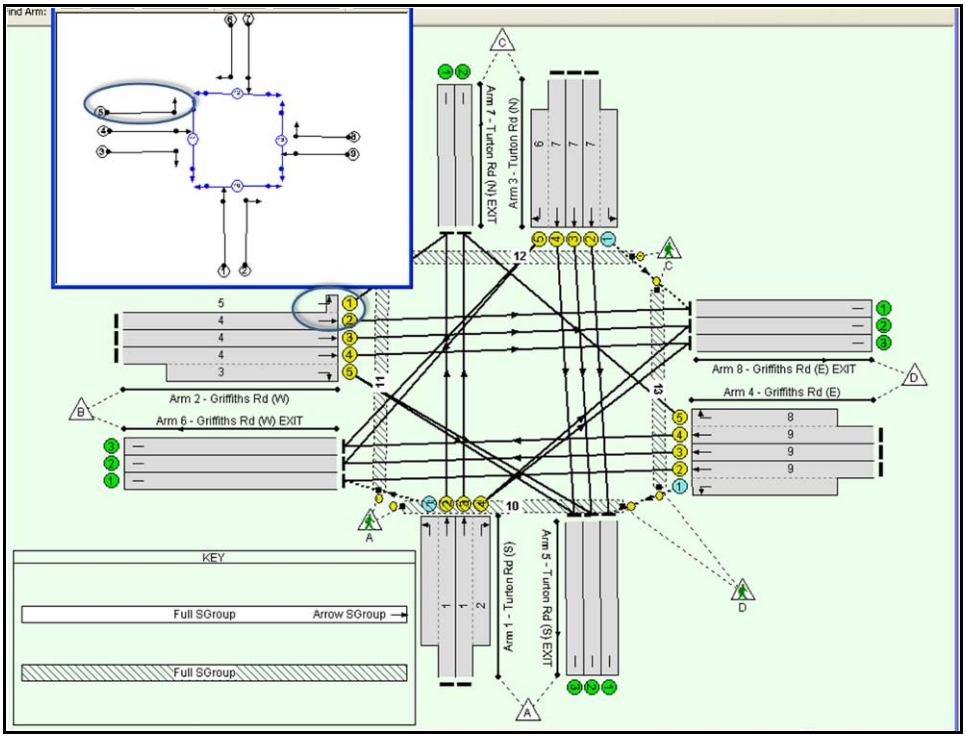


Figure 13.2 Left turn green arrow coding

Turning movements in dedicated lane giving way to pedestrians – Where a dedicated turning lane exists it is sufficient to create a dummy signal group with a signal group gaining equal to the average delay turning traffic receives as a result of pedestrians crossing. In the example shown in Figure 13.3 the start of dummy signal group 13, which controls the left turn on Arm 2, can be clearly seen to start after the through movement (signal group 4).

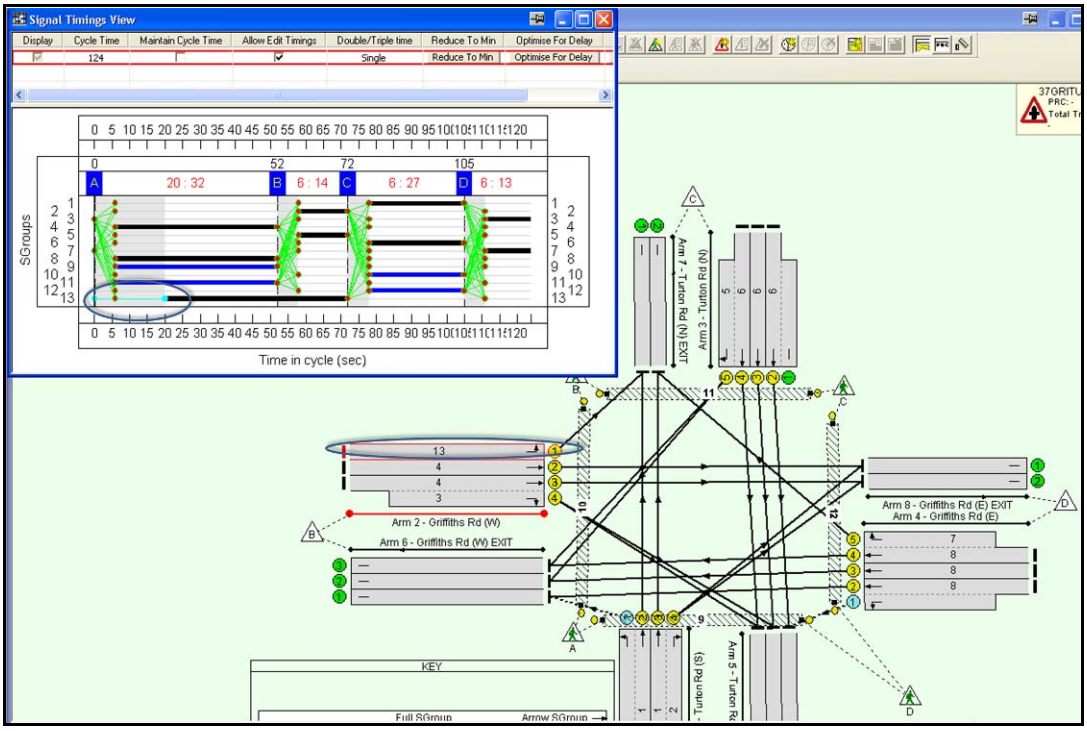


Figure 13.3 Modelling delay to left turners in dedicated lane

Turning movements in a shared movement lane giving way to pedestrians – In this situation the previous example will incorrectly impart delay to through traffic that is not blocked by turning vehicles giving way to pedestrians. This can be overcome by creating a dummy short lane (for the turning movement only) with a length equal to the storage space available before turning vehicles block

through traffic. This dummy lane should then be controlled by a dummy phase created in the same way as in the previous example as shown in Figure 13.4.

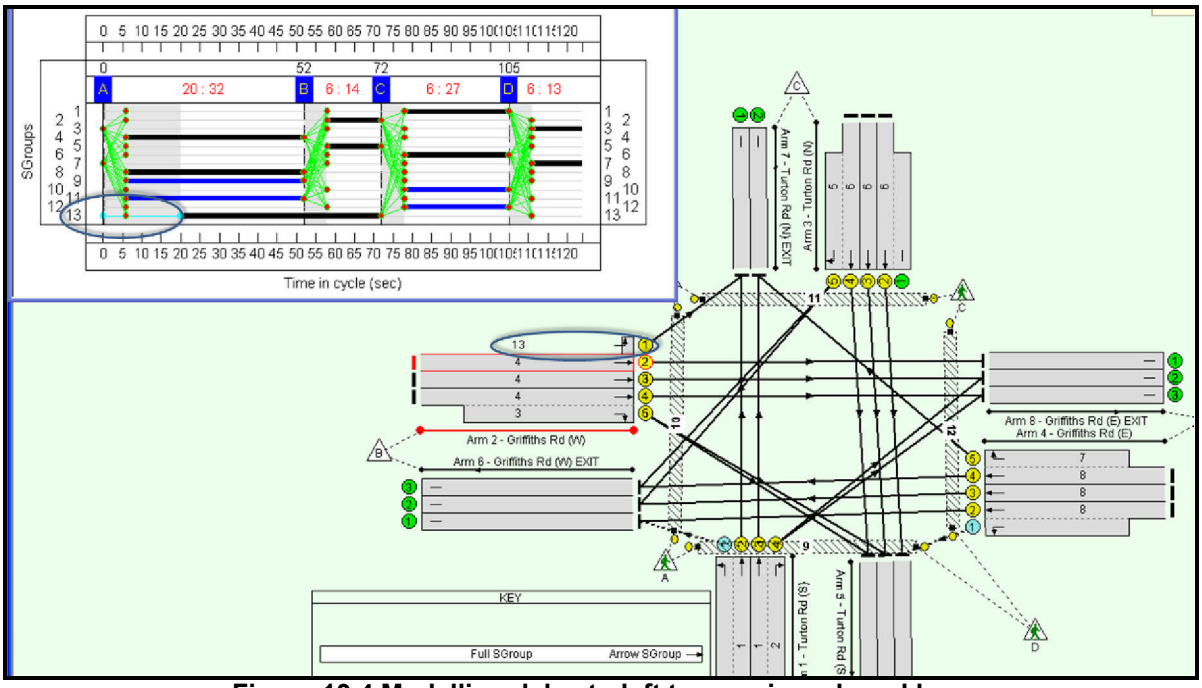


Figure 13.4 Modelling delay to left turners in a shared lane

13.3.7 Phase / signal group intergreens

The phase intergreen (or interphase) is defined in LinSig as the longest signal group intergreen (see Glossary). Signal group intergreen values must be entered for all conflicting signal groups and for a given phase transition they will all usually be the same. The only exception is where a signal group is controlling a late start or early cut off movement.

Historically default values of six seconds tend to be used, but intergreens do vary from site to site so care should be taken that the correct values are used as this directly impacts upon lost time and therefore capacity at the intersection. Acquiring the phase intergreen values for a signalised intersection is not always straight forward as they are stored in the controller personality. Data that includes the coded phase intergreens for each personality will be contained in the intersection controller specification, or alternatively, a phase clearance is specified in the SCATS Intersection Data. Whilst the SCATS phase clearance will not always be accurate, it does represent a good source of intergreen data for intersections.

13.3.8 Signal group delays

Signal group delays are expressed in seconds and there are three types:

Absolute signal group gaining delay – Used to delay the start of a signal group beyond the entered intergreen value. Absolute delay is measured from the end of the green of the preceding phase as shown in Figure 13.5.

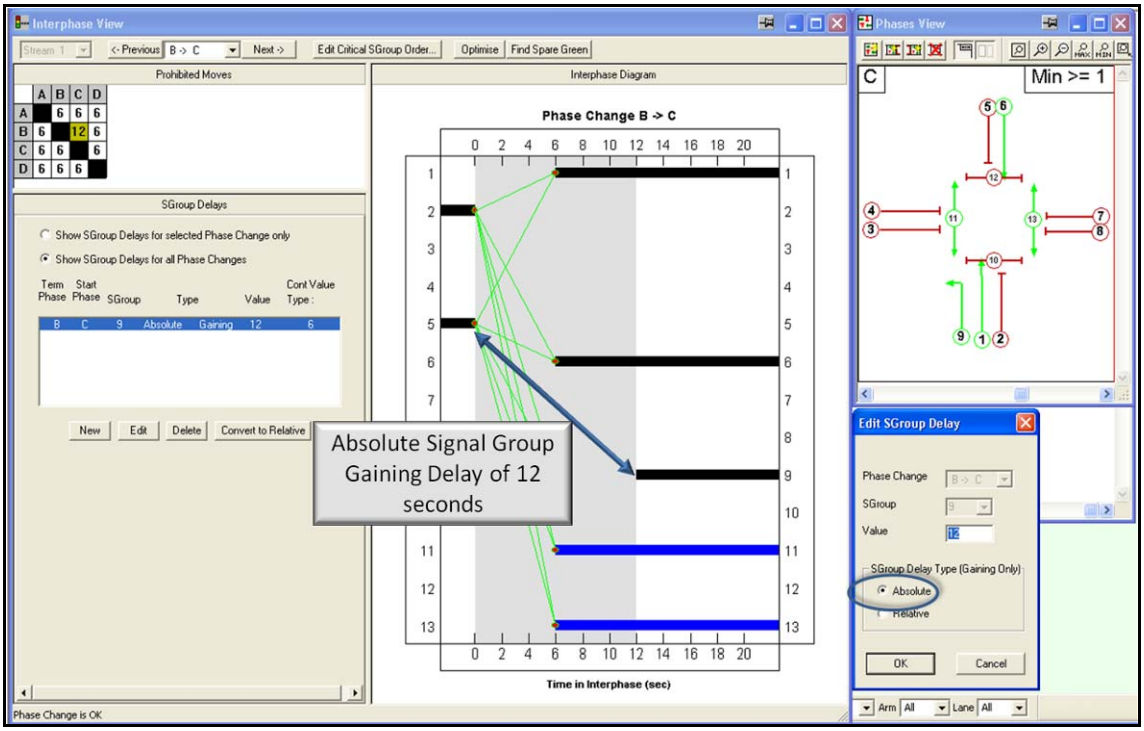


Figure 13.5 Absolute signal group gaining delay

Relative signal group gaining delay – Used to delay the start of a signal group beyond the entered intergreen value. Relative delay is measured from the start of green for other signal groups in the current phase. As shown in Figure 13.6.

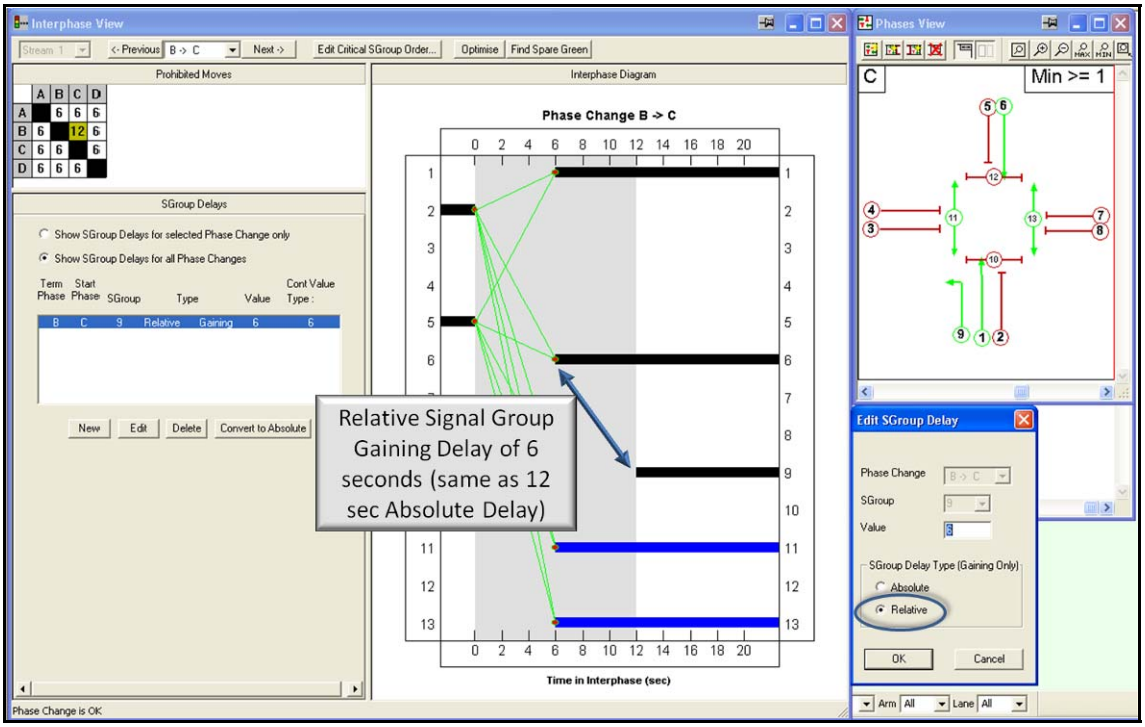


Figure 13.6 Relative signal group gaining delay

Signal group losing delay – Used to delay the end of the green for a signal group. It is a relative value measured from the end of green for other signal groups in the same phase as shown in Figure 13.7.

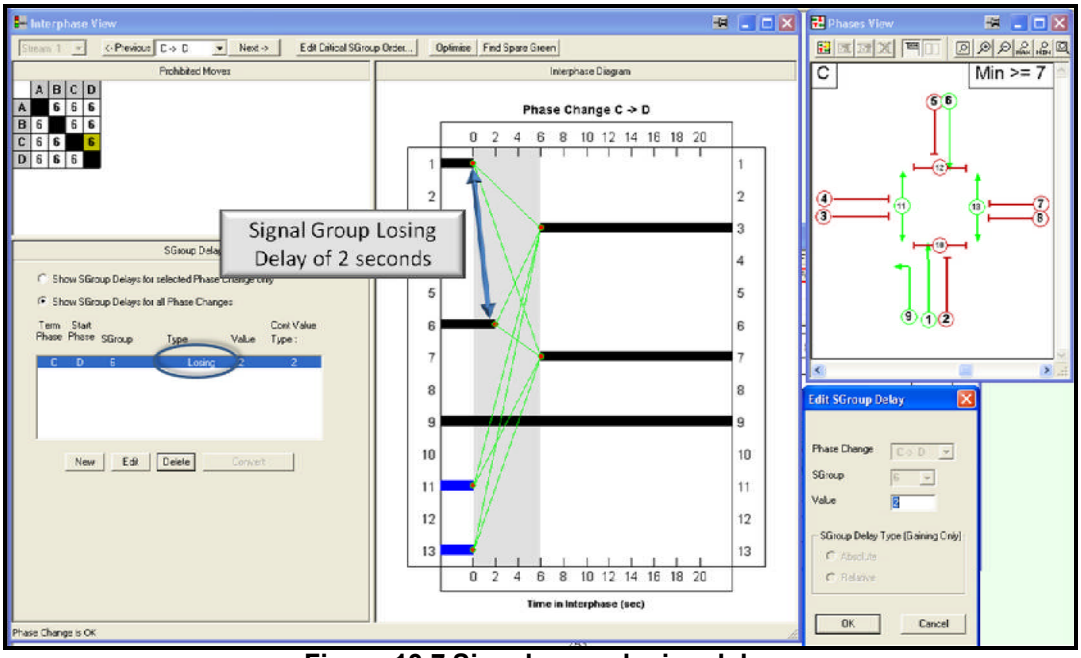


Figure 13.7 Signal group losing delay

Signal group delays provide a useful way of delaying the start or end of individual movements and should be used to simulate the following situations:

- Increased loss time that occurs to particular movements as a result of parallel pedestrian movements or underutilised green time.
- Increased effective green on particular movements as a result of yellow light that occurs in the existing network.

13.3.8	Proposed intersection designs should not incorporate adjustments for yellow light running. The design must work satisfactorily without the need for the additional capacity such an adjustment provides.

Using signal group delays in this way also makes the model easily auditable as it isolates the green time adjustments due to variable network characteristics, from the fixed phase intergreens.

13.3.9 Phase definition and sequence

Phases should be coded in accordance with the TCS plot for the intersection. Phase minimums will only be correctly defined if pedestrian signal group minimums are defined using the method previously described. While this method results in the pedestrian signal group being green for the entire phase, it ensures pedestrian walk and clearance times are not violated in the model.

13.3.9	Under this methodology, pedestrian delays cannot be extracted directly from the model. It is therefore recommended that if pedestrian delay times are required they be calculated using an external tool or spreadsheet.

Accurate phase minimums are critical; it is common for a phase controlling a side road and parallel pedestrian movement to have its minimum length dictated by the pedestrian clearance time rather than the volume of side road traffic. If this minimum is not correctly coded into LinSig the optimisation process could specify phase times that violate the side road phase minima and over estimate capacity on the main road.

The phase sequence must reflect the operational plan being run during the modelled time period. Care must be taken where phase alternatives exist as SCATS IDM data will not identify whether these phases appear during on-street operation.

13.3.10 Phase times

In a LinSig base model the phase times for each intersection should be based on the average times identified for the modelled period. Acquisition of these average timings is either via site observation or through tools such as SCATS IDM, SCATS Reporter or SCATS History.

13.3.11 SCATS IDM interpretation

A screenshot of SCATS IDM data is shown below in Figure 13.8. The modeller should use the Av per cent (average percentage phase times) column of the IDM table to calculate the average phase times. These percentage phase splits should be applied to the average cycle time for the controlling intersection in the model to ensure all intersection cycle times are equal (with the exception of those intersections that are double or triple cycling which can be coded as such). Using the average percentage phase times from the IDM data will also account for infrequently demanded phases.

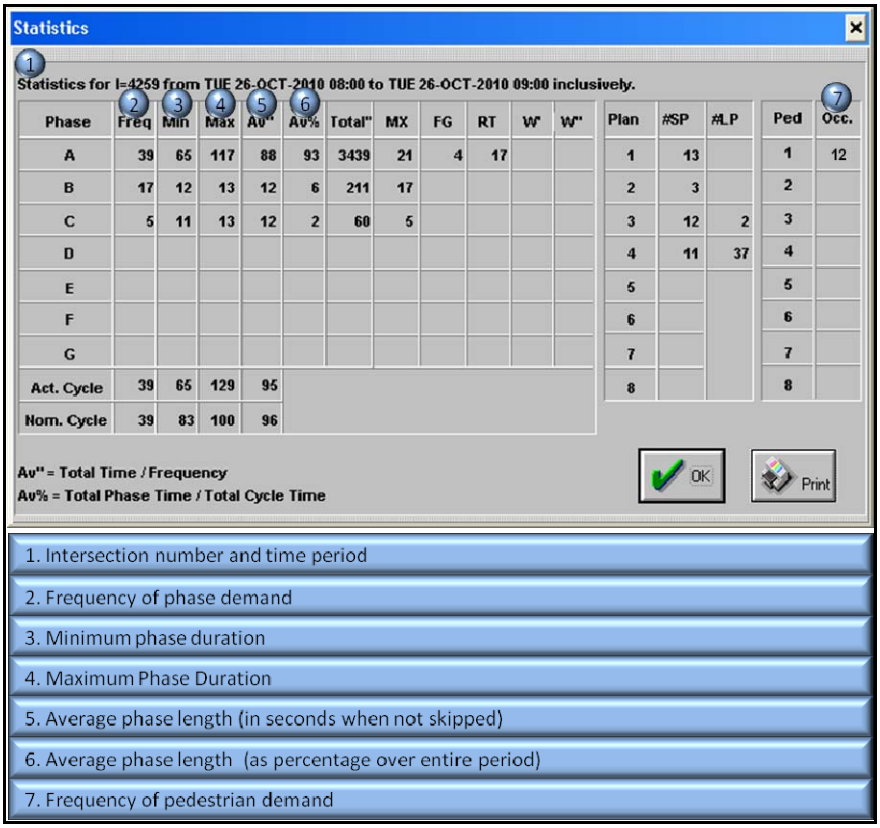


Figure 13.8 Scats IDM screenshot

13.3.12 Diamond overlaps

In the case of diamond overlap phasing, SCATS IDM data is not able to give the proportion of the green time that the diamond phase and alternative phase(s) receive. If the average green time received by these phase alternatives cannot be measured on site then an assumption should be made based on the opposing right turning volumes.

13.3.13 Infrequent phase demand

When a phase is not demanded, the green time it would have received is reallocated to another phase in the sequence that has a current detector demand. The modeller should account for this by modelling the hourly average phase times for the intersection in LinSig.

13.3.13	Example. At a three phase intersection, due to low demand, Phase B only runs in 50 per cent of the cycles during the AM peak hour. When Phase B fails to run, Phase A receives all additional green time. In a cycle that completes the full three phase sequence, phase times are: Phase A = 80 s Phase B = 20 s Cycle time = 80 + 20 + 30 = 130 seconds Phase C = 30 s The LinSig modelled phase times should be as follows: Phase A = 80 + (0.5 x 20) = 90 s Phase B = 20 x 0.5 = 10 s Cycle time = 90 + 10 + 30 = 130 seconds Phase C = 30 s

	The modeller should be aware that where a phase is rarely demanded, it is possible for the hourly average phase time to violate the phase minimum. If this occurs the appropriate LinSig signal group minimums should be reduced to allow this phase time to run, as the key concern is accurately modelling existing intersection capacity for the main movements. The modeller must be careful in applying the same assumption to future year scenarios as it may no longer be valid if side road demand has increased. In the case of SCATS controlled intersections the average percentage values of phase length from the IDM data will correctly account for infrequent phase demand.

13.3.14 LinSig network structure

Intersection approach arms should be numbered in a clockwise direction starting from the south. Such a convention is consistent with other modelling tools currently in use by RMS.

Exit arms should be included for each individual intersection modelled. Exit arms should be the last in the sequence of arm numbers for an intersection and should also be numbered in a clockwise direction starting from the south. The use of exit arms at each intersection allows geometric delay to be specified using the mean cruise time on the lane connector. All exit lane saturation flows should be specified as unconstrained with a nominal length of 1 pcu. Figure 13.9 provides an example of the above arm numbering convention.

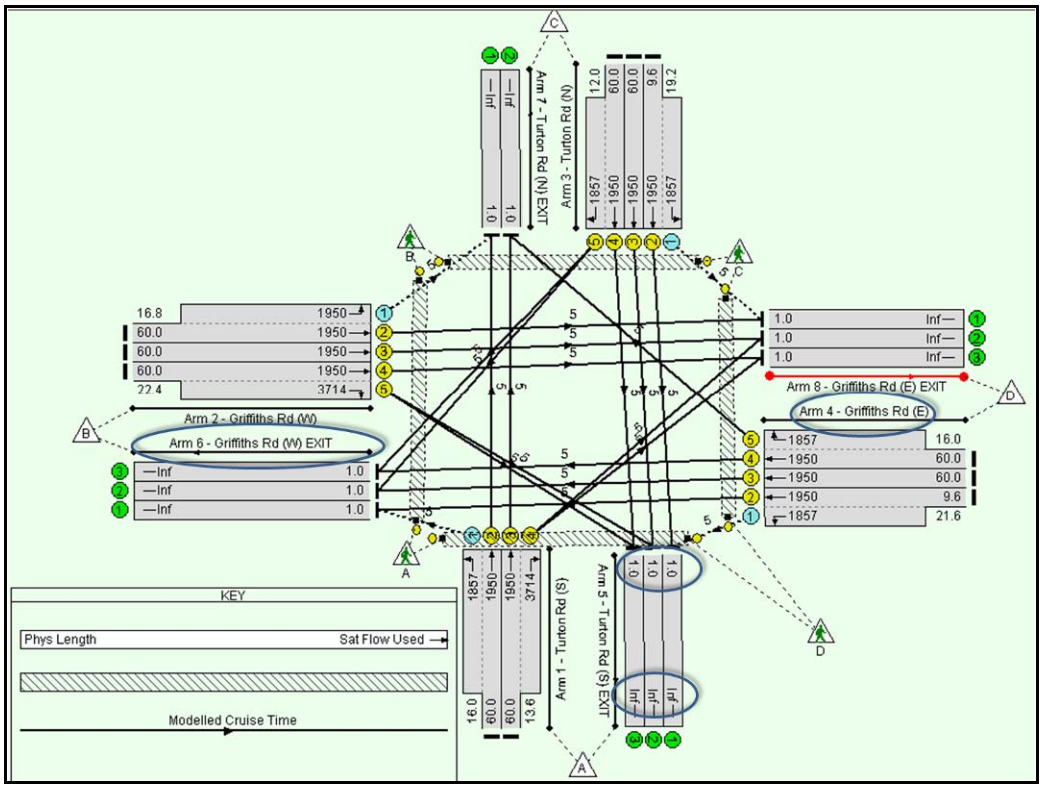


Figure 13.9 LinSig arm numbering

13.3.15 Lane data

The required lane data varies depending upon the type of lane and form of control under which it operates. Data that is consistent across all lane types are:

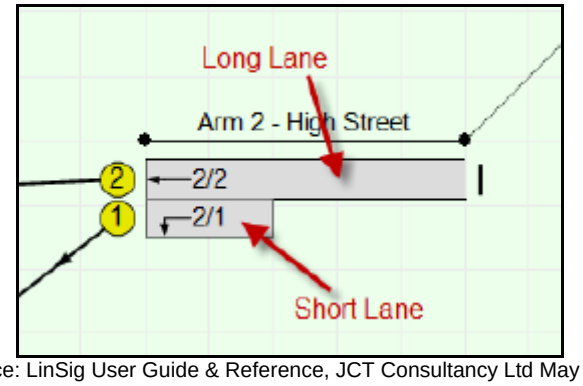
Physical lane length – This length is given in pcus and is measured from a point on the exit of the upstream intersection (usually the far side of any pedestrian crossing) to the stopline.

Saturation flow – These are a critical input to LinSig and the modelled values should be based on observed values wherever possible. LinSig has integrated the RR67 saturation flow calculation method based on intersection geometry. This should only be used where it is not practical to measure

saturation flow on street (eg where the intersection does not yet exist or traffic flows are not significant enough to enable measurement).

13.3.16 Short lanes

The LinSig short lane model works on the basis of a lane group, which consists of one infinitely long lane and one short lane. A short lane in LinSig must always be associated with an adjacent long lane which feeds traffic into it (see Figure 13.10).



Source: LinSig User Guide & Reference, JCT Consultancy Ltd May 2010

Figure 13.10 LinSig lane definition

Associating long and short lanes in such a way that enables the blocking effects that can occur to be modelled in detail. If we consider a lane group in isolation, there are two scenarios that can occur as traffic queues at the red signal:

Turn bay overflow – In the situation where there is a heavy demand for the turning movement the turn bay(s) may overflow and turning traffic will begin queuing in the long lane (see Figure 13.11). This causes a loss of capacity for the through movement, which varies depending on the point in the cycle the overflow occurs and for how long.

Turn bay starvation – In the situation where the through movement demand is heavy, the through traffic could queue back beyond the start of the turn bay. This prevents right turning vehicles from entering the turn bay(s) and a loss of capacity will occur to the right turning movement (see Figure 13.12).

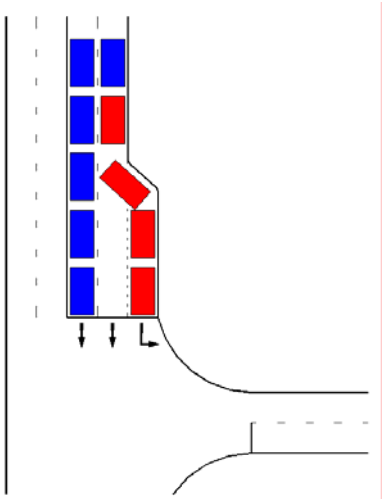


Figure 13.11 Turn bay overflow

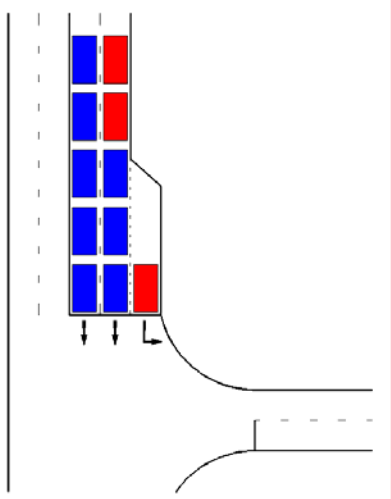


Figure 13.12 Turn bay starvation

13.3.17 Modelling multiple turn bays

LinSig version 3.0 only allows a single short lane to be associated with a long lane. This prevents accurate graphical representation of approaches that have multiple short lane turn bays, as is common in NSW. This issue is likely to be addressed in a future release of the software.

The current recommended method for modelling multiple right turn bays is highlighted below.

No matter how many turn bays are present for a particular movement they should always be modelled as a single short lane attached to the next continuous adjacent lane.

In the majority of situations the length of the short lane should be set equal to the combined length of all the turn bays it represents. This lane structure will accurately predict the effects of turn bay overflow.

The only exception is where the through movement consistently blocks access to the turn bays. In order to model these effects accurately, the turn bay should be specified to be of a length equal to the longest turn bay. This lane structure will accurately predict the effects of turn bay starvation.

In both situations the LinSig short lane saturation flow needs to represent the effective saturation flow provided by all the short lanes it represents. Effective saturation flow can be calculated using the equation shown Figure 13.13.

Figure 13.13 Multiple turn bay saturation flow example

Source: Adapted from Google maps, AECOM March 2011

TBl_1 = Turn bay length lane 1 (pcu)

TBl_2 = Turn bay length lane 2 (pcu)

TBs_1 = Turn bay lane 1 saturation flow (pcu/hr)

TBs_2 = Turn bay lane 2 saturation flow (pcu/hr)

g = Green time (sec)

Where $TBl_1 > TBl_2$ and $TBq_2 < g$

Calculate vehicle headway for shortest lane $(TBh_2) = 3600 \div TBs_2$

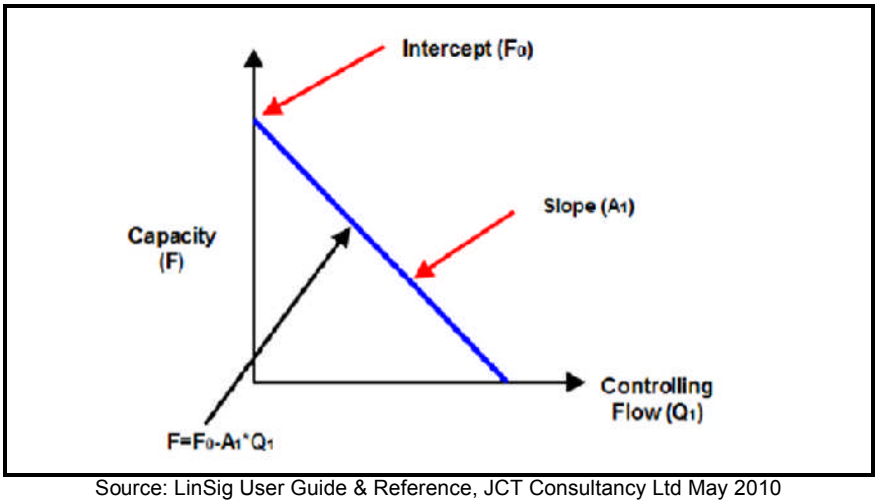
Calculate queue clear time for shortest lane $(TBq_2) = TBl_2 \times TBh_2$

$$\text{Effective saturation flow} = \frac{[TBs_1(g - TBq_2)] + [(TBs_1 + TBs_2) \times TBq_2]}{g}$$

13.3.17	Should the green time for the movement be less than or equal to the queue clear time for the shortest lane, then the effective saturation flow is equal to TBs1+TBs2

13.3.18 Give way parameters

Unlike tools such as SIDRA, the LinSig give way model is not based on gap acceptance theory, but on a linear relationship between the controlling (opposing) flow and the give way lane capacity. This relationship is based on research conducted in the UK by Kimber & Coombe and is presented in TRRL Supplementary Report SR 582 “The traffic capacity of major/minor priority junctions”. This relationship is demonstrated in Figure 13.14.



Source: LinSig User Guide & Reference, JCT Consultancy Ltd May 2010

Figure 13.14 LinSig give way model

The maximum flow and coefficient values must be entered for each lane that exhibits a level of priority control, namely:

- Priority controlled intersections or movements (eg left slips).
- Filter right turns at signalised intersections. These have further data entry requirements relating to storage space within the intersection. Advice on these parameters can be found in Section 3.3.7.3 of the LinSig user guide.
- Roundabouts.

Default parameters for a range of situations are given below in Figure 13.15. Refinement of these values based on site specific observations is important given these default values have been developed from UK based research and it is not yet clear whether these results are valid in an Australian context. Particular care should be taken when applying defaults in the following situations:

- At roundabouts, the geometric characteristics play a large part in defining capacity, so the application of default parameters is not recommended. It is essential to calculate the maximum flow and coefficient values using the Design Manual for Roads and Bridges (DRMB) formulae and to then further calibrate these based on queue length measurements.
- At left turn slips the default maximum flow value assumes there is no merge lane available. Where merge lanes are used, this value should be increased based on the length of the merge.

An improvement upon the default values is to calculate specific give way parameters using formulae based on intersection geometry and presented in the DRMB Volume 6 (TA 23/81).

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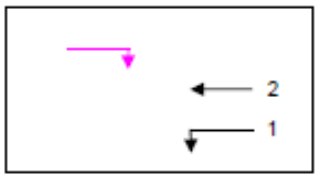
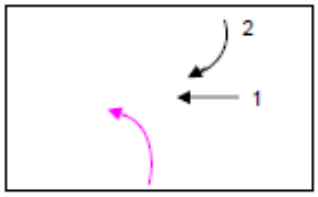
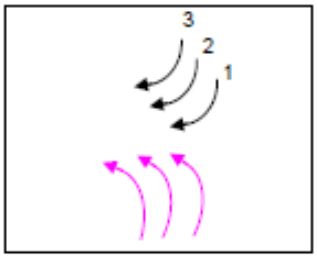
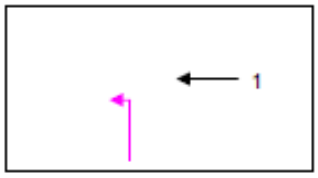
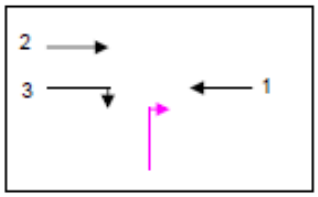
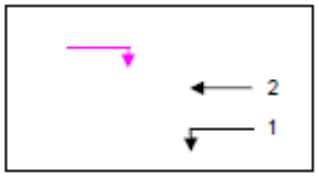
		Opposing Link	Coefficient	Opposed Max Flow (Intercept)	Sat Flow when Opposing Traffic is stopped
	SIGNAL JUNCTION – Opposed Movements				
1	 Right Turn Opposed Movement	1 2	1.09 1.09	1439	Lane Sat Flow
2	 Left Turn Give Way Slip	1 2	0.22 0.22	715	Maximum Flow
	NO SIGNALS – Roundabout Entry				
3	 Give Way at Roundabout per lane	1 2 3	0.33 0.33 0.33	1000 (per lane)	Maximum Flow
	NO SIGNALS – Priority Junction				
4	 Left Turn Give Way	1	0.22	715	Maximum Flow
5	 Right Turn Give Way	1 2 3	0.22 0.19 0.19	600	Maximum Flow
6	 Right Turn Opposed Movement	1 2	0.35 0.35	850	Maximum Flow

Figure 13.15 UK Default give way parameters

13.3.19 Matrix estimation and traffic assignment

The main method for entry of traffic demand in LinSig is via demand matrices and a delay based equilibrium assignment. Very often however, particularly for smaller traffic networks, the only demand data available is intersection turning counts. LinSig can synthesise a demand matrix based on these turning volumes and the process is described previously. If a demand matrix has been acquired either

through origin-destination surveys or manual calculation then the modeller can proceed directly to the traffic assignment.

13.3.20 Flow balancing

LinSig is able to synthesise a demand matrix from intersection turning counts but the quality of this calculated matrix and resulting assignment is highly dependent upon a set of quality, balanced intersection turning counts. In this instance the term balanced turning counts means all intersection inflows = intersection outflows.

In a network of intersections the raw classified turning counts collected through surveys will very rarely achieve this balance. The key reasons being:

- Survey data can only be collected to a certain degree of accuracy.
- Traffic entering and leaving unsurveyed side roads.
- Adjacent intersections may have been surveyed on different days.

It is therefore highly recommended that the raw turning counts are processed so that a balanced set of demands are used by the LinSig assignment. Any adjustments made to the raw data should be documented to enable review; this is best done via a network flow diagram that shows the surveyed and adjusted values along with notes justifying major discrepancies. As a general rule, the higher value should be used for flow balancing. An example of a simple flow diagram is shown in Figure 13.16.

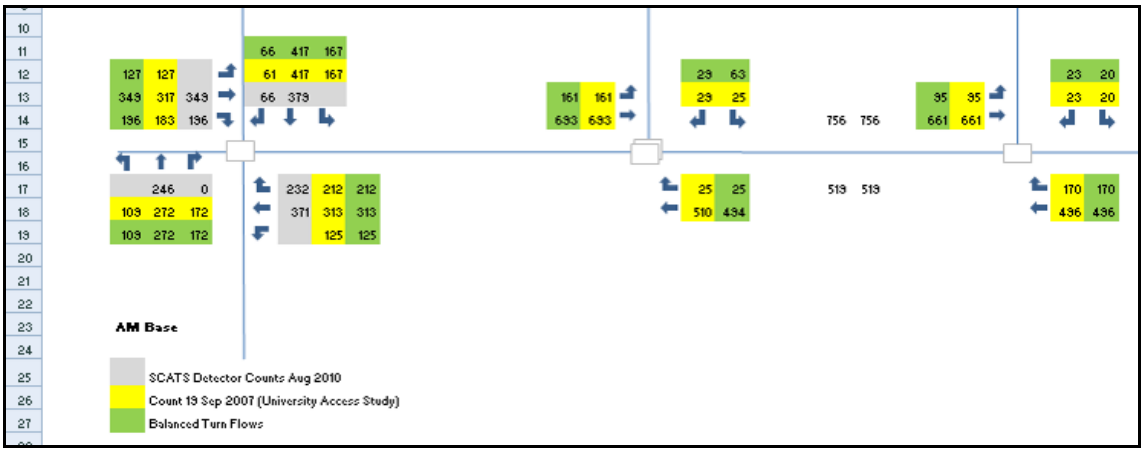


Figure 13.16 Network flow diagram

The danger of not using a set of balanced demands is that:

- LinSig may not be able to reach a converged assignment solution.
- LinSig is more likely to produce a set of unrealistic zonal demands.
- The assignment process can take much longer.
- Checking and auditing of assigned traffic volumes becomes very difficult.

13.3.21 Matrix estimation

The matrix estimation and assignment processes are very closely linked and need to be run iteratively. If matrix estimation is being used, all intersections in the model should have turn counts entered and these should be based on the above balanced counts not the raw survey data. If counts are only entered for some intersections or major flow discrepancies exist then the estimation process is likely to produce poor results.

13.3.21	A modeller using their local knowledge of the network to correct count discrepancies before entering these as junction turn counts will always result in a higher quality estimation than leaving LinSig to produce an estimation based on inconsistent data.

13.3.22 Traffic assignment

Having defined an origin destination matrix, either through estimation, or as a direct input, the demand then needs to be assigned onto the model network. The traffic assignment works on a lane by lane basis, meaning routes are made up of sequences of lanes (and lane connectors) taken by traffic through the network. The demand is then assigned to these routes so no other route for a given O-D pair will result in a lower level of delay. This is a complex process as the volume of traffic assigned on a particular route affects the level of delay experienced by all other routes that share at least one lane for part of their length.

The assignment process needs to be run a number of times to ensure that the network is coded correctly and the model reflects any onsite observations of lane utilisation. In general where two lanes share the same movement and signal group, it would be expected that the amount of delay and DoS for these lanes should be roughly equal (this is not true where lane under utilisation exits). Key things to look out for during the process are highlighted in Table 13.3.

Table 13.3 Traffic Assignment Issues

Issue	Issue type	Possible solution
There is a desired flow for an O-D pair but the actual flows are zero	Matrix	The sequence of connectors necessary to allow traffic to travel between the two zones have not been coded.
Desired junction turn count for a movement does not match actual	Assignment	Unbalanced traffic flows entered. Missing counts for a movement. Insufficient weave connectors to enable enough upstream traffic to make the turn. There are a number of unrealistic routes through the network, eg u-turns.
Adjacent lanes sharing same movements and signal group have very different levels of delay	Assignment	There are insufficient upstream weave connectors to enable the traffic to distribute across both lanes. An associated short lane, with a different movement (eg turn bay) overflows during part of the green.

13.3.23 Weave connectors

Lane connectors that allow traffic to weave across lanes between intersections are an important component of a LinSig model. Weaving is inherent to multi-lane roads, as vehicles need to manoeuvre into the required turning lane. Lane connectors are required to permit these weaving movements in LinSig, but care should be taken that the number of connectors is kept to the minimum required to reflect on street operation. This is because each connector in the model adds to the total number of possible routes traffic can take through the network and this has a major impact on the speed of the traffic assignment process.

13.3.23	TIP: Connect weave connectors to an unconstrained lane (such as an intersection exit arm) as this prevents the model incorrectly reporting the build up of sliver queues on the downstream link (see Section 13.3.25 on Sliver Queues for further information). TIP: When building your network, start with the bare minimum of connectors required to get all the “actual” network demands and junction turn counts to match the “desired” values. Then begin adding weave connectors to balance lane delays as necessary. Remember to rerun the assignment after each change and once satisfied with the lane connector structure run the matrix estimation a final time to ensure all the new routes are taken into consideration.

13.3.24 Manual adjustment of routes

Following an initial assignment it is always necessary to go through the identified routes to confirm their validity. In a number of situations the automatic estimation and assignment process will not produce accurate results because it is assigning traffic to invalid or unrealistic routes. In these situations it is the responsibility of the modeller to manually adjust the routes identified during the assignment. The main reasons for manual adjustment of routes are:

- The modelled network includes a roundabout or U-turn movements and LinSig has assigned unrealistically high volumes to these routes.
- Bus lanes are in the model and usage needs to be restricted to public transport vehicles.
- Underutilisation of lanes needs to be captured.

Routes can be manually adjusted via the Route List View. Those routes that are unrealistic or are banned should be set as impermissible. To force the level of utilisation of a lane to match on-street conditions or restrictions, the route flows must be manually entered and then locked to prevent the assignment process from rebalancing the flows if it is run at a later date. The level of underutilisation due to downstream merges should be refined based on site observations.

13.3.24	TIP: If a u-turn manoeuvre at a roundabout or intersection is permitted, but very few vehicles are observed to use it and those that do have no impact on overall intersection capacity, consider removing the u-turn connector and ignoring those u-turning vehicles.

13.3.25 Sliver queues

Sliver queues are in effect phantom queues that can occur in a LinSig model but not on street. They are identified using the queue graph by having a high back of queue value, but a low number of vehicles in the queue (see Figure 13.17). The main causes are:

- In LinSig vehicles are modelled as travelling at cruise speed along a lane, until they hit a red light at a signal stopline. In reality if a queue exists at a stopline but is beginning to move off, drivers travelling along the lane will reduce their speed and never actually join the back of it.
- If two connectors are feeding into the same lane, the arrival rate of traffic from the two feeding lanes can exceed the rate at which they can leave the single lane and so a queue forms. In the case of short merges on the exit of intersections this queue maybe valid (although LinSig tends to overestimate the extent of these queues), but if the merge occurs over a long distance or the two connectors are representing a weaving movement of traffic as they travel along the lane, the resulting queue is not realistic.

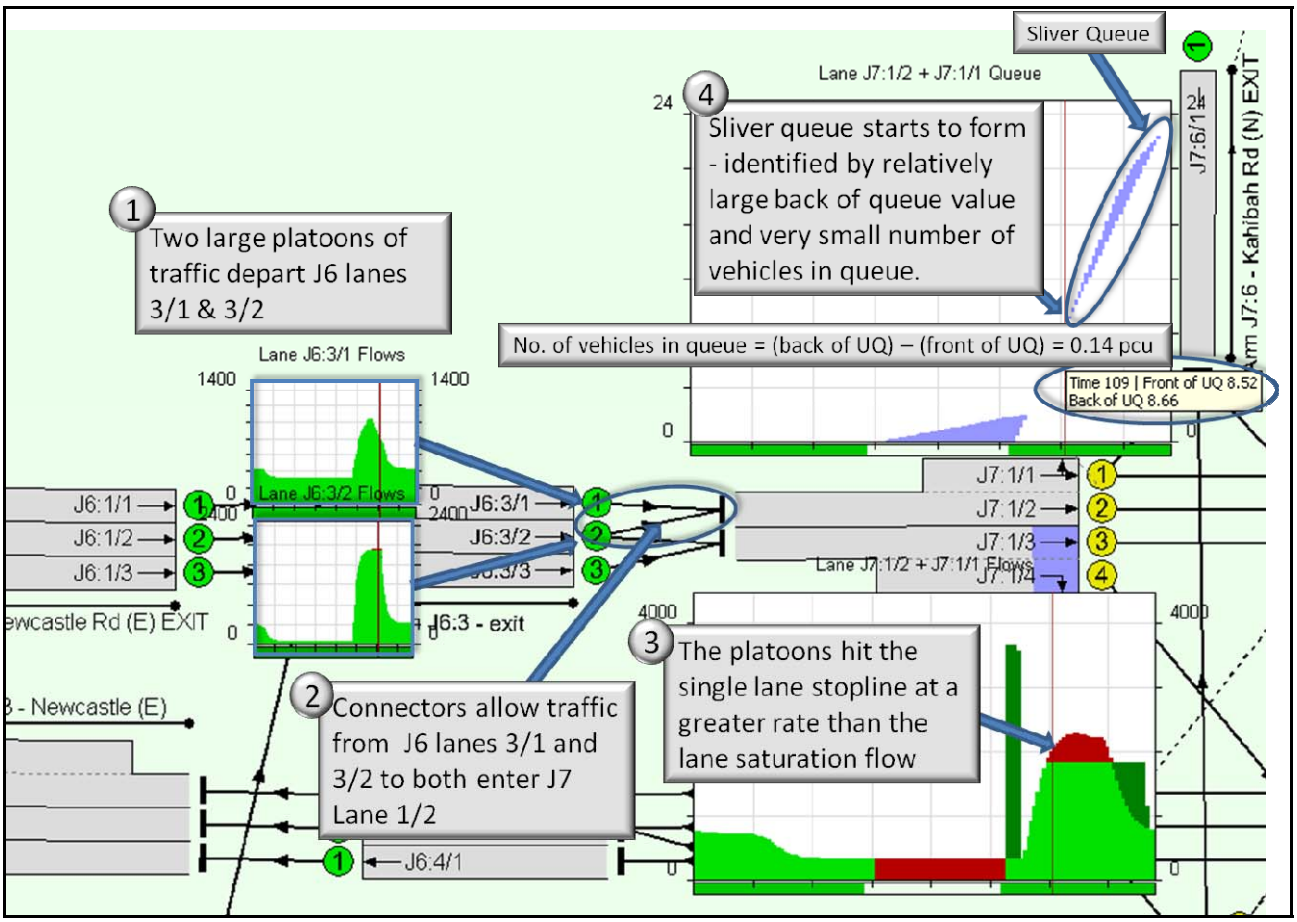


Figure 13.17 Example of sliver queue

The modeller can take a number of steps to reduce the occurrence of these sliver queues and to prevent them from providing an unrealistic reported mean max queue:

- Only provide weave connectors to unconstrained lanes, such as intersection exit lanes. Whilst this does not strictly show the correct point at which the weave occurs, it prevents a sliver queue occurring because the capacity of the unconstrained lane is higher than the feeder lanes.
- Use the de-sliver threshold to specify that a queue of excessive length, but containing a minimal number of vehicles is a sliver queue and therefore invalid. This value should never exceed two pcus and should never be used as a parameter to calibrate queue lengths.

13.3.25	LinSig is primarily a tool focused on traffic signal operations. It cannot accurately model the midblock delay caused by merges and side friction behaviour such as parking or stopping buses. These effects can be accounted for through longer connector mean cruise times to ensure signal offsets are accurate, but this requires collection of cruise times on street. If detailed assessment of midblock capacity constraints is required, microsimulation is better suited to this task.

13.3.26 Public transport

In order to assess public transport in LinSig additional origin destination zones are recommended for all public transport routes in the model. These zones must only contain public transport trips and will need to be fed into and out of the network via dummy arms as shown in Figure 13.18. If the model is using pcu values, public transport trips should also be specified in pcus. The available routes LinSig identifies between these public transport zones then need to be analysed via the “Route Lists View” and any unrealistic routes disabled. Where bus only lanes exist the same menu should be used to exclude general traffic routes from these lanes. Following correct coding of public transport routes and their network, the route journey times and delay per vehicle can then be extracted from the “Travel time/Delay Matrices” view.

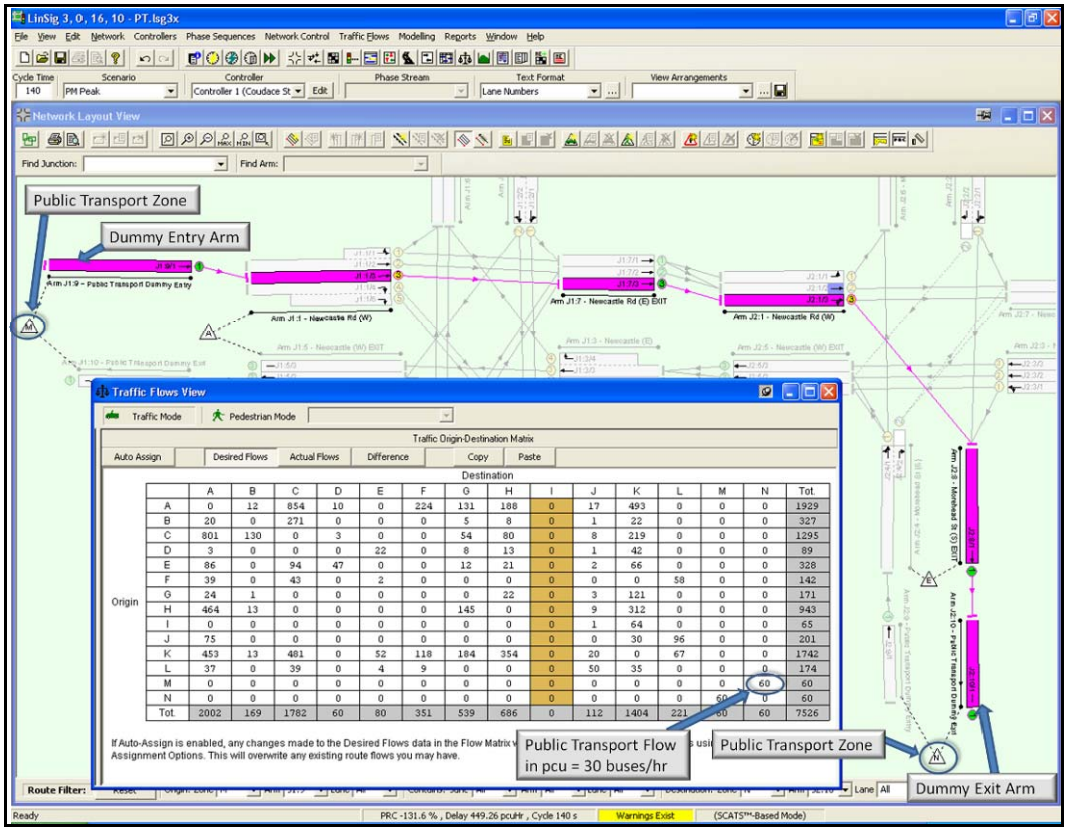


Figure 13.18 Public transport network coding

The above process of disabling invalid routes can be lengthy, particularly if it is a large network with public transport vehicles running in a mixture of general traffic and bus only lanes. Within LinSig 3.0 there are no tools specifically designed for public transport assignment, necessitating the current approach. JCT have however indicated their intention to add functionality that makes working with public transport routes more streamlined in later versions.

13.4 LinSig calibration requirements

The calibration of LinSig models requires the collection of site data which is used as a basis to make adjustments in the model to replicate current performance. In the vast majority of instances it is not sufficient to take default model values and parameters and achieve a level of realism in the model that gives confidence in its accuracy and ability to forecast future operations. Each intersection is unique; not only in terms of geometry and traffic flow patterns, but also in terms of activities that occur in close proximity such as parking and loading, pedestrians, underutilised green time and road condition. All of these influence approach capacity and many of the characteristics can vary by time of day. Default parameters are not able to capture all these interactions and the modeller cannot hope to account for them without a site visit and appropriate site data. This section highlights some of the key calibration parameters and how to incorporate them into a LinSig model.

13.4.1 Saturation flows

Each lane at a signalised stopline will exhibit a unique saturation flow based upon intersection characteristics such as geometry, turning radii, visibility, on-street parking, proportion of turning traffic and pedestrian activity. Whilst there are methods available for estimating the effect of these characteristics on saturation flow (eg AustRoads[15] and RR67[16]) they cannot capture all the complex traffic interactions and it is recommended saturation flows are measured on-site for all critical movements. Advice on the manual collection of saturation flows can be found in the HCM 2000[17] and ARR 123[18].

[15] AustRoads Guide to Traffic Management Part 3, Section 6.4.2
[16] Transport Research Laboratory (UK) RR67 Report
[17] Highway Capacity Manual Chapter 16 Appendix H, TRB
[18] Traffic signals: timing and capacity analysis, R. Akçelik, ARRB

13.4.1	The potential exists to make use of the SCATS Maximum Flow (MF) parameter, which provides a good estimation of lane saturation flow. To calculate a lane saturation flow from SCATS MF use the following equation: $$\textit{Lane saturation flow (veh/hr)} = \frac{\textit{Total phase time x SCATS lane MF}}{\textit{Phase green}}$$ SCATS MF Data may be made available by RMS. Contact the Manager, Traffic and Transport Modelling if MF Data is required.

13.4.2 Lane underutilisation

Lane underutilisation can occur for a number of reasons, the most common of which are listed in Table 13.4. The modeller needs to conduct a site visit to understand if these conditions are present in the network so that they can include the correct modelling adjustments.

Table 13.4 Causes of lane underutilisation

Cause of Lane Underutilisation	Accounted for in LinSig
Downstream lane designations and predominant turning movements cause one lane to be more attractive than the other	Yes (if correct lane connectors are coded)
A large number of heavy/slow moving vehicles in lane	Yes (if correct lane saturation flow is used)
Opposed right turns from the lane	Yes
Turning movements from the lane delayed by pedestrians	Yes (if correct level of delay is modelled using dummy signal group)
Short lane on the approach	Yes
Public transport vehicles stopping in the lane	No
A downstream merge of lanes or traffic flows	No

Of these the majority are accounted for automatically in LinSig, but two key causes require manual identification and adjustment of the model:

- Public transport vehicle stops are located in the lane.
- A merge on the exit of the intersection makes one lane less desirable than the other.

As discussed previously these effects need to be incorporated into the model through manual reduction and locking of route flows.

13.4.3 Delays to turning traffic

As a result of parallel pedestrian movements, left and right turning vehicles at most intersections receive additional delay as they give way to crossing pedestrians. This effectively results in the first part of the green signal being unusable by turning vehicles. The amount of vehicle green time that is lost is dependent upon the number of pedestrians crossing, the crossing distance, walking speed, frequency of pedestrian phase demand and the length of the green man invitation. Where there are high levels of demand for pedestrian or vehicle turning movements the extent of these delays needs to be measured on street. Where pedestrian and turning movement demand are low, it is sufficient to make an assumption on the amount of additional delay based upon the length of the green man and pedestrian clearance periods. Delays to turning traffic should be represented in LinSig using Signal Group Delays as described in previously.

13.4.3	The use of site measured turning vehicle delay due to the presence of pedestrians is particularly important in areas of high pedestrian activity as it is the only method that will capture these delay effects to traffic. As pedestrians can continue to commence crossing during the flashing red man the variability of this delay can be significant.

13.4.4 Underutilised green time

In congested urban networks, exit blocking or slow moving downstream queues can occur frequently resulting in the underutilisation of the available green time on an approach. When this occurs it has a significant impact on intersection capacity and must be incorporated into the LinSig model. The phenomenon of queues extending back from a downstream intersection are not automatically identified and accounted for in LinSig. In the case of base models, the modeller must observe when this occurs on-street and be able to quantify it so that it can be incorporated into the model.

There are two ways in which exit blocking or slow moving queues can be accounted for:

- Reduction of effective saturation flow – The lane saturation flows can be reduced to reflect the slower rate of discharge across the stopline as a result of the exit blocking. This method best replicates the effects of a continuous slow moving queue during the available green time for the lanes in question. At SCATS intersections the MF, VO, VK and DS values can be used to calibrate these reduced saturation flows.
- Reduction of effective green time – The signal group green time for the lanes that experience exit blocking can be reduced to reflect the fact that for part of the green signal no vehicles are able to leave the stopline. This approach best models the effect of downstream queues that extend back to the upstream intersection for a part of the green period, but are then released allowing traffic to be free flowing for the rest of the green. This is best modelled either by introducing a dummy all-red signal phase or by applying a signal group phase delay for the effected movement.

In the case of future year models the modeller must be able to identify when a modelled queue is forecast to exceed the storage capacity of the link and take measures to prevent this occurring (such as the use of excess queue weightings). If it is not possible to prevent it then, the model needs to be adjusted to account for the reduction in capacity that it causes.

13.4.4	Be aware that both of the above methods for accounting for underutilised green time need to be removed before carrying out any signal optimisation. The calibration measures are dependent upon the signal timings in operation and as such calibration adjustments to saturation flows or green times are not likely to be valid for ant future set of signal timings.

13.4.5 Yellow light running

If drivers make excessive use of the yellow light at the end of a phase it may be necessary to account for this by increasing the effective green for the movements on which this occurs. This can be done using signal group delays as outlined previously. The length of the additional green time provided should be based on site observations and should never exceed the length of the yellow signal.

13.5 LinSig validation requirements

Validation of base LinSig models is essential as it provides proof of the accuracy of the model's representation of the current road network. Provided that the only model parameter changes in the future scenario models are those relating to the planned network or demand options, the model outputs can be thought to be reliable.

13.5.1 Queue length

Queue lengths give a useful indication of un-serviced demand and lane utilisation, but as a LinSig model validation parameter it is unreliable. It is popular as a validation parameter due to these data being readily collectable by survey companies and a visual, easily understood indicator of intersection performance. The issue with the use of queue lengths is twofold:

- Whilst survey companies are able to provide queue lengths as standard it is often difficult to define whether a vehicle is actually queued or not and a queue will vary considerably depending on the point in the signal cycle time at which it is measured.
- Queue lengths become highly variable on approaches that are operating at or close to capacity. As such LinSig struggles to provide an accurate prediction under these conditions and unless the site

observations are based on a large sample size, the surveyed average queue length may not be representative.

If it is to be used the modeller should ensure that the queue at the start of green is that captured, rather than queue lengths at arbitrary points during the survey period.

13.5.2 Degree of Saturation (DoS)

DoS is a ratio of traffic volume ÷ capacity (expressed as a percentage) that is provided as an output by LinSig to provide an indication of how close to capacity an approach is operating. For validation purposes the DoS should be measured on-street for each lane or group of lanes. An outline method for collection of these data can be found in the Transport for London Modelling Guidelines[19].

This represents the best validation criteria for LinSig models. Provided base models are built using stopline turn counts no lane DoS should exceed 100 per cent, if they do this indicates an error in the model that needs rectifying. DoS validation should be to within ±five per cent on critical approaches to ensure delay and queues on these approaches are correctly represented.

13.5.2	It should be noted that for new intersection designs a DoS of no higher than 90 per cent should be aimed for. This is what is known as the practical operating capacity, above this threshold (due to random traffic arrival patterns and driver inattentiveness) queues and delays can become excessive. Where this is not possible due to existing traffic congestion the project should aim to improve upon the base case DoS.

13.5.3 Journey times

Due to the way LinSig simplifies midblock traffic flows and does not account for side friction from activities such as parking and loading, it can often be difficult to accurately model corridor journey times. There can also often be difficulty in capturing a sufficiently large sample of observed journey times during the peak hour to ensure the average observed value is not skewed by one or two outlying runs. For these reasons modelled journey times within 15–20 per cent of an observed average (dependent upon corridor length) can be deemed validated.

13.5.3	Development of future year scenario models should only commence following satisfactory validation of the base models. Using a copy of these models as the starting point, the future year network can then be coded, leaving all parts of the model that are unaffected by the future year scenarios unchanged from the base model. In this way the calibration and validation can be retained with only the relevant changes re-coded in the model.

13.5.4 Cycle time optimisation

LinSig has a cycle time optimisation tool that plots Practical Reserve Capacity (PRC) and delay for a range of cycle times. From this the modeller can identify an optimal cycle time for use with the network. In practical terms the cycle time impacts not only on intersection delay and capacity but also on pedestrian delays, queue length and coordination. As a result of this cycle times are often constrained by factors other than those considered in the LinSig cycle time optimisation process. To ensure the correct cycle time is adopted for the network, RMS guidance should be sought on a project by project basis.

13.5.5 Signal timing optimisation

The signal timing optimisation tool represents one of the main features of LinSig. Through a number of the settings discussed in this section the modeller can tailor the level of optimisation and bias certain movements or corridors.

In order to properly identify the effects of future network and/or demand changes on the existing operation of signalised intersections then the timings obtained from a calibrated model of existing conditions should be compared with those obtained from the LinSig optimised timings. In this way

[19] Transport for London Modelling Guidelines Version 3 Part B section 2.4.8, TfL September 2010

differences can be compared and an explanation provided as to why they may exist. This comparison is useful in identifying:

- Incorrect model assumptions in respect of traffic behaviour (saturation flows, delays due to pedestrians, queue storage space etc).
- Incorrect model assumptions in respect of signal operation assumptions (ie alternative phase calls, phase skipping, offset, cycle times, minimum greens, clearance times etc).
- Incorrect SCATS setup.

Table 13.5 provides a summary of the steps involved to properly distinguish between an optimised existing model and SCATS operations to avoid future scenario assumptions being erroneously attributed to "improving" SCATS operations. These steps also ensure that the real value of infrastructure works or signal operation changes are identified.

Table 13.5 Suggested method for distinguishing optimiser effects

Step	Description	Outcome
1	Establish existing calibrated/validated model that reflects SCATS operations and observed saturation flows.	Calibrated existing model
2	Re-run model from step 1 with appropriate optimiser settings(1)	Optimised existing mode(2)
3	Compare calibrated and optimised models and provide description and explanation of differences.	Summary of differences make decision to amend & re-run (or not)
4	If required under Step 3 then, make changes to previous models, re-run and compare to the revised calibrated existing model.	Provide discussion on differences.

Notes (1) The optimisation process should be based on intersection/network delay with common cycle time generally reflecting the master intersection in the sub system. Other optimiser settings may well be appropriate depending on SCATS setup in the vicinity. Traffic Network Operations staff can help identify local SCATS settings.

(2) Depending on the scenarios to be examined it may be appropriate to use the optimised existing model as the base for comparison purposes.

13.5.5	Timings obtained from a calibrated model of existing conditions should be compared with those obtained from the LinSig optimised timings. Differences can be compared and an explanation provided as to why they may exist. Table 13.5 provides a summary of the steps required to distinguish optimiser effects when undertaking any analysis involving LinSig optimisation. When calculating future option assessment signal timings, the LinSig optimisation process should generally be constrained to the RMS standard signal diagrams (see section 14.2.9 for examples) with appropriate pedestrian behaviour also reflected.

13.5.6 PRC or delay optimisation?

LinSig comes with two methods for signal optimisation: delay based and PRC based. As the names suggest the former aims to find a set of signal timings that minimises network delay whilst the latter maximises network capacity. It is recommended that delay optimisation be used in LinSig as this most closely matches the SCATS optimisation model (albeit without the same optimised solution).

13.5.7 Optimiser weightings and queue constraints

The traffic signals optimiser in LinSig will produce a set of signal timings that provide the lowest level of total delay across the entire network (provided delay optimisation is used). However, the control objectives for the network may not be focused on minimising network delay but may instead be attempting to maximise capacity for a particular movement along a corridor, eg AM peak citybound movement on an arterial corridor. The modeller can influence this optimisation to achieve the overarching objectives through the use of three parameters that are applied to each lane as necessary:

- ***Stops weighting*** – This parameter factors up the cost associated with a vehicle stopping in the lane, causing the optimiser to provide the lane with additional green time or a more favourable offset, so that the number of stops is reduced.
- ***Delay/DoS weighting*** – Depending upon the type of optimisation being carried out, this parameter factors up the cost associated with delay or DoS in the lane, causing the optimiser to provide the lane with additional green time or a more favourable offset, so that delay or DoS is reduced.
- ***Queue constraints*** – These can be used to keep queue lengths below the available storage space for the lane. The excess queue limit specified as part of this parameter acts as a threshold above which penalties are given to either delay or DoS. If appropriate values are entered, this encourages the optimiser to find a set of timings that prevent the queue in the lane exceeding available storage space.

These weightings need to be carefully refined. Apply factors that are too high and the optimiser can increase delays, queues and DoS on side roads to unacceptably high levels. If the factors are too low then the lane will not have sufficient importance in the optimisation process to override competing approaches.

13.6 LinSig outputs

One of the major strengths LinSig has is the ability to adapt the model outputs and present them in a Microsoft Word format report. This allows reports to be tailored to the project type and project sponsors requirements. The following sections give a little detail on some of the key outputs and appropriate considerations, for more detail please refer to the LinSig user manual.

13.6.1 Network results

As LinSig reports network performance at a lane level rather than at a movement level a number of statistics can be generated for each lane including:

- Capacity.
- Degree of saturation.
- Average delay.
- Mean maximum queue length.

It does not currently provide Level of Service or 95th percentile queue. Level of Service can be calculated in an external spreadsheet using the average delay experienced on each approach.

13.6.2 Cyclic flow profile graphs

Cyclic Flow Profile Graphs (CFPs) are a graphical representation of how the traffic platoons arrive and depart from a stopline during a single cycle. These graphs represent a useful tool for the modeller to understand the level of coordination in the network and where there may be available green time in the cycle that is not efficiently used. In the case of priority controlled side roads they also aid the calibration of give-way parameters as the departure profile from the side road can be observed and adjusted to match observations. These graphs can be added to the network diagram for ease of assessment as shown in Figure 13.19.

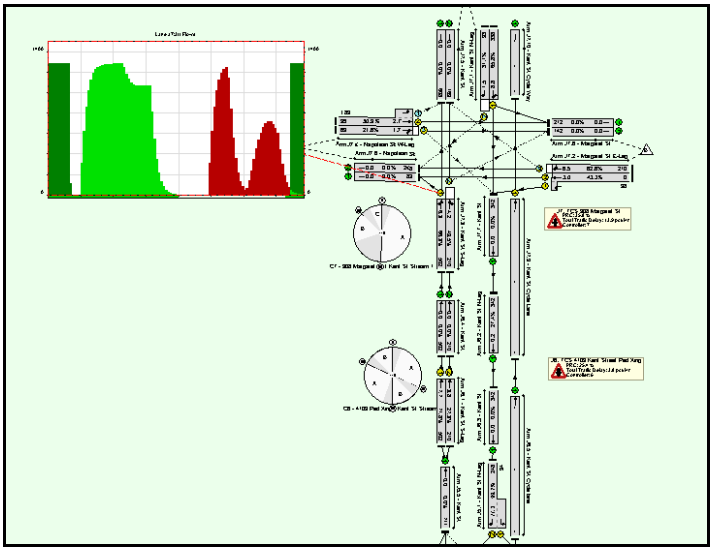


Figure 13.19 LinSig cyclic flow profile graph

13.6.3 Time distance diagrams

Time distance diagrams provide a clear picture of how traffic platoons progress along a route between multiple signalised stoplines. They allow for manual adjustment of traffic signal offsets to favour particular movements. Unlike CFPs however, they do not show the relative volumes of traffic that are in each platoon. This means they are suited for use on corridor networks where there are clearly dominant traffic movements, but are less suited to the assessment of grid networks where there maybe numerous competing demands. A LinSig time distance diagram is shown in Figure 13.20.

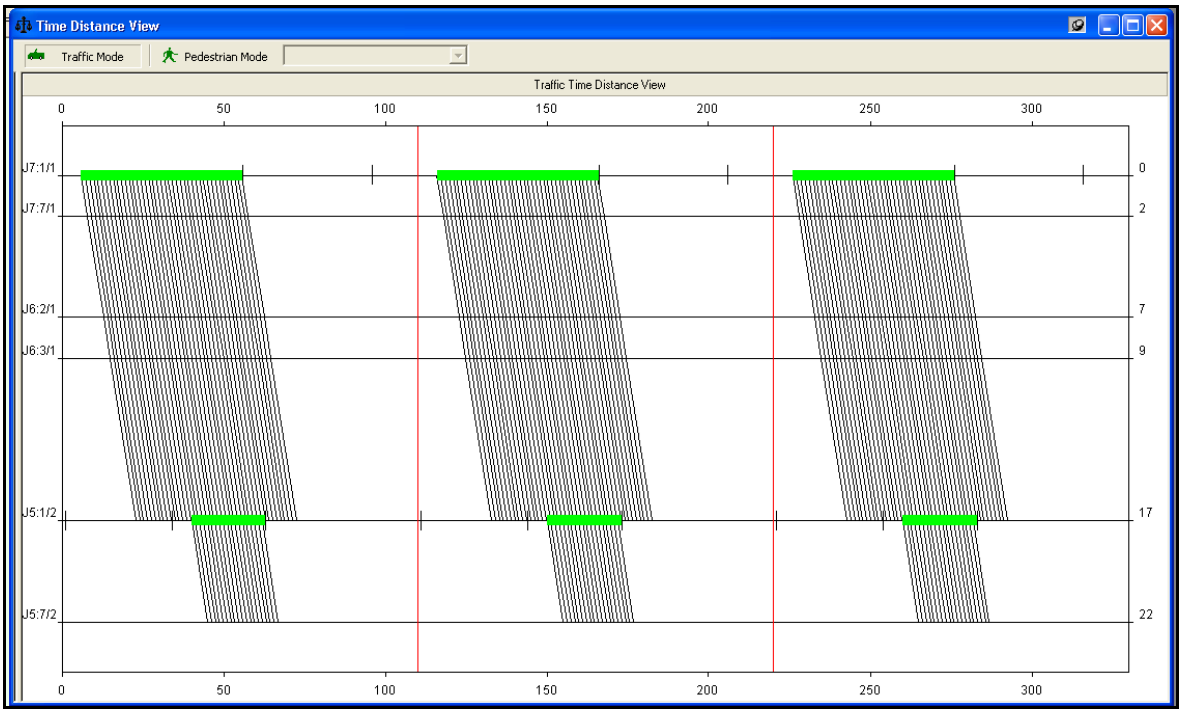
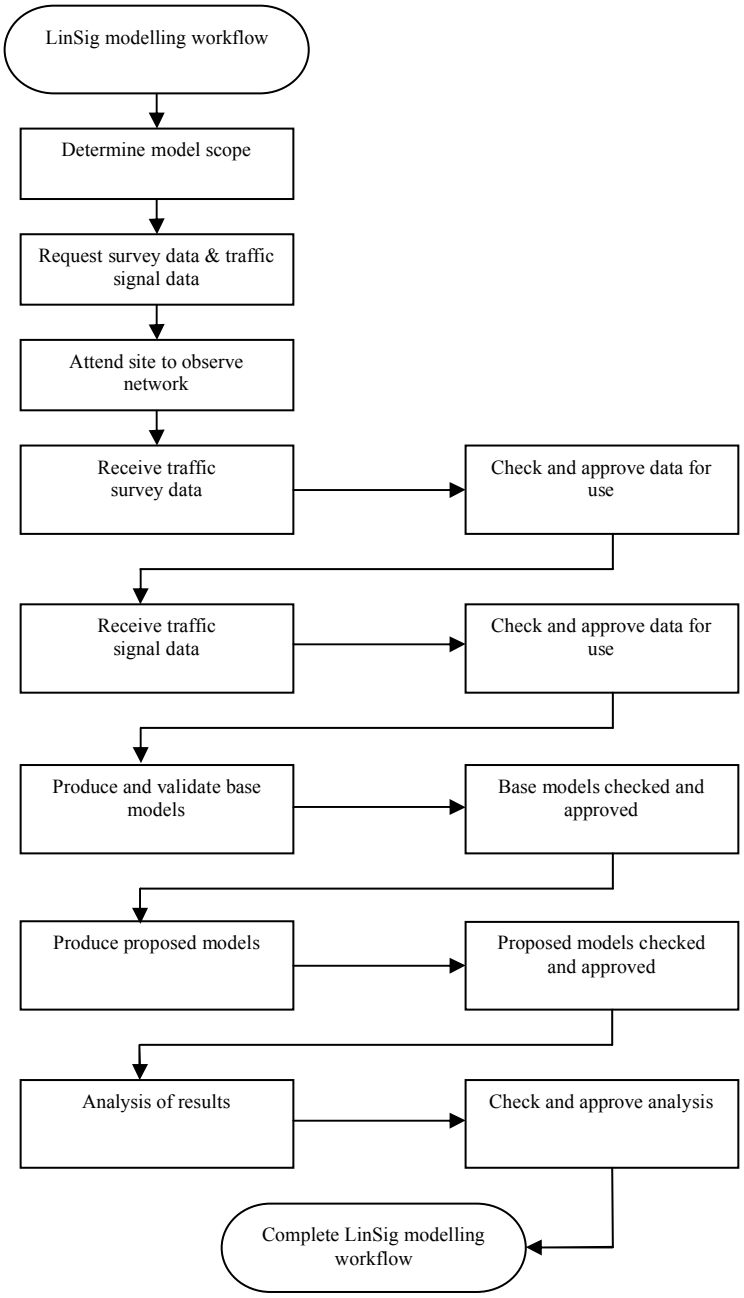


Figure 13.20 LinSig time distance diagram

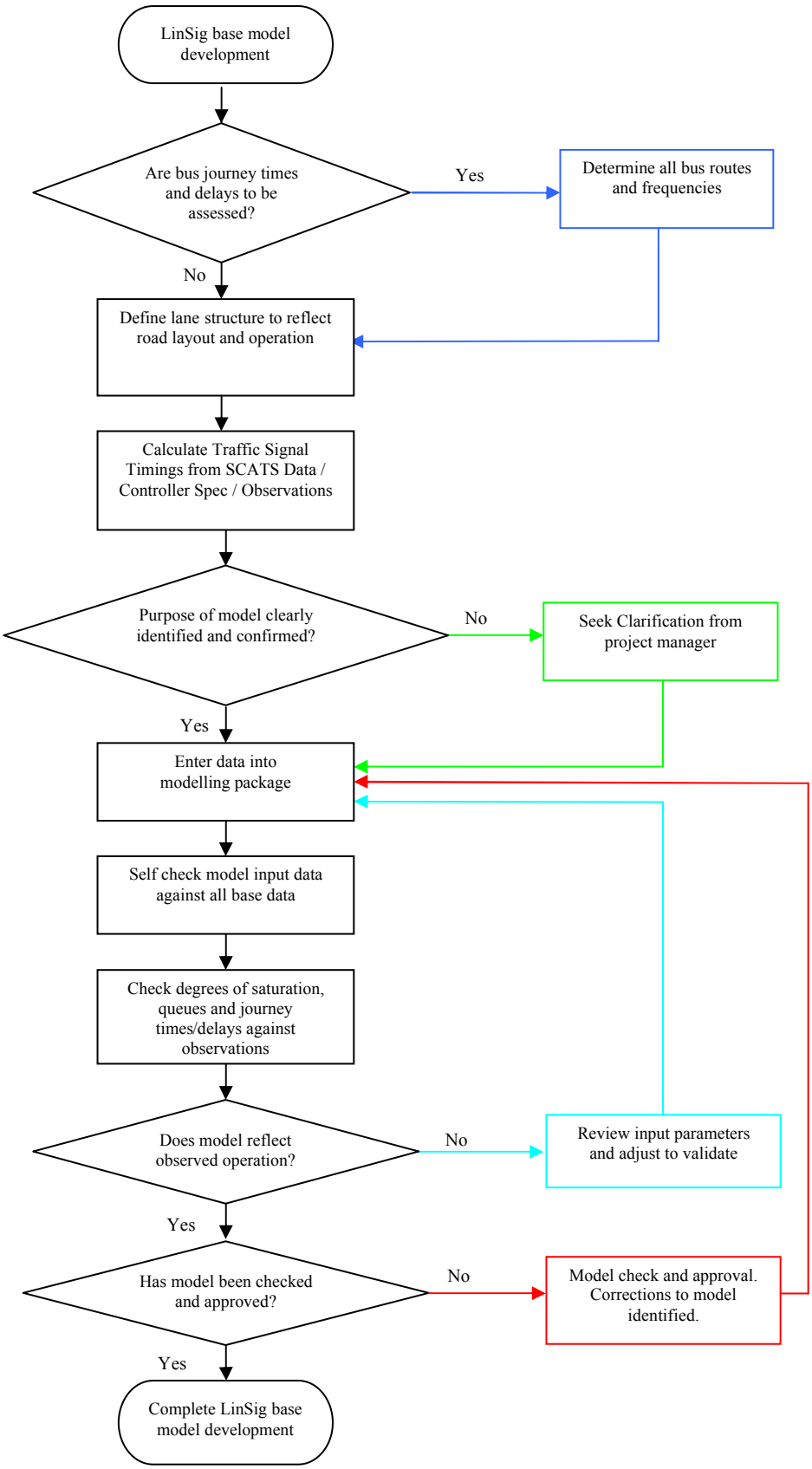
13.7 LinSig modelling process

The following flow charts provide a summary of the process that should be followed when developing LinSig models. This process emphasises the need for regular checking of both model inputs and outputs for the purposes of quality assurance and to ensure delivery of models that meet project requirements.

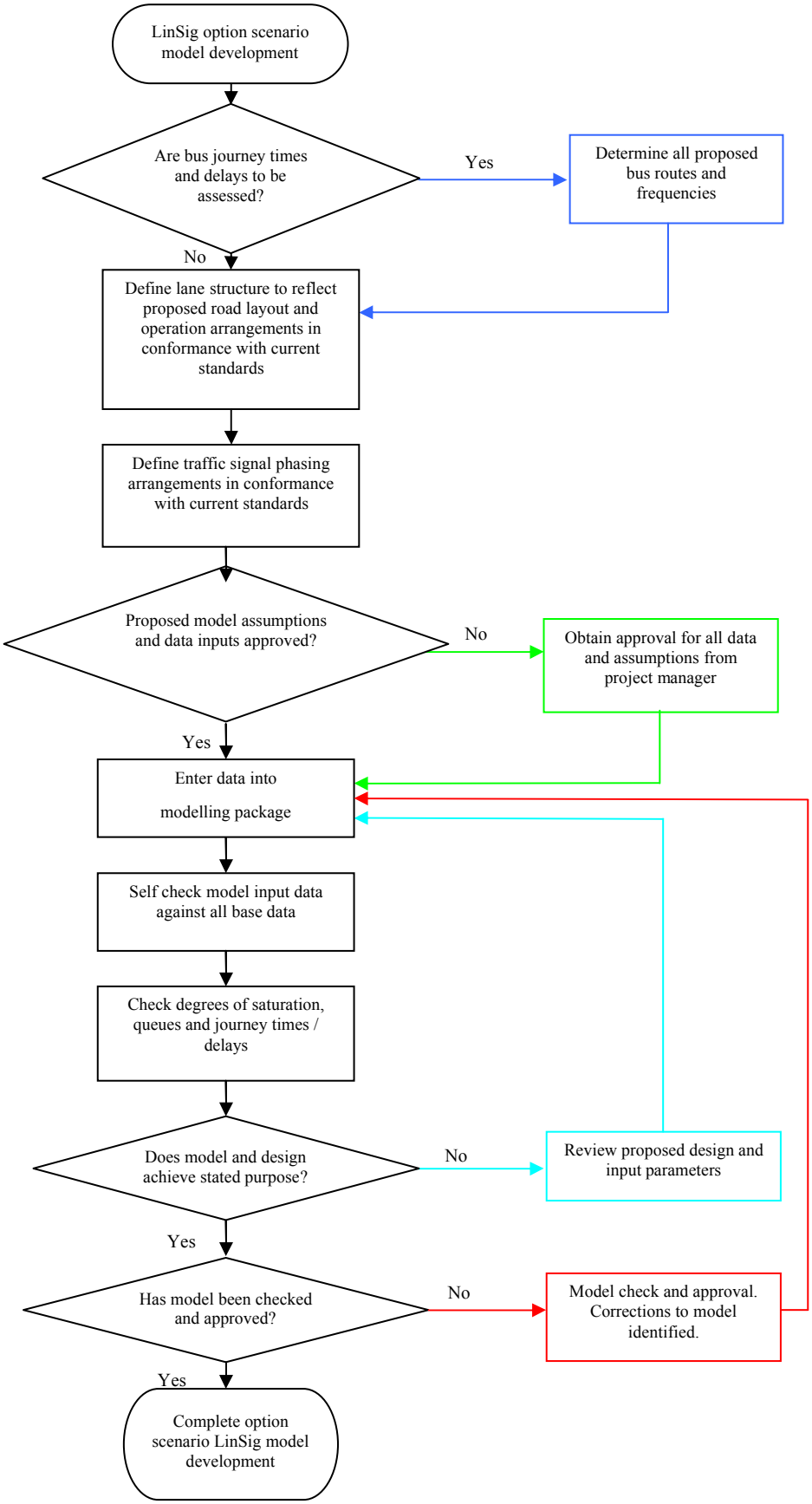
13.7.1 LinSig modelling workflow



13.7.2 LinSig base model development



13.7.3 LinSig option scenario model development



14 Single intersection modelling

14.1 Introduction

RMS wish to thank and acknowledge SIDRA Solutions for permission to use extracts from the *SIDRA User Guides* within this guideline.

The SIDRA INTERSECTION software is a micro-analytical tool for evaluation of intersection performance mainly in terms of capacity, level of service and a wide range of other performance measures such as delay, queue length and stops for vehicles and pedestrians, as well as fuel consumption, pollutant emissions and operating cost. The SIDRA software can be used as an aid for design and evaluation fixed-time/pre-timed and actuated signalised intersections, signalised pedestrian crossings, signalised single point interchanges, roundabouts, roundabout metering, two-way stop sign control, all-way stop sign control, and give-way/yield sign-control.

These guidelines have been prepared to address the issue of number of SIDRA input parameters that can be altered and the significant effects it may have on the output results of the SIDRA model. The guidelines not only set out the acceptable parameters for input but allow for flexibility in the analysis of unusual or specialised intersections.

The objectives of this section of the RMS guidelines are to:

- Provide guidance on what are the acceptable input parameters, performance measures, calibration requirements and reporting structure in SIDRA modelling to both RMS staff and those submitting work to RMS.
- Develop consistency in traffic modelling practice and promote high quality model outputs that will lead to high quality project design.
- Ensure that all intersections are being modelled accurately.

These guidelines are not limited to the above list of requirements and RMS reserves the right to undertake further assessment with different criteria. The subject guidelines are based on the SIDRA Version 5.0.

14.1.1 Getting Started

The following general requirements are to be met in order to model any intersection using SIDRA software:

- The latest version/update of SIDRA INTERSECTION should be used where possible.
- All projects created in SIDRA should be modelled as Standard Left.
- Level of Service (LoS) method should be set to NSW RMS (RTA).

Any changes to input as part of the calibration process should be incorporated into the future model.

14.2 Input

14.2.1 Intersection dialogue

The following is required as a minimum in the intersection dialogue (but not limited to):

- A description title of the intersection including location and purpose and if signalised, the TCS number.
- The details of the user/developer/analyser of the model must also be included in the title.
- Unit time for volumes and peak flow period should reflect data of the intersection counts where the: maximum unit time for volumes is 60 minutes (unit used is dependant on actual flow data and any variation should be discussed with RMS Manager Traffic & Transport and documented).
- Maximum peak flow period is 30 minutes.
- Peak flow factor (volume dialogue box) should be carefully assessed to replicate “actual Peak Period”

- Geometry should closely resemble actual alignment and orientation of the intersection.
- Signal analysis method for signalised intersection should reflect the actual or proposed intersection operation such as fixed timed /pre-timed or actuated.

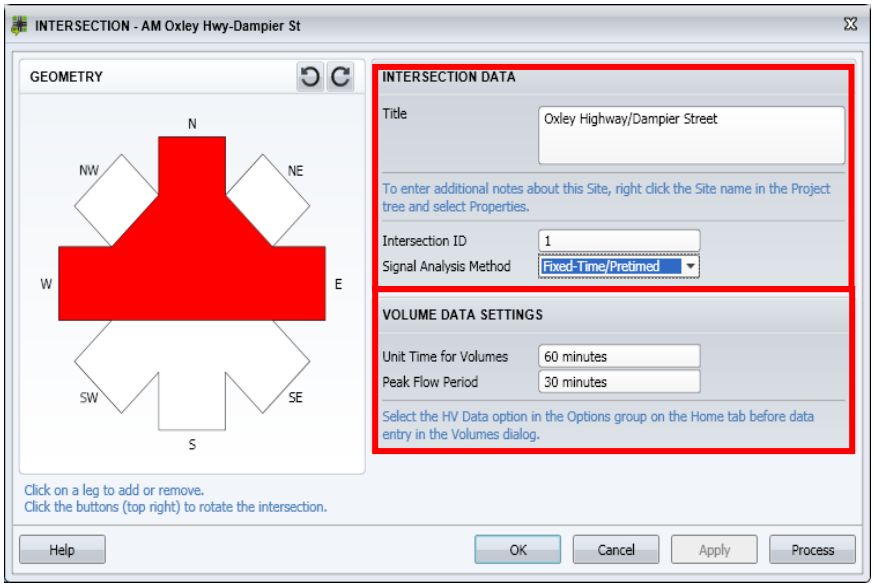


Figure 14.1 Screen shot of intersection dialogue

14.2.2 Geometry dialogue

The following is required as a minimum in the Geometry Dialogue:

- Approach and exit lane data are to be as per the existing geometry for constructed intersections and/or for “Construction Plans” for approved intersections.
- If slip lanes or continuous lanes already exist then the appropriate selection is required in the dialogue.
- Values for extra bunching should be used if there are upstream signals in close proximity. Extra bunching should only be applied to sign-controlled and roundabout intersections. Maximum values to be used to simulate the effects of extra bunching should be as per the Table 14.1 below.
- The maximum basic saturation flow should be 1950 tcu (through car units)/hr (SIDRA Default). Any higher or lower values than default value should be supported by appropriate data. Saturation flow measurements should be undertaken whenever possible on approaches that are heavily congested or forecasted to be heavily congested.

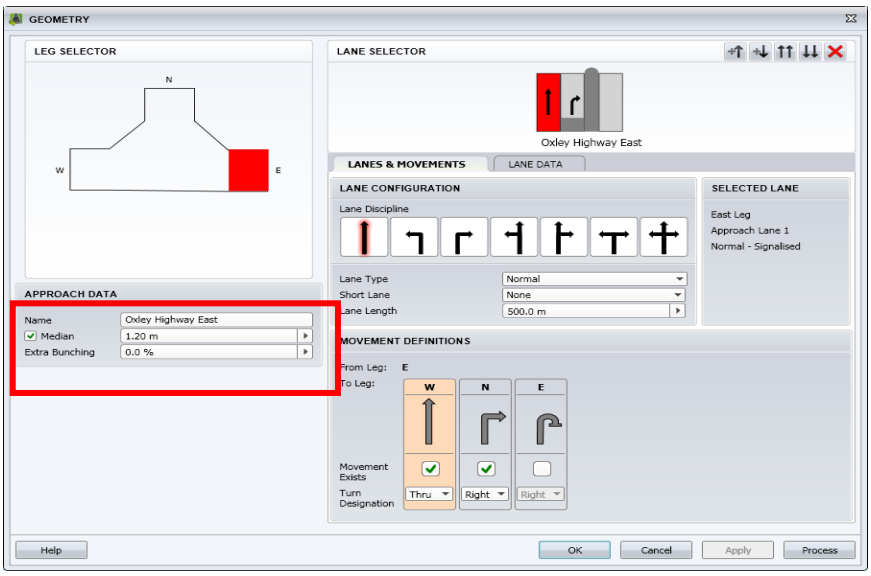


Figure 14.2 Screen shot of geometry dialogue (lane and movement tab for signalised intersection)

Table 14.1 Maximum values for extra bunching

Distance to upstream signals (m)	< 100	100–200	200–400	400–600	600–800	> 800
Extra bunching (per cent)	25	20	15	10	5	0

Utilisation Ratio, Saturation speed and capacity adjustment data values should only be changed subject to appropriate intersection data being collected or provided. The Turning movement designation should be allocated as per the existing or proposed operation of the intersection.

For wider lane approaches SIDRA Intersection model should show how intersection is used rather than how it operates. A wide approach is where width of the lane allows two vehicles to stand next to each other at a stop line or operate the road as two lane road even though the road is marked as one lane only.

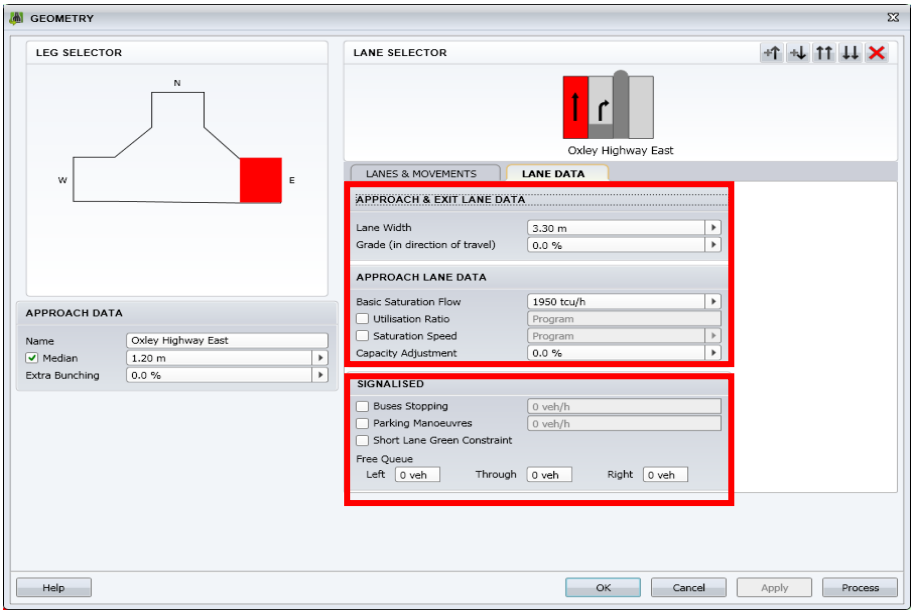


Figure 14.3 Screen Shot of Geometry Dialogue (Lane Data Tab for Signalised Intersection)

For signalised intersections, the parameters for Buses Stopping, Parking Manoeuvres, Short Lane Green Constraints and free queue should only be inserted if the appropriate intersection data is available. **If this data are likely to have significant impact on the performance of the intersection, then these data should be collected and included in the model.**

For roundabouts, the island Diameter, circulating width and number of circulating lanes should be as per the existing or proposed geometry. This data must be specified for each approach. The accuracy of the input data is critical as this data is used by SIDRA for the calculation of approach capacity.

For SIDRA roundabout, Environment Factor can be used to calibrate the capacity model to allow for less restricted (higher capacity) and more restricted (lower capacity) roundabout environments. Standard SIDRA default value for this is 1.0 and Default value of the US HCM models is 1.2. However, a value in the range 0.50 to 2.00 can be specified. Any changes to Default value should be well justified. The Environment Factor adjusts the dominant lane follow-up headway at zero circulating flow. As a result, the dominant lane follow-up headway values at all circulating flows are adjusted. This leads to the adjustment of subdominant lane follow-up headway, as well as adjustments of critical gaps for all lanes. Capacity increases with decreasing value of the Environment Factor.

Roundabout capacity model can be calibrated by choosing the appropriate level of this adjustment using the observed or expected local driver behaviour characteristics. The options available from the drop-down menu are High, Medium, Low and None. The SIDRA default setting is Medium. The selected option determines the adjusted dominant lane follow-up headway at zero circulating flow. The adjustment is effective for low to medium circulating flow rates. Capacity is highest when High is selected, and lowest when “None” is selected.

The calibration parameters in the roundabout data section should only be changed as part of the model calibration.

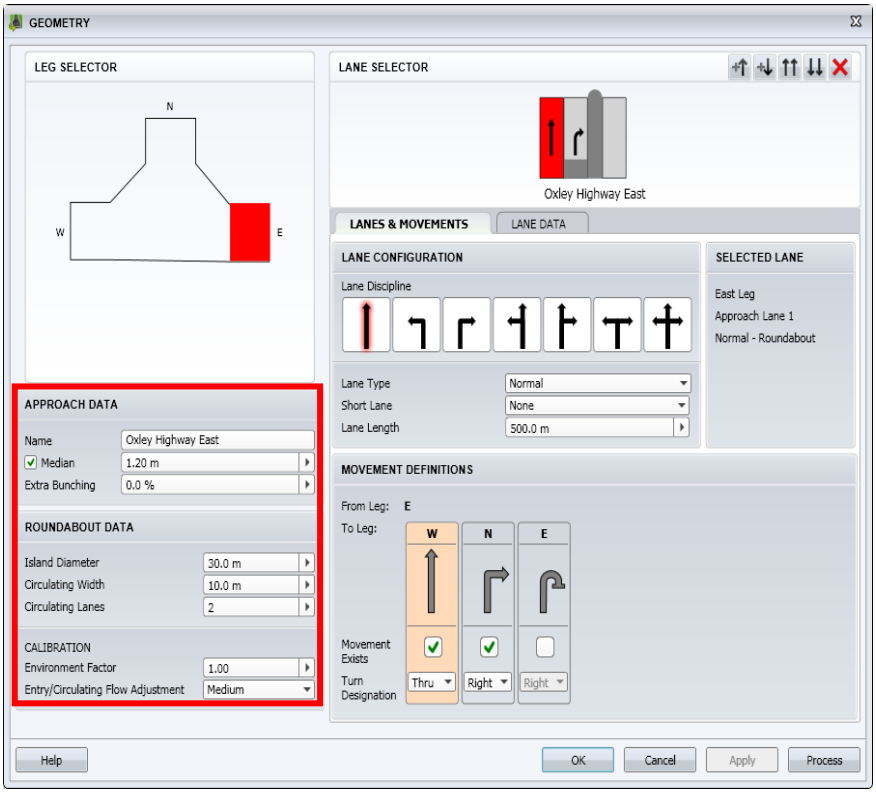


Figure 14.4 Screen shot of geometry dialogue (lane data tab for roundabout)

14.2.2	Saturation flow measurements should be undertaken whenever possible on approaches that are heavily congested or forecasted to be heavily congested. Friction due to the presence of bus stops, short lanes and on-street parking should be correctly accounted for as part of model calibration.

14.2.3 Volumes Dialogue

The Volumes dialog has two data groups, Volumes and Volume Factors. Before using the Volumes dialog, it is important to select the appropriate Volume Data Method (HV Option) parameter needed to use such as separate light vehicles (LV) and heavy vehicles (HV), Total Vehicles and HV (per cent) or total vehicles and HV (veh) from the drop-down list in the “Options” group located on the top menu bar. The volume data fields will be displayed according to the method chosen.

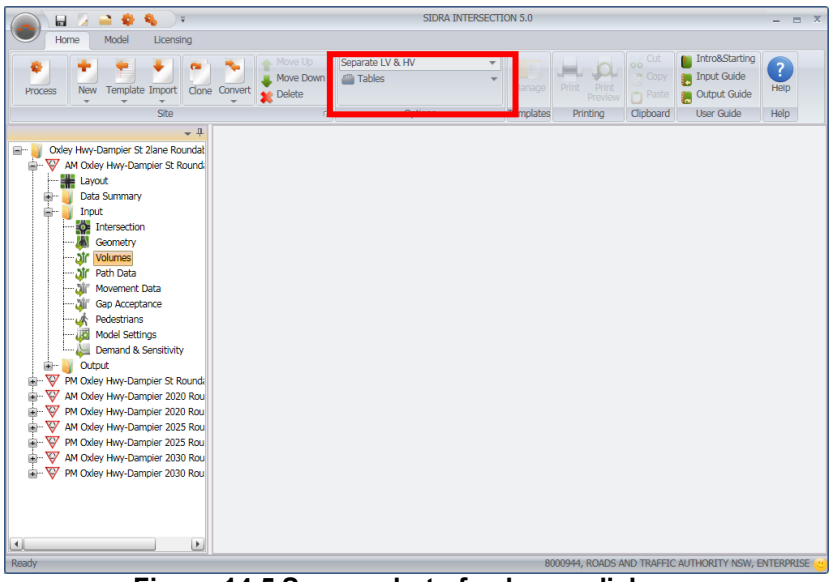


Figure 14.5 Screen shot of volumes dialogue

The following is required as a minimum in volumes dialogue:

- Vehicle volumes are to be based on the most current data collected through an intersection survey / count.
- SIDRA default peak Flow Factor of 95 per cent is acceptable. Analysis of intersection data collected may impact the Peak Flow Factor Used. Supporting documentation is required to justify the factor used other than the default peak factor of 95 per cent.
- The appropriate Growth Rate parameter should be used in consultation with RMS if completing a design life analysis on the intersection.
- Growth rates used for future volume estimation and/or the justification of the methods used to determine future volumes should be included in the final report.

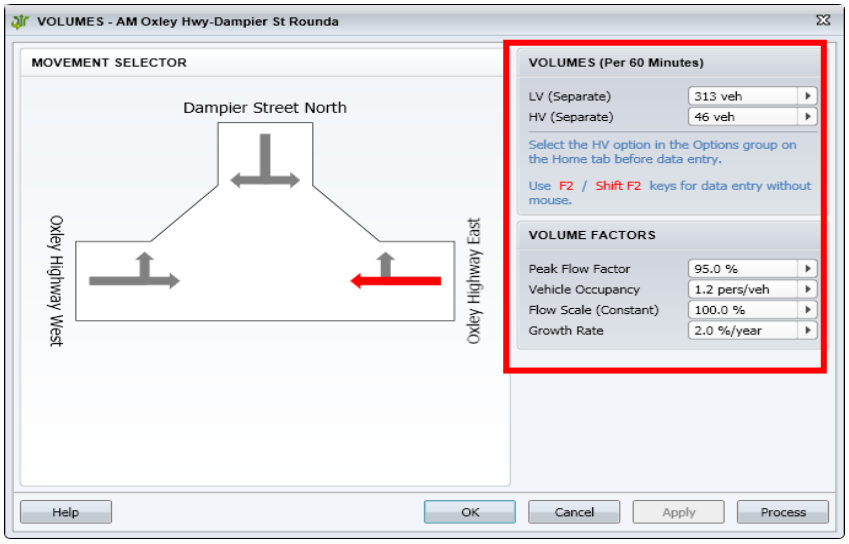


Figure 14.6 Screen shot of volumes dialogue

14.2.4 Path data dialogue

Movement path data – The Approach Cruise Speed and Exit Cruise Speed for existing intersections should reflect the present intersection conditions. The Approach Travel Distance should be changed to reflect the existing and/or proposed operation of the intersection. The Negotiation Speed and Negotiation Distance can be changed manually to indicate the physical parameters for intersections that have unusual geometry features. Justification should be given for the values used for the intersections of unusual nature. All other items in this dialogue should be the SIDRA default values.

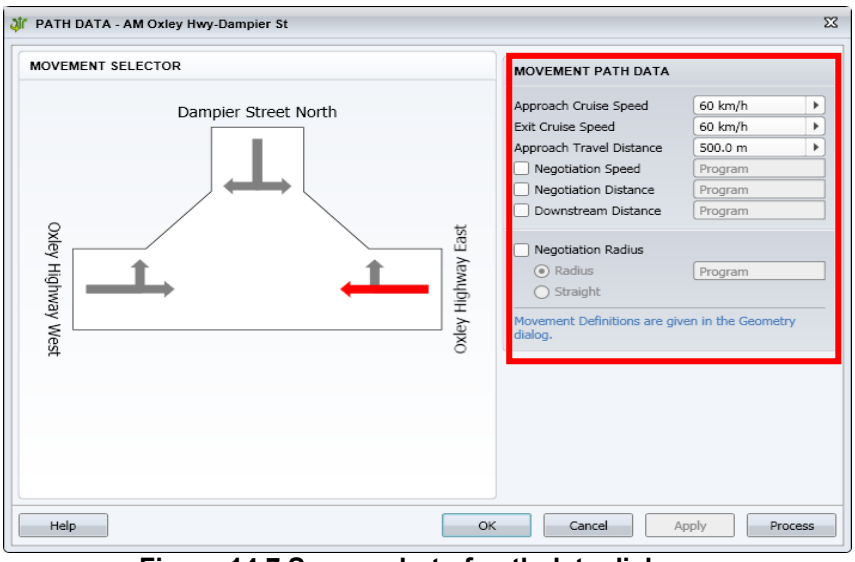


Figure 14.7 Screen shot of path data dialogue

Movement data dialogue – In the Movement Data input dialog some of these data items may not be available depending on the intersection type (eg Figure 14.8 outlines data only applicable for Signalised intersection) and the characteristics of the movement. The default values in the Movement Data Dialogue box should be used unless evidence is provided indicating different set of values are appropriate. Data in "Pedestrian Effects" section can be manually inserted; however appropriate justification should be provided.

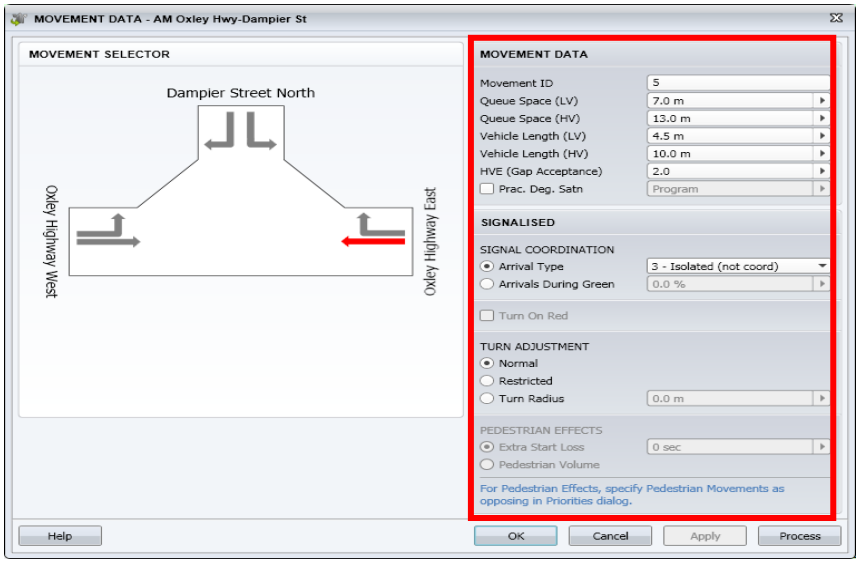


Figure 14.8 Screen shot of movement data dialogue

14.2.5 Priorities dialogue

The Priorities node will not appear in the project tree in the case of:

- Roundabouts where all entry movements are opposed automatically.
- Pedestrian crossings (signals) where filter (permitted) turns are not relevant.
- All-Way Stop Control where the gap-acceptance model is not applicable.

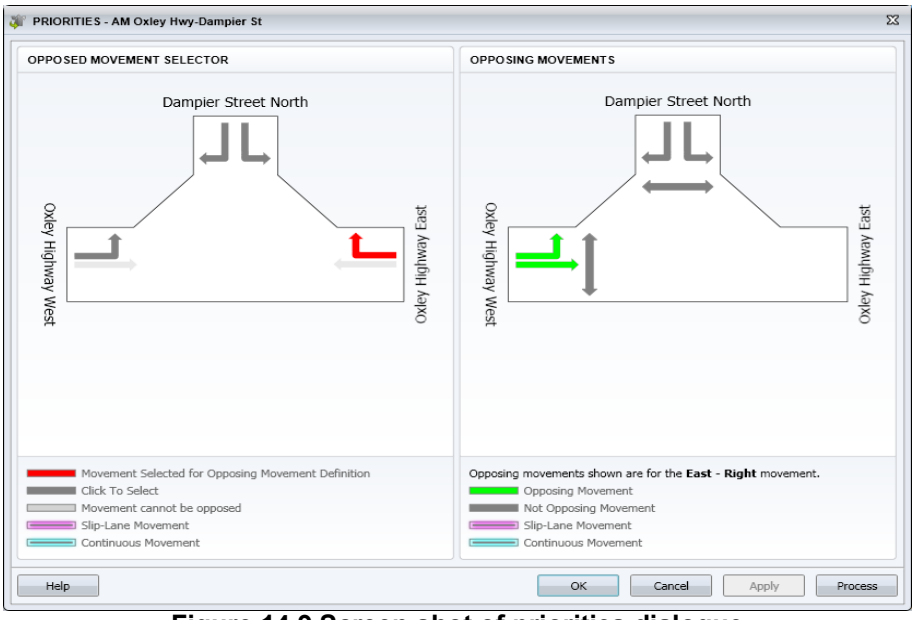


Figure 14.9 Screen shot of priorities dialogue

Default opposing movements should be used unless evidence is provided showing actual opposing movements are different. This may be the case for intersection with unusual geometry, turn designations or specialised treatments.

14.2.6 Gap-acceptance data dialogue

In the SIDRA INTERSECTION roundabout model the default estimates should be used unless the User-Given Parameters checkbox is checked and data is manually inserted.

For two-way sign control and signalised intersections, SIDRA relies on user-specified critical gap and follow-up headways. SIDRA default values for all sign-controlled (stop-sign and give-way/yield sign) intersections are based on a two lane main road. Default values should be adjusted under different geometric arrangements. It should be noted that the capacity and performance of sign-controlled intersections are particularly sensitive to the values of these parameters. Therefore, gap-acceptance parameters applicable to particular intersection geometry and flow conditions should be selected by using good judgement and taking into account the local driver characteristics.

The default values of the gap-acceptance parameters for signalised intersections, roundabouts and sign-controlled intersections are given in Tables 12.2.5 of the SIDRA manual which are also attached in Appendix E to these guidelines. **Appropriate judgement is required while selecting the critical gap and follow-up headway values to suit the circumstances** considering grades, sight distance conditions, opposing movement speeds, number of lanes, and one-way or two-way conditions. Any changes to these values should be justified.

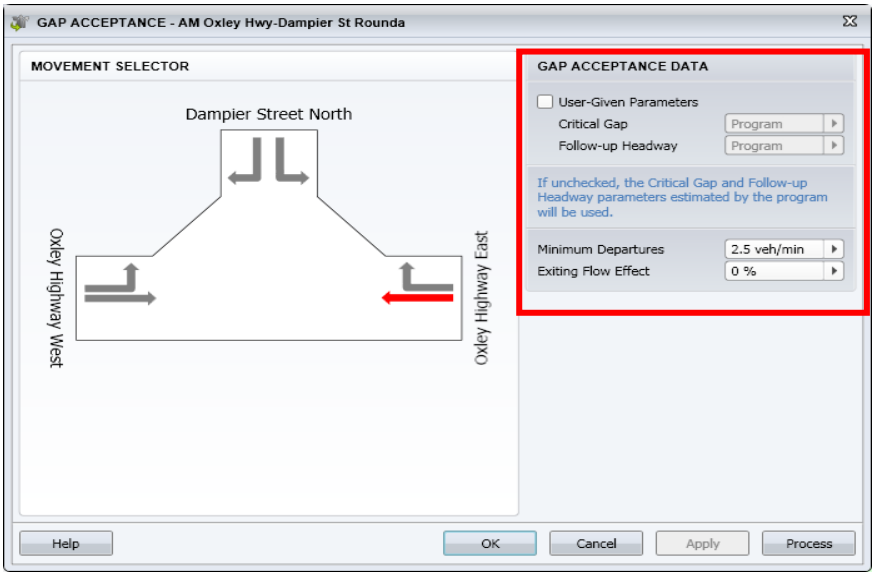


Figure 14.10 Screen shot of gap acceptance data dialogue (roundabout)

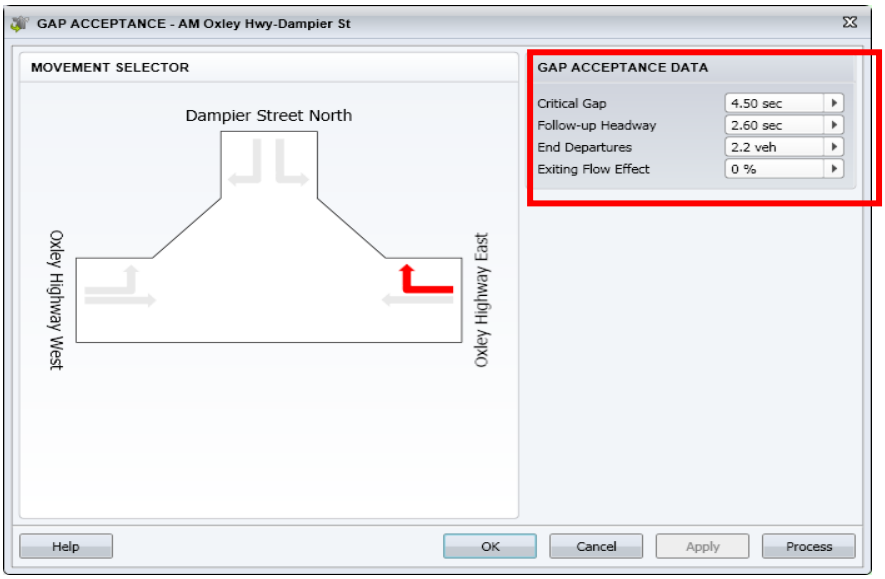


Figure 14.11 Screen shot of gap acceptance data dialogue (signalised intersection)

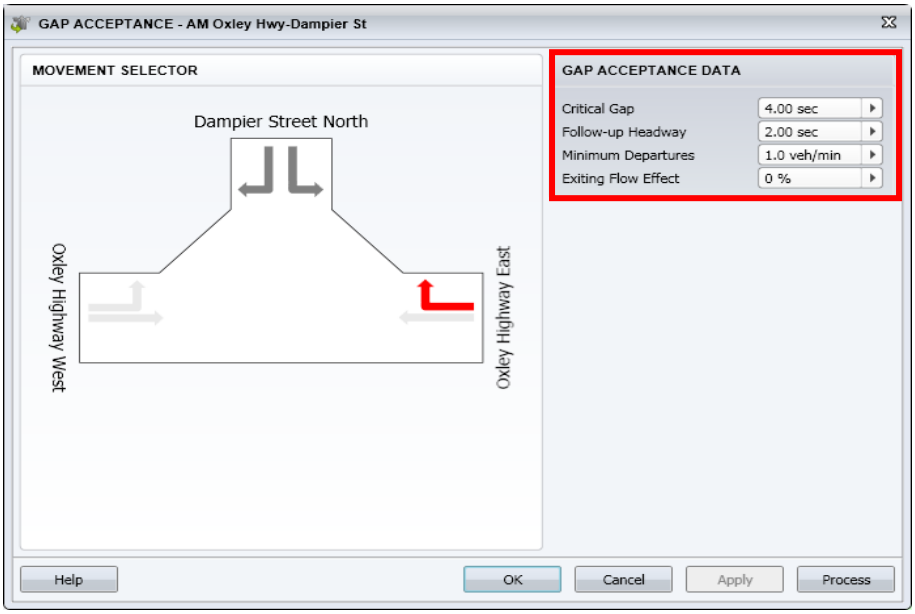


Figure 14.12 Screen shot of gap acceptance data dialogue (priority intersection)

14.2.6	Adjust default values for gap-acceptance parameters (ie critical gap and follow up headway) to local site conditions and provide justification.

14.2.7 Pedestrian dialogue

The Pedestrians input dialog only applies to all types of Roundabouts and signals including signalised pedestrian crossings. This dialog does not appear for sign-controlled intersections.

The volume of pedestrians and Peak flow Factor can be altered to suit the intersection counts obtained. The growth rate used under Pedestrian Data should be justified and explained. Data for Crossing Distance, Approach Travel Distance, and Downstream Distance can be changed to reflect the geometry of the existing intersection and if this data is available. Default values should be used for all other parameters in this dialogue.

SIDRA default for Pedestrian walking speed (Average) in Pedestrian Data dialogue box is 1.3 m/sec. A value of 1.2 m/sec should be used for pedestrian modelling in NSW.

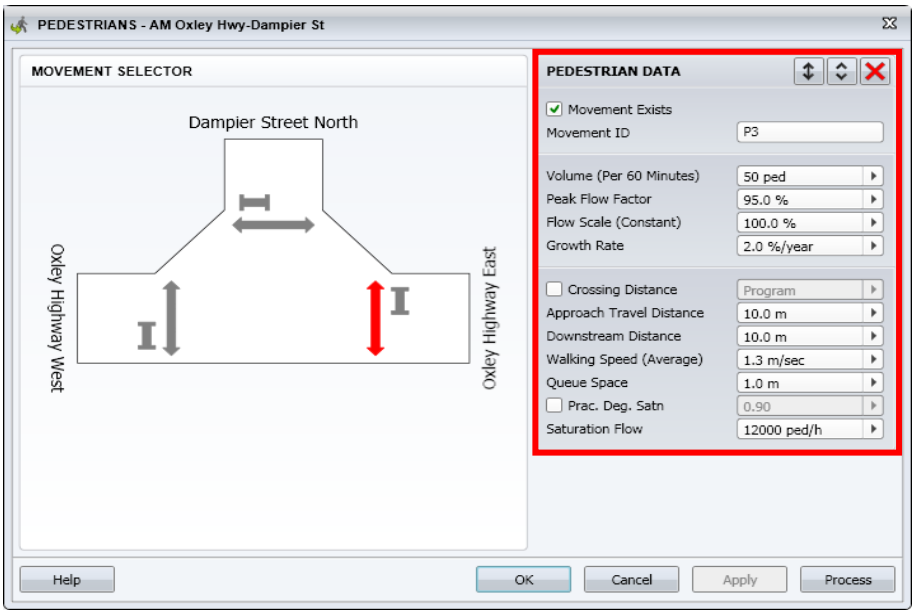


Figure 14.13 Screen shot of gap pedestrian dialogue (signalised intersection)

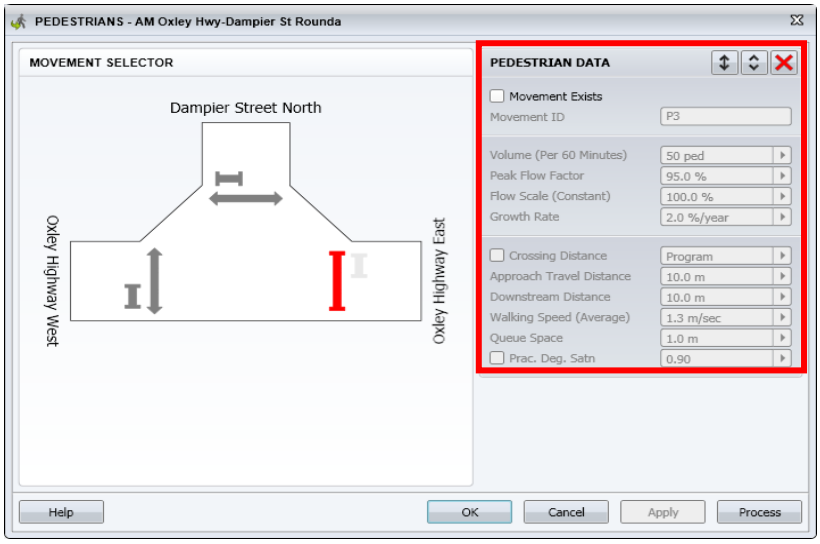


Figure 14.14 Screen shot of gap pedestrian dialogue (roundabout)

14.2.8 Phasing and timing dialogue

The phasing and timing on signalised intersections can be altered to determine the most appropriate solution. However, when modelling the existing intersection, the phasing and timing should be representative of current Phasing and Timing of that intersection. **Intersection surveys should be undertaken if the necessary data is not available.** Default yellow time of four seconds and red time of two seconds should be used if the measured data is not available.

When setting the phasing sequence, observed phasing should be included in the base case model. For design cases phasing should follow standard RMS phasing arrangements[20] .

The accepted maximum practical cycle length for traffic signals under saturated conditions is 120–150 seconds. Under these conditions 120 seconds is near maximum for two and three phase intersections and 150 seconds near maximum for complex phase designs. In heavily pedestrian areas such as Sydney CBD a cycle time of 110 seconds is used in the peak period.

Cycle time is generally controlled by the SCATS master subsystem. Therefore the cycle time for all intersections linked with the master subsystem should use the same cycle time.

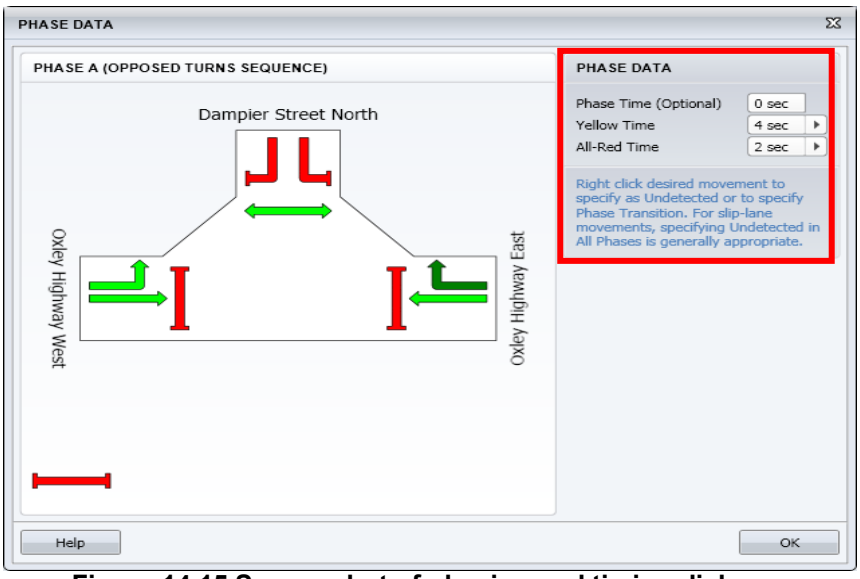


Figure 14.15 Screen shot of phasing and timing dialogue

[20] See section 14.2.9 for standard signal phasing diagrams

14.2.8	The phase sequence and timings should be obtained from the site visit or directly from RMS as IDM data. Cycle time, offset and phase sequence to be in accordance with RMS advice.

14.2.9 RMS' Standard Traffic Signal Phasing diagrams

RMS has standard phasing arrangements in one of the following forms:

- Conventional phases.
- Conventional phases with turning leading, trailing or repeat right turn phases.
- Diamond Phase.
- Split phases.

These phase arrangements should be used in intersection modelling. The following figures show the standard phasing arrangements for four-way intersections.

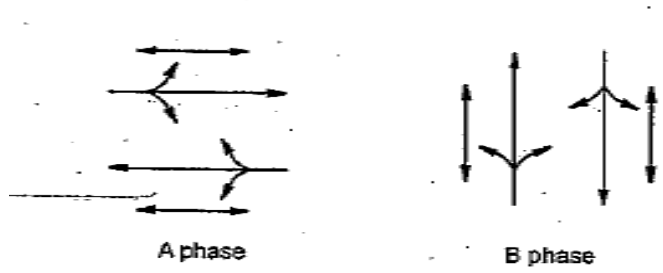


Figure 14.16 Conventional (two-phase) signalised intersection phasing

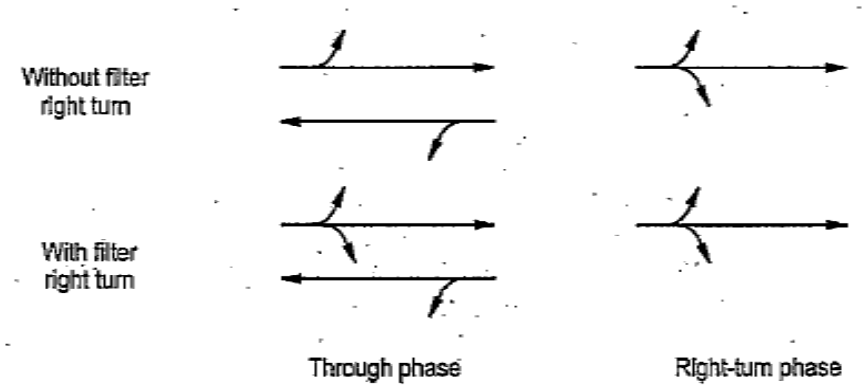


Figure 14.17 Trailing right turn (for use with conventional phasing)

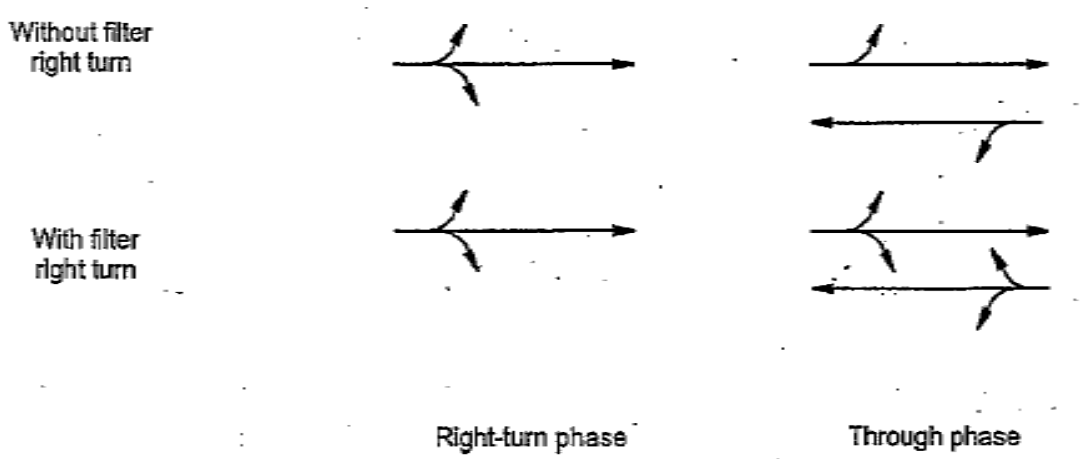


Figure 14.18 Leading right turn (for use with conventional phasing)

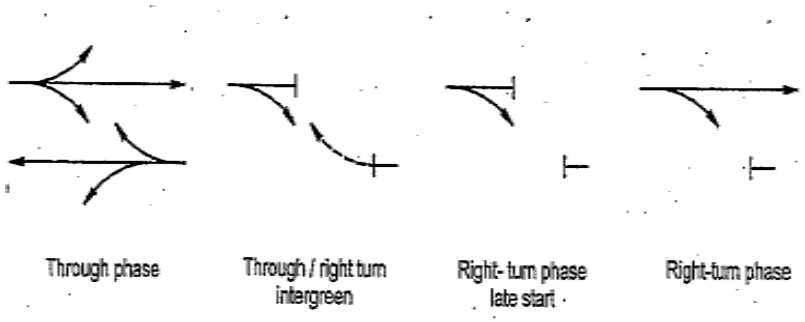


Figure 14.19 Late start when controlled right turn follows opposing filter right turn (for use with conventional phasing)

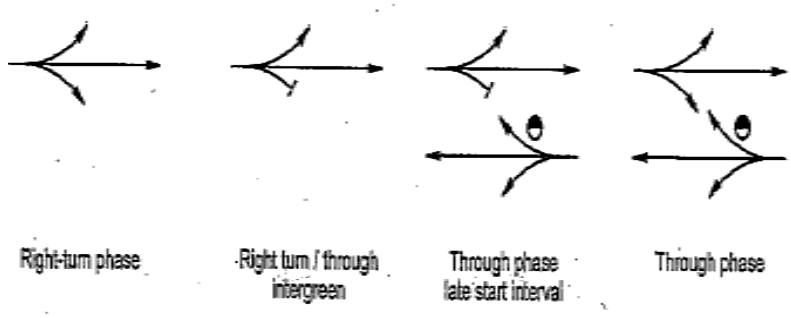


Figure 14.20 Late start when filter right turn follows controlled right turn (for use with conventional phasing)

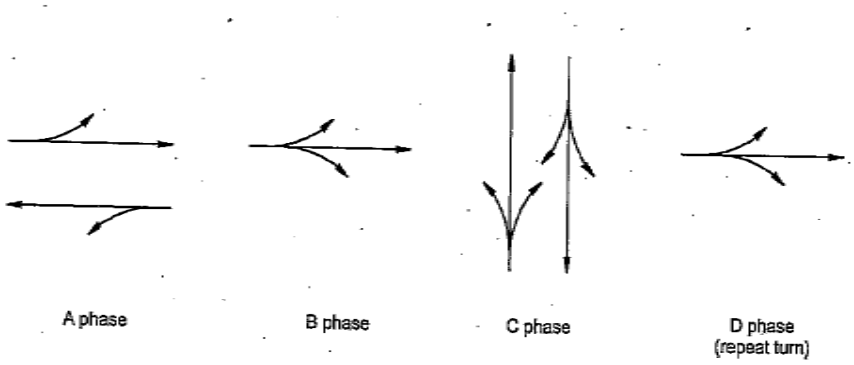


Figure 14.21 Repeat right turn (for use with conventional phasing)

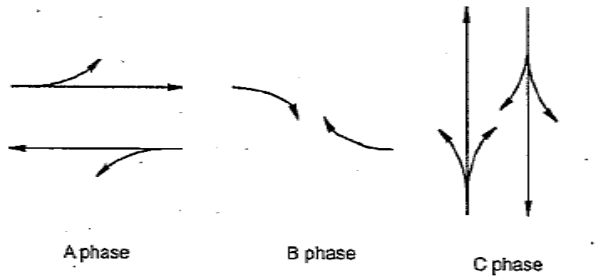


Figure 14.22 Diamond phasing

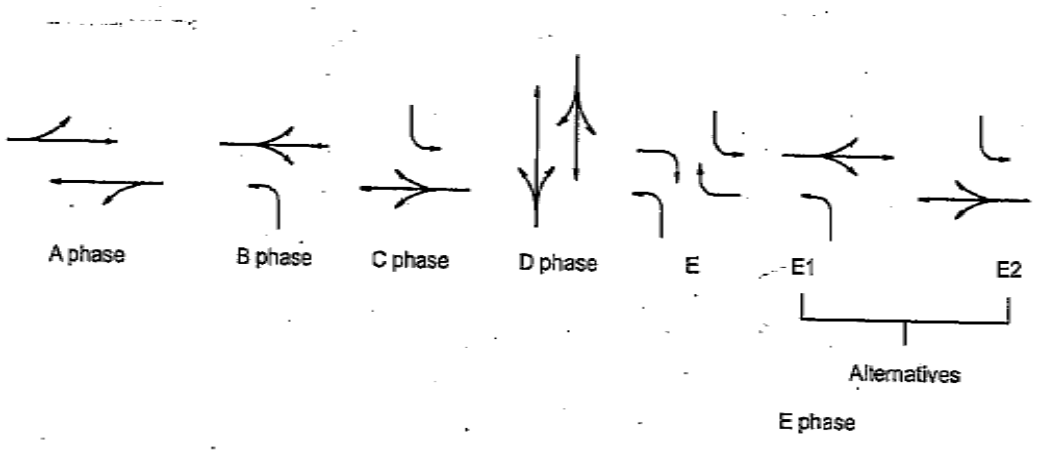


Figure 14.23 Single diamond overlap phasing

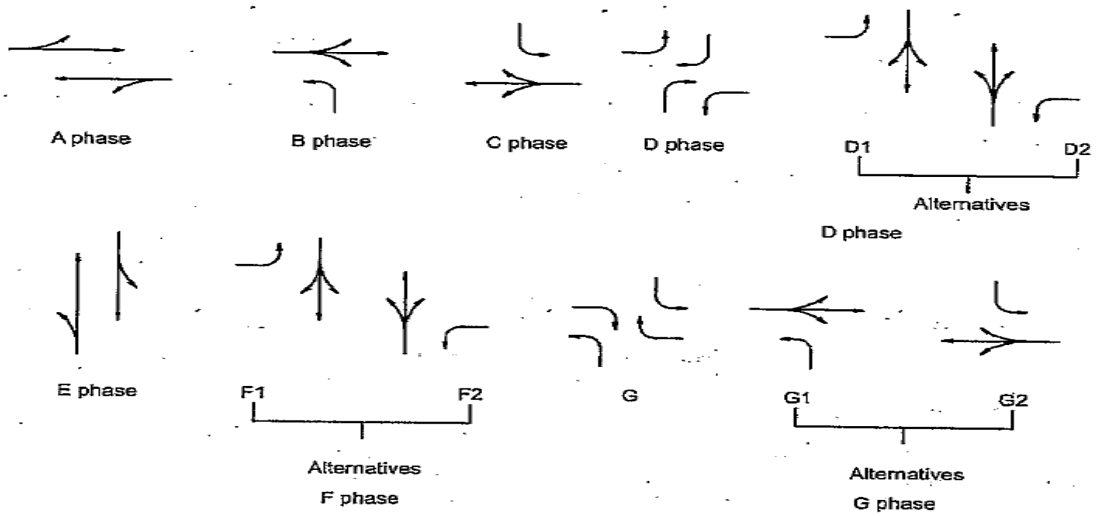


Figure 14.24 Double diamond overlap phasing

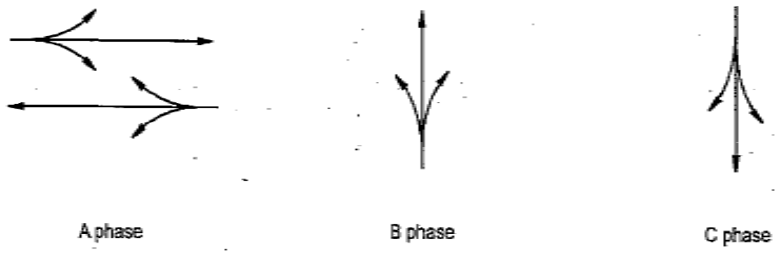


Figure 14.25 Split phasing

14.2.9	Use RMS' Standard Traffic Signal Phasing diagrams.

14.2.10 Model setting dialogue

The Model Settings input dialog can be used to select various model options and specify some model parameters in the General Options and Roundabout Models data groups. The Roundabout Models data group will be shown only if the site type is roundabout.

The parameters in this dialog apply to the intersection as a whole and are relevant to all SIDRA models. These are important parameters that affect the results significantly. Level of Service Method should be set to RTA NSW and Level of Service Target should be set to "LOS C". For other parameters SIDRA default values can be used.

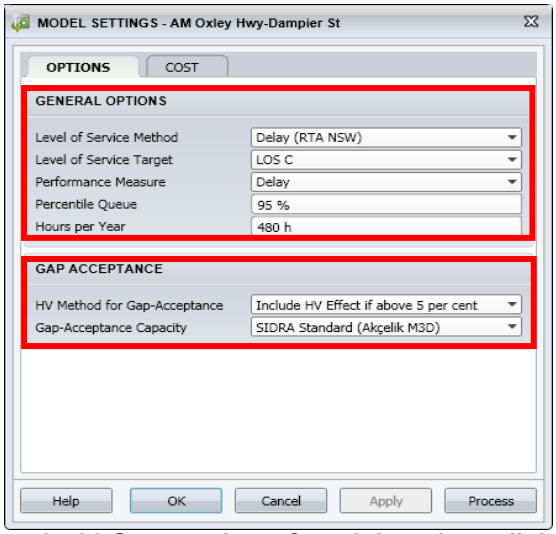


Figure 14.26 Screen shot of model settings dialogue

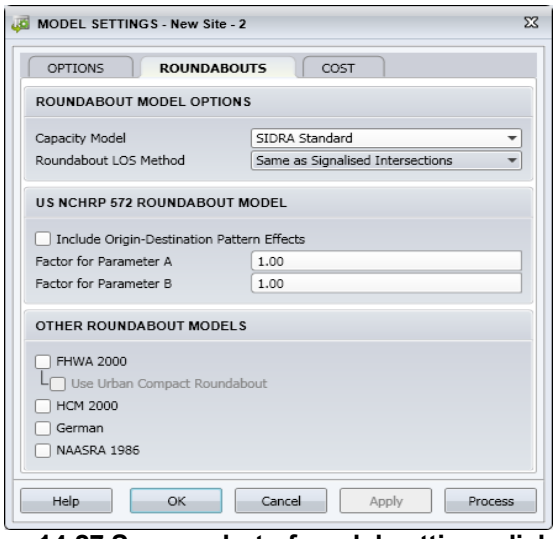


Figure 14.27 Screen shot of model settings dialogue

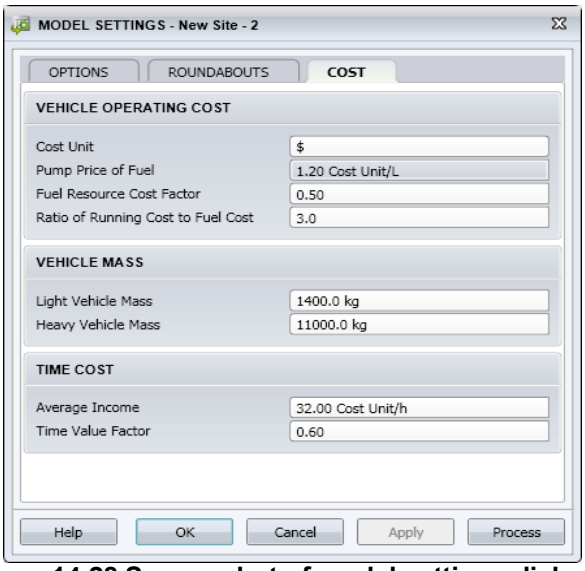


Figure 14.28 Screen shot of model settings dialogue

14.2.10	Values associated with model settings dialogue should be updated if possible using the *RTA Economic Analysis Manual*.

14.2.11 Demand and sensitivity dialogue

The Demand and Sensitivity dialog includes the Design Life, Flow Scale and Sensitivity options specific to each Site. Use the drop-down lists to select the appropriate option. After selecting the options and changing parameter values where relevant, click OK to close the dialog and click the Process button at the right had bottom of the dialogue box.

It should be noted that specification of an option in this dialog will override the Optimum Cycle Time option chosen in the Sequence Data dialog unless the parameter chosen for Sensitivity is not applicable to the site. For example, if the Roundabout Island Diameter is selected, the Optimum Cycle Time option will still be valid for a signalised intersection.

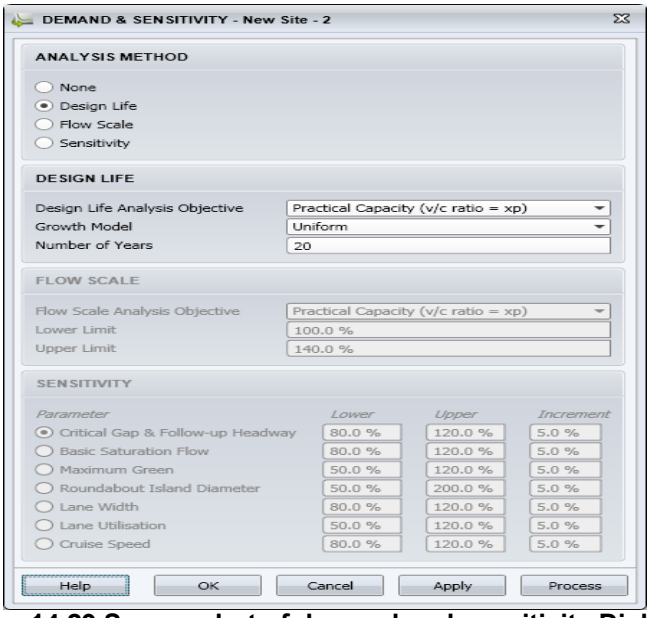


Figure 14.29 Screen shot of demand and sensitivity Dialogue

14.2.12 Roundabout Metering

Roundabout metering signals are installed on selected roundabout approaches and used on a part-time basis since they are required only when heavy demand conditions occur during peak periods. The use of metering signals is a cost-effective measure to avoid the need for a fully-signalised intersection treatment. The term Metered Approach is used for the approach stopped by red signals (approach causing problems for a downstream approach), and the term Controlling Approach is used for the approach with the queue detector, which is the approach helped by metering signals. When the queue on the Controlling Approach extends back to the queue detector, the signals on the Metered Approach display red (subject to signal timing constraints) so as to create a gap in the circulating flow. This helps the Controlling Approach traffic to enter the roundabout. When the red display is terminated on the Metered Approach, the roundabout reverts to normal operation.

The Roundabout Metering input dialog includes a graphical data entry box to specify the Metered and Controlling Approaches, and various input data fields which are not tied to specific approaches. All timing parameters are numerical and the distance parameters are real numbers.

The roundabout metering dialogue can be altered to determine the most appropriate solution, however when modelling the existing intersection these data used should be representative of that intersection. Intersection surveys should be undertaken if the appropriate data is not available.

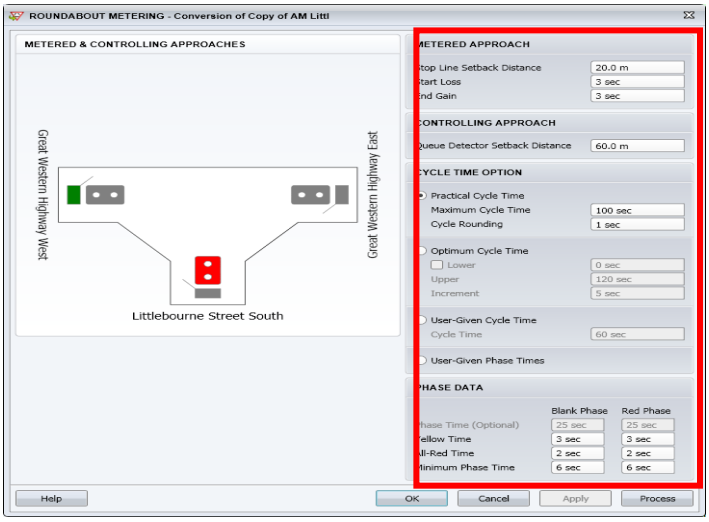


Figure 14.30 Screen shot of roundabout metering dialogue

14.3 Output

SIDRA offers a variety of output features that can help in the analysis and reporting of model performance, which are detailed in this section. The core performance elements that should be assessed for any intersection modelling using SIDRA Intersection are:

- Degree of Saturation (DoS).
- Level of Service (LoS).
- 95 per cent Back of queue distance.

14.3.1 Degree of Saturation (DoS)

Degree of saturation (x) is defined as the ratio of demand (arrival) flow to capacity, x = qa /Q (also known as volume / capacity, v / c, ratio). DoS above 1.0 represent oversaturated conditions (demand flows exceed capacity), and degrees of saturation below 1.0 represent undersaturated conditions (demand flows are below capacity).

The following table represents Practical Degree of Saturation for different intersection types. If the value is greater than the corresponding values provided in the table for any lane, then the intersection requires appropriate treatment to maintain the acceptable level of DoS. Any change in these values should be justified and evidence provided as to why the value should be changed.

Table 14.2 Maximum practical degree of saturation

Intersection type	Maximum practical degree of saturation
Signals	0.90
Roundabouts	0.85
Sign-controlled	0.80
Continuous lanes	0.98

14.3.2 Level of Service (LoS)

SIDRA INTERSECTION output includes LoS results based on the concept described in the US Highway Capacity Manual (HCM) and various other publications. The HCM 2000 (TRB 2000) uses the average control delay (overall delay with geometric delay) as the LoS measure for signalised and unsignalised intersections.

SIDRA INTERSECTION offers the following options for LoS determination:

- Delay (HCM method).
- Delay (RMS NSW method).

- Delay and DoS using a method proposed by Berry (1987).
- DoS only (SIDRA Method).
- DoS (ICU Method).

The delay (RMS NSW) option uses the guidelines specified in following Table 2 of the "*Guide to Traffic Generating Developments*" published by the Roads and Traffic Authority of New South Wales, Australia (draft version 2.2 of October 2002). This is the default method when the NSW version of SIDRA INTERSECTION is used.

The following table represents LoS definitions for vehicles (RMS NSW method) based on delay only.

Table 14.3 Control delay for vehicle LoS calculations

LoS	Control delay per vehicle in seconds (d) (including geometric delay)
	All intersection types
A	d < 14
B	d < 15 to 28
C	d < 29 to 42
D	d < 43 to 56
E	d ≤ 57 to 70
F	d > 70

The average delay for level of service E should be no more than 70 Seconds. If the average vehicle delay is more than 70 seconds, the intersection should be assumed to be at Level of Service F.

Note: For traffic signals, the average movement delay and level of service over all movements should be taken. For roundabouts and priority control signals intersection (with Stop and Give Way signs or operating under the T-junction rule) the critical movement for level of service assessment should be that with the worst movement delay.

The following table represents Level of service definitions for pedestrians (HCM method) based on delay only.

Table 14.4 Control delay for pedestrian level of service calculations

Level of Service	Average delay Per Pedestrian in Seconds (D)	
	Signals	Unsignalised intersections
A	d ≤ 10	d ≤ 5
B	10 < d ≤ 20	5 d ≤ 10
C	20 < d ≤ 30	10 < d ≤ 20
D	30 < d ≤ 40	20 < d ≤ 30
E	40 < d ≤ 60	30 < d ≤ 45
F	60 < d	45 < d

14.3.3 95 per cent back of queue distance

A percentile queue length is a value below which the specified percentage of the average queue length values observed for individual cycles fall. For example, the 95th percentile queue length is the value below which 95 per cent of all observed cycle queue lengths fall, or five per cent of all observed queue lengths exceed. The standard SIDRA INTERSECTION default method uses the 95th percentile value of the back of queue. This value also represents the storage length of a lane and forms part of the overall lane length.

14.4 Calibration

The calibration process should be based on various traffic surveys and site observations. All changes required in order to calibrate the model should be fully documented with an explanation and justification of the change. SIDRA User Guidelines should be referred to for possible calibration methods.

In order to properly identify the effects of future network and/or demand changes on the existing operation of signalised intersections then the timings obtained from a calibrated model of existing conditions (based on observed signal times) should be compared with those obtained from the SIDRA optimised timings. In this way differences can be compared and an explanation provided as to why they may exist. This comparison is useful in identifying:

- Incorrect model assumptions in respect of traffic behaviour (saturation flows, delays due to pedestrians, queue storage space etc).
- Incorrect model assumptions in respect of signal operation assumptions (ie alternative phase calls, phase skipping, offset, cycle times, minimum greens, clearance times etc).
- Incorrect SCATS setup.

Table 13.5 in the previous section provides a summary of the steps necessary to properly distinguish between an optimised existing model and SCATS operations to avoid future scenario assumptions being erroneously attributed to “improving” SCATS operations. These steps also ensure that the real value of infrastructure works or signal operation changes are identified.

14.4	All changes required in order to calibrate the model should be documented. Table 13.5 provides a summary of the steps to be taken if any future scenarios require the optimisation of signal timings.

14.5 Guide to Traffic Generating Developments

RMS’ Guide to Traffic Generating Developments should be used to determine the traffic generation rates for the various types and components of the development. Where the traffic generation rates are not provided or available in the guide, appropriate rates should be determined by undertaking survey of the similar facilities within NSW and / or area under study.

14.6 Future traffic growth

There are several methods for estimating future traffic growth. Any of the methods are acceptable provided appropriate justification to their use can be made. Methods include:

- Annual percentage growth.
- Growth based on local development growth and estimated trip distribution.
- Growth from larger scale (network model).

Note that turn movements from a strategic highway assignment model should not be input directly into a SIDRA. The level of detail in a strategic highway assignment model is not suitable for turn movement development. Growth in turn movements can be obtained from a strategic highway assignment model and then applied to observed turn movements. It is generally accepted that absolute growth provides a better growth outcome (when compared to growth factoring), particularly in areas of high growth.

14.7 Reporting requirements

All SIDRA analysis reports should be completed and/or reviewed by experienced modellers. An accompanying statement with name and signature of the checking personnel should accompany the final report.

The report must justify and explain the reasons for using any input or output values other than those indentified in this guideline.

Following is the list of files, tables and diagrams required (as minimum but not limited to) that should be submitted with the report for the analysis:

- Electronic SIDRA intersection Project File (.sip) including input and output files for all scenarios used. All scenarios should be named appropriately.
- Electronic SIDRA input file should include:
  - Intersection layout and data summary for the existing and proposed intersections.
  - Input report.
- Electronic SIDRA output file should include:
  - Intersection summary.
  - Movement summary.
  - Lane summary.
  - Phasing summary (signalised intersection).
  - Roundabout metering summary (metered roundabouts).
  - All other tables and figures in detailed output.
- Draft design plans for the proposed modifications to the intersection showing the extent of modification, physical constraints and existing intersection layout.
- All traffic counts and ancillary data used in the intersection assessment.

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Appendix A Model technique selection

RMS model selection guide

Based on: Austroads NS1371: Guidelines for Selecting Techniques for the Modelling of Network Operations (ver. 2) by ARRB Group Ltd. 2009 1

Project Name:

Step 1: Project objectives

1A: Key issues and objectives:

1B: Alternative schemes and decision criteria:

Step 2: Preliminary analysis

2A: Type of preliminary analysis undertaken:

2B: Preliminary analysis results:

2C: Issues to be settled by modelling:

2D: Recommendation for further analysis by modelling (circle one): yes no

Step 3: Review system elements

(Highlight areas that are required for consideration on this project)

		Strategic highway assignment	Meso highway assignment	Multi-intersection modelling	Micro - simulation	Single intersection modelling
INPUT						
Demand	Origin-Destination (>100 zones)	S	S	U	P	U
	Origin- Destination (<100 zones)	P	S	S	S	S
	Turn movement demand (traffic states)	U	P	S	S	S
	Daily traffic volumes	S	U	U	U	U
	Hourly traffic volumes	S	S	S	S	S
	Profiled traffic demand (within peak)	U	S	S	S	P
	Time varying demand	U	S	S	S	U
	Person trips	S	U	U	P	U
	Passenger car-equivalent trips	S	S	S	S	S
	Multi-class	S	S	S	S	S
	Bicycles	U	U	U	P	P
	Pedestrians	U	U	P	P	P
	Fixed route (bus, tram etc)	P	P	S	S	S
Network	Multi-modal – wide area	S*	S*	U	U	U
	Multi-model – local area	S*	S*	U	U	U
	Road network – link based	S	S	U	U	U
	Road network – lane based	U	S	S	S	S
	On-road public transport	P	P	P	S	U
	Cycle facilities	U	U	U	P	P
	Pedestrian facilities	U	U	P	S	S
	Parking – on-road	U	U	P	S	P
	Parking – off-road	U	U	U	P	S
	Toll plazas	U	U	U	S	U
	Signal control – SCATS	U	U	U	S	U
	Signal control – coordinated (not adaptive)	U	P	S	S	S
	Signal control – vehicle actuated	U	P	S	S	S
	Signal control – fixed time	U	S	S	S	S
	Priority intersections – roundabout	U	S	S	S	S
	Priority Intersection – sign control	U	S	S	S	S
	Merge areas	U	P	U	S	U
	Weave areas	U	P	U	S	U
	Managed lane use	U	P	U	S	U
	Ramp metering	U	P	U	S	U
	Variable speed limits	U	P	U	S	U
	Work and construction zones	U	S	S	S	P
	Traveller information	U	S	U	S	U

		Strategic highway assignment	Meso highway assignment	Multi-intersection modelling	Micro - simulation	Single intersection modelling
MODEL SPECIFICATION						
Geographic Scope	Isolated site	U	U	U	S	S
	Corridor – arterial	U	S	S	S	U
	Corridor – freeway	U	S	U	S	U
	Small area/network	P	S	S	S	U
	Regional centre (population < 20000)	P	S	U	S	U
	City	S	S	U	U	U
	Region	S	P	U	U	U
Timeframe	Operational level (no change in current demand or travel patterns)	U	S	S	S	S
	Short-term (some change in route choice expected)	S	S	S	S	U
	Near-term (some change in route choice or model share expected)	S*	S*	U	U	U
	Medium term (some change in route choice, mode share, trip making or trip pattern expected)	S*	S*	U	U	U
	Long term (some change in route choice, mode share, trip making, trip pattern or land use expected)	S*	S*	U	U	U
Traveller Response	Change in trip generation	S*	S*	U	U	U
	Change in destination choice	S*	S*	U	U	U
	Mode change	S*	S*	U	U	U
	Change in departure time	S*	S*	U	U	U
	Route diversion (en-route)	U	S	U	S	U
	Route diversion (pre-trip)	S	S	S	S	U
	Toll choice (willingness to pay)	S	S	U	P	U
	Vehicle-to-vehicle interactions	U	P	P	S	S
	Driver response	U	P	U	S	U
Model Functionality	Land use and transport interaction	S*	S*	U	U	U
	Static traffic control	S	S	S	S	S
	Dynamic traffic control	U	S	S	S	U
	Time-of-day measures	U	S	S	S	U
	Signal optimisation	U	P	S	P	S
	Gridlock/high degrees of saturation	U	S	P	S	U
	Temporary blockages	U	S	S	S	U
	Random incidents	U	S	S	S	U
	Pricing schemes	S	S	U	P	U
	Public transport schemes	S	S	U	P	U
	Shockwave effects	U	S	P	S	U
	Bottleneck Effects	U	S	P	S	U

		Strategic highway assignment	Meso highway assignment	Multi-intersection modelling	Micro - simulation	Single intersection modelling
OUTPUTS						
Performance Measures	Delay	P	S	S	S	S
	Intersection delay	U	S	S	S	S
	Travel times	P	S	S	S	U
	Degree of saturation	U	P	S	S	S
	Level of service – nodes	U	P	S	S	S
	Level of service - links	S	S	S	S	S
	Vehicle hours of travel (VHT)	S	S	S	S	U
	Vehicle kilometres of travel (VKT)	S	S	S	S	U
	Average queue	U	S	S	S	S
	Maximum queue	U	P	S	S	S
	Traffic volume	S	S	S	S	U
	Origin-destination demands	S	S	U	U	U
	Emissions (not including stops)	S	S	S	S	S
	Emissions (including stops)	U	S	S	S	S
	Fuel consumption (not including stops)	S	S	S	S	S
	Fuel consumption (including stops)	U	S	S	S	S
	Impacts of peak spreading	U	S	S	S	U
	Link speed	U	S	S	S	S
	Route speed	S	S	S	S	S
	Patronage (public transport)	S*	U	U	U	U
	Vehicle occupancy	S*	S*	U	U	U
	Intersection throughput	U	P	S	S	S
	Number of stops	U	P	S	S	S
	Travel time reliability	U	P	U	S	U
Required Accuracy	Planning stage (low level)	S	S	S	P	P
	Preliminary option testing (low level)	S	S	S	P	S
	Ranking of alternatives (low level)	S	S	S	P	S
	Ranking of alternatives (detailed)	P	P	S	S	S
	Design Stage (high level)	P	P	S	S	S
Audience	Technical	S	S	S	S	S
	Non-technical	P	S	P	S	P
ASSESSMENT						
	SUM TOTALS OF S/U/P	S / U / P	S / U / P	S / U / P	S / U / P	S / U / P
		/ /	/ /	/ /	/ /	/ /

S – Suitable P – Partially suitable U – Unsuitable

S*– suitable in conjunction with a multi-modal model such as the Sydney Strategic Travel Model (STM)

Step 4: Outcome from assessment

Recommended technique is one with most “suitable”. If two techniques have equal “suitable” the “partially suitable” assessment criteria should also be used.

4A: Recommended technique:

_____

4B: Limitations of modelling technique:

_____

_____

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Appendix B Site visit checklist

Site visit checklist

Project:	
Study area (geographic extents of site inspection):	
Date:	**Time (start):**
Weather:	**Time (end):**
General traffic conditions (light/heavy/incident etc):	
Study area layout:	
Land use within/adjacent to study area:	
Traffic network operation (signal times, queues etc.)	

Traffic issues and causes (queue spillback, blocking, merge etc.). Include clear description of location and effect.

Public transport (stops, dwells, interaction with general traffic) – include clear description of location.

Active transport (pedestrian interaction/cycle interaction) – include clear description of location.

Network boundary effects (blocking back, queue formation, signal timings) that influence behaviour on the network.

Other relevant information

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Appendix C Statistical Toolkit and Glossary

Easy reference statistical toolkit

	1. Before running the model		
1.1	**Choose summary measure, its statistics and precision levels**		
1.1.1	*Enter the summary measure:*	Summary measure =	
1.1.2	*Tick statistics chosen:*	Mean (*x*) *	□
		Median (*med*) *	□
		Mode *	□
		Standard deviation (*s*) *	□
		95 per cent percentile	□
		Range	□
		Interquartile range	□
		Minimum	□
		Maximum	□
		Sample size (*n*)	□
		Confidence Intervals (CIs) for *	□
1.1.3	*Tick precision level about summary measure:*	1 per cent □ 2 per cent □ 5 per cent □ Other: _____ per cent	
	Tick confidence level	95 per cent □ 99 per cent □ 90 per cent □ Other: _____ per cent	
1.2	**Choose initial no. of runs (to be reiterated at 2.2):**	n_i =	
	2. Model output analysis		
2.1	**Describe outputs**		
	Tick plot completed:	Scatter plot	□
		Box plot	□
		Histogram	□
		Descriptive statistics	□
2.1.1	*Check for independence between results using scatter plot*	No Correlation	□
		Randomly scattered	□
		No sudden or large shifts	□
2.1.2	*Screen for extreme points box plot*	Outlier runs at:	
2.1.3	*Assess model variability using histogram*	Location checked?	□
		Shape? Eg normal, skewed, bimodal:	
2.1.4	*Do sensibility check of descriptive statistics and enter results:*	Mean (*x*) & CI of *x* :	
		Median (*med*) & CI of *med*:	
		Mode:	
		Standard deviation (*s*) & CI of *s* :	
		95 per cent percentile:	
		Range:	
		Interquartile range:	
		Minimum:	
		Maximum:	
		Sample size (should equal n_i):	

2.2	**Complete required no. of runs**		
2.2.1	**Enter initial number of runs**	ni=	
	Enter desired confidence level	Confidence level=	
	Enter desired precision (Confidence Interval half-width)	Precision=	
	Select precision type (from drop-down list)	Precision type=	
	Enter sample mean from initial runs	x=	
	Enter sample standard deviation from initial runs	s=	
	Calculate desired confidence interval half-width	w=	
	Calculate no. of runs n_1 for precision level chosen at 1.1.3	n1 =	
	Complete additional runs required i.e do n1 – ni runs	Max(n1-ni,0)=	
	Total runs so far	Max(n1,ni)=	
2.2.2	*Calculate no. or runs n^ now required after completing n1 runs*		
	Enter recalculated mean (x)	x=	
	Enter recalculated standard deviation (s)	s=	
	Calculate desired confidence interval half-width	w=	
	Calculate n* needed for desired precision level from 1.1.3	n* =	
	Complete additional runs required i.e do n- n_1 runs*	Max(n* - n1,0) =	
	Total runs so far	Max(n1,ni,n*)=	
2.2.3	*Calculate Confidence Interval for Mean*		
	Enter recalculated mean (x)	x=	
	Enter recalculated standard deviation (s)	s=	
	Calculate actual CI	Upper CI =	
		Lower CI =	
	Calculate current precision level based on n_i	Current precision level =	
2.3	**Assess model stability**		
	Note down extreme points as a tool for assessing model stability:	Run(s):	For Model:
		Run(s):	For Model:
		Run(s):	For Model:
		Run(s):	For Model:
		High incomplete trips?	
		High unreleased vehicles?	
		Low total throughput of vehicles?	
2.4	**Test for bias due to incomplete and unreleased vehicles**		
		add back of summary measure (eg dVHT):	
		Vehicle Add Back per cent:	
2.5	**Compare models**		
		Confidence level=	

	Mean (of differences) x_z=	
	Standard deviation (of differences) s_z=	
	Number of runs for both scenarios n=	
2.5.1 Compare means (t-test)	Minimum	
	Maximum:	
	Upper CI =	
	Lower CI =	
	p-value of t-test:	
	Ratio (of std devs) r_{sd} =s_1:s_2:	
	Minimum	
2.5.2 Compare variance (F-test)	Maximum:	
	CI of r_{sd}:	
	p-value of F-test:	

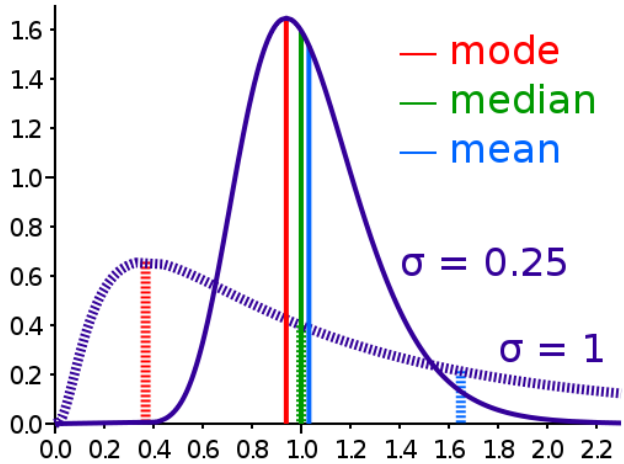
Glossary

Descriptive statistics:

Confidence interval (or CI): is a range of values around a "sample" statistic (such as mean, median, mode, standard deviation) where the 'true' statistic can be found. It has a level of confidence (or confidence level), usually set at 95 per cent. It does not mean that the true value has a 95 per cent chance of being in the interval, providing that the statistical framework is correct. The two major factors determining the width of a confidence interval are the sample size and the variation of these data – the larger the sample size, the more reliable its mean; the larger the variation, the less reliable the mean.

Measures of central tendency: Are a way to specify the central value of the simulation model, which should always be reported with their corresponding confidence intervals. There are three types listed in this glossary: mean, median and mode. For a normal distribution the three measures are equal.

Figure G1 is a comparison of the three measures from two distributions of differing skewness. Note how the median maintains its location regardless of variation of the values as opposed to the mean and mode.



Source: http://en.wikipedia.org/wiki/Arithmetic_mean: cited 09/11

Figure G1. Comparison of mean, median and mode from two distributions with different skewness (σ= standard deviation)

Mean: denoted by x throughout the guidelines, it is the average of the values from the simulation model, eg for VHT the mean VHT would be their sum divided by the number of runs in the model. The mean can be affected by extreme points.

Median: If the model outputs are placed in order from lowest to highest, the median is the middle value. When the number of runs in the sample is even, the median is computed as the average of the two middle values. It is less affected by extreme points than the mean and so can be more "robust" (if there is a substantial variation in the values of the runs).

Mode: the value that occurs most frequently in the model output.

Measures of dispersion: measures that reflect how the outputs vary or how they are dispersed (i.e. their variability).

Inter-quartile range (or IQR): is the range of the middle 50 per cent and is equal to Q3 - Q1

Percentile (or centile): the value of for example VHT below which a certain per cent of runs fall, eg 95 per cent percentile is the VHT value below which 95 per cent of runs are found.

Quartiles: Q1 =the 25th percentile or 1st quartile; Q2 =the median or 2nd quartile; Q3 = the 75th percentile or 3rd quartile

Range: the maximum minus the minimum

Standard deviation: denoted by s throughout the guidelines; it is *a measure of variation* or "dispersion" from the mean (in fact it is the square root of the variance) A large s indicates the runs are vary widely

from the mean VHT whereas a small s indicates that they vary more closely around the mean VHT. Figure 11.12 in the guidelines illustrates how models with the same mean can differ in their "spread". Like the mean, the standard deviation is also affected by extreme points.

Sample size: the number of runs; larger sample sizes lead to increased precision for model outputs (based on model inputs); it is important to have between 20–30 runs at least (see central limit theorem).

Common statistical terms

Accuracy: of the model output is how closely it represents the true value(s) of the network.

Central limit theorem: is a probability theory that underlines the foundation for many statistical procedures; it results in the understanding that the average of the model outputs will tend to be normally distributed as the no. of runs (sample size) increases, even if the actual network the model is based on is not normally distributed; it is suggested to use a minimum of 20 runs (observations).

Confidence level: see confidence interval

Extreme points: *sometimes called outliers;* they are the runs that are very different to all the others or a large section of the others; they are easily displayed in box plots (by "*'" and need to be investigated to ascertain if they are caused by an error in the simulation or are actually indicative of the network being simulated; can be defined as a point that falls > 1.5 times the inter-quartile range away from the "box" in a boxplot.

Normal distribution: is illustrated by a bell-shaped histogram – meaning there is symmetry about the mean. The comparison of the means of two models uses a paired t-test which assumes the models are normally distributed which stresses the importance of having 20–30 simulation runs.

Precision: is a function of the scale of the test. It has two different meanings depending on the context:

When trying to detect a difference between two scenarios: the precision is the size of the difference the study is trying to detect, eg a study aiming to detect a 1 per cent difference in results between two scenarios will need a larger number of runs than if only trying to detect a 10 per cent difference.

In a single model analysis precision of an output (for example Mean VHT): precision is the desired width of the confidence interval for the output.

Skewness: a measure of the asymmetry of the model. Can be positively (right tail longer) or negatively skewed (left tail longer); see histogram shapes for examples.

Variance: squared value of standard deviation.

Statistical hypothesis tests – for comparing models:

Alternative hypothesis: of the test, usually denoted by H1. Here it is that the measures being compared are not equal.

F-Test: the statistical test used to compare the variances/standard deviations from two models

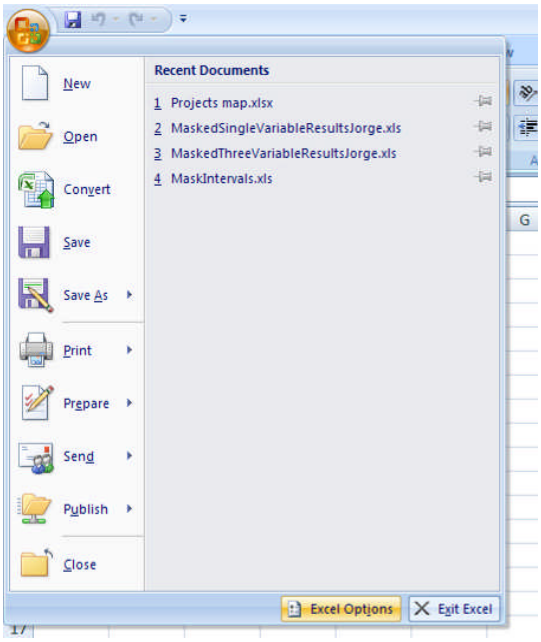
Null hypothesis: the general position usually denoted by H0 of a hypothesis test. Here it is that the measures (eg mean, variance) being compared are equal.

Paired T-test: the statistical test used to compare means from two models.

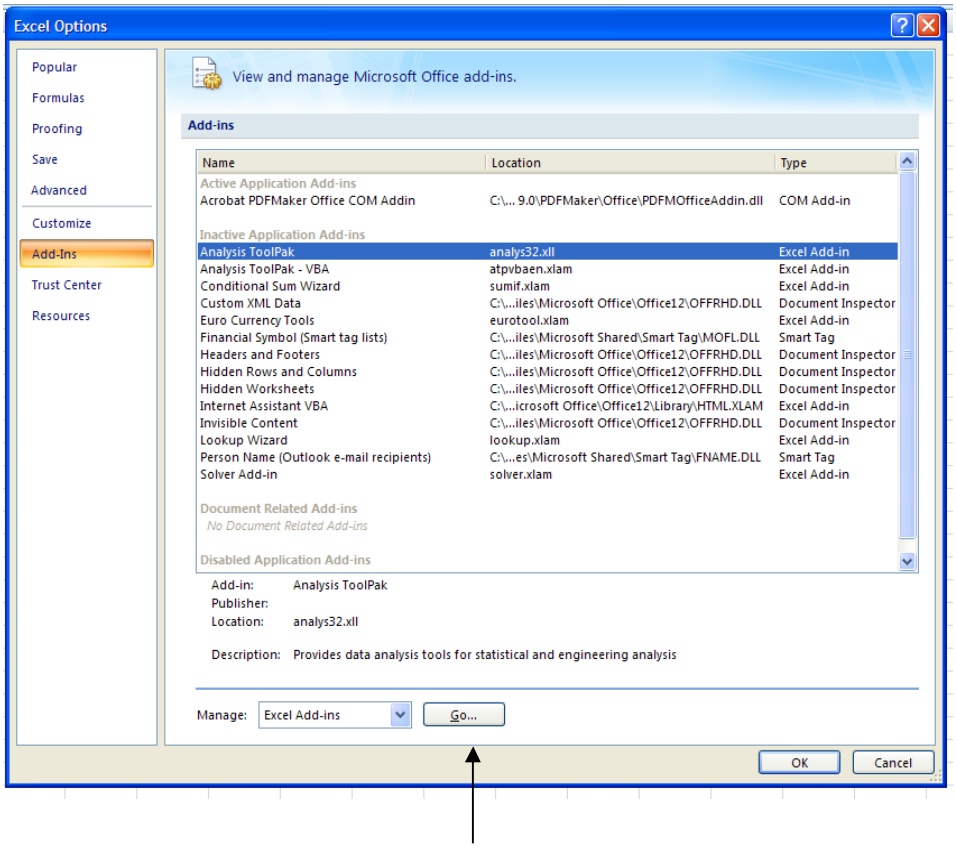
Obtaining the statistical tools in Excel called “Analysis ToolPak”.

Excel has some useful statistical tools available that are provided as an “Add-in” called the “Analysis ToolPak”. The following is a set of instructions on how to install this:

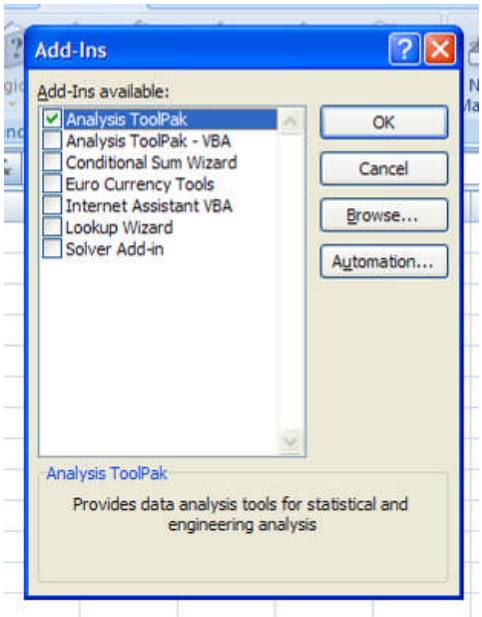
1 Click on the Office button in the top left hand corner and select the button at the bottom of the menu.



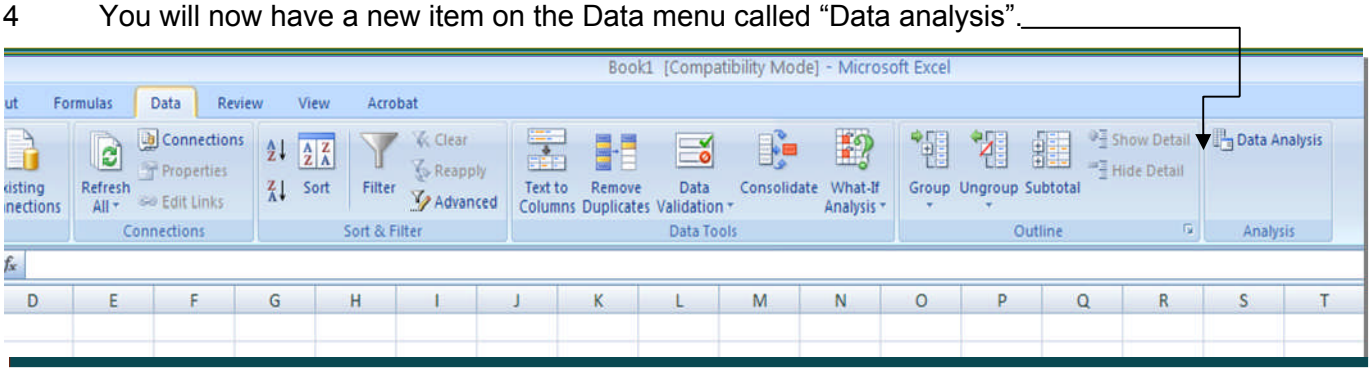
2 Choose Add-Ins then click on the Go ... button at the bottom of the dialog box.



3 Choose Analysis ToolPak and click on OK. Say yes if you get an error asking to install it.



4 You will now have a new item on the Data menu called “Data analysis”.



Appendix D SCATS standard port numbering

Instance	Region	SCATTERM	SCATS Access	Central Manager	Simulator
1	ALB	3001	3101	2007	3201
2	BEL	3002	3102	2007	3202
3	BEX	3003	3103	2007	3203
4	BLA	3004	3104	2007	3204
5	CAM	3005	3105	2007	3205
6	CHA	3006	3106	2007	3206
7	CITY	3007	3107	2007	3207
8	COU	3008	3108	2007	3208
9	DARL	3009	3109	2007	3209
10	DY	3010	3110	2007	3210
b11	EPP	3011	3111	2007	3211
12	EVE	3012	3112	2007	3212
13	FAI	3013	3113	2007	3213
14	FIDO1	3014	3114	2007	3214
15	FIDO2	3015	3115	2007	3215
16	FIDO3	3016	3116	2007	3216
17	FIDO4	3017	3117	2007	3217
18	GOS	3018	3118	2007	3218
19	HAM	3019	3119	2007	3219
20	HOR	3020	3120	2007	3220
21	HOXPK	3021	3121	2007	3221
22	KOG	3022	3122	2007	3222
23	LEW	3023	3123	2007	3223
24	MAY	3024	3124	2007	3224
25	NAR	3025	3125	2007	3225
26	NEW	3026	3126	2007	3226
27	NSYD	3027	3127	2007	3227
28	PAR	3028	3128	2007	3228
29	PEN	3029	3129	2007	3229
30	PUN	3030	3130	2007	3230
31	RAND	3031	3131	2007	3231
32	RIC	3032	3132	2007	3232
33	ROZ	3033	3133	2007	3233
34	RUS	3034	3134	2007	3234
35	RYDE	3035	3135	2007	3235
36	SHELL	3036	3136	2007	3236
37	SIL	3037	3137	2007	3237
38	TAR	3038	3138	2007	3238
39	ULT	3039	3139	2007	3239
40	WAR	3040	3140	2007	3240
41	WAT	3041	3141	2007	3241
42	WEN	3042	3142	2007	3242
43	WOL	3043	3143	2007	3243
44	ZET	3044	3144	2007	3244
45	STL	3045	3145	2007	3245
46	HAY	3046	3146	2007	3246
47	RED	3047	3147	2007	3247
48	Spare	3048	3148	2007	3248
49	Spare	3049	3149	2007	3249
50	Spare	3050	3150	2007	3250
51	Spare	3051	3151	2007	3251
52	Spare	3052	3152	2007	3252
53	Spare	3053	3153	2007	3253
54	Spare	3054	3154	2007	3254
55	Spare	3055	3155	2007	3255
56	Spare	3056	3156	2007	3256
57	Spare	3057	3157	2007	3257
58	Spare	3058	3158	2007	3258
59	Spare	3059	3159	2007	3259

Instance	Region	SCATTERM	SCATS Access	Central Manager	Simulator
60	Spare	3060	3160	2007	3260
61	Spare	3061	3161	2007	3261
62	Spare	3062	3162	2007	3262
63	Spare	3063	3163	2007	3263
64	Spare	3064	3164	2007	3264

Appendix E Recommended gap acceptance parameters

Recommended values of gap acceptance parameters:
Based on AUSTROADS (2002, 2005) Guides

Type of movement	AUSTROADS (2002, 2005)		Default or recommended values and ranges for use in SIDRA INTERSECTION	
	Critical gap (seconds)	Follow-up headway (seconds)	Critical gap (seconds)	Follow-up headway (seconds)
Left turn (1)	5	2 - 3	(3 - 6)	(2.0 - 3.5)
1-lane opposing			4.5	2.5
2-lane (or more) opposing			5.0	3.0
Through movement crossing one-way road				
2-lane one-way	4	2	4.5 (4 - 5)	2.5 (2 - 3)
3-lane one-way	6	3	5.5 (5 - 6)	3.0 (2.5 - 3.5)
4-lane one-way	8	4	6.0 (5 - 8)	3.5 (3 - 4)
Through movement crossing two-way road				
2-lane two-way	5	3	5.0 (4.5 - 5.5)	3.0 (2.5 - 3.5)
4-lane two-way	8	5	6.5 (5 - 8)	3.5 (3 - 5)
6-lane two-way	8	5	7.5 (7 - 8)	4.5 (4 - 5)
Right turn from major road (2)				
Across 1 lane	4	2	4.0 (3.5 - 4.5)	2.0 (2 - 3)
Across 2 lanes	5	3	4.5 (4 - 5)	2.5 (2 - 3)
Across 3 lanes	6	4	5.5 (5 - 6)	3.5 (3 - 4)
Right turn from minor road (3)				
One-way	3	3	Use Left turn values above	
2-lane two-way	5	3	5.5 (5 - 6)	3.5 (3 - 4)
4-lane two-way	8	5	7.0 (6 - 8)	4.0 (3 - 5)
6-lane two-way	8	5	8.0 (7 - 9)	5.0 (4 - 6)
Merge from acceleration lane	3	2	3.0 (2.5 - 3.5)	2.0 (1.5 - 2.5)

Notes (1) to (3) below are not included in the AUSTROADS Guides.

(1) This is considered to apply to left-turn movements from minor road, as well as slip-lane left-turn movements from minor road.

(2) This case is relevant to two-way major road conditions with one direction of the major road opposing (1-lane, 2-lane or 3-lane).

(3) The conditions specified (one-way, 2-lane two-way, 4-lane two-way, 6-lane two-way) are relevant to the opposing movement lanes on the major road.

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References

STRATEGIC MODELLING

[1] Bureau of Transport Statistics (2012) *Sydney Strategic Travel Model (STM) Modelling future travel patterns*, Bureau of Transport Statistics, February 2011.

HIGHWAY ASSIGNMENT MODELLING

[2] Austroad (2010) *Guidelines for Selecting Techniques for Modelling Network Operations*, Austroads Research Report, January 2010. <https://www.onlinepublications.austroads.com.au/items/AP-R350-10>

[3] Akcelik and Associates (2011) *General Framework for Road Traffic Models*. <http://www.sidrasolutions.com/traffic_resources_models.aspx>

[4] Akcelik R. (2006) *Speed – Flow and Bunching Models for Uninterrupted Flows*. Paper presented at the Transportation Research Board 5th International Symposium on Highway Capacity and Quality of Service, Yokohama, Japan, July 2006. <http://www.sidrasolutions.com/documents/TRBIntCapSymp2006Paper_AKCELIKSpeedFlowBunching.pdf>

[5] Transport for London (2010) *Traffic Modelling Guidelines, TfL Traffic Manager and Network Performance Best Practice*, *Version 3.0,* September 2010 <http://www.tfl.gov.uk/assets/downloads/businessandpartners/traffic-modelling-guidelines.pdf>

[6] Department for Transport (UK) (1997) *Design Manual For Roads And Bridges*, Volume 12, Sections 1 and 2, November 1997 <http://www.dft.gov.uk/ha/standards/dmrb/index.htm>

[7] Hidas, P. and Milthorpe F. (2010) *How Can Traffic Counts Best Support Strategic Transport Model Validation?* Paper presented at the Traffic Flow Theory and Characteristics Committee (AHB45) Summer Meeting of the Transportation Research Board, Annecy, France. <http://www.tft2010.inrets.fr/papers/10-7-28.pdf>

[8] NZ Transport Agency (2010) *Economic evaluation manual* (Volume 1). January 2010 <http://www.nzta.govt.nz/resources/economic-evaluation-manual/volume-1/docs/eem1-july-2010.pdf>

[9] ADB30 Transportation Network Modelling Committee (2010) *A Primer for Dynamic Traffic Assignment*. Transportation Research Board <http://www.fsutmsonline.net/images/uploads/mtf-files/dta_primer.pdf>

[10] Florida Department of Transportation Systems Planning Office (2008) *FSUTMS-Cube Framework Phase II. Model Calibration and Validation Standards. Final Report*. October 2008. <http://www.fsutmsonline.net/images/uploads/reports/FR2_FDOT_Model_CalVal_Standards_Final_Report_10.2.08.pdf>

[11] Wilson M. Guo X. And Daizlu M.*, Convergence of the Sydney Strategic Traffic Model – Implications for Economic Analysis of Urban Road Project.* <http://www.inro.ca/en/pres_pap/international/ieug06/6-4_Xiaoping_Guo_report.pdf>

MICROSIMULATION

[12] Transport for London (2010) *Traffic Modelling Guidelines, TfL Traffic Manager and Network Performance Best Practice*, *Version 3.0,* September 2010

[13] Roads and Traffic Authority (2009) *Paramics Microsimulation Modelling – RMS Manual v1.0*

[14] UK Highways Agency (2007) Guidelines *for the use of Microsimulation Models*

[15] Austroads (2006) *The Use and Application of Microsimulation Models*

[16] SIAS (2005) *Microsimulation Consultancy Good Practice*

[17] Federal Highways Agency, USA (2004) *Guidelines for Applying Microsimulation Traffic Models*

[18] Department of Transport, UK (1996) *Design Manual for Roads and Bridges – Traffic Appraisal in Urban Areas*

SCATSIM

[19] Austroads (2003) *Guide to Traffic Engineering Practice Series, Part 7, Third Edition*

[20] Roads and Traffic Authority, NSW (2005) *Traffic Signal Design, Section 11*

LinSig

[21] AKÇELIK, R., BESLEY, M. and ROPER, R. (1999) *Fundamental relationships for traffic flows at signalised intersections*

[22] Austroads, *Austroads Guide to Traffic Management Part 3*, Section 6.4.2

Transport Research Laboratory (UK) *RR67 Report*

[23] TRB, *Highway Capacity Manual* Chapter 16 Appendix H

R. Akçelik, ARRB, *Traffic signals: timing and capacity analysis*

[24] Transport for London (2010) *Traffic Modelling Guidelines, TfL Traffic Manager and Network Performance Best Practice*, *Version 3.0,* September 2010

SIDRA

[25] Akcelik & Associates Pty Ltd (2010), *SIDRA Intersection User Guide*, Part 1, 2, 3, & 4 July 2010

[26] Transport for London (2010) *Traffic Modelling Guidelines, TfL Traffic Manager and Network Performance Best Practice*, *Version 3.0,* September 2010

[27] Gladstone Regional Council (2010), *SIDRA Intersection user Guidelines*, Version 1.0, July 2010

[28] Roads and Traffic Authority NSW (2002), *Guide to Traffic Generating Developments* version 2.2 October 2002.

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