DTO Modelling Guidelines

Traffic Schemes in London Urban Networks

Status: Final
Version: 2.0
Date: July 2006

DOCUMENT CONTROL

ISSUE	DATE	STATUS / NOTES	BY	CHK	APP
0.5	16/06/2004	Issue for DTO comment	JPR	TE	TE
0.6	07/07/2004	Issue for NMG comment	JPR	TE	PBD
1.0	31/07/2004	Issue for use	JPR	TE	TE
1.1	04/08/2005	1st review – internal comment	JRC	II	
1.2	04/01/2006	2nd review – internal comment	II	JPR	
1.3	20/03/2006	2nd issue for DTO comment	II	NC	JPR
2.0	13/07/2006	Final – issue for use	II	NA	TE

Changes made since issue 1.0 are indicated with vertical line in right margin.

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1. INTRODUCTION

1.1. Background

TfL Surface Transport installs and operates all traffic signal equipment in London. The Directorate of Traffic Operations (DTO) within TfL Streets is the principle Directorate in this area. This is done in partnership with Road Network Development (RND), who oversee the design and development and Road Network Performance (RNP), who provide a Network Assurance role, fulfilling the role of Traffic Manager under the Traffic Management Act 2004.

The key departments within DTO are Traffic Infrastructure (DTO-TI) and Urban Traffic Control (DTO-UTC)

DTO-TI and DTO-UTC are dependent on comprehensive modelling and supporting information from clients (including Boroughs and TfL departments) as well as consultants in order to assess, implement and operate traffic schemes effectively.

The information received by DTO-UTC and DTO-TI in the past associated with both minor and major signal schemes in London has varied greatly in quality. In some cases the modelling techniques are highly questionable. This can compromise the final objectives of the scheme.

If formally presented information is inadequate this can lead to design concepts and purposes at local and network level being overlooked or simply misunderstood. Historically, in many cases interpretation of the scheme has been left to the individual DTO-UTC / TI engineer to turn into a workable method of control and then to relate this to the rest of the network. This may not result in delivering the clients objectives, and with the increasing number and complexity of schemes in London, this is no longer a viable option from a resource perspective.

The client or client’s consultant is ultimately responsible for producing a successful scheme. This can be facilitated by following correct modelling procedures under guidance from DTO.

In many cases expert level modelling skills do not lie with the client of the scheme and therefore work is entrusted to an external body to study and promote a specific scheme. Subsequently the client is not sufficiently knowledgeable to determine if the modelled results are suitable when related to a complex urban network. This can lead to inappropriate scheme designs, which once budgets are committed to, gain significant momentum and when implemented have adverse effects on the network.

In summary, appropriate, comprehensive and accurate modelling is necessary to ensure traffic schemes can be:

- Fully assessed for impacts and benefits
- Effectively designed to satisfy the original objective and mitigate any impacts
- Clarified to avoid confusion or misinterpretation of the design
- Effectively and efficiently implemented and operated

Subsequently DTO has produced this guidance document to assist the Modelling of Traffic Schemes in Urban Networks in London.

1.2. Objective

The overall objective of this document is to provide guidance on the appropriate standard of modelling required when proposing a traffic signal scheme in London's urban network.

The specific aims are to:

- Advise traffic modellers of modelling techniques
- Provide informative assistance to scheme sponsors
- Facilitate the scheme assessment process by indicating the minimum standard of modelling required by TfL to facilitate scheme approval

To be of value to engineers and modellers, it is important that this document remains of a technical nature. Therefore to ensure all aspects of the content are fully presented it has not been overly summarised. Key points are presented in the main chapters with further supporting detail provided in the appendices.

1.2.1. Balancing Competing Demand

An area of key concern for TfL is the need to strike a balance for all road users, often where there are competing priorities.

Urban Traffic Control (UTC) signal plan optimisation techniques generally aim to set signal timings, which reduce delays and stops by choosing the combination of cycle time, offsets and green splits that minimise the network Performance Index. This is purely a numerical exercise and to base signal timings on this criterion alone is insufficient. It is of fundamental importance to give full consideration to the following:

- The Mayor's Transport Strategy
- The strategic and policy requirements of the highway authority
- Safety issues
- Measures to facilitate public transport, especially bus passengers
- The requirements of pedestrians
- The requirements of cyclists
- Whole route strategies

Specifically, signal schemes should try to:

1. Build and operate our UTC systems infrastructure to be policy responsive and facilitate dynamic control of our traffic signals
2. Minimise cross junction exit blocking, thus reducing wasted green time and secondary congestion on opposing movements
3. At junctions with all round pedestrian stages, pedestrian "walk with traffic" movements, or sites with dedicated cycle phases, maximum wait times for pedestrians or cyclists not to exceed 83 seconds.
4. Buses in bus lanes to clear junctions in one cycle and be protected from congestion
5. Queue lengths alongside bus lanes not to impede buses at the bus lane entry point during the hours of operation
6. Links containing significant numbers of high patronage buses that are not protected by bus lanes not to exceed 95% saturation.
7. Where common network cycle time and capacity allow, isolated pedestrian crossing cycle times to default to double cycle. Where only single cycling is possible, pedestrian wait times not to exceed 60 seconds
8. Pedestrian crossing points at signals to be protected from exit blocking and queue formation under normal network operation, being mindful of safety and localised pollution from exhaust emissions
9. Multiple and staggered pedestrian crossing movements to be linked where possible to favour the larger pedestrian movement relative to the time of day
10. For internal links on signalled gyratories and roundabouts, static queues on internal links not to exceed 2/3 of the link capacity and remain below 85% saturation.

Road safety is an area of key concern for TfL. Scheme objectives should always include improvements to safety, however this may not be immediately conducive to modelling. Nevertheless changes to operations of junctions can have significant influence on the safety of road users, including pedestrians, powered two wheeled vehicles, cyclists and general vehicular traffic. Although this will not be easy to introduce to the modelling in quantitative terms it needs to be considered as part of the overall scheme objective.

The London Road Safety Unit (LRSU) can advise on modelling safety factors in a traffic context. The SAFENET modelling tool has been developed for this purpose and the LRSU should be consulted to obtain advice on its application.

In particular, designers and modellers should be mindful of policy 4G.1 of the Mayor's Transport Strategy, which stresses the focus on safe and expeditious movement of people, not simply vehicles or even PCU's (passenger car units).

Additionally, attention should be paid to the different types of road usage. Policy 4G.2 of the Transport Strategy states the following:

"In balancing the use of street space, account should be taken of the objectives of the Transport Strategy and the current London road hierarchy. On the Transport for London Road Network (TLRN) and most other 'A' roads there is a general presumption in favour of distribution, particularly for those making business journeys, bus passengers and commercial vehicle operators. On other London roads there is a presumption in favour of access and amenity, particularly for residents, buses, pedestrians and cyclists, and where necessary, business access."

In summary it is essential to balance the needs of general vehicular traffic with safe operation of the network, priority for public transport passengers, encouraging cyclists in appropriate locations and providing pedestrians with the opportunity to conveniently cross the road. Effective modelling is a vital requirement for achieving such a balance.

1.2.2. Modelling Output

This document will detail the high standard of information that should be presented by the modeller. This will result in a proposal that satisfies the following requirements:

- Provides a comprehensive report on the impact of the scheme to allow a fully considered assessment
- Considers the needs of all road users in a balanced manner
- In a "working" format and not to an "in the order of" standard
- Each element of the design and modelling being inter-related
- Material must be easy to audit and not left to the auditor's interpretation, so that modifications can be made at a later date if required
- Individual modellers and designers working on separate elements of the scheme should be easily identifiable so that in partnership with others, a degree of intellectual ownership is carried through to implementation

1.3. Scope

As a minimum this guidance should apply to traffic signal schemes in London where the scheme:

- will have significant impact on the existing network, especially bus passengers;
- is within an urban network;
- includes signals controlled by UTC;
- includes new signals, modifications to existing signal design or modernisation / upgrade of signalling equipment.

The document focuses on UTC controlled signal schemes as these are generally found in London's more complex urban areas that often require advanced modelling techniques. However, it is advised that this guidance should be followed for all traffic signal schemes.

It is also suggested that the general spirit and any applicable sections be applied to the modelling of all traffic schemes, such as road space reallocation, bus priority or speed restriction measures and safety, pedestrian, cycling or interchange schemes.

It should be noted that this document is aimed primarily at local level schemes that can be modelled using detailed "tactical" models such as LINSIG, TRANSYT and micro-simulation products. However, the document can and should be applied, where appropriate, to major developments and the subsequent use of strategic and in particular assignment modelling tools such as SATURN or VISUM.

1.3.1. <u>Audience</u>

It is intended that a broad traffic engineering community should read this document. The primary audience is scheme designers and modellers, including TfL internal staff and external consultants. However, it will also be of use to clients or sponsors of schemes including Boroughs and developers. This document, and in particular chapter 8, is intended to provide valuable information to assist a sponsor when assessing scheme design.

In this way it is anticipated that proponents of schemes will be better informed and scheme design will become more focused at the outset.

1.4. Authors

The following members of the DTO-UTC Department have contributed significantly to this document:

- Tony Earl: Head of Urban Traffic Control (UTC) – DTO
- Jason Robinson: Chief Engineer, UTC Systems and Projects – DTO
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- Ajay Tailor: Senior Traffic Control Engineer – DTO-UTC

Acknowledgement is also given to numerous additional contributors. These are identified in Appendix H.

Collectively the key contributors to this document possess over 70 years of traffic engineering and modelling experience. This has been gained through major and minor scheme traffic modelling, scheme assessment, scheme implementation and the undertaking of modelled timing reviews to provide balanced optimisation of London's road network.

1.5. Partnership

The process of scheme design and audit for new/modified schemes is a partnership. The free flow of information between all parties concerned is vital in order for a positive outcome to be achieved. It is expected that this may be an iterative process following design audits.

It is essential that there is regular dialogue between the following primary stakeholders throughout all stages of scheme development:

- The client;
- The Highway Authority (if not the client);
- The scheme designer or modeller;
- DTO – Traffic Infrastructure (TI);
- DTO – Urban Traffic Control (UTC);
- RNP – Network Assurance Team;
- TfL London Road Safety Unit (LRSU).

It is vital that all parties understand the workflow of communication between these stakeholders and the primary responsibilities of each party.

2. KEY TRAFFIC MODELLING CONSIDERATIONS

2.1. Base Model Accuracy (Existing Situation)

The main purpose of modelling schemes is to assess their impact on the existing network and to determine how best the scheme may be incorporated into the network. Therefore, to understand the changes and take appropriate measures to manage them, it is essential that the base case is known from the modelling aspect.

In all cases, it is a fundamental requirement of the design process that accurate models are built of the existing situation. These models must be fully validated using site-measured data to ensure that any scheme proposals can be fully compared to a reliable baseline. This allows proper consideration of the scheme impacts and ensures there is a fair assessment of the scheme.

There are often many models in existence for the areas concerned. The likelihood of them being accurate, up to date and to the standards required is unlikely - even if DTO-UTC or DTO-TI originally created them. This is mainly due to changes in how the network operates, which can be attributed to a variety of reasons including:

- Major schemes such as World Squares, Congestion Charging, Vauxhall Cross and Bus Priority Corridor initiatives
- Changes through the introduction of bus lanes
- Major and minor changes in methods of control at signals
- Introduction of new installations
- Changes to region/group boundaries
- Changes to UTC timings
- Installation of SVD
- Installation of advance cycle stop lines

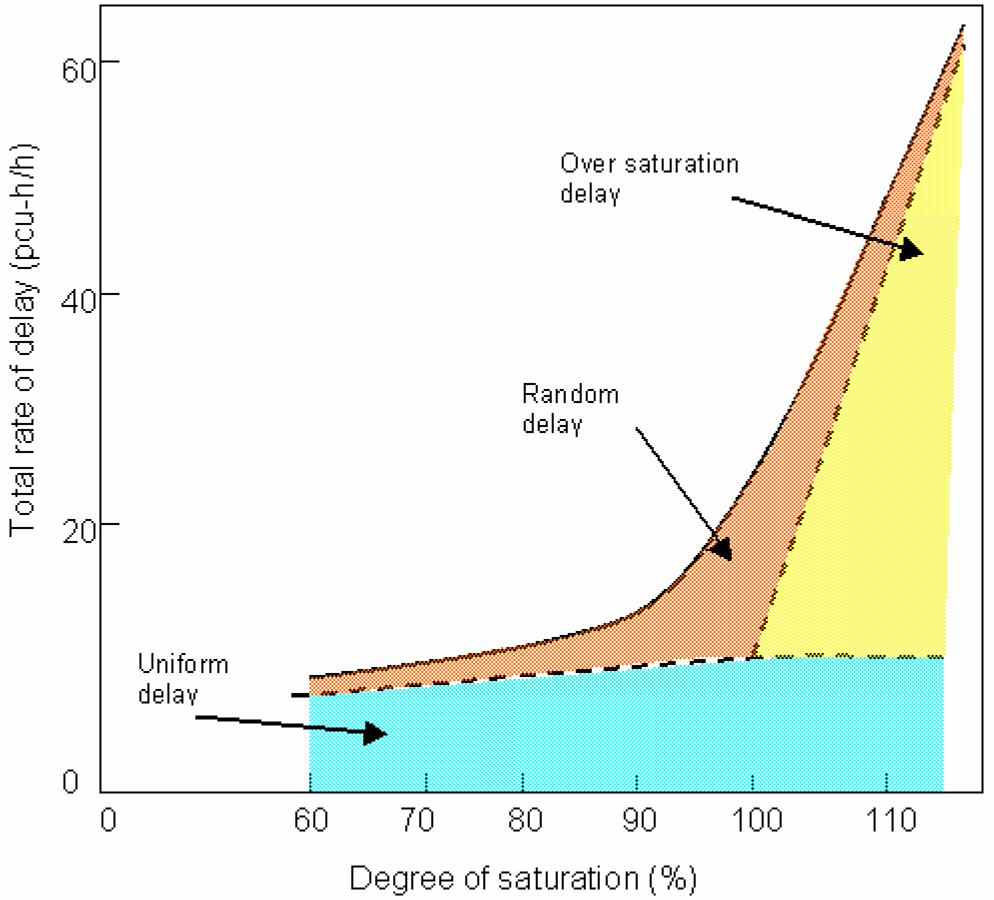
In general, pre-existing models may become invalid very quickly unless they are kept up to date. If any such existing model is to be used it will have to be thoroughly checked for accuracy on all key areas including link choice, traffic flow and signal control information. This is a fundamental requirement, as this model must form the basis of those used for the design process.

Where such models are used, it is the responsibility of the scheme designer/modeller to undertake a thorough audit of the model and ensure that it is fit for purpose as described. It is not acceptable to assume that the model is correct.

The preferred option is that a new existing situation base model is developed. The input data, development techniques and fine-tuning requirements for such a model are detailed in chapters 3, 4 and 5 respectively.

2.2. Delay / Saturation Relationship

It is vital to be aware of the relationship between delay and Degree of Saturation (DOS). Delay begins to increase exponentially at high DOS (>85%). At junctions operating close to zero practical reserve capacity (90% DOS), even small reductions in capacity can result in a significant increase in delay. A DOS of 90% should be the upper limit of practical capacity for signalised junctions. Unsignalised junctions typically have a lower practical capacity limit, at a DOS in the range 80-85%.



2.3. Urban Traffic Control (UTC)

Within central London and in major satellite urban town centres the role of Urban Traffic Control (UTC) is crucial to the operation of the network.

London has approximately 6000 traffic signal installations. Of these, nearly 2800 are controlled centrally via the Urban Traffic Control (UTC) computer through either fixed time signal plans or adaptive SCOOT control. Over half the current UTC sites run SCOOT.

The following sections provide additional background on the key aspects of urban traffic management. These should be considered when designing and modelling a traffic scheme.

2.3.1. Contingency Signal Timings

Beyond weekly automatic signal plans, there is a need for additional signal plans to cater for unplanned incidents. Examples include road closures and traffic diversions in addition to planned events such as demonstrations and the Notting Hill Carnival.

Scheme designers must be mindful of contingency issues and be aware of contingency requirements in the design process where necessary. Designers are encouraged to contact DTO-UTC for advice on contingencies.

2.3.2. Fixed Time and Adaptive Control

Fixed time signal plans are pre-calculated timings, usually derived through off-line traffic modelling techniques, implemented by the UTC computer relative to distinct time of day and day of week network conditions. Fixed time plans are relatively easy to model.

SCOOT is a dynamic, real time, demand responsive traffic management system and now forms greater than 50% of the network controlled under UTC. It is important to note that SCOOT is continually optimising the signal timings and therefore the modelling of SCOOT controlled signals requires more careful attention.

2.3.3. 24/7 Operation

The operation of the network 24 hours a day, 7 days a week is becoming increasingly important as travel demand in London expands beyond the weekday peak times.

Scheme designers and traffic modellers must ensure that the scheme design and modelling fully considers impacts at all times of day and the issues that may arise outside of the traditionally modelled periods. Of particular concern in this respect is the current lack of consideration given to weekend operation, where traffic demand may be similar to that of a weekday but capacity constrained by relaxation of parking, waiting and loading restrictions.

2.3.4. Cycle Time Constraints

Ideally, pedestrian waiting times should not exceed 83 seconds. A general guideline in London is not to exceed an 88-second (SCOOT compatible) cycle time, especially on a junction with an all round pedestrian stage. However, where the junction is controlled within a UTC group or linked locally through Cableless Linking Facility (CLF) signal timings, increasing the cycle time at one junction may give the opportunity to produce pedestrians benefits at other installations by providing extra capacity thus facilitating double cycling/double greening or providing an extra pedestrian enabled stage within the cycle.

For pedestrian, pelican and toucan crossings it is recommended to allow 20 seconds for road traffic before the pedestrian movement is enabled again. This recommendation must take into account the normal constraints of capacity and linking on a common cycle time. Usually double cycling is sufficient if the crossing is controlled within a linked UTC group.

Consideration should also always be given to situations where linking from one pedestrian phase to another (perhaps on an associated parallel stage stream pedestrian crossing) is a possibility, thus providing pedestrian movement progression through the crossings. Again, practical constraints with respect to capacity need to be considered.

2.4. Model Boundaries

It is essential to assess and model the full impact of a scheme on all road users over the surrounding area. In general the model boundary should encompass the area within which link flows, journey times or delays will be significantly affected by the implementation of the scheme.

As a minimum the boundary should include junctions:

- where traffic flows are changing significantly as a result of the proposal;
- that include geometric layout changes, regardless of changes to flow;
- that include changes to the signal control, regardless of changes to flow;
- that are expected to suffer exit blocking as a result of the new scheme or change of traffic control strategy.

In addition, if the study area is part of a CLF or UTC group or region then provided that the cycle length stays the same the whole group/region does not have to be included in the model. If a cycle length change is proposed, or other issues which affect the whole group/region arise, then the whole group/region will have to be included in the model.

In summary, the impact of the scheme on the surrounding network must be modelled, not simply the individual junction(s) or area of works proposed in the scheme. The model boundary should initially be a matter of judgement by the modeller but should be revised at the outset after consultation with DTO.

Finally, although traffic modelling may not strictly be required to cover these issues, consideration must be given to the following:

- The routes currently being used (or likely to be used in the future) by traffic affected by the scheme
- The areas where significant relief would be provided by the scheme
- The areas susceptible to significant dis-benefits produced by extra traffic induced by the scheme
- The impact of changes in traffic levels on both existing and new or improved roads in the area
- The area over which economic benefits are to be assessed

2.5. Modelling Expertise

The modeller undertaking the development of the scheme model should ideally possess:

- Considerable modelling experience in the products being used (e.g. LINSIG, TRANSYT, VISSIM, PARAMICS, SAFENET, SATURN).
- Considerable experience in site data collection of traffic control parameters including saturation flows, degrees of saturation, lane utilisation identification, wasted green identification.
- A good understanding of the capabilities of microprocessor based controllers, particularly with respect to interstage design and phase gaining and losing delays
- Experience of modelling microprocessor based controllers using LINSIG
- A good understanding of the Mayor's Transport Strategy for London and how this relates to signal timing work.

It is strongly recommended that all clients and scheme sponsors ensure that consultants are competent in the above areas.

3. TRAFFIC MODELLING DATA

Accurate and up to date data is essential for correctly calibrating traffic signal models. All data must be version controlled and indexed, to allow cross-referencing (e.g. layout drawings related to flows, signal timings, model versions etc.).

Depending on the modelling tool to be used and the extent of the study area, different data requirements exist. The following sub-sections indicate the minimum general requirements for an accurate model. Additional information is provided in Appendix A.

3.1. Site Data

Where this data needs to be collected from site the modeller must ensure that network conditions and traffic signal(s) are operating typically and there are no other unusual activities or travel patterns, this includes but is not limited to:

- School holidays
- Road works
- Temporary road closures
- Demonstrations
- Festivals
- Traffic incidents occurring
- Temporary loss of UTC control (local control)
- Temporary use of UTC contingency timing plans and strategies

When determining the programme for the traffic surveys and other site data collection the modeller should consult with the TfL London Traffic Control Centre (LTCC) to check that normal traffic control conditions are possible during the planned times of the traffic survey. Information may be gained from the LTCC information desk (Tel: 020 7126 2582, email: LTCCInfoDesk@streetmanagement.org.uk).

Data should be collected for all critical time periods being studied. It is recommended that the following time periods should be used:

- AM peak
- Midday peak
- PM peak
- Saturday midday peak
- Sunday PM peak
- Late evening where heavy conditions occur (e.g. London West End)

The above list is not exhaustive. Additional time periods may be required depending on specific traffic patterns and flow profiles. The start time and duration of each time period will also vary.

3.2. Geometric Layout Drawings and Traffic Diagrams

As a minimum the following drawings and diagrams should be used and included:

- Staging and Inter-stage diagrams (or timing sheets for existing junctions)
- Separate geometric layout drawings, to scale (usually 1:500) and dimensioned, for the existing and each proposal containing at least:
  - Lane markings (fully dimensioned), distinguishing between continuous lanes and lanes of limited length (flares);
  - Bus lanes with start and finish points with time of operation and location and length of bus stop cages;
  - Cycle lanes and cycle advanced stop lines
  - On street parking (legal or illegal) by time of day;
  - Any frequently used loading bays and any other kerbside activity (Taxi ranks, drop off points, coach bays etc.) that forms a physical bottleneck to the network

3.3. Flow Data

In all cases traffic flows should be collected and details are provided below. If different types of models are prepared for the same area (e.g. TRANSYT and micro simulation) then the traffic flows of corresponding internal links of the two models, when expressed in PCUs per hour should be within a GEH value of 5. (See Appendix D for a description of the GEH statistic and how it is calculated).

3.3.1. <u>Isolated Junctions</u>

The following flow data should be collected for isolated junctions:

- Peak hour classified turning movements for each approach:
  - o with appropriate PCU weightings applied
  - o profiled in 15 minute intervals
  - o including cars, buses, articulated buses, HGVs, LGVs, trams, taxis; and
  - o motorcycles and pedal cycles where flows are significant.
- Junction bound Automatic Traffic Counts (ATCs) upstream of longest queue in study period
- Average number of vehicles queuing in short lanes at the beginning of green.
- Average cycle length and stage green times for each modelled period.
- Number of opposed right turn vehicles clearing during intergreen (per cycle).
- Number of ahead vehicles sharing an offside lane with right turning vehicles (per cycle).

Surveys should cover at least two hours in each peak to ensure the peak hour is captured. Flows outside of the conventional study periods can be calculated using factors derived from 24-hour automatic counts. However, if travel patterns are significantly different from the observed peaks, classified flows should be obtained for these specific periods.

On parts of the network controlled by SCOOT, 24-hour traffic flow profiles are available from the ASTRID database.

3.3.2. Networks

In addition to the data identified for isolated junctions, when the study area contains several junctions (forming a network) instead of collecting turning movement counts for every junction, the network equivalent is needed.

The same traffic flow time period should be applied to all junctions being studied. This period should be determined from the critical junction or set of junctions (closest to capacity or over-saturated) in the network.

As a minimum, classified turning movements should be obtained. While VISSIM can use ‘number of vehicles’ directly from the observations, count data must be converted to PCUs before being used in TRANSYT.

Where motorcycles and bicycles have a significant impact on road capacity, they should be included. As described above, VISSIM can include motorcycles and bicycles explicitly, while PCU conversion is required for TRANSYT.

Classified turning movement surveys have inherent limitations. Before they are used to load traffic onto a model, a check must be made to see whether traffic leaving one junction arrives at the neighbouring junctions. If there is a discrepancy of more than 5 percent between junctions the modeller should augment the classified counts with short site surveys to determine if there are other major sinks and sources of traffic (side roads, car park entry/exits) that were not captured in the original survey.

This should include a manual origin / destination assessment of each link to ascertain the distribution of movements to downstream links. Appendix A describes how this manual origin / destination survey can be carried out.

However, for complex networks, especially gyratories, more comprehensive surveys should be obtained. Ideally for every study period, a full origin / destination matrix (by vehicle type) for the whole network should be commissioned. Each entry/exit point to the network and each major source/sink of trips in the network such as car parks should form an origin and destination in the matrix.

An acceptable source of such matrices could be other transportation planning models or vehicle registration matching surveys. If these matrices are more than 18 months old, or there have been significant changes to network conditions, they should be updated using recent traffic counts.

Alternatively, If the scheme is low cost and the traffic model budget is limited then the routes of the major movements and their corresponding traffic volumes, by vehicle type, through the network should be provided instead. Vehicle registration matching surveys of the major routes are sufficient for this information to be established. The desired number of these routes and their extent through the network should be determined depending on the size of the model.

For networks where bottlenecks exist, either physically or due to operational conditions (loading bays, frequently used bus stops, starts of bus lanes, uncontrolled or zebra pedestrian crossings etc.), a fifteen minute traffic count needs to be made of the number of vehicles passing through the bottleneck. This count should be repeated for each traffic model time period.

3.4. Traffic Signal Data

Traffic signal control information must be obtained from a variety of sources. The central contact within TfL when requesting such data is the Signal Data Requests Office (Tel: 020 7126 2370, Fax: 020 7126 2303).

Essential signal information includes:

- Current method of control, including banned movements
- Phase intergreen table
- Phase delays
- Phase minima
- Phase maximum in case of VA operation
- CLF plans (only if non-UTC sites)
- Special conditioning (such as locally invoked bus priority SVD, hurry calls etc.)

The above data should be obtained from the latest version of the TfL “blue” copy of the specification of the controller (NOT the signal timing sheet). In addition the traffic modeller must check with DTO-TI to confirm any Random Access Memory (RAM) changes that are current in the controller which have overridden the blue specification settings.

When modelling signal controlled junctions operating in isolation (VA or MOVA) the phase and cycle lengths will have to be derived by site observations during each time period for which a model is being prepared. These lengths should represent averages observed over several cycles. If traffic flow demand is profiled over the simulation period in short time intervals then ideally the phase and cycle lengths should also be averages over the same time intervals.

3.4.1. UTC Plan Data

When modelling existing junctions controlled under UTC, the following is required:

- Fixed Time Operation
  - Current signal timing plans from the UTC system library
- SCOOT Operation
  - SCOOT average cycle and stage lengths from the SCOOT ASTRID database 'bacfiles' for the same day as the traffic flow data was collected, and **not from SCOOT background plans**
  - Average SCOOT offsets from SCOOT "M18 message" ideally on the same day as the traffic survey was done, and **not from SCOOT background plans**
  - If M18 message information is not available TRANSYT offset optimisation can be used, however this is unlikely to be indicative of actual operation as offset biases may exist in SCOOT and manual adjustments (e.g. grouping of nodes) will be required to ensure validation.
  - Confirmation that the street traffic conditions are typical is required.
  - Details of any SCOOT parameters or constraints that may affect the timings (e.g. weightings of splits or offsets).
- Appearance frequency of demand dependent stages (using the UTC system ACHK command), ideally for the same day as that when the traffic flow survey took place.
- Stage length allocation to other stages when demand dependent stages are not called (according to existing plans)
- Details of any SVD bus priority measures in operation
- Details of any system activated strategies in operation (SASS and gating)

The above data should be obtained from DTO-UTC via the Signal Data Requests Office for each modelled period. It is advised that a member of the DTO-UTC Department is consulted when obtaining SCOOT and/or bus priority data in order to clarify details.

3.5. Additional Data

In addition to traffic flow data, the following essential data should be collected or measured. Appendix A contains advice on how to measure key items.

3.5.1. <u>Bus frequency data</u>

Bus frequency by route should be collected from TfL buses for the time of day the model applies. Bus route maps and timetables are available from the TfL Buses web site at: http://www.tfl.gov.uk/buses/. Additionally, small scale surveys should be carried out to determine the mean dwell time and standard deviation at the busiest bus stops in the model area. Bus cruise times should be assumed to be the same as cruise times for general traffic on the same type of link.

3.5.2. <u>Accident Data</u>

It is vital to consider the safety implications of a scheme. Existing accident data should be obtained. The London Road Safety Unit (LRSU) within TfL should be consulted when considering safety issues. (MartinBrophy@streetmanagement.org.uk)

3.5.3. <u>Calibration Data</u>

- Pedestrian and bicycle flows are required where:
  - pedestrian/bicycle activity is moderate to high;
  - the scheme significantly impacts pedestrian or bicycle movements;
  - changes to pedestrian or bicycle phases are proposed;
- Where detailed simulation of Puffin or Toucan crossings is to be undertaken counts should be subdivided into ‘crossing with signals’ and ‘crossing through gaps’ in traffic.
- In addition to pedestrian and/or bicycle flows, mean crossing time and standard deviation should be measured when converting fixed invitation and clearance crossings to those with extendable timings.
- Free running travel time (mid platoon) from each stopline to all downstream stoplines in seconds. NOTE: **default cruise speeds are not acceptable** – cruise speeds if used must be measured on street for each 200m section of the link and averaged.
- Minimum acceptable give way gaps (seconds) for each give way.
- Measured saturation flows for each lane / group of lanes (link), NOTE: TRL RR67 calculation should only be used for non-critical approaches or where site measurement is not possible (such as links that are always exit blocked or short greens are normal). Any calculated saturation flows must be checked during validation. Forward planning is essential to ensure that traffic conditions are typical when measuring saturation flows.

- Start and end of green lost time / lags for critical approaches.
- In addition, an experienced engineer should visit the site on each study period to observe traffic lane usage at each approach of the junction. This is to determine the number of full and partial lanes used according to vehicle destination through the junction. Additionally any unusual traffic conditions should be determined (bottlenecks, fanning, funnelling, illegal parking etc).

3.5.4. Validation Data

The following data (for each study period) is essential for validating models as these parameters are easily derived from most models and therefore a direct comparison between surveyed and modelled data can be made.

- Stopline traffic flow (PCU/hour)
- Degree of saturation, calculated from:
    - actual green time;
    - Average cycle time;
    - traffic flow spot count for each link
- Queue length (in PCUs at the start of green)
- Average Journey Time (aggregated free flow time plus delays for key specific routes through multiple signal controlled junctions) for buses and general traffic.
- Cyclic flow profiles can be easily collected with the widely available software CFP distributed with TRL's bundle suite and can be a very good source of identifying areas of model inaccuracy from direct comparisons with TRANSYT traffic flow profile graphs.

The above data should be collected at the time saturation flows are measured.

4. TRAFFIC MODELLING TECHNIQUES

There are many different modelling packages currently available. These packages vary in their applicability to accurately model different traffic situations and behaviours. Some were developed specifically to represent urban traffic behaviour found in urban networks like London, which have a high level of interaction between the different road users.

The most common modelling packages for optimising signal controlled junctions are LINSIG and TRANSYT. However, these may not necessarily be typical of London in terms of driver behaviour and care is required to ensure they are accurately calibrated before they are used to assess schemes in London.

In addition there are a variety of micro-simulation packages available. The most widely used packages are VISSIM and PARAMICS for simulating traffic and network conditions.

Micro-simulation models have the ability to model each individual vehicle within a road network providing a realistic representation of actual driver behaviour. They are the only modelling tools with the capability to realistically examine certain complex traffic situations common in London.

The drawback of micro-simulation tools is that they require significantly more time from a skilled resource to develop an accurate model. In addition, there is a significant appeal in using the powerful animation functions, which show individual vehicles traversing networks. This can lead to the development of a model simply to produce an attractive animation, rather than an accurate simulation of reality.

Further information on the major differences between empirical modelling products and micro-simulation packages is provided in Appendix B.

The following sections provide advice on modelling methods and highlight key areas where mistakes and omissions often occur.

Finally, there are numerous additional tools to support the modelling of specific scenarios. These are not fully explored in this document but are mentioned here to indicate their applicability.

These tools include the following:

- SAFENET, which should be used to model road safety issues;
- SATURN, VISUM and other strategic modelling tools, which should be used to model the impact of schemes that cover a large boundary. This is particularly important where traffic re-assignment is anticipated due to the introduction of the proposed scheme.

4.1. Model Identification

All traffic models should identify the following:

- Site number(s) (obtained from TfL Traffic Infrastructure division)
- UTC group/region number (if modelling a network, obtained from DTO-UTC).
- Existing situation or evaluation of a proposal
- Code number/letter of the proposal
- Period of the day under consideration
- Date when traffic flow data was collected
- Name of the person who prepared the model
- Model version number

4.2. Fundamental Modelling Issues

This section highlights key issues that can be overlooked or omitted in traffic models. These issues are outlined below and Appendix C provides further detail.

- **Signal controller Phase Delays** must be correctly modelled to ensure accuracy
- **Pedestrians** phases must be modelled and defined as separate links (for pedestrian linking assessments)
- **Bottlenecks** must be used when lane widths reduce, particularly on down stream exits to junctions
- **Saturation Flows** must be measured and accurately reflect street conditions
- **Give Ways** must be included with site measured coefficients
- **Right Turning Vehicles** should be modelled using give ways and end lags where appropriate. Their impact on ahead traffic should be accurately reflected
- **Buses and bus lanes** should be modelled separately, especially if there is high bus flow or the scheme will have significant effect on network performance.
- **Flared Approaches** must be carefully modelled as short lanes with maximum stacking capacity considered including the impact of blocking adjacent lanes.
- **Shared Links** (TRANSYT) should be used if complex travel patterns occur
- **Fanning and Funnelling** should be correctly modelled to ensure over or under saturation is avoided.
- **Exit blocking** must be properly considered, especially as many models do not simulate this adequately.

4.3. Isolated Schemes

Schemes impacting purely on a single junction should be modelled with LINSIG and evaluated for both existing (base) and proposed cases.

Note however, that if this junction is part of an UTC Group or Region and requires a change to the cycle time then the entire Group or Region should be modelled using TRANSYT.

4.4. Area Wide Impact Schemes

Where a scheme covers a wide area that has impact on a number of signal junctions LINSIG is insufficient to model the scheme. In this instance the technique used is dependent on the level of saturation of the network as follows:

- For under-saturated networks TRANSYT is appropriate.
- For over-saturated networks a micro-simulation model is required, in addition to a TRANSYT model for signal optimisation.
- For major development schemes it will be necessary to use a strategic traffic assignment model in addition to TRANSYT, and possibly a micro-simulation model for over-saturated parts of the network.

Details of the recommended techniques for each of the options are provided below.

4.4.1. <u>Under-saturated Networks</u>

When a scheme is predicted to have network wide impact but no links with significant over-saturation or exit blocking are predicted, then the TRANSYT model tool is deemed to be sufficient as a means of optimising and evaluating the performance of alternative proposals.

TfL Surface Transport currently recommends that TRANSYT models be built using the latest version of TRANSYT. Alternatively the TranEd interface allows the TRANSYT link diagram to be coded graphically, becoming part of the input file.

Modellers should carefully evaluate the link structure and consider all traffic and pedestrian movements as well as uncontrolled sinks and sources. All major exits from the network (those with significant flows, e.g. over 15% of the main route flow) should be modelled as uncontrolled exit links. Lane usage and short lanes (flares due to parking, bus lane set backs etc.) should be carefully defined.

Node / Link Numbering

TRANSYT nodes should be numbered according to their characteristic TfL signal site number. For example site 01/099 in the city of Westminster (01) should be TRANSYT node 99.
Links on the node should be numbered using the node number followed by the link number as a suffix e.g. 991. The links should be numbered in a clockwise order with link 991 being uppermost (North), link 2 being (East), and so on (Fig 1 - below).

Where there are additional links for alternative movements (eg right turn), where possible, these should be labelled on a 'second sweep' basis. This enables easy identification of links from TRANSYT outputs, as generally the following will apply:

Link Suffix	Direction	Movement
xx1	southbound	primary ahead / left
xx2	westbound	primary ahead / left
xx3	northbound	primary ahead / left
xx4	eastbound	primary ahead / left
xx5	southbound	secondary ahead / right
xx6	westbound	secondary ahead / right
xx7	northbound	secondary ahead / right
xx8	eastbound	secondary ahead / right

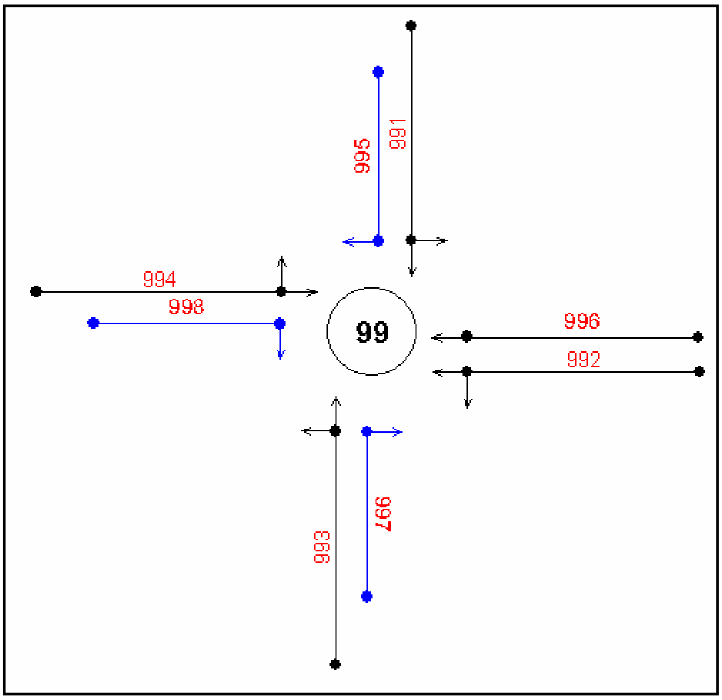


Fig 1 – 4 arm node labelling example

Fig 2 (below) further illustrates the ideal labelling structure where the junction layout is not the standard 4 approaches.

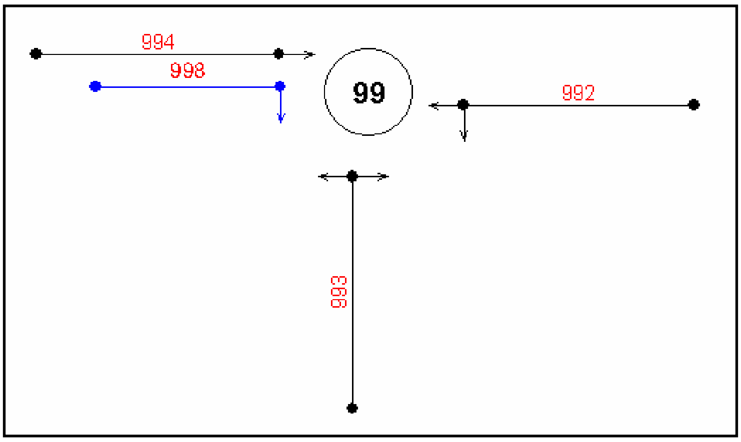


Fig 2 – 3 arm node labelling example

Parallel stage streams should be modelled as separate nodes with their own distinct TfL signal site number.

Any new nodes should be numbered as 1, 2 and so on. The TRANSYT model should have the interstage design accurately coded for each existing and proposed junction as defined by the existing / proposed controller specification.

Traffic must be assigned to links such that upstream feeder links are declared and flow proportions are indicated.

4.4.2. Over-saturated Networks

Micro-simulation models are much better suited to modelling heavily congested conditions, including exit blocking because of the spatial nature of queue formation, the interference of queues on other traffic and the discharge of vehicles from upstream junctions.

In networks where significant over saturation or exit blocking is expected, micro simulation models will be expected to accompany the TRANSYT models. The micro-simulation model should stretch far enough beyond the boundaries of the TRANSYT model to encompass the extent of the impact of the over-saturated links.

DTO accepts micro-simulation models developed using both VISSIM and PARAMICS. As DTO currently has most of its expertise concentrated in VISSIM, DTO recommends its use when consultants are building micro-simulation models for TfL Surface Transport in order that analysis, audit and impact assessment can be carried out as quickly as possible.

4.4.3. Major Development Schemes

For schemes over £2M in cost or those with considerable or wide reaching network impacts a traffic assignment model should be used and iterations with the local area models (TRANSYT / VISSIM / PARAMICS) be undertaken.

Micro simulation should be used to determine the capacity impact of adaptive control (SVD, SCOOT, SASS). Subsequently the timing plans of the TRANSYT and assignment models should be adjusted accordingly.

The assignment model should be defined as accurately as possible with up to date timing plans and turn saturation flows. The link saturation flows that result from them should correlate with those in the local area models.

The travel demand O/D matrices should also be recently validated and traffic assignments should correlate with observed traffic flows according to criteria specified in the Design Manual for Roads and Bridges (DMRB) Chapter 12 (i.e. at least 85% of links to within GEH of 5).

Once the scheme with its traffic capacity implications is coded in the assignment model, traffic flow re assignment is likely to result. According to this, the scheme performance should be studied again with the local area models and new timing plans should be coded in the assignment model.

To avoid running the risk of oscillating traffic flow patterns from one iteration to another (between assignment and local area models) it is recommended that timing plans in the assignment model are adjusted only TWICE as a result of detailed studying of the scheme in TRANSYT.

5. MODEL FINE TUNING

5.1. Base Model Validation (Existing Situation)

Simulation models need to be calibrated and validated so that observed traffic conditions are replicated and the model can be relied upon for use in accurately simulating planned proposals. It must be confirmed that the model is performing logically and that elements of the networks are accurately represented.

It is likely that some initial errors will be made either in simple data entry or in modelling detail. These mistakes are not always obvious and therefore the model developer should provide evidence that calibration and validation has been undertaken.

A key element is the need for the model performance indicators to mirror site observations. These can fall within certain tolerances (see 5.1.1). However, the traffic flow inputs on <u>external</u> links of micro-simulation and signal optimisation models should <u>exactly</u> match each other, taking into account the PCU conversion for optimisation models.

It is essential that the model be validated against the existing network by modelling the existing signal timings and running the model without optimisation to obtain key results.

Where SCOOT is in operation care must be taken when validating the model, as the timings are continually optimising. Average split, cycle and offset SCOOT data for each modelled period should be used to build the existing model. It is advised that the DTO-UTC Department be consulted when attempting to validate a model of a SCOOT region.

The same issues apply if System Activated Strategy Selection (SASS) or selective vehicle detection (SVD) bus priority is in operation as signal timings may vary according to active strategies or bus presence. As above, it is advised that the DTO-UTC Department be consulted to determine the average signal timings.

5.1.1. Validation Parameters

The model output results on existing critical links (or links likely to become critical following the proposal implementation) should be compared with spot checks to discover possible problems. Typically, for validation, modelled values should be between five and fifteen per cent of the observed values for the same period depending on the parameter. The following parameters can be used for validation.

For Linsig models (Table 2 – Appendix F):

- Degree of saturation within 5 % of observed value
- Average queue lengths at the start of green by link, to within 10% of observed values.
- Flare length in model within 10 % of measured use of flare.

For TRANSYT models (Table 3 – Appendix F):

- Degree of saturation within 5% of observed value.
- Measured Cyclic Flow Profiles (CFP) for critical links showing similar peaks, dispersion and spacing as modelled ones.
- Capacity of links leading to pedestrian or cycle crossings within 10 % of observed values.

It is vitally important that checks for over saturation are made for TRANSYT models against existing timings. Should a link have a degree of saturation which is over 100% at this stage, it is critical to resolve it before continuing, otherwise the model may be seriously in error.

For VISSIM models (Table 4 – Appendix F):

- Traffic flow validation criterion as described in section 3.3
- Saturation flows within 10 % of observed values or values used in the corresponding TRANSYT model.
- Critical junction approach capacities within 10 % of measured values or values estimated from the corresponding TRANSYT model.
- Journey time along certain sections of the model for buses and general traffic within 15 % of observed values. N.B. Because journey time observations vary greatly in the real world, a sufficient number of observations should be made in order to show an accuracy of 10% (at 95% confidence level). This accuracy level will determine the required sample size of observed journey times. A description of how the required number of observations is calculated from the desired level of accuracy can be found in Ch 11 of the COBA 9 manual.

Appendix D demonstrates how to determine site-measured degree of saturation and details specific validation issues with LINSIG, TRANSYT and VISSIM.

6. PROPOSAL EVALUATION

When producing models of the proposed scheme it is essential that the model accurately reflects the changes to signal timings, network geometry, traffic assignment and traffic signals. Care must therefore be taken to ensure any new data are verified when introduced to the model. The proposed junction interstage designs will have to be modelled to the level of detail that is necessary for controller specification writing. Frequency of demand dependent stages will have to be judged either based on information from the existing situation or based on the predicted level of the traffic demand using the stages in question.

In general, when producing an optimised model of the proposed scheme it is important to consider the traffic management objectives of the scheme. Whilst overall performance measures (e.g. TRANSYT Performance Index) should be considered, these should not override policy requirements and the Mayor's Transport Policy objectives.

As mentioned in this report, careful consideration must be given to cycle times in order to balance road traffic demand with pedestrian delay at signals. Cycle times should be kept as low as practically reasonable, delaying pedestrians by a maximum of 83 seconds. At junctions where pedestrians require a dedicated stage, this equates to a maximum cycle time of 88-seconds. Where pedestrians 'walk with traffic', higher cycle times may be acceptable. The existing situation must be considered when looking to change cycle times and careful consideration given to the Mayor's transport strategy and pedestrians as well as surrounding linked signals.

The recognised default for pelican type sites is to double cycle where appropriate. Where this contravenes the strategy being designed, further advice should be sought from the DTO-UTC Department.

Note: The lowest SCOOT compatible cycle time possible is 32 seconds. Network cycle times of 60 seconds would therefore prohibit any double cycling so, 64 seconds is the preferred lowest option where there are pedestrian crossings.

6.1. LINSIG

The link structure and basic parameters should reflect the proposed geometric layout and method of control.

Proposals should be assessed using the same indicators as used during the validation stage. For isolated junctions these are degree of saturation for all critical approaches, average queue lengths and delays. This will allow a direct comparison with the existing situation.

The interstage period should be designed with the final scheme objectives in mind. Appendix E indicates where standard optimisation may not apply.

When a design involves a lane used by a mixture of opposed and unopposed traffic, LINSIG cannot predict how many unopposed vehicles can clear in any given cycle. In such circumstances the modeller should estimate the impact of the opposed vehicles on the saturation flow of the mixed link using the formula for opposed movements in TRL RR67.

If the geometric layout involves short lanes (flares) modellers should not assume that they will be used to their full stacking potential by default. It is advisable that the LINSIG auxiliary program LINSAT is used for each study period. This can determine the extent of short lane usage based on the proportion of turning traffic on each approach of the junction.

6.2. TRANSYT

The initial stage of a proposed scheme's optimisation is the choosing of an appropriate cycle length. Only SCOOT compatible cycle times are to be considered, even in UTC fixed time and non-UTC areas. This is due to system considerations associated with bus priority SVD, and applies to non-UTC sites to cover potential for future conversion to UTC control.

Where the proposed cycle time results in pedestrian wait times above 83-seconds, or where a cycle time increase or decrease is proposed, further advice should be sought from the UTC Department of DTO.

The default for pelican-type sites is to double cycle. Where this contravenes the strategy being designed, further advice should be sought from the DTO-UTC Department. Further advice on the selection of cycle times is provided in Appendix E.

Initially, the network will be fully optimised according to any network constraints that will have been identified during the validation stage. This is not sufficient to produce a final proposal. TRANSYT has limitations in taking account of the effect of exit blocking and it doesn't accurately predict the performance of networks operating close to their capacity. Therefore additional steps must be carried out to ensure the proposal is sound. These steps are outlined below and explained in more detail in appendix E.

- Full optimisation, without weightings
- ascertain problems, eg capacity, queuing, exit blocking
- If problems exist with traffic capacity make adjustments to the method of control and repeat full optimisation with weightings on selected links.
- If problems with queue storage capacity are still present fix stage lengths manually and perform offset optimisation only, grouping nodes together if necessary.
- When problems are resolved check
    - Degree of saturation of external links

   - o Front and back offset co-ordination
- To ensure the network is robust:
   - o Manually adjust green splits to achieve front and back co-ordination between consecutive links
- If the network is close to its practical capacity limit, manually adjust green times to fully saturate entry links. This will protect the network even when there are unexpected traffic fluctuations.

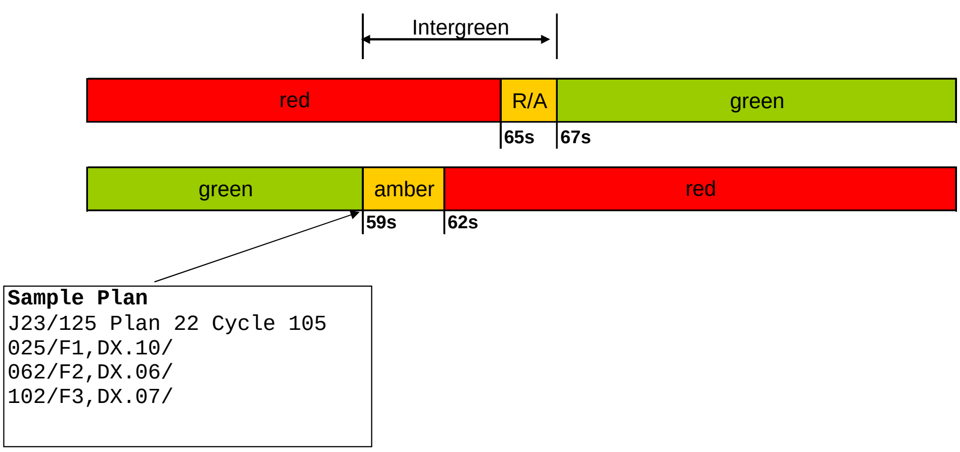
The modeller should also undertake sensitivity tests on key validation data, e.g. increase flows by at least 5%, to check the robustness of the model.

6.3. VISSIM

VISSIM models will generally be prepared in cases where a proposed scheme is likely to over-saturate the network. In such cases what is of interest is the impact of over-saturation on upstream junctions and how can their method of control and timing plans be modified to make sure that effective congestion management strategies can be designed and tested.

Neither VISSIM nor any other micro-simulation model can optimise traffic signal timings to respond to network problems. Therefore, the initial signal control information for a VISSIM model must come from the final optimisation of the traffic signal model, either LINSIG or TRANSYT. <u>All models must maintain their common data</u>.

When coding fixed-time signal plans in VISSIM, an adjustment should be made to account for the fact that VISSIM treats red-amber periods as though they were green time. The engineer must set the red-end time in VISSIM to the time of green-start from the timing plan. This will make the intergreen appear wrong in VISSIM but vehicle behaviour will more accurately reflect actual response time and acceleration of drivers as they receive red-amber followed by green.



Traffic congestion strategies can be in a form of fixed time plans or stage length adjustments. However, the modeller will have to write the control logic, which will tell VISSIM how to adapt signal control during the simulation period under different traffic conditions. This can be done using the auxiliary traffic control logic program VISVAP.

Suitable signal timings can often be derived by running the simulation within fixed time signal control mode by making small manual adjustments to the timing plans and studying the effects on the network.

It will add to the level of accuracy of the overall network performance if the traffic flow demand through the network is profiled in 15-minute intervals. If the origin destination matrix or fixed route traffic flow information is not disaggregated at such intervals an acceptable alternative is a profile based on the traffic flow profile from automatic counters in the area that is being studied. An alternative source of traffic flow profiles in areas with traffic signals controlled by SCOOT is “bacfiles” of “detector flow” from the ASTRID database system.

Depending on the size of the model there should be between 15 and 30 minutes of simulation time for loading up the network before performance indicators are collected for evaluation purposes. Flows during this loading period should be the same as the study period unless survey data is available to provide real figures.

If the effect of the proposed scheme needs to be examined from the perspective of different types of street users (specified in the study brief from the promoter), these should be included in the VISSIM model and the performance indicators of the scheme for each street user studied separately

6.3.1. <u>Route Assignment</u>

For VISSIM networks with limited or no route choice, traffic can be assigned onto the model using static routes which makes lane use validation easier. If travel demand information is available in O/D matrix format, dynamic assignment is also acceptable but the modeller must close all spurious routes and intra-node edges manually to facilitate the assignment of traffic on realistic paths.

Where route choice is possible through a multitude of routes, dynamic assignment is not recommended by VISSIM but the use of an assignment model like SATURN or VISUM is recommended instead. From the result of these models, static routes could then be built to assign traffic in the VISSIM models to study in greater detail.

Where dynamic assignment is chosen as a means of assigning traffic on a VISSIM model the modeller must provide proof of convergence of the assignment process. Two techniques are recommended for achieving convergence with dynamic assignment. These are outlined in appendix E.

If traffic is assigned through fixed routes and a proposed scheme over-saturates part of the carriageway or the network studied, the modeller is expected to reassign traffic to alternative fixed routes or dynamically assign traffic through VAP files to come up with a more evenly saturated network in order to accurately simulate real driver behaviour.

6.4. Model Auditing Guidelines

The submission and auditing of models can be a lengthy process with several iterations before the model is found to be fit-for-purpose. DTO has therefore produced model auditing guidelines to help streamline the process.

The TRANSYT Model Auditing Process (TMAP) has been designed to complement the Modelling Guidelines. It provides a framework to ensure that all parties involved are aware of their responsibilities. The aim is to promote communication, clarity of purpose, quality and consistency.

Broadly, the Modelling Guidelines detail what's required. TMAP details who does it, and when.

In TMAP, the auditing of the detailed design of a proposal is broken down into six stages:

- Stage 1 Scheme & Network Scope Checkpoint Meeting
- Stage 2 Calibrated TRANSYT Base Model Submission
- Stage 3 Validated TRANSYT Base Models Submission
- Stage 4 TRANSYT Proposed Models Checkpoint Meeting
- Stage 5 TRANSYT Proposed Models Submission
- Stage 6 Submission of TSSR to Promoter

There are clear criteria for passing from one stage to the next.

For Stages 2, 3 and 5, there are Check sheets to be signed off by the Promoter's Design Engineer, the Promoter's Checking Engineer and the DTO Model Auditing Engineer.

The following key points should be noted.

- All model submissions should be version controlled.
- All model submissions should be checked (internally audited) by a senior modeller (checking engineer) prior to submission.
- All formal correspondence to DTO should be sent via the Promoter (not direct from the design engineer to DTO). This includes modelling submissions.

The full details of TMAP, an Overview Sheet and associated check sheets can be found in the TRANSYT Model Auditing Process Guidance Notes, which can be found in the Traffic Signal Section of London Streetworks (http://www.londonstreetworks.net/).

Similar guidelines are being developed for the auditing of VISSIM models. These will be published in due course.

7. TRAFFIC MODELLING DELIVERABLES

In order that the client and / or highway authority have a clear understanding of the scheme design, it is essential that sufficient information be provided to allow a comprehensive assessment of the scheme proposal. It is also important to provide evidence that the model construction is suitable for the intended purpose.

Comprehensive, but concise, relevant information should be included in a report that indicates the objectives of the scheme and to what degree the proposal meets the requirements. This chapter indicates the data that should be included in the report in order to enable adequate assessment of the proposed scheme and the modelling itself.

It is fundamental to the implementation of signal schemes that the modelling supports sound engineering principals of a scheme.

7.1. Assessment of Schemes

The full impact of the scheme compared to the existing base situation must be presented in a clear and concise manner, including how the proposal meets the requirements of the brief.

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

- Degree of saturation (per link) all models
- Link capacity (PCU/hour) – all models
- Junction practical reserve capacity (%) – all models
- Maximum average queue length per link – (Linsig models)
- Cyclic flow profiles (CFP) for critical links (short/highly saturated) – TRANSYT models
- Percentage green per junction wasted due to exit blocking (TRANSYT, micro-simulation)
- Average delay per vehicle per link
- Average delay per bus per link
- Percentage of buses by bus services waiting more than a cycle to clear nodes – micro-simulation
- Mean travel time private/public transport and standard deviation along predefined routes – micro-simulation
- Mean pedestrian travel time along predefined routes – micro-simulation

There may be occasions when it will 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 with DTO and key stakeholders e.g. Network Assurance and the local boroughs, before they are produced.

Comparisons are essential to allow a balanced assessment of the scheme's impact. The report should always include full modelling of the existing situation as well as proposals so that relative impacts can be gauged.

All deviations from default values in the base models should be listed and justified. All proposals should also be listed and their purpose towards achieving the overall scheme objectives should be explained.

Tabulated statistics of existing and all proposed scenarios for each modelled period must be included to assist in this comparison. Examples of such tables are provided in Appendix F (Table 2-4).

When comparing proposals with SCOOT operation it is important to note that SCOOT is continually optimising the signal timings. Therefore great care must be taken to ensure "existing" base models are accurate.

Auditing of modelling work is essential to ensure that oversights are captured. The report should include evidence that the report / model has been checked and reviewed by a qualified specialist other than the author(s).

7.2. Traffic Modelling Report

The TRANSYT Model Auditing Guidelines describe three stages, each of which requires a report to be produced:

- Calibrated Model Technical Note;
- Validated Base Model Report; and
- Proposed Model Report.

This section summarises the contents of each of these reports.

7.2.1. Calibrated Model Technical Note

Calibrated model submissions must be accompanied by a technical note. This note should contain:

- The stated **Purpose** of the model as agreed with Model Auditing Engineer.

- A list of all the **TfL-referenced nodes** in the network with addresses.

  (For further details on both of these, please refer to the TRANSYT Model Auditing Process Guidance Notes referenced in Section 6.4).

- Clear notes on all **site observations**, covering both the physical constraints of the network and vehicle behaviour. Where the behaviour is specific to a time of day, this should be noted. It is important to clearly explain how these factors have determined the structure of the model.

- Site datasheets with **measured saturation flows**.

- Table of **saturation flow** for each link in the network. The table should indicate clearly whether the value has been measured on site or has been calculated using RR67. Where RR67 has been used an explanation should be given of why it couldn't have been measured.

- Site datasheets with **measured cruise times (not speeds)**.

- The derivation of the **signal timings**. In the case of Fixed Time junctions the UTC signal plans should be included. For SCOOT junctions, average representative timings should be calculated from ASTRID data and displayed clearly.

7.2.2. Validated Base Model Report

Validated base model submissions must be accompanied by a validation report. Where a Calibrated Model Technical Note has been previously produced, this should form the first part of the report. Where a calibration note wasn't produced previously, the validation report should contain all the information required at the calibration stage.

In addition, the following information should be included:

- Detail on the flows used
  - When were the traffic surveys done and by whom?
- Demand dependency calculations
  - A clear explanation of how the frequency of demand dependent stages has been accounted for by comparing calibrated model timings to the validated model timings.
  - If pedestrian surveys are undertaken, the frequency of a pedestrian phase can be recorded on-site. In any event a UTC ACHK should be carried out to confirm site observations. The output of the "A Check" is a record of how often demand dependant stages are called, and this should be included in the report.
- Evidence of validation, including a comparison between on-street observations and model results
- Flare usage observed on site
- Flashing amber usage at pelicans
- Queue lengths
- Bottlenecks observed
- Detail on parking/loading
- Detail on give-way
- Detail on exit blocking observed.

7.2.3. Proposed Model Report

An example template of the report required to accompany the modelling of proposed schemes is provided in Appendix F. This includes the following sections:

- Scheme Summary
- Objectives / Problem
- Strategy
- Evaluation of Results
- Conclusions and Recommendations
- Appendices
  - Signal Design Summary Sheet(s)
  - Network (Link / Node) Diagram(s)
  - Statistics
  - Source Data
  - Modelling assumptions
  - Electronic copy of model input file, output files and graphical output results for baseline existing and all proposals
  - Electronic copy of LINSIG stage and interstage diagrams
  - Model audit trail and version control cross reference table

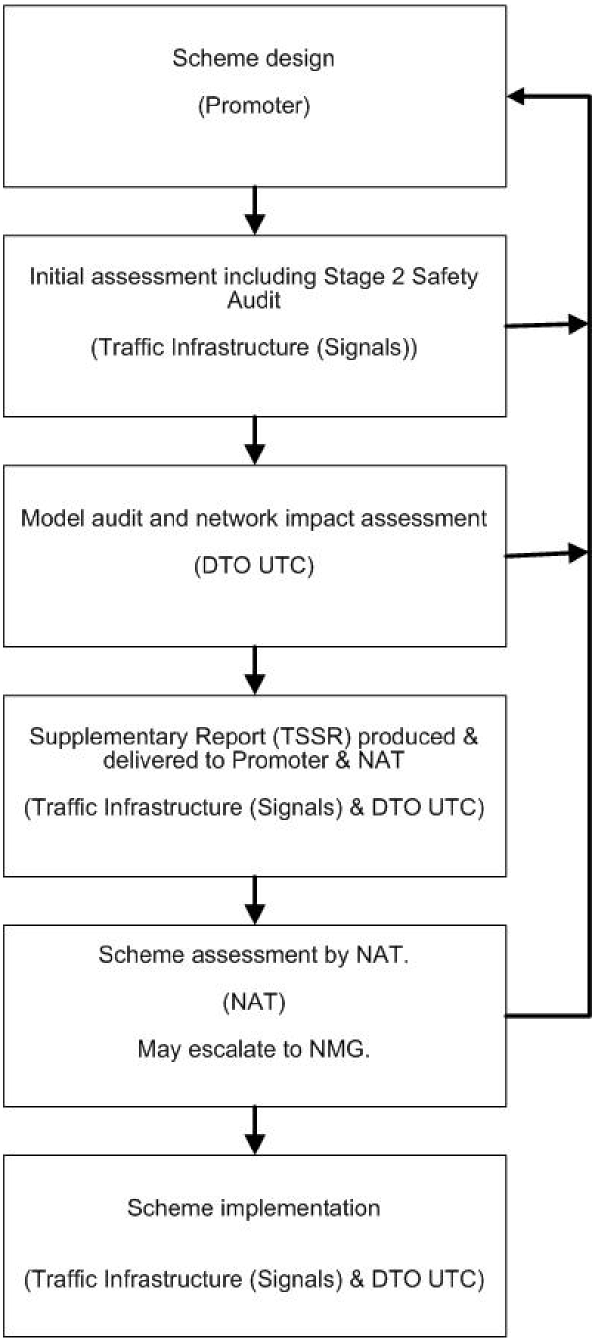
Version control information for all design documents (cross referenced) is essential to avoid ambiguity and ensure all parties are aware of the current design.

It is important that any report produced by the modeller contains the content described in Appendix F. However, the format is indicative only.

8. ADVICE FOR SCHEME SPONSORS

The sponsor of a scheme, or other party who has requested that modelling work be undertaken, should be in a position to appraise the modelling to determine if it is suitable for the intended purpose.

As a guide to the involvement of relevant Departments of DTO at different scheme design stages, an outline of the design audit process is shown below. It describes the scheme processes and involvement of key TfL departments. The complete Scheme Design Audit Process is included in Appendix I.



The report content specified in the previous chapter will provide significant information to assist with assessment of the modelling. However, this may not be sufficient to provide a full appraisal.

This document is intended to assist modellers to generate models to the required standard. It is therefore recommended that the appraiser is familiar with the content of this document. Ideally the appraiser will also possess the following:

- A basic awareness of the modelling tool(s) used
- A reasonable level of traffic engineering experience
- A good knowledge of local traffic behaviour, supported by site observations

This coupled with checks on the input data and validation processes described in this document are the key factors.

The following items provide a minimum checklist to assist with the assessment of modelling work:

- Check network dimensions (lane widths etc.), network coding (nodes and links) and traffic and signal data input (signal plans)
- Visually check the base (existing) model results, using graphical outputs for individual links and overall network performance. Look for any anomalies.
- Compare the model with the network by examining validation statistics and outputs, particularly for the following:
    - Degree of saturation
    - Queue lengths
    - Lane usage
    - Journey time
    - Delay
    - Cyclic flow profiles (traffic patterns and behaviour)
- Examine key area wide parameters compared with recommended values and ensure differences are explained
- Check proposal assumptions are valid, e.g. traffic re-assignment, changes to geometric layout, alteration to bus routes
- Check that fundamental parameters are consistent between existing and proposed models

If in any doubt, the appraiser is recommended to seek advice from the DTO-UTC Department.

9. APPENDIX A – MODELLING DATA

The following table summarises the data requirements for most models.

Type	**Data Requirements**	**Notes**
Network data	Scheme Layout Plans	- digitised maps/junction arrangements - plans also could be built using aerial photographs - actual on the ground lane allocation and lane markings, including cycle lanes, bus lanes, loading bays (and time periods when active) advance cycle and stop lines
	Detection	- location and configuration
	Bus stop locations and dimensions	
Traffic data	Classified Junction turning and throughput (at stop lines)	- expressed as turning proportions or origin and destination matrix in a maximum 15 minutes segments - presented as PCUs per hour - may be obtained from registration plate surveys, existing trip matrices or junction turning movements
	Traffic volumes	- manual or automatic upstream counts at queue free locations (include queue lengths as appropriate) broken in 15 min intervals.
	Traffic Composition (classification)	- proportion of cars, taxis, LGVs, HGVs, buses, trams, motorcycles and cyclists
	Bus frequencies	- frequency distribution obtained from London Buses.
	Bus dwell times	- average and standard deviation of dwell time defined for bus stops from surveys or existing data
	Parking data	- by type and duration
	Pedestrian data	- Hourly flows at crossings and pedestrian stage call rate if appropriate. Pedestrian flows along footways where constrictions or reductions are proposed.

<u>**Table 3 (continued over…) – Data Requirements Summary**</u>

Type	Data Requirements	Notes
Signal data	Signal timings, intergreen and phase delays, CLF, VA logic at signal junctions	- traffic signal controller specification - UTC / SCOOT outputs - must correspond to traffic survey periods
	Stage / phase data	- phase and stage minimum times - VA phase max timings (VA sites) - VA average cycle length and phase length times for each time period.
	Banned movement / One way etc	- site observations - details of any violations
	Bus lane operation times	- site observations, as built GIS maps and overlays
	Selective Vehicle Detection	- location and configuration and - UTC outputs and - traffic signal controller specification
	Detection	- location and configuration
	On street parking regulations	- site observations / As built GIS maps
	Saturation flow	- measured on site
Give ways	Critical gaps accepted by right turners	- Small scale surveys should determine these parameters.
	Number of ahead going vehicles from shared ahead & right turning lanes per cycle	
	Number of right turning vehicles stored in the middle of the junction and clear in the intergreen.	
Performance Data	Journey/ Travel time	- minimum, maximum and average site observation using statistically robust sample - this data is required for validation and scheme impact assessment
	Queue length by lane	
	Pedestrian crossing time distribution	
	Percentage of pedestrians crossing through gaps in traffic vs those waiting for invitation.	
	Degree of saturation	
	CFP for critical TRANSYT links	

9.1. Traffic Model Data Measurements

9.1.1. Link Platoon Journey Time Measurement

Cruise times must reflect the TYPICAL UNDELAYED CRUISE TIME from stopline to stopline of vehicles in the middle of their respective platoon as if there were no signals on site causing a loss of speed.

It may prove difficult to obtain cruise times in congested conditions. A good time in the day to measure free flowing time is quite late in the evening or early during the weekend. It is recommended that 10 typical readings (discarding abnormal readings) are taken and an average obtained.

Where full link measurements cannot be made the measurement should be performed in the free flowing part of each approach and the value found extrapolated for the whole length from stopline to stopline. Specifically this requires measuring the journey time for the free flow section of the link, then measuring the distance of this section and multiplying up for the entire stopline to stopline distance. The free flowing part of the carriageway starts from the exit of the junction and stops where flowing vehicles start decelerating before they join the back of the downstream queue or are influenced by the downstream traffic control system.

When measuring the free travel time from a stopline around a bend the measurement should be broken into two values:

i) A time to travel around the bend itself and
ii) A time to travel the straight line stretch

9.1.2. Saturation Flow Measurement

Saturation flows need to be measured for each lane or group of lanes and for each period where flow conditions change.

Forward planning and operational checks are essential to ensure that traffic conditions are typical when measuring saturation flows.

Ideally the TRL bundle suite of programs should be used for this measurement. If the TRL Bundle is not available a manual measurement should be undertaken. The minimum length of time when there is saturated discharge across the stopline for this survey should be 12 seconds. The start time of recordings should be the first red/amber second and the end time should be the first red second if the approach is fully saturated.

If the saturated discharge finishes part of the way during the green the engineer performing the measurement should have the experience to recognise the end of saturated discharge and end the recording for that cycle there. At least 10 cycles should be recorded of which approximately 5 should be fully saturated for a good average value of the saturation flow and start and end lost time.

For minor links in the model or for links where saturated flow conditions with free flowing exit cannot be found (including those links with less than 12 seconds of green), TRL RR67 should be used to estimate their saturation flow. The modeller must clearly indicate which links have been calculated using TRL RR67.

9.1.3. Cyclic flow profiles (CFP) measurement

Cyclic flow profiles can be measured with the CFP program of the TRL bundle suite for a PDA palm top. The location of the recorder should be somewhere near the back of the queue of a link from where the main stopline should be visible as well. The recorder should read the CFP manual provided with the bundle suite for details on how to use the program. Before recording the actual CFP, consideration must be given to the fact that the queuing model of TRANSYT assumes vehicles queue vertically (i.e. do not occupy any physical space). The CFP should be measured in whatever units the traffic flow is in the model (normally PCUs).

9.1.4. Give Way Time Lag Measurement

When there are give way (gap accepting) stoplines or right turning signal controlled traffic through opposing flow, a small-scale survey is advisable to find the shortest acceptable time gap drivers are prepared to accept. The survey should concentrate in collecting a few time gaps that are rejected by 10-20 gap-seeking vehicles and a few gaps that are accepted in order to determine the minimum acceptable time gap. This can then be used in the model to accurately reflect discharge, instead of using default figures.

9.1.5. Manual Origin Destination Survey

It is fundamental to TRANSYT to identify where traffic goes once it has entered the network. Unless a full origin / destination matrix has been commissioned the modeller must carry out a manual survey.

On short links where sight lines are clear it is sufficient for one person to carry out this function. Two observers, in communication, are necessary on long links, one at the upstream and one at the downstream junction.

For each link the upstream observer identifies a random vehicle (using the number plate technique) and relays this information to the downstream observer, who notes its destination. It is recommended that a minimum of 20 readings be taken for each link where the traffic assignment is not obvious.

The example below indicates how this survey should be recorded.

(From) UPSTREAM SOURCE LINK NUMBER AND FLOW (a)	(To) DOWNSTREAM DESTINATION LINK NUMBER	NUMBER OF VEHICLES	LINK TOTAL (b)	COMBINED TOTAL OF (b) (c)	PERCENTAGE OF VEHICLES ASSIGNED = b/c x 100% (d)	NUMBER OF VEHICLES ASSIGNED = (d) x (a)
1001 400 pcu	1111 1112 1113	1111111111 11111 11111	10 5 5	20	10/20=50% 5/20=25% 5/20=25%	200 pcu 100 pcu 100 pcu

Table 4 – Sample Sheet For Manual Traffic Flow Assignment

10. APPENDIX B – COMPARISON OF MODELLING PRODUCTS

The common traffic modelling packages (LINSIG, TRANSYT etc.) use empirical algorithms based on historic data to provide an aggregated representation of demand. This may not be appropriate to all traffic conditions.

Micro-simulation models have the ability to model each individual vehicle including general vehicular traffic, pedestrians, buses, taxis, cyclists and trams. This enables realistic representation of actual driver behaviour such as lane changing and overtaking. These are the only modelling tools with the capability to realistically examine certain complex traffic issues and network performance such as:

- Blocking back at junctions
- Closely linked traffic signals
- Effects of incidents
- Parking
- Road works
- Impact of bus priority on the network
- Impact of trams on the network
- Special controller conditioning
- Demand dependency

However, there are some limitations that should be recognised and addressed when undertaking micro-simulation projects. For example:

- Pedestrian modelling is possible although it is not fully represented. The main attention is given to the effect of pedestrians on vehicle movement. VISSIM supports the different pedestrian facilities and provides assessment of delay while crossing the road at crossings. PARAMICS is mainly a vehicle modelling tool package as pedestrian modelling only entails incorporating pedestrian stage at the signals based on pedestrian flow.
- The current versions of VISSIM and PARAMICS do not yet have the ability to optimise traffic signals settings. As a result, TRANSYT and LINSIG will continue to be the packages used to undertake this function.

Before commissioning the development of micro-simulation models the limitations of the package in question should be considered. Such limitations may have an impact on the attempt to effectively represent site conditions or scheme proposals.

The table below summarises the differences between empirical and micro-simulation modelling packages.

Feature	**Conventional**	**Micro-simulation**
Example software	LINSIG, TRANSYT-TRANED	VISSIM, PARAMICS
Simulation of traffic flow	Assumes uniform arrival rate modelled time segment	Realistic variation in traffic within modelled time segment
Driver behaviour & vehicle characteristics	All vehicles have the same behaviour and queuing models are generic	Individual vehicles have different behaviour and more detailed simulation of queuing is possible
Modelling principles	Empirical based on site observations	Simulation of driver behaviour and vehicle characteristics
Animation	None or limited graphics	Yes
Network characteristics	Can only represent conventional layout and junction characteristics and common cycle at signalised junctions	Recognises site specific characteristics e.g. atypical junctions, different cycle lengths across signal controlled networks, vehicle actuation (VA), mixture of VA, fixed time control as well as priority and roundabouts in the same model and special conditioning at traffic signals to deal with bus priority or traffic congestion.

<u>Table 5 – Comparison of Modelling Packages</u>

11. APPENDIX C – MODELLING TECHNIQUES

11.1. Phase Delays

Most traffic signal controllers in the network of concern will be microprocessor based. These controllers have the distinct advantage of being able to minimise "lost" time during the interstage, as the conflicting phases have their own critical intergreens.

The above often leads to phases starting at different points during their preceding interstage or terminating at different times due to phase delays, especially where parallel pedestrian phases are present.

It is essential that modellers have a full understanding of the above principles to ensure model accuracy.

11.2. Pedestrians

All pedestrian phases must be modelled as follows:

- As an individual link, especially if they run in parallel with traffic phases. These will generally have large clearance periods due to TTS 6 criteria being applied, and therefore they will control the stage minima
- With proxy flows and saturation flows. Note: where pedestrian flows are high and standard (TTS 6) stage minima are insufficient the model should reflect actual required crossing times (e.g. Oxford Circus). In this instance such non-standard minima must be agreed in advance.
- Where TTS6 are not installed on an existing site, scheme modelling should include results with "existing" and "existing plus TTS 6 timings"
- Without weighting factors

Staggered crossings should have each pedestrian link connected to the other on the second leg of the crossing to reflect progression of pedestrians.

All round pedestrian stages may be modelled as a single link even though there are several phases that run in that stage. However, the modeller must ensure that the largest clearance period is used to determine the stage minima and that the appropriate start and end lags are worked out correctly for the proceeding and following traffic phases (links).

LINSIG can be used to model the controller data to quickly derive this information. The required information can then be clearly seen either graphically or in table form.

11.3. Demand Dependent Stages

There are two kinds of demand dependent stages in signal control, pedestrian and traffic stages.

Normally, pedestrian travel demand is not measured in detail in traffic surveys and the frequency of these stages therefore has to be measured / estimated by data out of the UTC system or on street observations. Once this frequency is determined it can be applied to models depending on type of model.

In Linsig, it can be applied by running the stage sequence for multiple cycle lengths with the demand dependent stage appearing only once in the total sequence.

TRANSYT simulates only one typical cycle and the above approach is not possible. For this reason the demand dependent stage can either be called in the stage sequence at a fraction of its normal length depending on its frequency or not used at all and the interstage of the stage following normally the demand dependent stage increased by a fraction of that stage to take account of its infrequent occurrence.

The modeller must ensure that there is a version of the model that indicates permanent demand. This is to ensure that offsets can be confirmed and situations where detection becomes faulty can be assessed.

In VISSIM models, VAP can be used to bring the demand dependent stage regularly every so many cycles according to its measured or estimated demand.

If the scheme involves detailed simulation of pedestrian interaction with pedestrian responsive control of their crossing and the actual pedestrian flows are used then instead of estimating the frequency of use of the pedestrian stage, the modeller can validate the model using VAP to simulate the particular pedestrian controller logic for the crossing involved.

When traffic demand dependent stages are involved in a controller's method of control then the frequency of demand should be validated with the use of simulated detectors and the appropriate logic in a VAP file as the traffic demanding the use of this stage should be accurately known in the model.

11.4. Bottlenecks

Bottleneck links should be modelled as though they are permanently green at the reduced measured saturation flow for each study period.

11.5. Saturation Flows

A major source of error is the over estimation of saturation flows. These have often been estimated rather than measured or calculated. It is therefore essential that the approaches to stoplines are carefully considered and modelled accurately. The default for good scheme development is to measure the saturation flows (see Appendix A for guidance on saturation flow measurement).

TRL RR67 calculation should only be used for non-critical approaches or where site measurement is not possible (such as links that are always exit blocked or short greens are normal). Any calculated saturation flows must be carefully checked during validation to ensure accuracy of the model is maintained.

Saturation flows must take into consideration flared approaches, oblique stop lines, curved approaches or gradient. This can lead to problems when estimating saturation flows especially at roundabouts. Consequently, where possible and for all critical links, saturation flows should be measured.

11.6. Give Ways

Give way stoplines or gap accepting links against opposing flow of traffic should have their capacity estimated from the minimum time gap drivers are prepared to accept when they are waiting to go through gaps.

Give ways at junctions in TRANSYT should be modelled as 'virtual' signal controlled junctions with stop lines at give ways. The 'virtual' junction should be represented by a dashed line and solid stop lines for priority links on the link diagram. The give way coefficients depend on:

- Width of give way approach
- Width of main road
- Visibility to the right
- Visibility to the left
- Volume of the controlling flow(s).

These coefficients and how they fluctuate according to geometric parameters are described in detail in the appendix of TRL report LR 888

11.7. Bus Lanes

The location of bus lanes may be particularly important. The available green time and the discharge at the downstream node should have determined the bus lane set back. If the green time and set back are not matched, then maximum efficiency will not be achieved from either the bus lane or the green time.

Bus lanes should be modelled as separate links in TRANSYT. If there is a set back the start lag must be increased by the time taken for buses to travel from the end of the "effective" bus lane to the signal stopline. The effective set back should be recorded by time of day and modelled as a flared link for main traffic.

11.8. Right Turning Vehicles

All opposed right turners from dedicated right turning lanes at signal controlled junctions in TRANSYT should be modelled as a signal link and a give way link using card type 30 and 31. The former defines the give way gap seeking properties of right turners during part of the cycle when they are opposed. The slope of the relationship between opposed and opposing capacity should be set to 50 and the intercept of the equation set on 1000 (PCU/hour).

Card 31 defines the actual period(s) in the cycle when the give way traffic might either look for gaps while opposed, and/or proceed on a full green arrow stage, unopposed.

Right turning vehicles that wait ahead of the stopline and clear in the intergreen should be modelled by the addition of end lags (usually 2 seconds per vehicle). This lag can be adjusted to compensate for errors in modelling gap-accepting vehicles. This method can only be used if the right turners use a dedicated lane and link.

In many cases opposed right turning traffic shares a lane with unopposed ahead traffic and impedes the ahead flow. The mixed use link could be modelled as an unopposed link with reduced saturation flow or as an opposed link that has a proportion of its traffic representing unopposed ahead and left turning vehicles explicitly defined in card type 30. The former method is more accurate and if it is adopted the saturation flow should be estimated by using the technique described in the Appendix of TRL RR67 for mixed use of opposed and unopposed vehicles.

11.9. Flared Approaches

Approaches to stoplines can be affected by various properties such as bus lane set backs, taxi ranks, parking, road narrowing etc. This is often missed in modelling and full lane length saturation flows are used inappropriately.

Flare length utilisation must be considered according to the proportions of turning movements and effective flare lengths should be used in traffic models rather than physical lengths.

11.10. Exit Blocking

In many cases VISSIM must be used to correctly model exit blocking. Because the TRANSYT model stores queues vertically at the stoplines, care should be exercised on the effect of exit blocking on the rate of discharge of upstream links. TRANSYT cannot automatically predict the effect on adjacent or upstream links of a queue that extends beyond the links storage capacity.

If using TRANSYT the traffic modeller has to extract this information during both validation and evaluation of the proposals and take it into account by adding effective lost time in the respective link starting and ending lags. A full explanation of such adjustments must be provided.

The precise length of lost time during the upstream green is estimated by studying the queue graph. This graph describes the precise start and end time in the cycle and the uniform queue of each link that will exceed its storage capacity.

By combining this information with the start and end of actual green of upstream links the duration of any wasted green upstream can be determined and accounted for in the start or end lag of the upstream link.

11.11. TRANSYT Shared Link Facility

The shared stop line facility in TRANSYT should be used where appropriate to model different vehicle categories or platoons of traffic that will take different routes downstream of the node. This is important where complex travel patterns occur, such as roundabouts. Bus movements should always be modelled with shared links unless there is a dedicated bus lane. Bus timetable / frequency information should be used as a base.

These links facilitate the following of vehicle progression of a particular platoon through the network.

Up to 5 separate classes of vehicles or platoon sources may be represented in any single queuing situation. In reality of course they form a single queue.

11.12. Fanning and Funnelling

The treatment of “fanning” and “funnelling” traffic is a source of possible modelling error.

“Funnelling” occurs when a greater number of lanes at one signal controlled stopline exit into a fewer number of lanes downstream.
“Fanning” is the opposite, where fewer lanes flow into more lanes.

When “funnelling” is taking place in very short distance, serious under utilisation of upstream lanes could result. This will have to be reflected in the link structure of the model or the saturation flow assumption for the upstream links. Many times, lanes of continuous length behave like flares in such situations. If this is the case the model should reflect this in the link structure.

When traffic is “fanning” into a wider carriageway downstream the extra downstream lanes will only contribute towards the capacity of their stopline if in general the offset is fixed between the two links through which “fanning” is taking place.

In general this offset should ensure the downstream link is “saturated”. To achieve this saturation the offset should be set so that the upstream link receives green while the downstream is in red for the duration of vehicles flowing into the extra lanes.

If this is not possible the extra downstream lanes will contribute very little, if at all to the stopline capacity as normal driver behaviour shows that drivers do not change lane as they move through successive stoplines when they are on green.

This may not be an issue if the additional capacity provided by the extra lanes is not required. In any case, the modeller will have to make a judgement about which way is preferable for the network to operate and reflect this decision into the link structure and saturation flow assumptions.

12. APPENDIX D – VALIDATION

12.1. Calculating Degree of Saturation

To measure the actual degree of saturation on site the actual average green time and cycle length must first be measured along with a spot count of the traffic flow. The actual degree of saturation is then calculated as:

(spot count of traffic flow x average cycle time) divided by (average effective green x measured saturation flow). This can be represented as follows:

$$\text{Percent sat.} = \frac{q * C}{G_e * S} \times 100\%$$

Key	q	=	spot count of traffic flow (PCU/hour)
	C	=	average cycle length (seconds)
	G_e	=	average effective green (actual green + leaving amber - start and end lost time)
	S	=	measured saturation flow (PCU/hour)

During the model validation stage the degree of saturation derived by the model should not normally rise above 100 percent. This is assuming that the assigned traffic flows have been taken by a stopline traffic count. If instead they represent the true traffic demand as it is designed by an assignment model or survey well upstream of the back of any queue then the degree of saturation can of course exceed 100%. In this instance the validation should focus on comparing the capacity of the link in the model and site based spot counts of stopline throughput.

Possible causes of invalid degree of saturation values in the model include:

- The measured flow data allocated to that link is suspect with regard to its accuracy or an error has been made in transferring the flow data into the TRANSYT model.
- The saturation flow is too low.
- The existing signal timings have been input into the model incorrectly.
- The junction associated with the link has one or more demand dependent stages that are not called on a permanent basis, therefore allowing other phase capacities to increase when the demand dependent phases are absent.

12.2. The GEH Statistic

The GEH statistic is a standard measure of the “goodness of fit” between observed and modelled flows. Unlike comparing flows using percentage difference the GEH statistic places more emphasis on larger flows than on smaller flows.

The GEH is calculated as follows:

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

where M and C are the modelled and observed flows respectively. Smaller GEH values indicate a better the “fit” between observed and modelled flows. As a guide, modellers should aim for GEH values less than 5.

Below is a sample set of results:

M (PCU)	C (PCU)	GEH	% Difference
10,000	9,000	10.3	10%
1,000	900	3.2	10%
100	90	1.0	10%
10,000	9,520	4.9	5%
1,000	850	4.9	18%
100	57	4.9	75%

An alternative method of comparison of flows is to plot observed flows versus modelled flows and carry out a correlation analysis. This method provides an indication of the goodness of fit (R correlation statistic) and whether the model is over or under representing flows.

12.3. Validation Issues

12.3.1. LINSIG

When validating models of isolated junctions built in LINSIG the degree of saturation should form a validation parameter for all critical links.

An additional parameter that should be used is the average queue length.

LINSIG estimates the queue length at the beginning of green according to an empirical formula taken from Webster and Cobbe that normally underestimates the actual queue size by about 5 – 10 percent for under-saturated approaches. The figures are approximate but if a fair comparison is to be made with actual values of queues, their lengths should be measured at the beginning of green during the traffic survey stage.

12.3.2. TRANSYT

For validation purposes the TRANSYT model should have the EQUISAT and optimisation parameters set to zero.

As in the case of models built in LINSIG the degree of saturation is one of the most important parameters to use for validation.

The TRANSYT queuing model does not produce very reliable estimates of the actual queue lengths. The mean max queue that TRANSYT reports is not a queue length at some fixed point in the cycle but a distance from the stopline of the last stationary vehicle before it moves off due to vehicles in front of it starting to move. Even if this figure were being estimated accurately it would be very difficult to measure that distance in real life. Engineering judgement is required to determine the on street equivalent of the TRANSYT queue. Therefore this parameter is not recommended for the validation of TRANSYT models.

The traffic flow profile graphs produced by TRANSYT are very useful for validating the model. They should be used to compare on street offset times and vehicular platoon arrival and discharge patterns to check they match those predicted by the model.

An example flow profile from TRANSYT is provided in Diagram 1 overleaf.

Saturation flow (shown here at 3400)

Discharge at saturation flow. This traffic was previously delayed by red signal.

Traffic arriving undelayed during green.

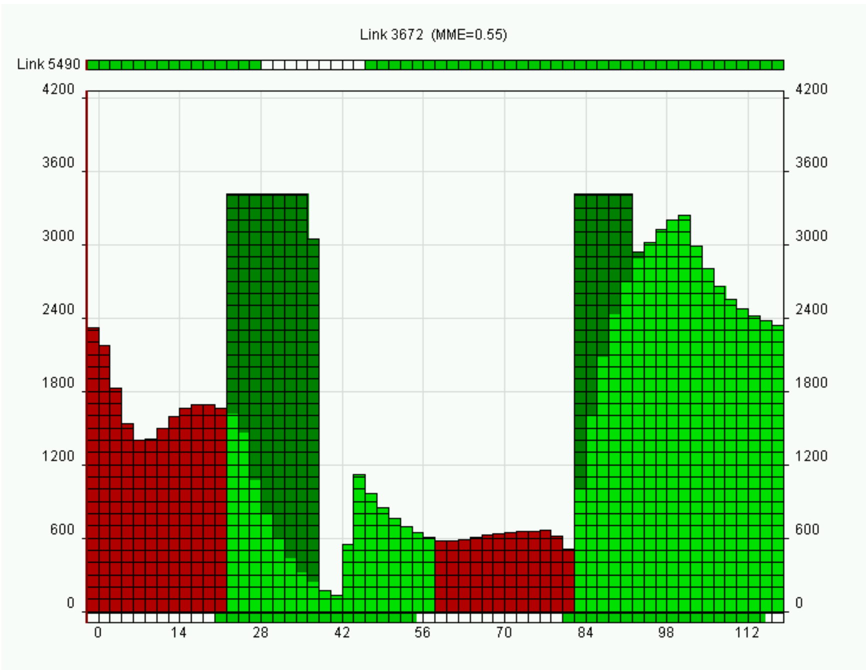
Traffic delayed by red signal.

```
    I
    I
    I
    I
4000+
    I
    I
    I           ^^^^^^^                       ^^^^^
    I           ^^^^^^^                       ^^^^^  @@@
3000+           ^^^^^^^^                      ^^^^^^@@@@@
    I           ^^^^^^^^                      ^^^^^@@@@@@@
    I           ^^^^^^^^                      ^^^^@@@@@@@@@@
    I           ^^^^^^^^                      ^^^@@@@@@@@@@@@@@@1
    I1          ^^^^^^^^                      ^^^@@@@@@@@@@@@@@@1
2000+1          ^^^^^^^^                      ^^@@@@@@@@@@@@@@@@1
    I11         ^^^^^^^^                      ^^@@@@@@@@@@@@@@@@1
    I111  111111@^^^^^^^                      ^@@@@@@@@@@@@@@@@@1
    I11111111111@@^^^^^^                      ^@@@@@@@@@@@@@@@@@1
    I11111111111@@^^^^^^   @                  ^@@@@@@@@@@@@@@@@@1
1000+11111111111@@@^^^^^   @@                 @@@@@@@@@@@@@@@@@@@1
    I11111111111@@@@^^^^   @@@@               @@@@@@@@@@@@@@@@@@@1
    I11111111111@@@@@^^^  @@@@@@@@111111111111@@@@@@@@@@@@@@@@@@@1
    I11111111111@@@@@@@^  @@@@@@@@111111111111@@@@@@@@@@@@@@@@@@@1
    I11111111111@@@@@@@@@@@@@@@@@@111111111111@@@@@@@@@@@@@@@@@@@1
    +=========#.........1........=#=========#.........1........=#
     Eff. Red     Eff. Green        Eff. Red      Eff. Green
```

M.M.E. 0.9

Diagram 1 – TRANSYT Profile of Flow against Cycle Time

The equivalent CFP diagram from TranEd2 is shown below.



Notes:

M.M.E. = Mean Modulus of Error (Range 0.0 - 2.0).
M.M.E is a measure of the Degree of Bunching of a platoon. A higher value indicates greater benefits of linking.
Informal advice from TRL states that values greater than 0.3 are said to produce benefits in linking terms.

12.3.3. VISSIM

Validation of VISSIM models requires even more care and attention to detail. It is a requirement that VISSIM modellers are experienced traffic engineers who have studied real traffic behaviour in congested urban networks.

The effects of “exit blocking” are easier to study in VISSIM models because of:

- the spatial nature of queue formation;
- the consequent interference of them;
- the impact on the rate of discharge of vehicles from upstream junctions.

However, lane utilisation is something the modeller has to carefully define by designing the link structure of the model and assigning different proportions of traffic demand across the carriageway until the simulated queue lengths closely match the actual queues observed during the traffic data collection stage.

Demand dependent stages, stage extensions or curtailments due to special conditions should be modelled in VISSIM using the traffic control logic builder it is associated with and is known as VISVAP.

In VISSIM the concept of a “junction” does not exist. Therefore the model should have a comprehensive set of priority rules on how vehicles give way to each other on paths that are in conflict with each other. The “gap” vehicles seek to proceed against opposing traffic should reflect the average minimum “time lag” vehicles are looking for as measured during the data collection stage.

Calibration of Saturation Flows

For models with closely spaced signal controlled junctions it is very important to get the rate of discharge or saturation flow right across the major stoplines.

VISSIM does not accept the saturation flow of a link as a direct input value. Instead it has two alternative tools through which it can influence the rate at which vehicles travel over signal controlled stoplines. These are the "driver behaviour" model and "speed reduced areas”. Where saturation flows appear to be modelled incorrectly throughout the model, it may be appropriate to adjust the parameters of the driver behaviour models. Where there are local inconsistencies in saturation flow rate, “speed reduction areas” are more appropriate.

Users should exercise caution when changing the parameters of the driver behaviour model as this may change driver behaviour in unexpected locations. The user is reminded that a driver behaviour model is associated with a link type and therefore a change in the driver behaviour parameters will affect all the links for which that behaviour model is associated.

VISSIM has two different driver behaviour models, one suggested for urban conditions and one for motorways. The most appropriate model to use in an urban environment containing signalised junctions is the Wiedmann 74 model. The parameters of Wiedmann 74 that influence saturation flow are the “average standstill distance”, “additive part of safety distance” and “multiplicative part of safety distance”. The VISSIM manual (section 5.4.6) provides an example scenario to demonstrate the effect changing these parameters has on saturation flow.

The parameter that influences saturation flow through “reduced speed areas” is the chosen “speed range” by vehicle class.

DTO-UTC strongly advises that modellers are not satisfied following the specific example saturation flows in the VISSIM manual. They should use a combination of “driver behaviour” parameters and “reduced speed areas” that will result to time headways under-saturated conditions during simulation that closely match values measured on site.

During the process of calibration, time headways can be studied in two ways:

- “special evaluation files” as described in the VISSIM manual (section 10.20); and
- by producing output from a VAP routine that records and reports “headways” across detectors that can be placed on top of stoplines.

The Use of Seed Values

Traffic conditions vary day-to-day as a result of random driver behaviours, e.g. speed selection, lane changing, driver route choice, bus and parked vehicle dwell times. The stochastic micro-simulation traffic model VISSIM attempts to replicate this day-to-day random variability by basing simulated driver decisions on a set of random numbers. This set of random numbers is generated from an initial “seed” value which is specified at the start of a simulation run. A single set of random numbers, generated by a single seed value therefore represents one potential result, or one particular day of traffic operation. The actual value of the seeds chosen is irrelevant, but they must be different from each other.

Basing results on a single seed value therefore has the potential to bias the overall result. The commonly accepted method to reduce the potential for bias is to run several simulations using a range of initial seeds and average the results.

It is important to note that the more saturated a network becomes, the more variable the result. This occurs because small changes (e.g. lane change) have a more significant impact in a congested network, than in an uncongested one. It is necessary therefore that more simulation runs be done for saturated models. As a guide somewhere between 5 and 10 runs are appropriate. Furthermore, if the required confidence level is known it is possible to calculate the number of simulations necessary to produce a reliable result.

The use of seed values should be clearly described in the validation report. A sample range of results, using different seed values, should be provided for the base model to demonstrate the variability between simulation runs.

Results from Micro-simulation

VISSIM models produce many useful results for assessing the accurate validation of a network. The "data collection points" are useful and can be scattered at any mid – link locations where traffic flow counts exist.

An equally useful feature is the "node evaluation" file. All critical junctions can be described as "nodes" in VISSIM and the model can collect a whole array of parameters for every turning movement, vehicle type and time slice of each junction. Such parameters can be traffic flow by vehicle type, average delay by vehicle type, average and maximum queue lengths per link.

Finally, a whole series of routes can be defined across the model and journey times can be studied by vehicle types and compared against surveyed journey times for validation purposes and against the corresponding values of alternative proposals for evaluation and choosing the one that best meets the study objectives.

13. APPENDIX E – PROPOSAL EVALUATION

13.1. Stage Design Options

The objectives of some schemes may not require the maximising of capacity for all traffic phases in the design of the interstage period

Sometimes, according to the overall strategy, certain phases may be deliberately left with suboptimal interstage design, such as in cases where a traffic phase with a full phase delay may cause over-saturation downstream.

Conversely, extra traffic stages can be used in the method of control to satisfy phase minima if the absolute minimum lost time has to be suffered by a traffic phase for which maximum capacity has to be given.

13.2. Proposed Cycle Time Considerations

An indication of the appropriate cycle time selection (including single / double cycle options) in networks can be derived from the critical node as shown in the CYOP outputs in TRANSYT. This indicates suitable cycle times for each node in isolation and provides performance indices for a range of cycle times. However, the factors outlined below need to be considered.

Cycle times that cause pedestrian wait times over 83 seconds are not recommended. At junctions where pedestrians require a dedicated stage, this equates to a maximum cycle time of 88-seconds. Where pedestrians 'walk with traffic', higher cycle times may be acceptable.

Available SCOOT compatible cycle times are 32, 36, 40, 44, 48, 52, 56, 60, 64, 72, 80, 88, 96, 104, 112 and 120.

It should be noted that although increasing cycle time generally provides greater capacity at a junction, the rate of increase diminishes at higher cycle times. This is due to the proportion of additional time compared to lost time; e.g. raising from 52 to 56 seconds is likely to provide greater capacity improvements than raising from 88 to 96 seconds.

It should be noted that in SCOOT areas there is a need to allow for an additional 4 seconds over and above the summation of stage minima per node when considering running low cycle times or looking to double cycle nodes.

As stated earlier, network cycle times of 60 seconds prohibit any pedestrian crossing double cycling and 64 seconds may be a better option.

13.3. TRANSYT Optimisation Process

TRANSYT has limitations in taking account of the effect of exit blocking and it doesn't predict accurately the performance of networks operating close to their capacity. As a result, after the initial optimisation, the modeller will have to study the traffic profile and queue graphs and try to establish when in the cycle, different links are likely to suffer from exit blocking and for how long.

Once the reasons for these findings are known, new stages in the method of control can be considered and full optimisation can be repeated with appropriate delay, stop and queue weightings added.

If problems with queue storage are still apparent after this stage, the modeller should manually change the splits to achieve a more balanced loading of the network and then perform an offset optimisation only. At this stage the modeller could decide to group nodes together in cases of closely spaced links where for efficiency the offsets should be fixed at particular values (problems of fanning, funnelling or exit blocking being considered).

Once the modeller is satisfied with the operation of the models internal links a final manual stage of optimisation should be performed. This stage should achieve two things:

a) Ensure appropriate front and back end co-ordination exists between closely spaced links.
b) Adjust green times to saturate any under-saturated external links

The first stage is to make sure that any traffic control strategy is implemented properly (fanning, platoon compaction, clearing in the end of green etc.) by careful adjustment of offsets.
The second is necessary for networks operating close to their practical capacity to protect internal links from becoming overwhelmed with traffic they cannot physically store if there is a sudden surge in the rate of arrival from upstream under-saturated external links.

13.4. Dynamic Assignment Convergence

Two techniques are recommended for achieving convergence with dynamic assignment in VISSIM, these are outlined below:

a) Choose a fairly large number (30-50) of iterations. If congestion is expected in the network, assign the travel demand matrix/ces in batch mode using: *"VISSIM.exe something.inp -s9 -v10*" at the command prompt. Before running this process, the simulation should start with only 20% of the total O/D matrix/ces. The batch mode then ramps up demand over each successive simulation to 100% - e.g. 20%, 30%, 40%,…and so on.

   Then by starting with the path and cost files from the previous process, assign traffic for 30 to 50 iterations in batch mode whilst updating these costs and paths. After each iteration cost and path files should be renamed and saved in a separate folder. By default they are overwritten with each iteration. The convergence evaluation file (*.CVA), produced at the end of each run, should also be saved with the cost and path files.

   N.B. If the network is not congested then the first step of loading the O/D matrix/ces incrementally can be omitted. Then the assignment iterations can start with no initial cost and path files.

   When all the iterations finish the trend of path and edge traffic flow and travel time convergence from the *.WGA and *.CVA files should be studied to decide if convergence is achieved, at what iteration and whether it is maintained for subsequent iterations.

   Convergence will be deemed to have been satisfactorily achieved when the following criteria have been met over the peak hour:

   - 95% of all <u>path traffic volumes</u> change by less than 5% for at least 4 consecutive iterations; and
   - 95% of <u>travel times on all paths</u> change by less than 20% for at least 4 consecutive iterations.

   If convergence has been achieved for four iterations but is then lost in subsequent iterations, note should be made of the number of iteration when convergence was achieved and the assignment and validation should be performed with the use of the cost and path files (*.BEW, *.WEG) from the last of the four converged iterations.

   These convergence criteria have been based on the DMRB criteria for highway assignment models and aim to confirm a stable and converged assignment.

If the convergence criteria cannot be achieved using the method (a) convergence can be improved using the following technique.

b) The O/D matrix/ces are assigned partly on fixed routes and partly dynamically. The part on fixed routes can be thought of as the part of the travel demand that is unaware of the possible routes and rat runs in the network and sticks to the main signed routes and the part that dynamically assigns could be thought of as the part of the travel demand that knows the network and its performance very well and exploits any possible route that is available.

DTO does not have any advice at the moment to offer to modellers on how to split the O/D matrix/ces in the two parts and this will have to be left to the modeller's discretion. The fixed routes for the first part of the travel demand could be chosen either by local knowledge or determined by assigning that part of the matrix/ces dynamically with a high value for Kirchhoff's exponent. This should concentrate this part of the O/D matrix/ces to a few fast routes and then the modeller can convert them to static routes if he/she is happy with the choice and number of paths found.

The part of the travel demand that is assigned dynamically should do so over a number of iterations and the same procedure as described in part (a) should be followed to show convergence of assignment.

For modellers that have access to the highway assignment model VISUM there is a third alternative. Assignment of travel demand can be undertaken in VISUM where convergence is guaranteed and the path and cost files can be exported to VISSIM for detailed simulation and analysis.

14. APPENDIX F – SCHEME REPORT / NETWORK IMPACT

Scheme Name: **Scheme Location:**

Modeller Name: **Organisation** **Date:**

List of attachments (drawing numbers / titles, Design Summary Sheets etc.):

Problem / Objective

The statement given should indicate the problem and the reason for the proposal. It should outline the scheme objective, e.g. safety measures, provision of additional pedestrian facilities, reduction of delays to buses. This section should clearly outline, and quantify where appropriate, the intended benefits of the scheme.

Strategy

In this section the review of the current situation should be presented followed by each proposal. This should include details of the following:

- The modelling work undertaken for scheme design
- Impact assessment
- Area network management issues
- The basis for selection of the model boundaries for the scheme
- Modelled periods
- The reason for using specific modelling products and techniques as well as any complimentary modelling, e.g.:
    - Use of LINSIG for isolated signal scheme design for given capacity and evaluating the impact of any proposals;
    - TRANSYT for cycle time consideration and its impact on adjacent signals co-ordination and network performance;
    - VISSIM micro-simulation where significant over-saturation is expected, complex traffic conditions exist or when a variety of cycle lengths and traffic control techniques coexist in the area of influence of a scheme.
- Any observations and assumptions made that are incorporated in modelling relating to:
    - traffic signals network
    - traffic assignment
    - traffic management measures
    - lane usage
    - pedestrians
    - parking
    - bus operation and routes
- Average site observed validation data

These observations and assumptions should be recorded by the modeller in a summary of evidence, e.g. table 1. A list of all attached drawings and data should be provided.

Results

This should include design, capacity, impact and performance assessment of the base, proposed and preferred option models.

The statement given should fully detail the benefits and disbenefits of the proposals and the preferred option referring to the different class of road users and how their needs are balanced by the results.

Models generate a wide range of outputs that provide an accurate indication of the performance. In addition to the observed data types used for model validation, the minimum performance statistics that should be provided are as follows:

- Lane usage
- Queue lengths
- Degree of saturation
- Average journey time or speed
- Average delay per vehicle
- Average delay for buses (weighted by passenger numbers)
- Maximum delay for pedestrians
- Cyclic flow profiles – traffic patterns and behaviours

The performance statistics shall be tabulated (an example is provided in table 2) for comparisons between the observed and modelled (base) performance as well as between the scheme and options for all periods.

For micro-simulation models a minimum of 6 simulation runs must be performed with a range of seed values. The above performance statistics should be reported as the average across all simulation runs. In addition, a demonstration of the variability between different seed runs for the most critical results is required to give confidence in the reliability of results.

Key Impacts and Proposed Mitigation

This section should highlight any significant impacts the scheme has on network performance, including buses and pedestrians. It should clearly indicate how such impacts will be mitigated by the design, or complimentary measures.

Conclusions and Recommendations

This section should provide a useful summary of the key points delivered in the report. It should outline the objective, benefits, disbenefits, key issues and mitigation of the major adverse impacts.

Attachments

The attachments should include the following:

- Signal Design Summary Sheets (for each node)
- Source data: all relevant data input for the base and proposed models (scheme / signal / traffic and network data)
- Statistics: details of Calibration / Validation and method for selecting final performance
- Electronic: model/graphical outputs of the results
- LINSIG input and analysis (min. cycle and interstage diagrams)
- Model Audit details and table with cross indexing of version controlled data

The Signal Design Summary sheet is essential as it contains much vital data including method of control, intergreen data, phase minimum and delay data, stage and interstage data and TRANSYT stage pulse points.

Submission Checklist

Table 6, shown below, should be used to confirm included documentation and information. This table should be read in conjunction with the following pages, which provide some examples.

Items	**Example**	**Comments**	**Yes / No / NA**
Existing Drawings			
Proposed Drawings			
Signal Data (e.g. Design Summary Sheet)	See Example 1		
Traffic Data Provision Traffic Assignments		Traffic & Turning Volumes for AM, OP, PM, Weekend including date counts taken	
Traffic Modelling LINSIG TRANSYT Micro-Simulation – VISSIM	See Example 2	Existing (base) and proposed models. TRANSYT models should include graphical flow profile outputs (from Card Type 35)	
User and Network Impacts (traffic and bus)			
Supporting Correspondence			
Modelling Data	See Table 1		
Performance Statistics Comparative Results	See Table 2	Based on Observations, Baseline and Proposed Models	

Table 6 – Submission Checklist

Example 1

SIGNAL DESIGN SUMMARY SHEET (for each Node)

JUNCTION ADDRESS:
JUNCTION NUMBER: /

UTC – FIXED TIME OR SCOOT?	
HAVE "TTS 6" PEDESTRIAN CROSSING TIMES BEEN APPLIED?	
IS AN ALL RED REQUIRED, WHICH IS CONTROLLED IN UTC?	

STAGE DIAGRAM

1	2	3	4

INTERSTAGE

F/T	1	2	3	4	STAGE MINS
1					
2					
3					
4					

PHASE INTERGREENS **MINS**

F\T	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	MINS
A																
B																
C																
D																
E																
F																
G																
H																
I																
J																
K																
L																
M																
N																
O																

PHASE DELAYS
(include non sequential)

FROM STAGE	TO STAGE	DELAY PHASE	BY (SECS)

UTC - TRANSYT PULSE POINTS (not durations)

PLAN NO.	TIME PERIOD	CYCLE TIME	STAGE 1	STAGE 2	STAGE 3	STAGE 4
01	MORNING PEAK					
02	OFF PEAK					
03	EVENING PEAK					
08	LATE EVENING					
05	OVER NIGHT					

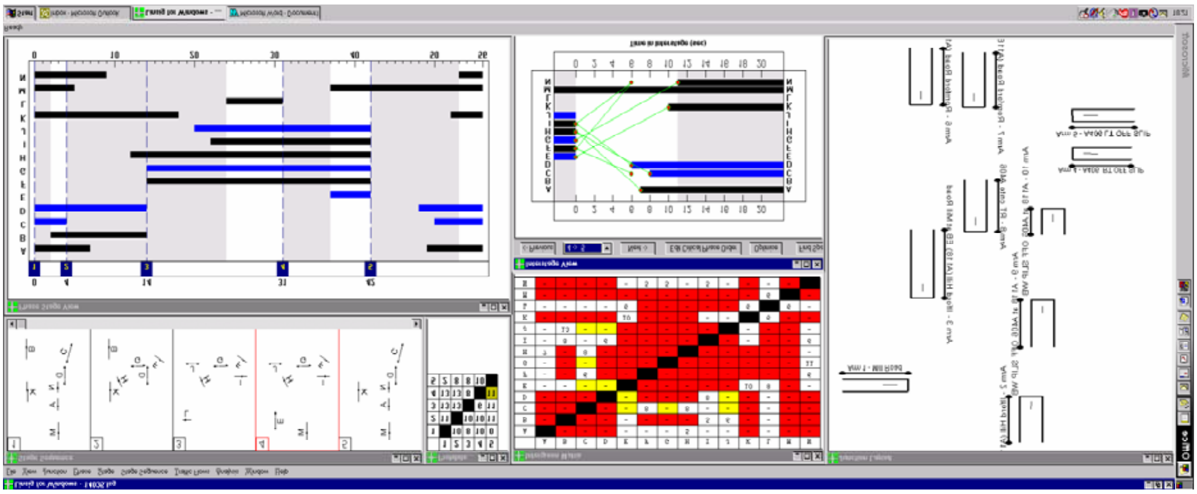
WHERE SCOOT IS ACTIVE, THE DURATIONS ONLY GIVE AN INDICATION OF POSSIBLE AVERAGE TIMES. EVENT TIMES MAY VARY FOR OFFSET PURPOSES
.

COMMENTS:

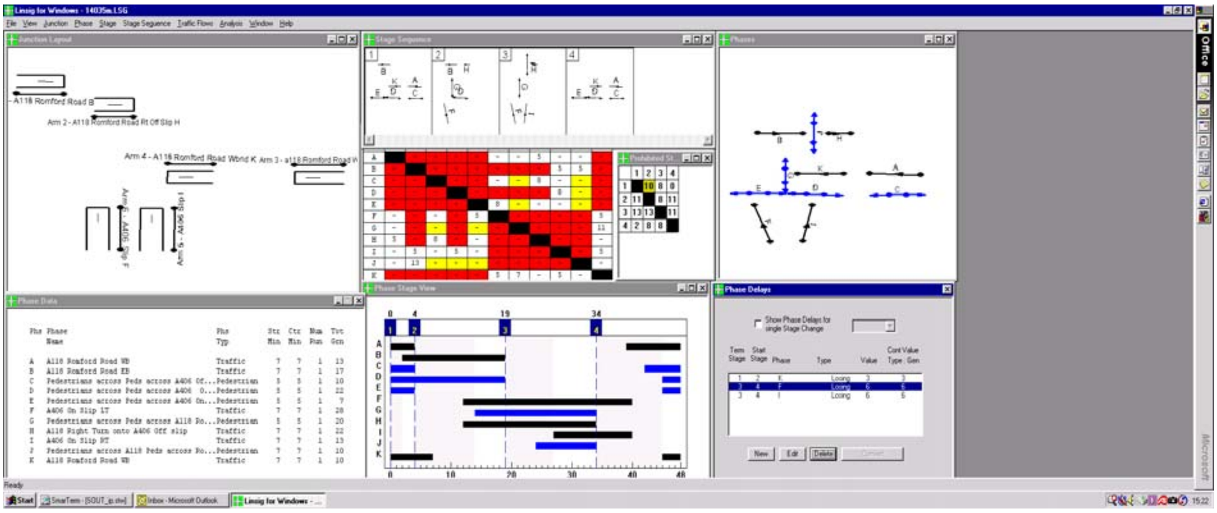
Designed by: **Issue No:** **Date:**

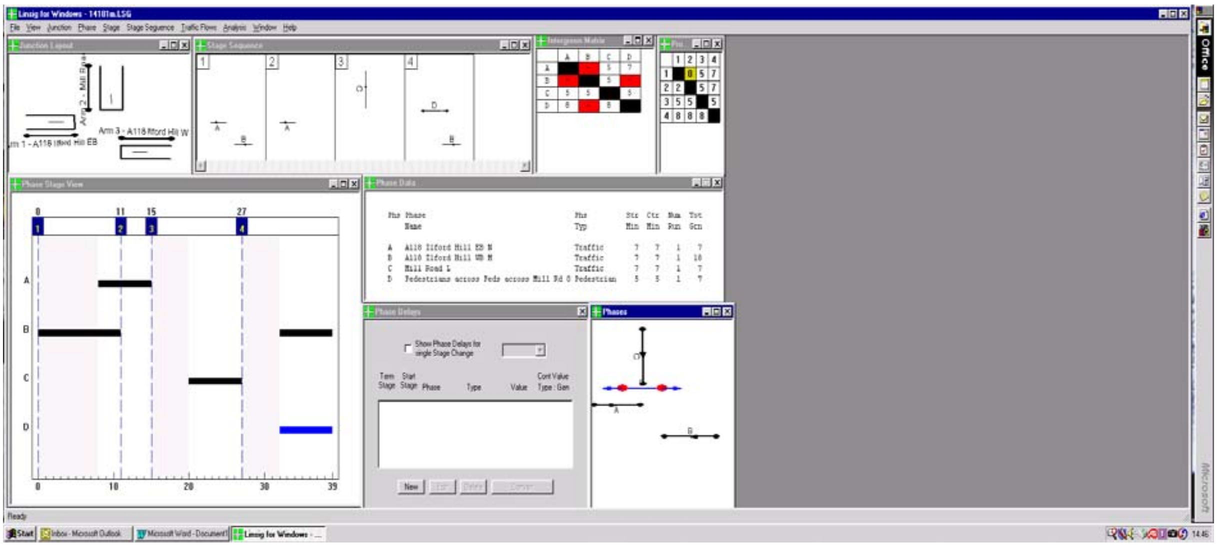
Example 2

Existing – Method of Control: Single Stream



Proposed – Method of Control: Parallel Streaming





Type	Description	Examples	Observation / Survey Periods	Base Model Identification	Proposed Model Identification	Check List
Network	Network Diagram / Dimensions.	- GIS Digitised maps/ junction node and link arrangements, - Site Layout drawings scale 1:500 for geometric layout, actual on the ground lane allocation and lane markings. - LRT/Bus route – lanes /stop locations and dimensions location and configuration should be revealed				
	Network Coding/Modelling	- Lane usage - flares, fanning and funnelling - Give way – priority at junctions - Right turns - controlled and uncontrolled - Bottlenecks - exit blocking due to loading, parking etc. - Shared stop line – complex O-D travel patterns e.g. roundabouts, buses with general traffic. - Bus TRANSYT – bus routes with dedicated lanes				
Traffic	Traffic Composition	- Proportion of cars, taxis, HGVs, buses, motorcycles and cyclists				
	Traffic volumes	- Peak hour manual or automatic counts at queue free locations ***(include journey times, queue lengths, degrees of saturation as appropriate)***				
	Classified junction flow turning and throughput (at stop lines)	- Expressed as turning proportions or origin and destination matrix in a maximum 15 minutes segments - These may be obtained from registration plate surveys, existing trip matrices or junction turning movements				
	LRT/Bus operation – frequencies and dwell times	- Bus lane operation times –GIS maps and overlays - Actual bus arrival profiles from timetable/observations - Average and standard deviation of dwell time defined for bus stop from surveys or existing data				
	On street parking data	- On street parking regulations by type and duration				
	Pedestrian flows &call rate	- Obtained from site observation surveys or UTC ACHK facility				
	Banned movement/ One way etc	- Site observations				
Signal	Signal Control Methods – UTC FT/SCOOT, SVD. NON UTC CLF and VA Logic	- Current design summary sheet and controller (blue) specification - Proposed Signal Design Summary Sheet see ***Example 1*** - Signal Method of Control ***see Example 2*** - LINSIG outputs of inter-stage designs including phase delays - Filter/Indicative Arrows - Phase/Stage demand dependency counts for UTC use ACHK.				
	Signal Plan Timings	- Current timing sheet and controller (blue) specification - Current UTC, CLF, VA Max plan timings - Optimised model outputs - Plan timings must correspond to traffic survey period				
	Special Conditioning	- Location and configuration and - UTC outputs and - Traffic signal controller specification				
	Saturation flow					
*Performance	Journey / Travel time (traffic and bus)	- Minimum, maximum and average site observation using statistically robust sample - ***(*): See table 2 for Comparative Performance Statistics*** - ***Electronic copies of the model and outputs MUST be included (e.g. graphical flow profile outputs and CYOP outputs).***				
	Queue length; per link and lane					
	Delay per vehicle per lane (traffic and bus)					
	Degree of Saturation					
	Pedestrian delay at crossings					

<u>Table 1 – Modelling Data Summary</u>

Period	Arm/Link		On Street Observations				Base Model				Proposed Model			
	Link Number	Link Description	Traffic Spot count (pcu/hr)	DoS (%)	Q Len (pcus	Flare usage (pcus)	Traffic flow (pcu/hr)	DoS (%)	Q Len (pcu's)	Flare length (pcus)	Traffic flow (pcus/hr)	DoS (%)	Q Len (PCU's)	Flare length (pcus)
Weekday														
AM Peak														
	Cycle Time													
	PRC (%)													
	PI													

Period	Arm/Link		On Street Observations				Base Model				Proposed Model			
	Link Number	Link Description	Traffic Spot count (pcu/hr)	DoS (%)	Q Len (pcus	Flare usage (pcus)	Traffic flow (pcu/hr)	DoS (%)	Q Len (pcu's)	Flare length (pcus)	Traffic flow (pcus/hr)	DoS (%)	Q Len (PCU's)	Flare length (pcus)
Weekday														
Off Peak														
	Cycle Time													
	PRC (%)													
	PI													

Period	Arm/Link		On Street Observations				Base Model				Proposed Model			
	Link Number	Link Description	Traffic Spot count (pcu/hr)	DoS (%)	Q Len (pcus	Flare usage (pcus)	Traffic flow (pcu/hr)	DoS (%)	Q Len (pcu's)	Flare length (pcus)	Traffic flow (pcus/hr)	DoS (%)	Q Len (PCU's)	Flare length (pcus)
Weekday														
PM Peak														
	Cycle Time													
	PRC (%)													
	PI													

Table 2 – Comparative Performance Statistics for LINSIG models

Arm / Link = Traffic, Pedestrians and Buses etc., i.e. buses, pedestrian phases and any other significant road user group should be modelled as separate links.
Link Description should include the link address, compass position and direction of movement (e.g. High Street West bound ahead)
DoS = Degree of saturation Q Len = Mean Max Queue Length PI = Performance Index PRC = Practical reserve capacity. This is calculated from the maximum degree of saturation on a link and is a measure of how much additional traffic could pass through the junction while maintaining a maximum degree of saturation of 90% on all links

Period	Arm/Link		On Street Observations				Base Model				Proposed Model			
	Link Number	Link Description	Traffic Spot count (pcu/hr)	DoS (%)	CFP	Traffic capacity (pcus/hr)	Traffic flow (pcu/hr)	DoS (%)	CFP	Traffic capacity (pcus/hr)	Traffic flow (pcus/hr)	DoS (%)	CFP	Traffic capacity (pcus/hr)
Weekday														
AM Peak														
	Cycle Time													
	PI													

Period	Arm/Link		On Street Observations				Base Model				Proposed Model			
	Link Number	Link Description	Traffic Spot count (pcu/hr)	DoS (%)	CFP	Traffic capacity (pcus/hr)	Traffic flow (pcu/hr)	DoS (%)	CFP	Traffic capacity (pcus/hr)	Traffic flow (pcus/hr)	DoS (%)	CFP	Traffic capacity (pcus/hr)
Weekday														
OFF Peak														
	Cycle Time													
	PI													

Period	Arm/Link		On Street Observations				Base Model				Proposed Model			
	Link Number	Link Description	Traffic Spot count (pcu/hr)	DoS (%)	CFP	Traffic capacity (pcus/hr)	Traffic flow (pcu/hr)	DoS (%)	CFP	Traffic capacity (pcus/hr)	Traffic flow (pcus/hr)	DoS (%)	CFP	Traffic capacity (pcus/hr)
Weekday														
PM Peak														
	Cycle Time													
	PI													

Table 3 – Comparative Performance Statistics for TRANSYT models

Arm / Link = Traffic, Pedestrians and Buses etc., i.e. buses, pedestrian phases and any other significant road user group should be modelled as separate links.
Link Description should include the link address, compass position and direction of movement (e.g. High Street West bound ahead
DoS = Degree of saturation PI = Performance Index CFP = Cyclic Flow Profile This is measured with the TRL software CFP for portable computers

Period	Arm/Link		On Street Observations				Base Model				Proposed Model			
	Link Number	Link Description	Traffic Spot count (pcu/hr)	Sat. flow (pcus/hr)	Traffic cap. (pcus/hr)	JT* (secs)	Traffic flow (pcu/hr)	Sat.flow (pcus/hr)	Traffic cap. (pcus/hr)	JT* (secs)	Traffic flow (pcus/hr)	Sat.flow (pcus/hr)	Traffic cap. (pcus/hr)	JT* (secs)
Weekday														
AM Peak														
	Cycle Time													
	Total traffic delay at crit. nodes for buses and gen. traffic (veh.hrs/hour)													
	Total traffic stops by vehicle type (veh.stops/hour)													

Period	Arm/Link		On Street Observations				Base Model				Proposed Model			
	Link Number	Link Description	Traffic Spot count (pcu/hr)	Sat. flow (pcus/hr)	Traffic cap. (pcus/hr)	JT* (secs)	Traffic flow (pcu/hr)	Sat.flow (pcus/hr)	Traffic cap. (pcus/hr)	JT* (secs)	Traffic flow (pcus/hr)	Sat.flow (pcus/hr)	Traffic cap. (pcus/hr)	JT* (secs)
Weekday														
OFF Peak														
	Cycle Time													
	Total traffic delay at crit. nodes for buses and gen. traffic (veh.hrs/hour)													
	Total traffic stops by vehicle type (veh.stops/hour)													

Period	Arm/Link		On Street Observations				Base Model				Proposed Model			
	Link Number	Link Description	Traffic Spot count (pcu/hr)	Sat. flow (pcus/hr)	Traffic cap. (pcus/hr)	JT* (secs)	Traffic flow (pcu/hr)	Sat.flow (pcus/hr)	Traffic cap. (pcus/hr)	JT* (secs)	Traffic flow (pcus/hr)	Sat.flow (pcus/hr)	Traffic cap. (pcus/hr)	JT* (secs)
Weekday														
PM Peak														
	Cycle Time													
	Total traffic delay at crit. nodes for buses and gen. traffic (veh.hrs/hour)													
	Total traffic stops by vehicle type (veh.stops/hour)													

Table 4 – Comparative Performance Statistics for VISSIM models

Arm / Link = Traffic, Pedestrians and Buses etc., i.e. buses, pedestrian phases and any other significant road user group should be modelled as separate links.
Link Description should include the link address, compass position and direction of movement (e.g. High Street West bound ahead)
JT= Journey time in seconds measured for whole sections across the network .

15. APPENDIX G – GLOSSARY

ASTRID............Automatic SCOOT Traffic Information Database
ATC..................Area Traffic Control
CFP..................Cyclic Flow Profile
CLF..................Cableless Linking Facility
COBA...............Cost Benefit Analysis program
CYOP...............Cycle Optimisation
DfT...................Department for Transport
DMRB..............Design Manual for Roads and Bridges
DOS.................Degree of Saturation
DTO.................TfL Streets Directorate of Traffic Operations
GEH.................A form of the chi squared statistic for flow comparison
GIS...................Geographic Information System
HGV.................Heavy Goods Vehicle
LBI...................London Bus Initiative
LGV..................Light Goods Vehicle
LRSU...............London Road Safety Unit
LTCC...............London Traffic Control Centre (within DTO)
MME................Mean Modulus of Error
MOVA..............Microprocessor Optimised Vehicle Actuation
NAT..................Network Assurance Team
NMD.................Network Management Duty
NMG................TfL Surface Network Management Group
O/D..................Origin-destination matrix
PARAMICS......Parallel Microscopic Simulation
PCU.................Passenger Car Unit (including cars, buses, articulated buses, HGVs, LGVs, trams, taxis, motorcycles and cycles)
PIAP.................Project Identification, Appraisal and Prioritisation process
RAM.................Random Access Memory
RND.................TfL Streets Directorate of Road Network Development
RNP.................Road Network Performance
SASS...............System Activated Strategy Selection
SATURN..........Simulation and Assignment of Traffic to Urban Road Networks
SCOOT............Split, Cycle and Offset Optimisation Technique
SLD..................Signal Layout Drawing
SVD.................Selective Vehicle Detection
TI......................Traffic Infrastructure (with DTO)
TLRN...............Transport for London Road Network
TMAP...............TRANSYT Modelling Audit Process
TRANSYT........TRAffic Network StudY Tool
TRL..................Transport Research Laboratory
TSSR...............Traffic Signal Supplementary Report
TTS..................Traffic Technology Services
UTC.................Urban Traffic Control / UTC Department (within DTO)
VA....................Vehicle Actuation
VAP..................Vehicle Actuated Programming
VISSIM............German acronym for Traffic In Towns: Simulation
VisVAP.............Visual Vehicle Actuated Programming

16. APPENDIX H – ACKNOWLEDGEMENTS

In addition to the key contributors identified in Section 1.4, acknowledgement is made of the contributions from numerous additional TfL staff including:

- Peter Brown — Chief Operating Officer – TfL Streets
- Phil Davies — Director of Traffic Operations (DTO)
- Mark Prior — Head of Network Assurance. NMG Chairman
- Kevin Gardner — Acting Assistant Director – Strategy. Head of Bus Priority Team. NMG member
- Jeremy Evans — Head of Traffic and Technology, Congestion Charging. NMG member
- Chris Lines — Head of London Road Safety Unit. NMG Member
- David Rowe — Head of Project Development. NMG member
- Del Cook — Acting Assistant Director, Road Network Operations – retired
- Chris Martin — Head of South Area Team – RND
- Neil Adams — Chief Engineer, Network Operations – DTO-UTC
- Ion O'Sullivan — Principal Traffic Control Engineer
- Mangal Singh — Principal Traffic Control Engineer
- John Courtney — Principal Traffic Control Engineer
- Nick Cottman — Principal Traffic Control Modeller

17. APPENDIX I – SCHEME ASSESSMENT PROCESS

The Traffic Management Act 2004 and the Network Management Duty placed on local traffic authorities requires audit / assessment processes to be in place to ensure the Duty is fulfilled.

This guidance note provides a high level outline of the process to audit signal schemes. The flow diagram (NA-TFL-DTO-NAT_Interfacial_Process-1) overleaf summarises the process.

Scheme Final Design Assessment

TfL's Network Assurance Team (NAT) assesses all schemes that may impact on the TLRN or SRN. Scheme Promoters are required to send formal Notification of their scheme to NAT. TfL is obliged to respond (approval / objection) within one month, after which approval is the default.

To assist NAT in this assessment, DTO produce a detailed analysis of the scheme's network impact prior to Notification. This is the Traffic Signal Supplementary Report (TSSR). DTO-Signals produce and complete the TSSR, with support from DTO-UTC where required (UTC networks, Pinchpoints, wide area impacts etc). DTO generate a TSSR for all signal schemes.

The audit process and development of the TSSR is a thorough and time consuming process and includes the following steps, in the order shown:

- Assessment of the detailed signal design, in the form of Stage 1 and 2 safety audit of each modified traffic signal installation – 1 month
- Model integrity checks, including data, coding, diagrams and report (in accordance with the DTO Modelling Guidelines) – 15 days
- Network impact assessment, including traffic re-assignment – 15 days

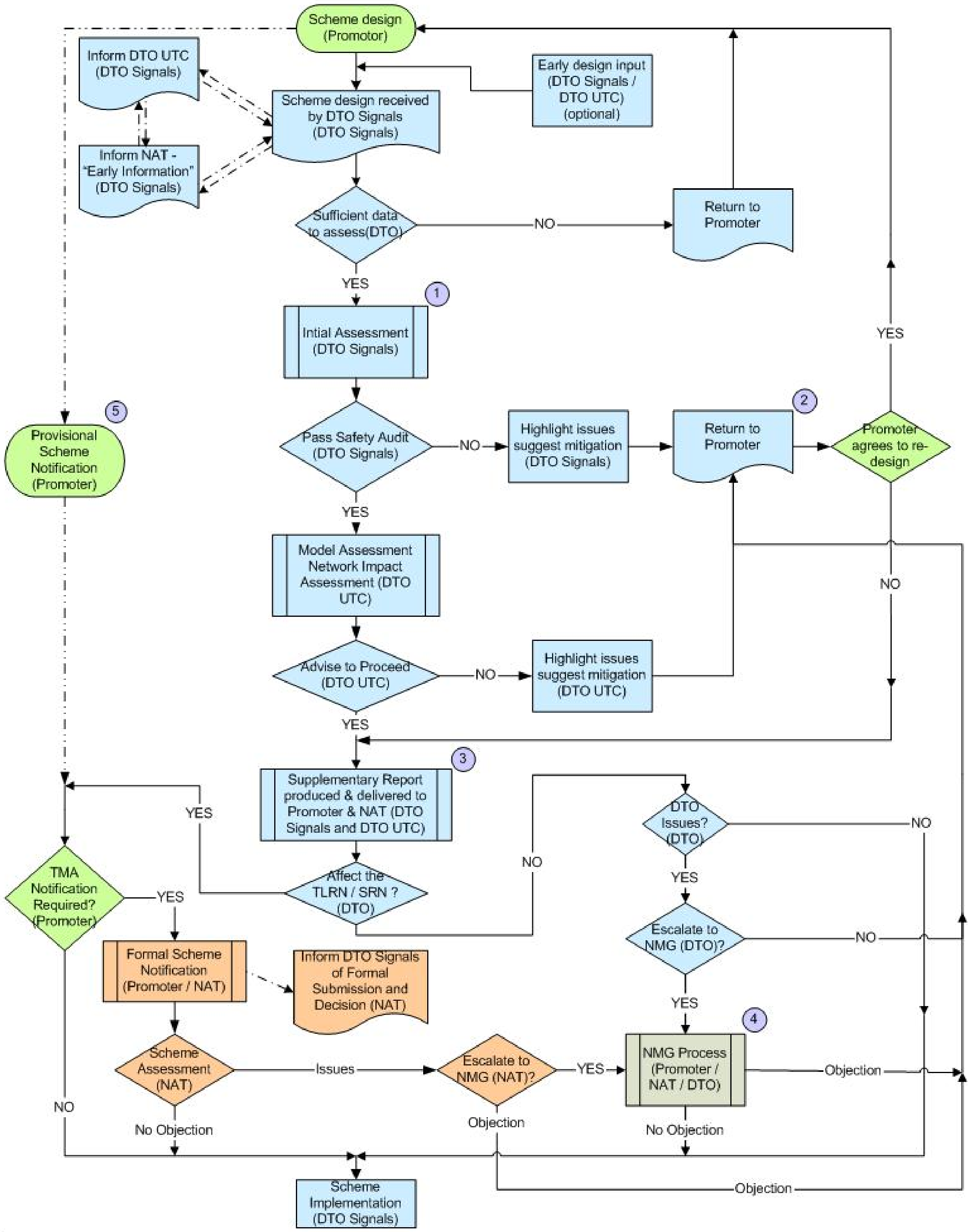
DTO will endeavour to complete the audit and TSSR process within 2 months. To limit the impact on DTO resources, a TSSR will only be completed following the submission to DTO of a scheme FINAL design, shortly before formal Notification. The TSSR is sent to the promoter for inclusion as additional information to the Notification. A copy is sent to NAT for information.

Scheme Preliminary Design Assessment

During preliminary stages of the design, DTO and NAT are keen to provide help and guidance to ensure that the design is on target to meet notification approval. The Promoter may wish to submit modelling of such preliminary designs. In this instance DTO can conduct a cursory examination of the modelling / design and provide advice. However, due to resource limitations, DTO will not conduct a detailed analysis of the design and modelling at this stage.

Promoters are advised to arrange independent audits of scheme preliminary designs, to ensure they meet TfL's guidance for signal modelling, are in line with the NMD and on target for notification approval. Should the Promoter require TfL to conduct such analysis, DTO will assist the Promoter in approaching Streets' Directorate of Road Network Development, who may be able to provide resources to carry out such an assessment. Note that these resources may be sourced from external consultants, and the Promoter should make their own consultant designers aware of this fact.

Traffic Signal Scheme – DTO Assessment Process



(1) 1) Includes Stage 2 safety audit checks on MOC, mins, intergreens, interstages, phase delays etc. In addition, the design submission should be checked against the DTO Modelling Guidelines (data, models, impacts report), to ensure adequate information is provided.

(2) 2) May include numerous iterations of request for additional data, suggested redesign and mitigation advice (DTO Signals and DTO UTC), in negotiation with the Promoter. Issues may also need to be escalated to NMG. Recommendations may be made to TfL's Traffic Manager who has the ultimate decision whether the proposal may go ahead when there exists conflict on the TLRN or SRN. Where the proposal does not affect the SRN or TLRN, the ultimate authority lies with DTO Signals.

(3) 3) The supplementary report will be produced by DTO Signals, with network impact assessment input from DTO UTC, where applicable.

(4) 4) The NMG process is detailed in the NAT Notification Process Guidance Document (WM-TfL-RNP-NAT-103).

(5) 5) Provisional Notification to NAT by the promoter is encouraged at any time prior to Formal Notification. NAT may assist the promoter identify what information is required and help identify potential conflicts.

Key: DTO NAT Promoter