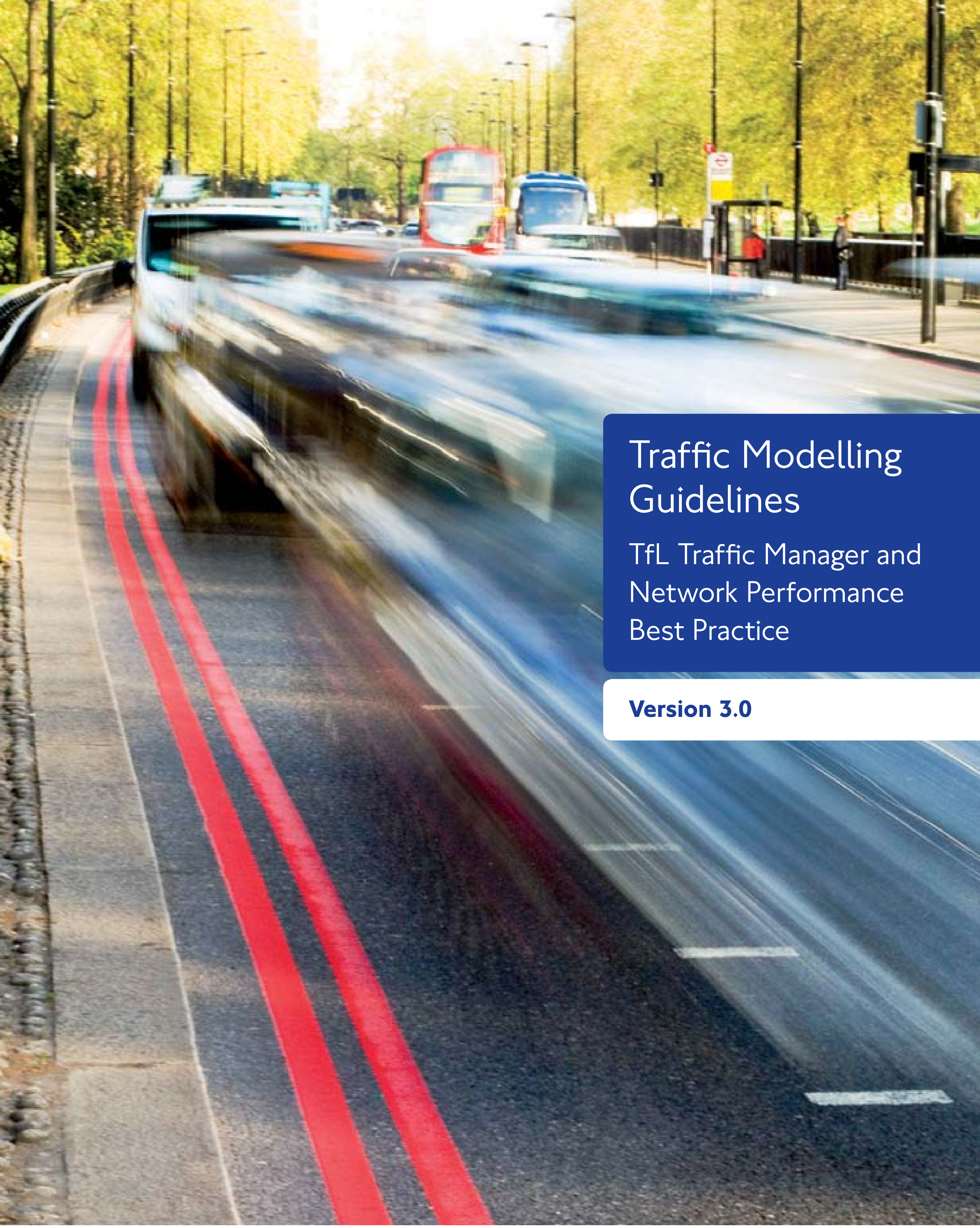


Traffic Modelling Guidelines

TfL Traffic Manager and Network Performance Best Practice

Version 3.0

MAYOR OF LONDON

Transport for London

Edited by
Dr James Smith & Robert Blewitt

Disclaimer

This publication is intended to provide accurate information. However, TfL and the authors accept no liability or responsibility for any errors or omissions or for any damage or loss arising from use of the information provided.

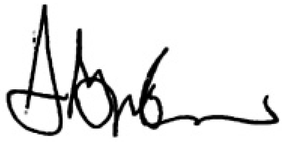
Foreword

The capacity of London's traffic network (both road and footway) is coming under increasing pressure and maintaining the smooth operation of this network is a challenging task.

A primary goal of the TfL Traffic Manager is to deliver journey time reliability and it is essential that traffic schemes are developed to a high quality and their impacts on the network are well understood and mitigated with journey time reliability as the ultimate outcome.

Traffic modelling plays an increasingly vital role in this objective and these guidelines provide invaluable support. They draw upon expertise from across the industry and form a comprehensive source of best practice.

It is TfL's remit to ensure that the effects of all planned interventions on the road network are thoroughly understood before they are implemented. These guidelines are fundamental in achieving this requirement.



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Acknowledgements

The editors would like to thank the following individuals for their support during the creation of this document:

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Introduction

The Traffic Modelling Guidelines have been produced by the Transport for London (TfL) Streets Traffic Directorate, with contributions from departments across TfL and external industry experts. The following document represents the views and needs of a broad spectrum of traffic model practitioners.

The TfL Traffic Director is the TfL Traffic Manager and therefore has a duty to secure the expeditious movement of people and goods (collectively termed 'Traffic' in this document as per the 2004 Traffic Management Act[1]). One of the key outcomes, and thus indicators, of network performance and expeditious movement of traffic is journey time reliability on the network. TfL Streets Traffic Directorate are dependent on comprehensive modelling and supporting information from clients (including Boroughs and TfL departments) and consultants in order to design, assess, implement and operate traffic schemes effectively.

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 adverse impacts;
- Clarified to avoid confusion or misinterpretation of the design;
- Effectively and efficiently implemented and operated; and
- Implemented with an accurate prediction of operation, i.e. 'no surprises'.

TfL Streets Traffic Directorate has developed these guidelines to help inform modellers, network operations practitioners and scheme sponsors. They encourage consistency, promote best practice and are intended to deliver improvements in modelling quality. The aim is that this will in turn promote high quality scheme design that delivers and maintains journey time reliability.

The previous version of the Modelling Guidelines[2] was published in July 2006. This new version has been produced to bring the document up to date and to ensure that guidance is compliant with current best practice. The guidance has also been expanded to include operational highway traffic assignment and pedestrian modelling.

1 Great Britain, *Traffic Management Act 2004: Elizabeth II, Chapter 18*, The Stationery Office, London, 2004.

2 *DTO Modelling Guidelines v2.0: Traffic Schemes in London Urban Networks*, Directorate of Traffic Operations, Transport for London, 2006.

The Traffic Modelling Guidelines have now been separated into two parts for ease of use:

Part A

Part A has been written to give a high-level understanding of traffic modelling as it applies in a TfL context. It is designed to be read by a wide audience, both internally and externally, including non-technical project managers and scheme sponsors. It does not assume any prior knowledge of traffic modelling.

Part B

Part B contains technical guidance relating to the use of modelling software. The first chapter covers topics which are common to all types of traffic model. Following this are software-specific sections providing guidance on modelling best practice for the corresponding software.

About the Authors

This guidance has been edited by the Network Performance department (formerly Urban Traffic Control), within TfL Streets Traffic Directorate. The Network Performance (TD NP) department possesses a high level of technical modelling expertise which has been developed since the 1970s (e.g. Greater London Council (GLC) and Traffic Control Systems Unit). The department (and direct predecessors) have been continuously responsible for the:

- Operation of London's traffic control systems;
- Design, audit and implementation of traffic schemes; and
- Traffic signal timing reviews.

The above activities provide an excellent grounding for developing traffic modelling skills. The department currently includes over fifty engineers who have advanced traffic modelling skills in deterministic (LinSig, TRANSYT), micro-simulation (VISSIM) and highway traffic assignment modelling (VISUM, SATURN). These skills have been developed through a three year training programme, alongside intense practical application.

TD NP includes many engineers who are respected as subject matter experts in the traffic modelling field. These key people have contributed significantly to the development and review of these guidelines.

PART A – MODELLING CONSIDERATIONS

Part A – Modelling Considerations Contributors

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1 Introduction

The Streets Traffic Directorate (TD), within the Surface Transport Division of Transport for London, is responsible for the management and operation of London's 6,000 traffic signals and their accompanying systems, technologies and equipment.

TD is a centre of traffic engineering expertise and uses traffic modelling in many areas:

- The Traffic Infrastructure section, which uses operational models for signal design and auditing of signal schemes;
- The Congestion Management team, which develops models in support of signal timing reviews and carries out audits of models developed in support of schemes; and
- The Intelligence & Traffic System section includes the Surface Transport core Operational Modelling team, which is responsible for the Model Auditing Process (MAP), provides expert modelling support, assesses new modelling software and manages the Operational Network Evaluator (ONE) assignment model.

Part A of these Traffic Modelling Guidelines has been written to give a high-level understanding of traffic modelling as it applies in a TfL context. It is designed to be read by a wide audience, both internally and externally, including non-technical project managers and scheme sponsors. It does not assume any prior knowledge of traffic modelling.

Part A introduces the background to traffic modelling in London including an outline of the policy considerations, in particular the Traffic Manager duties, and the need to deliver journey time reliability. It covers the reasons why modelling is appropriate, how modelling should be carried out and who is involved.

At the core of Part A the modelling hierarchy and interaction between the different modelling levels is explained. The key requirements to produce traffic modelling to a suitable standard are outlined along with a brief description of the presentation and submission process for modelling. Part A then covers the various factors which should be considered when commissioning modelling to support a scheme. The final chapter introduces a range of traffic modelling software and their applications.

2 Background to Traffic Signal Scheme Modelling in London

2.1 Introduction

This chapter discusses some of the background issues related to traffic signal scheme modelling in London. It provides a context for the remainder of the guidelines.

The legislative responsibilities are covered, followed by an outline of the modelling hierarchy showing how different levels of modelling relate to each other and the process of modelling as a whole.

> Developing models to a correct standard, and using these models to inform the design process, requires expertise and experience on behalf of the model developer and the design team. A scheme sponsor should ensure that any consultant they retain possesses the requisite experience and expertise.

This chapter provides guidance to the scheme sponsor on necessary expertise and outlines some of the basic fundamentals which must be met by the model developer and the design team using the model. In addition the model submission process and presentation of modelling results is also covered.

2.2 Legislative Responsibilities

The Traffic Management Act (TMA) 2004 places a Network Management Duty (NMD) on all Local Traffic Authorities (LTAs) in England. In London, LTAs are the Boroughs and TfL. As London's strategic traffic authority TfL has both a local and strategic NMD. The NMD requires the LTA to:

- Ensure the expeditious movement of traffic on its own road network; and
- Facilitate the expeditious movement of traffic on the networks of others.

Guidance was produced by the Secretary for State in 2005, but essentially the NMD requires an authority to manage all their activities in such a way as to minimise congestion on the road network. Each LTA must appoint a Traffic Manager whose role includes ensuring that the NMD is fully considered and applied throughout all the authority's functions.

Because congestion and expeditious movement are subjective terms, TD has produced a more practical network performance measure to help clarify the legislative responsibility. This measure is journey time reliability. TD is responsible for this measure across the Transport for London Road Network (TLRN). Journey time reliability is considered by TfL Streets as a good measure for smooth traffic flow, which is a TfL objective, identified by the Mayor of London and documented within the Mayor's Transport Strategy[3]. The Mayor's Transport Strategy was published in May 2010 and is available from **http://www.london.gov.uk**.

2.2.1 Applying the NMD in TfL

Within the TD Planned Interventions Department, the Forward Planning Team (FPT) works on behalf of the Traffic Manager to ensure that the NMD has been fully complied with in the development, design and implementation of highway and traffic proposals impacting on London's major roads – the Strategic Road Network (SRN) and TLRN.

Part of the NMD is to ensure the best possible movement of all modes of transport at signal-controlled junctions in the network. The modes of transport that need to be considered are, in alphabetical order: cyclists, pedestrians, private vehicles (including freight) and public vehicles (including taxis).

When a body proposes temporary or permanent changes that may impact on the operational performance of the TLRN and/or SRN, that body has to notify and gain approval through FPT. Additionally, TfL has made it mandatory within its organisation that any proposals developed internally that impact on the major roads must also be notified and approved through FPT. One of the key benefits of modelling is to support notifications to FPT by quantifying the impact on network performance.

Modelling can be a powerful tool in understanding the potential traffic impacts of proposals if used in an appropriate way. It can also enable strategies to be developed to mitigate adverse impacts.

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3 *Mayor's Transport Strategy*, Greater London Authority, 2010.

TD provides independent technical support to scheme promoters, in the form of a Traffic Signal Supplementary Report (TSSR) to enable FPT to make informed decisions when assessing and reviewing schemes. Paramount in any decision is whether the scheme has a detrimental impact on journey time reliability, which is directly correlated with smooth traffic flow.

2.2.2 Modelling Journey Time Reliability

Journey time reliability is considered by TfL Streets to be the key output measure to indicate smooth traffic flow and general traffic network performance in London. This is presently measured using Automatic Number Plate Recognition (ANPR) cameras, which feed anonymous number plate information to the London Congestion Analysis Project (LCAP) analysis system. This system provides continuous journey time information for key routes in London.

This is a reasonably new concept, and most traffic modelling tools are not developed to examine or optimise for journey time, let alone journey time reliability. Instead, most traffic modelling tools focus on minimising stops, delay and degree of saturation (DoS). In addition most tools apply equal priority to competing demand by aiming to balance DoS within a junction or network. This approach is unlikely to produce the most appropriate signal settings where a model includes priority arterial routes.

This is a current challenge for London, which has many key corridor routes. Until such time as traffic modelling products are developed to examine journey time reliability directly, proxies will need to be used.

2.3 Transport Modelling Hierarchy

Transport modelling operates at various levels of detail and scale, covering regions all the way down to single junctions. The hierarchy of modelling is illustrated below in Figure 1. The diagram indicates that data exchange should operate between different levels of modelling to promote analytical consistency.

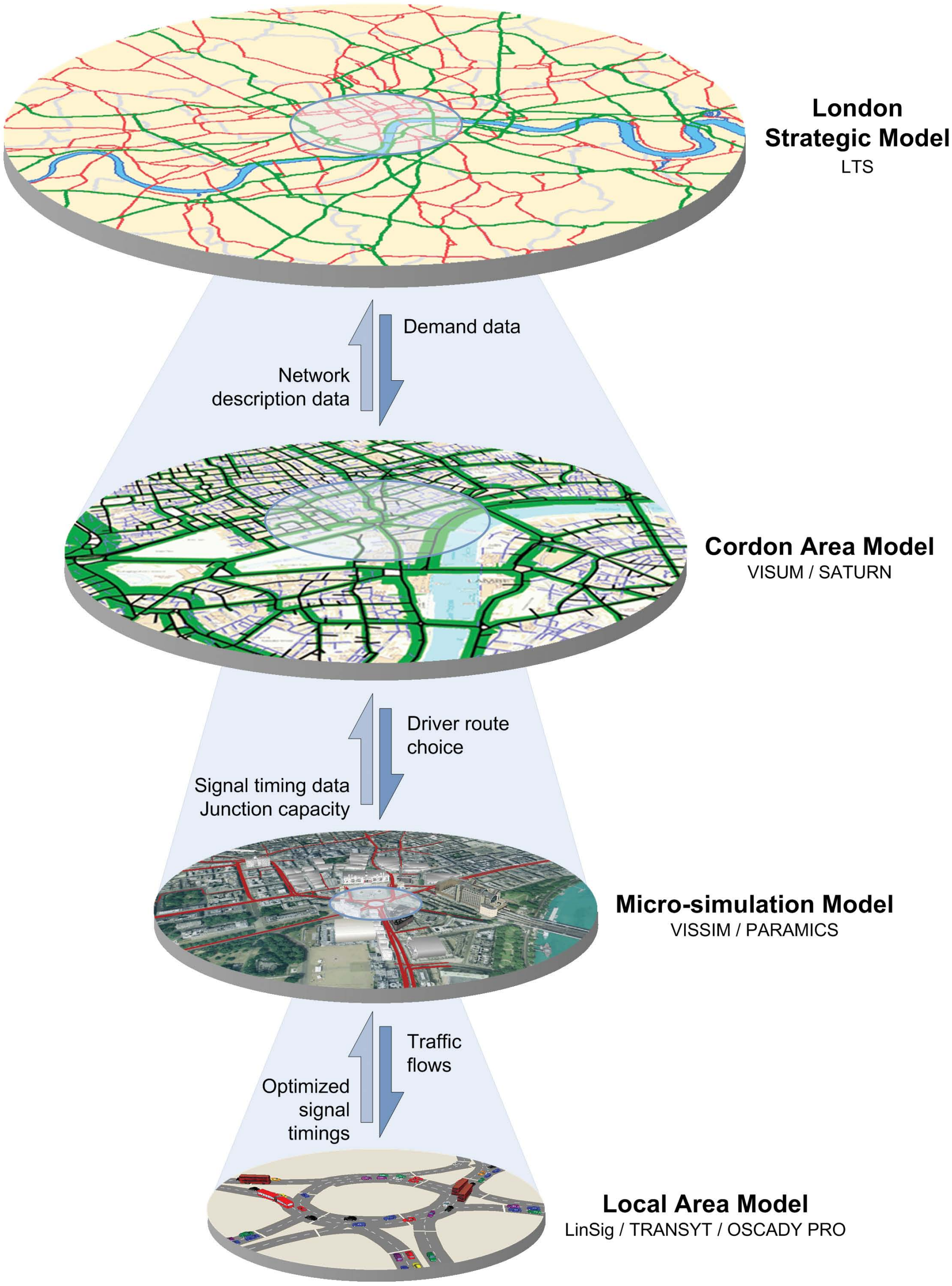

Figure 1: Transport modelling hierarchy.

2.3.1 Strategic

Strategic models typically cover very large areas and model the balance of trips between available modes. In order to manage simulation run times the road network is only modelled at an aggregate level of detail. Traveller demand is usually defined in person trips and is derived from demographic census data and observed trip making behaviour from surveys.

2.3.2 Cordon Area

Cordon area modelling – also referred to as Highway Traffic Assignment (HTA) or Tactical modelling – is usually commissioned to support major development schemes. This type of modelling is designed to predict the impact of area wide road-based trip diversion and route choice. As an alternative, this type of modelling analysis can be used to conduct an operational assessment to indicate the impact of a short-term change on the network. Junction capacity should be coded accurately to ensure that journey times between nodes, and delay within the model, are representative of on-street conditions. Mode choice behaviour is not explicitly modelled; however the effect of mode choice can be reflected at this level using derived outputs from higher level strategic models.

2.3.3 Micro-simulation

Micro-simulation modelling is able to simulate the movement of individual vehicles travelling within a road network through the accurate replication of driver behaviour. In this regard micro-simulation modelling is distinct from strategic, cordon area and local models within which all vehicles exhibit a common, uniform behaviour. Micro-simulation modelling can be applied across all spatial scales but the size of a model is normally restricted by the amount of data required to generate an accurate simulation.

Micro-simulation software typically uses a stochastic modelling approach that provides the capability to assess dynamic phenomena, for example selective vehicle priority. They are able to model the impact of variability upon network behaviour, and are therefore capable of representing complex traffic problems, for example the impact of parking or incidents upon the network.

2.3.4 Local Area

Local area modelling handles traffic moving through a localised network, ranging in size from an individual junction to multiple junctions. This level of modelling focuses in detail on the capacity of individual links and junctions, and the interaction between them. A high level of accuracy is required relative to cordon area modelling.

Junction design models focus predominantly on individual junctions to allow option testing of modifications to geometric layout and signal staging design. These models are sensitive to small changes in junction layout and/or signal control.

Both local area and junction design models cannot predict the impact of driver re-routing, nor can they predict changes in travel mode. These effects are critical to understanding the operation of large road schemes and must be modelled by higher-order assignment or strategic models.

2.3.5 Operational

Dynamic real time traffic control systems are not traditionally classed as traffic models but they operate using similar fundamental principles. Operational systems such as the one used in UTC SCOOT[4] optimise traffic signals using an online data model. The optimisation method used is similar to that employed by junction design and local area models. Operational models are coded and validated manually to ensure that accurate capacity estimates are generated. These models commonly use live data inputs from carriageway detectors to make decisions regarding the optimisation of network signal timings.

2.3.6 Model Integration

Information can be shared across model levels in order to improve consistency, although this is a manual process in most cases. Two examples of data sharing are:

- Junctions within a cordon area HTA model can be calibrated against the more accurate performance calculated by a junction design model. In this way the performance of the cordon area HTA model can be tested against the validated local model and if needed can be adjusted to improve realism; and
- Strategic or Tactical models produce demand flow data for the future/proposed scenario. This demand data can then be used in the local area modelling to assess the local impact upon the road network.

Data exchange is typically conducted multiple times to ensure consistency in model data across different software platforms (see Figure 1).

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4 http://www.scoot-utc.com

2.4 Modelling Standards

Successful traffic modelling requires experience on the part of the modelling engineer. Many techniques are acquired through trial and error during the development, calibration and validation process. Therefore some of the finer techniques used in traffic modelling are not documented in software manuals. This is especially true for complex situations where a level of pragmatism is often required.

It is therefore useful to provide modelling guidance, aimed at experienced practitioners, to document tried and tested practical modelling techniques. Where applicable, traffic modelling should be conducted according to existing standards of best practice set out by:

- The Highways Agency in the Design Manual for Roads and Bridges (DMRB)[5]; and
- The Department for Transport in Transport Analysis Guidance (WebTag)[6].

In addition to the guidance and advice set out in the above documents, the Traffic Modelling Guidelines provide the experienced practitioner with advice in the completion of the modelling elements of a traffic signal scheme.

The Model Auditing Process[7] (MAP) defines the standards expected for all modelling of TfL-sponsored schemes submitted to TD. The Traffic Modelling Guidelines indicate recommended 'Best Practice' relating to the approach and methodology of model development in order to reach those standards.

While TD will audit the final scheme models and prepare the TSSR, scheme sponsors and their agents have a responsibility to ensure that all scheme models meet the requirements set out within MAP.

2.5 Fit for Purpose Modelling

The level of detail and the accuracy of a model must reflect the purpose for which the model is intended. The objectives of a scheme will directly influence the type and purpose of any prerequisite modelling.

For a specific scheme a model may pass through a number of development phases, and at each subsequent stage the required level of detail and modelling accuracy increases. Common stages of development can be expressed as; study phase, business case support, option testing, developing preferred option and scheme approval. It should be noted that not all schemes will be developed to the point where approval is sought.

Traffic modelling to support a scheme through TD approval represents the highest level of detail and accuracy required of a model. In general the modelling guidance presented in Part B applies to this highest level of accuracy.

5 *Design Manual for Roads and Bridges*, Highways Agency, 1992 (as updated).

6 **http://www.dft.gov.uk/webtag/**

7 *TD Model Auditing Process: Traffic Schemes in London Urban Networks*, v2.2, Traffic Directorate, Transport for London, 2010.

2.6 Modelling Expertise

Lack of experience on behalf of the model developer is a common reason for modelling to not successfully pass through TD scheme audit.

The scheme sponsor is advised to ensure that the person(s) engaged to develop the modelling related to any scheme meet the following requirements:

- Considerable modelling experience with the relevant software;
- Considerable experience in on-site data collection of traffic control parameters including saturation flows, degrees of saturation, lane utilisation identification and wasted green measurement;
- A good understanding of the capabilities of microprocessor based controllers, particularly with respect to interstage design and phase delays; and
- Experience of modelling microprocessor based controllers using modelling products such as LinSig and OSCADY PRO.

The skills outlined above must exist as a senior audit function prior to delivery of any traffic modelling for TD.

2.7 Site Visit and Data Collection

It is not possible to develop a model to the standards exemplified in the Traffic Modelling Guidelines without the model developer having conducted site visits for each period being modelled.

Models commonly fail TD scheme audit due to a lack of familiarity with the site on the part of the model developer. It is therefore essential that the model developer conducts site visits to:

- Familiarise themselves with general traffic conditions and the surrounding environment;
- Confirm the accuracy and currency of supplied drawings;
- Understand how the junction/network operates in terms of traffic behaviour, capacity and safety; and
- Collect accurate data for developing the calibrated model and validating the base model.

Some of the data required to develop a model can be collected by a third-party survey company. However there are certain data which should only be collected by an experienced model developer. This data is a prerequisite for accurate modelling and has been identified in B2: Modelling Principles.

2.8 Assessing Future Scenarios

Almost all traffic modelling exercises are carried out with the purpose of predicting the operational performance of a future scenario. However the first step is to develop an accurately validated base model which reflects current conditions. This base model then serves as a benchmark for future scenario tests.

The base model is altered to produce a set of future 'do something' scenarios in line with scheme proposals. Proposals may be as a result of infrastructure modification, patterns of traffic growth, a change in traffic composition or a number of other interrelated factors.

During the development of future scenario models it is necessary to make assumptions regarding traffic behaviour under new proposals, since these cannot be observed or measured in reality. All assumptions made at this stage should be determined following a logical approach. This approach should draw upon available survey data and observations where possible. Often assumptions will depend on the nature of the scheme proposals, in which case an understanding of the wider project is essential.

In order that a TfL Auditing Engineer and Network Assurance Engineer understand the reasoning behind these assumptions, it is necessary to document all assumptions with explicit reasoning. Where used, third-party sources of information should be referenced.

2.9 Modelling Boundary

A scheme may have an influence beyond the boundaries of the physically modified area. The scheme designer is thus responsible for determining the extent of the area of impact. The area to be modelled is determined by the area which is deemed to be impacted upon by the scheme proposal. In order to properly assess the scheme proposals the modelling must cover this area.

The scheme designer is responsible for ensuring that these wider impacts are considered, discussed and where appropriate mitigated and that any mitigation forms part of the scheme proposals. Failure to model the area of impact and/or failure to provide mitigation against impact will result in modelling which is not fit for purpose.

It is the scheme sponsor's responsibility to assure TfL (FPT) that the proposed scheme can be accommodated in the network.

2.10 Presentation of Modelling Results

The model developer is responsible for presenting the results of the modelling. In the case of the base model the results are used to:

- Demonstrate the accuracy of the model against the existing situation; and
- Provide the reader with a comprehensive and detailed assessment of the existing situation.

In the case of the proposed scheme, model results are used to demonstrate the impact of the scheme on the road network. The model developer must ensure that any impact on the road network is presented and the cause for this impact discussed. Results for the proposed modelling should be compared with the corresponding results from the base models.

2.11 Delivery of Traffic Modelling

The process for auditing a model and submitting the modelling results is captured in MAP. This procedure has been developed by TfL in order to ensure consistency in both the production and auditing of traffic modelling.

From April 2008 MAP has applied to all TfL-sponsored schemes audited by TD. Full guidance relating to MAP can be obtained from the TfL website[8]. MAP sets out the stages which should be followed when submitting traffic models for auditing. It also defines a protocol for communication relating to model submission and auditing. Generally, MAP is designed to improve communication, and ensure that models are developed to a high standard and progress efficiently through TfL audit.

It is compulsory that schemes are registered on the TD Workbook before relevant TD engineers can be engaged and MAP applied to the scheme. Where a scheme is not on the TD Workbook, TD Chief Engineer authorisation is required prior to TD engineers undertaking significant work on the project.

The development of good quality preliminary design models, consistent with MAP and following the Traffic Modelling Guidelines may increase the chance that the traffic engineering design models which are audited by TD will only require minor amendment.

8 **http://tfl.gov.uk/streetspublications**

3 Scheme Considerations

3.1 Introduction

Meeting specific objectives is necessary for the success of any scheme. However it is equally important that scheme designers, modellers and traffic engineers consider wider strategic transport objectives.

3.2 Overarching Objectives

All design decisions must be made taking account of the requirements and objectives set out by the following:

- Mayoral Policy;
- The Network Management Duty as defined in the Traffic Management Act (2004); and
- The strategic and policy requirements of the local highway authority.

3.3 Interested Parties

There should be coordination and cooperation between interested parties in the design of scheme proposals.

All relevant parties should be consulted before undertaking the design of a new junction, or the re-design of an existing junction. Often a scheme sponsor will have a particular focus; however it is the responsibility of the scheme designer(s) to ensure that all junction users are considered. In addition the scheme designer should contact all relevant authorities, who have jurisdiction over the area being impacted by the scheme, to ensure that any concurrent scheme proposals are taken into consideration.

3.4 Scheme Design

The modelling of proposed schemes is assessed by TfL to ensure that it is correct and accurate. In addition to this role TfL must be satisfied that the proposed scheme design makes full consideration of the objectives outlined in section A3.2.

The existence of other proposed schemes could impact on traffic flows, junction layout and signal control. Failure to consider these impacts could result in modelling which would not be fit for purpose.

Before undertaking any design or modelling work it is strongly recommended that TD is contacted. The scheme sponsor or their consultant can discuss, with the appropriate TD team, the scope of the proposals and the area they affect.

As well as strategic objectives there are many local level considerations. The detailed considerations relating to the design of a scheme are outlined below to highlight some of the key areas for discussion.

3.4.1 Junction Layout

The layout of proposed junctions is determined by a wide range of factors. The final design must comply with the appropriate design standards and safety requirements. It must also deliver the best service for all road users that it is possible to achieve within the physical limitations of the site.

Often there will be a number of different junction layouts that comply with design standards and safety requirements. In this situation it is necessary to assess the impact of the different options on network capacity, in order to determine which layout delivers the best performance within any assessment criteria.

This assessment is critical within the design process, and accurate modelling is required in order to give confidence to any design decisions. The type of modelling software to be used depends on variables such as the size of the network being assessed and the level of congestion present within the study area.

3.4.2 Fixed Time and Adaptive Control

Fixed time signal plans are pre-calculated timings, which are usually used to operate a linked group of traffic signals. The timings are commonly derived through offline traffic modelling techniques and applied according to distinct network conditions relative to time of day and day of week. They are implemented either remotely by the Urban Traffic Control (UTC) system, or coded into the controllers using a Cableless Linking Facility (CLF).

UTC SCOOT is a dynamic, demand-responsive traffic management system which controls approximately 40% of the London traffic signal network. UTC SCOOT is an adaptive real time system which continually optimises signal timings to meet traffic demand. The modelling of UTC SCOOT-controlled signals requires a methodology outlined in section B2: Modelling Principles.

3.4.3 Traffic Signal Timing Plans

Modelling for a proposed scheme determines which signal timing plans may be implemented if a scheme was to be built. Hence it is extremely important that the plans which are developed are correct in terms of safety and functionality, and that they deliver the TfL objectives outlined in section A3.2 as much as possible.

For operational groups of traffic signals linked via UTC or CLF control, optimisation techniques (as commonly used by traffic modelling software) generally aim to set signal timings which reduce delays and stops. Care must be taken to ensure that signal timings cater for all road users and remain consistent for all junctions contained within the same operational group. Consideration should also be given to wider strategic objectives including journey time reliability, as explained in section A2.2.2.

For isolated junctions the signal timing plans can be developed, tested and optimised using modelling software for standalone junctions. Where two or more junctions operate within the same linked group, more complex software, able to optimise signal coordination, must be used. In certain circumstances, for example in over-saturated networks, micro-simulation software can be used to fine tune the optimised signal timings in an offline environment. Section A9 gives more detail on criteria which influence the selection of correct software for the modelling purpose.

3.4.4 Contingency Signal Timings

Junctions under UTC control require additional traffic signal plans to cater for unplanned incidents on the network. These contingency plans can also be used to mitigate the impact of planned road closures and traffic diversions needed for large events.

Scheme designers should be mindful of contingency issues and aware of any local requirements during the design process. Designers are therefore encouraged to contact TD NP for advice on necessary contingency measures.

3.4.5 24/7 Operation

Scheme designers and traffic modellers should ensure that any scheme design considers impact at all times and highlights any issues that may arise outside of the traditionally modelled peak periods. Consideration should be given to weekend operation, where traffic demand may be similar to that of a weekday but upon a capacity constrained network, for example through the relaxation of parking, waiting and loading restrictions.

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

3.4.6 Scheme Safety

Road safety is an area of key concern for TfL. Overall scheme objectives should always consider improvements to road user safety. Changes to operations of junctions can have significant influence on the safety of road users, including pedestrians, cyclists and general vehicular traffic.

Better Routes and Places Directorate (BR&P) can advise on best practice for modelling road safety factors within a traffic context. The SAFENET modelling tool was useful for networks but is no longer supported by TRL Ltd[9]. Old versions can, however, still be used and BR&P can discuss specific scenarios with scheme designers.

9 **http://www.trlsoftware.co.uk**

4 General Traffic Considerations

4.1 Introduction

The bulk of the data used in a traffic model will relate to general traffic, which includes private vehicles, taxis, freight, service vehicles and motorcycles. In this context 'general traffic' refers to all motorised vehicles (it does not cover cyclists) using the carriageway, excluding schedule-based or segregated services such as buses and trams.

The reason for excluding certain transport modes and services from the 'general traffic' category is that they have particular characteristics which result in behavioural differences. Scheduled services will not make decisions on route choice in the same way as general traffic. Non-motorised traffic exhibits significantly different performance characteristics, making it difficult to associate them with other modes included in the general traffic category.

4.2 Route Choice for Local Modelling

When developing a base model it is crucial to ensure that route choice within a model represents the on-street situation, which should be determined through site surveys. The base model must reproduce local on-site conditions, and route choice can be a key parameter in ensuring model accuracy. In order to determine route choice within a network it is advisable to capture 'origin-destination' data to inform the modelling engineer.

Proposed scenario modelling should take account of network alterations which influence route choice. Changes to route choice can be generated by the proposed scheme, local traffic management or other influences which can impact the network during scheme appraisal.

4.3 When to move from Local Modelling to Strategic Modelling

In order for any traffic modelling to achieve the intended purpose it is essential that the modelled area includes the entire network which may be affected by the proposals.

In some cases it may be impractical or impossible to accurately model the full impact of a scheme using 'local area' traffic modelling software. In these instances it may be necessary to employ a HTA model to represent effects across a larger area, as illustrated in Figure 1. Where a scheme is likely to have regional impacts, or where it will significantly change mode choice, it may be necessary to use a strategic modelling platform, under the guidance of TfL Planning and Policy Analysis.

5 Public Transport Considerations

5.1 Introduction

Traffic modellers should consider how public transport should be represented in their models, especially where a scheme interacts with existing or proposed public transport services such as bus or tram routes. It is sensible to consider the impact of public transport on traffic behaviour and network capacity. It may also be necessary for scheme modelling to predict the impact of a proposal on public transport performance.

5.2 Assessment of Buses

Correct representation of fixed bus routing within a network is important when building an accurate traffic model. Bus timetables and routing maps indicate the frequency of buses and bus type by time of day. Depending upon the focus of the scheme bus journey times within the network may need to be recorded from site visits in order to measure the accuracy of the public transport element of a traffic model.

The type of bus (articulated, single-decker or double-decker) has an impact on junction performance, for example, due to their size articulated buses have a potentially greater impact on junction performance relative to other bus models. It is also worth noting that bus acceleration and general speed are normally lower than for general traffic.

5.3 Bus Stops

A bus stop is an on-street location allowing for buses to pick up and drop off passengers. A bus stand is a facility which allows passenger pick up/drop off but also provides for terminating bus services to regulate headways and therefore to stop for a longer period. A bus station is an off-street location which allows for services to begin/terminate, passengers to board/alight and acts as a service interchange. The distinction between bus stops, bus stands and bus stations should be included within survey information.

In order to accurately replicate bus journey times it is important to account for stop dwell times for each route using the facility. The dwell time can include buses waiting due to driver rest stops, driver changeovers and layovers used to regulate the bus service timetable. It is useful to consider the interaction with general traffic that occurs when a bus is waiting at a stop, for example the modeller should observe whether approaching traffic can pass a stationary bus or whether they give-way to oncoming vehicles.

> Designers should consider the physical limitations of bus stops/stands and stations. Vehicle storage capacity can be assessed using scale plans combined with site observations to ascertain exact layout and operation. It is important these facilities are modelled correctly as network performance can be inhibited where bus demand exceeds bus stop storage capacity.

5.4 Bus Lanes & Pre-Signals

Bus lanes influence the amount of available road space for general traffic. The method used to model bus lanes should be considered on a site by site basis, where it is important to note the frequency and volume of buses, cyclists, motorcyclists and taxis using the bus lane.

> Bus lanes can impact the performance of a junction for general traffic. The distance at which a bus lane terminates before a junction needs consideration during most traffic modelling exercises as hours of bus lane operation can vary by day of week.

A pre-signal allows buses to clear a junction in advance of general traffic. This is achieved by segregating buses before the junction (e.g. through use of a bus lane), which then receive a green signal in advance of general traffic. The most suitable method for modelling a bus pre-signal will vary by software platform but generally it is useful to survey actual operation so observed pre-signal compliance can be replicated.

5.5 Bus Priority (BP)

Selective Vehicle Detection (SVD) BP is a facility that distinguishes buses from general traffic and provides them with priority at traffic signals. The overall aim of BP is to reduce delays and increase journey time reliability for timetabled buses. The potential benefit of SVD can be further quantified for a scheme by accurately modelling any proposed BP measures.

The use of BP at a junction does not prevent it from altering timings to alleviate general traffic congestion where other dynamic traffic control systems are in operation. Schemes that include the implementation of UTC SCOOT should initially make provision for SVD BP. An assessment of SVD suitability can be made using the SCOOT bus priority guidelines[10] to better understand the potential network impact. This guidance highlights how to compare the potential total benefits of SVD BP against the costs of implementation.

10 *Guidelines for Implementing Bus Priority in SCOOT using iBus System*, Transportation Research Group, University of Southampton, 2006.

6 Pedestrian Considerations

6.1 Introduction

Pedestrian facilities are provided to assist pedestrians in safely crossing the carriageway whilst exercising due care and attention. There are a number of signalised methods for achieving this and an engineer should consider which of these methods can be best applied to individual sites. In order to assess which method is most applicable it is useful to have knowledge relating to pedestrian flow patterns, vehicular degree of saturation and the topographical layout of the network or junction.

Software is available to model the interaction between pedestrians and general traffic at crossing facilities. Using this software it is possible to estimate the impact of pedestrians on road network performance or a new traffic scheme on pedestrians. Advice on pedestrian modelling using the Legion software product is covered by the TfL document 'Street Level Modelling with Legion – Best Practice Guide'[11].

Pedestrian models are particularly useful where proposed changes to land use or public transport provision may result in changes to pedestrian flows. Pedestrian behaviour may be affected by changes in total volume of people or their desired route. The results from pedestrian modelling can therefore be used to mitigate these issues and assist in designing appropriate signal schemes.

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11 *Street Level Modelling with Legion – Best Practice Guide*, Directorate of Road Network Performance, Transport for London, 2008.

The design of pedestrian facilities is governed by engineering standards produced by the Department for Transport (DfT). For facilities within London there is additional guidance and standards set out in the TfL document 'Design Standards for Signal Schemes in London' (specification SQA-0064)[12].

The SQA-0064 document provides essential guidance for traffic modellers involved in the assessment of pedestrian crossing facilities in London. SQA-0064 outlines minimum approved pedestrian crossing times based on crossing distance. All schemes which impact signalised crossings, regardless of whether the proposals physically affect the signal junction, are required to include as part of the scheme a review of all signal crossings to ensure they meet the standards as outlined in SQA-0064.

6.2 Pedestrian Demand and Desire Lines

Modellers should have an understanding of the volume and location of demand for pedestrian movements around the study area and particularly at junctions. This information is useful for accurate modelling and can be provided from surveys of pedestrian movement.

Pedestrian desire lines represent the major pedestrian movements within a network. An understanding of desire lines is useful for the design of junction layouts and signal timing plans and to ensure that any proposed facilities will be effectively used by pedestrians.

Signal timings and crossing points can be designed to allow a smooth progression of pedestrians in the direction of heaviest flow. The direction of pedestrian demand can vary according to time of day and day of week. Pedestrian waiting times should be minimised to prevent overcrowding during peak periods, particularly on central islands within the carriageway.

6.3 Isolated Pedestrian Crossings

Zebra crossings are signalled by flashing Belisha beacons which indicate pedestrians have right of way when traversing the carriageway via the crossing. The distinctive zebra markings are used where pedestrians have permanent right of way on the carriageway.

This right of way can present challenges for a traffic modeller where large numbers of pedestrians use a crossing. High numbers of pedestrians with random arrival patterns can be disruptive to general road network performance. It is possible to quantify and accurately model the impact of a zebra crossing but demand data should be accurately captured through careful site observation. TD NP engineers may be contacted for guidance on previously applied methodologies used for zebra crossing data collection and modelling.

12 *Design Standards for Signal Schemes in London*, Specification SQA-0064, Issue 1, Directorate of Traffic Operations, Transport for London, 2007.

6.4 Isolated Signalised Pedestrian Crossing Facilities

Three types of isolated signalised crossing facility are commonly used in London: Pelican, Puffin and Toucan.

The Pelican is a signal-controlled crossing using far side pedestrian signals. Pelican crossings have a vehicle red/pedestrian green crossing period followed by a flashing amber/flashing green man where pedestrians who are still on the crossing continue to have right of way. The correct modelling of Pelican flashing amber/flashing green man is important where heavy pedestrian demand exists on a crossing. Pelican crossings operate with a fixed pedestrian green and clearance periods. They can be controlled locally on-site or by a centralised computer system. Signal timings for Pelican crossings are usually coordinated with neighbouring junctions to allow for optimum pedestrian and vehicular progression through the network.

Puffin facilities allow a variable length crossing period according to the walking speed of users traversing the carriageway. Pedestrian occupancy on the crossing is measured by detectors placed on signal poles. Puffin pedestrian crossing times remain constrained by minimum and maximum values defined by carriageway width but they allow slower pedestrians to safely cross the road. The Puffin system does not employ a flashing amber/flashing green man period but traffic models should represent the variability in crossing period.

Toucan crossings are designed to assist both pedestrians and cyclists. Toucan facilities are typically used in association with cycle-paths and provide a green signal for cyclists allowing them to cross without dismounting. The Toucan does not use a flashing amber/flashing green period and can operate the same variable clearance found on Puffin facilities.

6.5 Pedestrian Facilities at Signalised Junctions

Accurate traffic modelling will aid an assessment of which type of signalised pedestrian control is most appropriate at a junction. It should enable an engineer to assess multiple options and support design decisions related to user safety, network performance, environmental concerns or physical constraints.

Engineers are reminded that it is important that the needs of all road users, including pedestrians, are addressed when considering design options at signalised junctions.

There are two main methods used for signalising pedestrian control at junctions:

- Full Pedestrian (see A6.5.1); and
- Parallel Pedestrian (see A6.5.2).

At locations where it is intended to use the full pedestrian method, consideration should be given to the competing needs of all road users while considering wider issues such overall network impacts, cycle time, capacity, congestion, and emissions.

6.5.1 Full Pedestrian

It is believed there are associated benefits to operating a full pedestrian strategy at a junction:

- Reduced journey time for pedestrians;
- Increased safety with easier pedestrian understanding; and
- The junction can cater for a higher number of preferred pedestrian routes.

Conversely, practitioners have noted a full pedestrian strategy can pose problems as all vehicular approaches are delayed for longer periods to clear pedestrians from the junction. The increase in delay associated with full pedestrian strategies can generate greater congestion for all other road users apart from pedestrians. In a group of coordinated junctions the common cycle time may be higher than ideal at other junctions which results in increased pedestrian delay. It is also worth noting that higher levels of congestion can increase vehicular emissions with consequent impacts on health so a balance must be sought between competing road users.

6.5.2 Parallel Pedestrian

An alternative to a full pedestrian strategy is to provide parallel pedestrian facilities. This is most easily achieved using staggered crossings where non-conflicting pedestrian movements can operate at the same time as traffic movements.

Parallel pedestrian strategies remove the need to simultaneously hold all vehicular approaches to a junction on red. A parallel strategy can improve the performance of the junction by increasing the flexibility by which a traffic signal engineer can reduce delay for particular approaches.

7 Cyclist Considerations

7.1 Introduction

The number of cyclists in London is growing, especially during peak periods, and on significant cycle commuter routes often exceed 10% of total vehicle flow[13]. A growth in cycling is integral to the Mayor's vision for London so it is important to consider the role and impact of cyclists upon the network. The magnitude of impact is normally a function of the number of cyclists as a percentage of total traffic.

The traffic modeller should consider carefully the effect of a proposed scheme on cycling (and any growth in cycle demand) before selecting the best software for the modelling exercise.

7.2 Junction Design

Schemes are advantageous to cycling if they help cyclists to maintain a steady speed and a direct course without interruption or obstruction from a position where they can be seen by drivers and pedestrians. For this reason the cyclist user experience can benefit from specialist provisions within a scheme. Cycle safety may be improved through the use of Advanced Stop Lines (ASLs), widened carriageways or dedicated

13 *London Cycling Design Standards – A guide to the design of a better cycling environment*, London Cycling Centre of Excellence, Transport for London, 2005.

cycle-lanes. In schemes where specialist provisions are proposed it is important to model the impact that these will have on all road users including public transport.

ASL's allow cyclists to position themselves at the front of queuing traffic where they are able remove themselves from conflict with general traffic. Where a scheme predicts a large number of cyclists an ASL can be assessed by traffic modelling. Consideration should be given to providing cycle feeder lanes to ASLs which allow easy access and safer cyclist progression within the carriageway.

Further guidance on cycle design can be found in Chapter 4 of the London Cycling Design Standards[13].

7.3 Inclusion of Cyclists

The volume of cyclists has a direct impact on the ability of traffic models to accurately represent their influence on network performance. As volume increases, their impact on general traffic behaviour generates issues that can require detailed assessment[14]. Where the volume of cyclists exceeds approximately 20% of the traffic volume on any one approach they may have a disproportional effect on modelling results and their influence may need further attention[15]. For this reason it is encouraged to ensure classified traffic surveys explicitly include cyclists.

Micro-simulation traffic modelling software is often capable of modelling basic cyclist behaviour. Care should be taken to ensure any model accurately represents both cyclist speed and vehicle overtaking behaviour. Where an engineer uses deterministic traffic modelling software the modeller can only reflect the aggregate impact of cyclists by directly modifying parameters which influence junction performance.

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14 Carrignon D, *Assessment of the impact of cyclists on heterogeneous traffic*, TEC Magazine, July 2009, pp323-325.

15 *Mixed Traffic Conditions in Parliament Square – Cyclists Impact Assessment Report*, London Cycling Centre of Excellence, Transport for London, July 2008.

8 Air Pollution Impacts

8.1 Introduction

This section introduces air pollution impacts that can be considered during road scheme design and assessment. Other environmental impacts such as noise may require consideration, but these are beyond the scope of this document.

The need and level of environmental appraisal required for a project should be determined in liaison with the TfL Surface Environment Team, in accordance with the Environmental Evaluation procedure which is part of TfL Streets Health, Safety & Environment Management System.

Road transport contributes significantly to the emission of air pollutants in the UK and London[16]. Air pollutants from transport sources can broadly be divided into two categories:

- Pollutants which have an impact on local air quality and human health. The most important of these pollutants, and the focus for TfL, the GLA and London Boroughs include the following:
  - Nitrogen dioxide (NO_2). NO_2 is mainly formed in the atmosphere from the nitric oxide (NO) emitted by road vehicles, but it is also emitted directly. By convention, the sum total of NO and NO_2 is termed 'nitrogen oxides' (NOx).

16 Mattai J & Hutchinson D, *London Atmospheric Emissions Inventory 2004*, Greater London Authority, 2008.

- Airborne particulate matter. Different metrics are used to define particulate matter[17], the most common being PM_{10} and $PM_{2.5}$.

- Greenhouse gases which have an effect on the global environment. The most important of these, due to the total volume of production, is carbon dioxide (CO2). Other pollutants, such as methane (CH4) and nitrous oxide (N2O), are stronger greenhouse gases but are emitted in smaller quantities and are not a focus for TfL.

Road traffic is one of the largest sources of CO_2. Around 44 million tonnes of CO_2 are emitted in London each year, and road transport accounts for 22% of the total production[18]. The Mayor's Climate Change Action Plan sets out a path for the delivery of London's CO_2 targets. In order to meet the Mayor's targets CO_2 emissions must be reduced by 60% by 2025 (compared with 1990 levels).

It is the statutory responsibility of each local authority in the UK to carry out a review and assessment of air quality in its area, and to work towards meeting the objectives defined by the National Air Quality Strategy (NAQS). At locations where it is unlikely that the NAQS objectives will be met, local authorities must declare Air Quality Management Areas (AQMAs), carry out comprehensive monitoring, and develop mitigation plans. As of March 2007, 31 out of the 33 local authorities in London had declared AQMAs. In most cases road traffic has been the principle reason for the AQMA. Indeed, road traffic is the main source of NO_x and PM_{10} in London.

Clearly, the efficient management and control of road traffic can play an important role in reducing the emissions of air pollutants. In London, the local authorities and TfL should refer to 'The Mayor's Air Quality Strategy'[19].

8.2 TfL Objectives

The TfL Surface Transport strategic environmental goal, as set out in the document 'The Way Ahead'[20], is to "*reduce carbon dioxide emissions, to improve air quality, to reduce noise pollution, and to enhance the urban environment*".

TfL's overarching environmental objectives are divided into three tiers which reflect their importance and the degree to which TfL has an influence upon them:

Tier 1 (most important)

- To reduce greenhouse gas emissions;
- To reduce pollutant emissions to air; and
- To reduce transport-related noise.

17 PM_{10} and $PM_{2.5}$ relate to particulate matter with a diameter of less than 10 μm and 2.5 μm respectively.

18 *Action Today to Protect Tomorrow – The Mayor's Climate Change Action Plan*, Greater London Authority, 2007.

19 *Cleaning London's Air - The Mayor's Air Quality Strategy*, Greater London Authority, 2002.

20 *The Way Ahead – Surface Transport's Strategic Direction*, Transport for London, 2007.

Tier 2

- To reduce resource consumption and improve green procurement;
- To maintain and, where possible, enhance the quality of London's built environment;
- To reduce the waste generated by TfL's activities by applying the principles of 'Reduce, Reuse, Recycle'; and
- To promote the sustainable transport of waste.

Tier 3

- To maintain and, where possible, enhance the quality of London's natural environment; and
- To reduce consumption of water resources and implement efficiency measures.

9 Which Traffic Modelling Software? Why?

9.1 Introduction

There are a wide variety of software packages available to the traffic modeller. These packages vary in their ability to accurately model different traffic situations and behaviours. Consequently it is often necessary to use a combination of two or more different packages to complete a full scheme design and assessment.

The most common modelling software for designing and optimising signal-controlled junctions are LinSig, OSCADY PRO and TRANSYT. These deterministic packages use empirical algorithms based on historic data which are not specific to London. For this reason extra care should be taken to ensure any chosen product is suitable for scheme assessment in London.

Micro-simulation tools cannot optimise signal timings but have the best capability to examine complex and congested traffic scenarios such as those found in London. Stochastic micro-simulation software has the ability to model individual vehicles within a road network and can provide a detailed representation of the complex spatial relationships which influence driver behaviour.

9.2 Deterministic Models for Traffic Signal Control

Offline software packages are often used to calculate optimised timings for a signalised junction or network. These deterministic models utilise empirical algorithms to calculate optimum settings based on fixed inputs. Model inputs vary by software type but serve to abstractly represent the traffic network and its underlying condition, for example by defining geometric details and traffic flow.

A deterministic model will generally be restricted to modelling within the physical boundary of a scheme or where equilibrium exists between neighbouring traffic management areas. Empirical models can predict the potential performance of a junction or network and allow for option testing of different signal timing strategies. Numerical output from these models can provide a general indication on whether a proposal will operate comfortably within a traffic network.

> Modelling is applicable to a spatial scale determined by the boundaries of the proposed scheme. The choice of an appropriate deterministic model is therefore dictated by the need to model either an isolated intersection or a linked series of intersections and whether the intersections will be signalised or operate with vehicle priority (i.e. give-way rules).

9.2.1 Isolated Signalised Intersections

The most widely used design and modelling tools for individual traffic signal junctions are LinSig and OSCADY PRO, which can be used to quickly assess the method by which traffic is controlled at a junction. Basic models can be built with only minimal input data, making these tools particularly suitable for preliminary design.

- **LinSig**

LinSig, developed by JCT Consultancy[21], can be used for detailed junction design, assessment of scheme proposals and the creation of skeleton models for checking against junction Controller Specifications. It combines traffic and controller modelling to replicate the microprocessor technology used to control traffic signals and allows a modeller the ability to maximise the efficiency of junction design. LinSig will optimise signal timings and provide an estimation of junction performance.

- **OSCADY PRO**

OSCADY PRO, developed by TRL[22], is a junction optimisation tool which can be used to assess the performance of scheme proposals. It has the capability to optimise alternative signal sequences at a junction by presenting the modeller with different potential configurations. OSCADY PRO requires input of all junction information which increases the time required for cursory checks of junction design. However, it can export any resulting design into a format compatible with other TRL products such as TRANSYT for use within a linked traffic control network (see section A9.2.3).

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21 **http://www.jctconsultancy.co.uk**

22 **http://www.trlsoftware.co.uk**

9.2.2 Isolated Non-Signalised Intersections

Non-signalised (priority) control is a common form of traffic control where a minor movement joins a major movement at an intersection. Traffic on the minor movement gives way to traffic on the major movement through the use of signs or markings on the carriageway. Vehicles on the minor movement are required to stop in accordance with current traffic regulation. The visibility and geometry of an intersection both influence the ability of traffic on the minor movement to progress while giving way to the major movement. Schemes which influence non-signalised intersections (i.e. give-ways) are suitable to be modelled with TRL software such as PICADY and ARCADY.

- **PICADY**

PICADY can be used to predict the performance of a non-signalised isolated junction in terms of potential queue lengths and vehicle delays. The software incorporates TRL research to encapsulate the influence of junction design upon driver behaviour and visibility at priority intersections with specific geometric characteristics. It is also able to model zebra crossings on the approaches to priority junctions.

- **ARCADY**

ARCADY is a recognised tool used to assess non-signalised roundabouts. It is a commonly used product within the UK and can model most types of roundabout to predict accident rates, performance and delay to traffic. Like ARCADY, It is also able to model zebra crossings on roundabout approaches.

9.2.3 Networks

In congested urban areas it is necessary to coordinate the movement of traffic in order to generate reliable, repeatable performance. The efficient control of vehicles in a network is usually promoted through the use of linked traffic settings. The most efficient traffic control strategy for an area will be defined by factors outlined in section A3. The optimum settings for coordinated control will vary according to time of day and day of week and for this reason they are usually derived from deterministic network models. This empirical approach approximates network performance based on fixed input variables and thus can provide an engineer the means of controlling urban congestion by minimising vehicle delay. There are two main packages used for the optimisation and evaluation of network signal design – TRANSYT and LinSig.

- **TRANSYT**

TRANSYT, produced by TRL, is widely used for modelling signalised networks within the UK. It is capable of developing optimum fixed signal settings for representative traffic conditions within a network. The development of these settings requires average traffic data to be collected and analysed for each modelled period and placed into an abstract network of links and nodes. TRANSYT optimisation is conducted using an iterative 'hill climb' algorithm which attempts to find optimal signal settings which minimise stops and delay in the network. TRANSYT can be used to optimise a wide variety of networks, from unsignalised intersections to signalised roundabouts. TRANSYT can also be used in conjunction with micro-simulation models, for example a linking product has been developed to communicate with VISSIM (see section A9.3).

TD currently believes TRANSYT is suitable for signalised networks which share a common cycle time.

- **LinSig**

LinSig, produced by JCT Consultancy, can model and optimise networks of several junctions as well as individual junctions (see section A9.2.1). It is designed to model small groups of junctions in detail rather than larger networks, although the latest versions support multiple controllers. It is comparable in approach to TRANSYT but represents the network as a series of geometrically conjoined lanes rather than abstract links. Recent versions have introduced network modelling tools such as delay based traffic assignment and entropy based trip matrix estimation, to provide the signal optimiser with traffic data.

TD currently believes LinSig is suitable for small urban networks consisting of signalised junctions which share a common controller.

9.3 Micro-simulation Models

Micro-simulation software is able to model the movements of individual vehicles travelling within road networks. They enable realistic representations of driver behaviour such as lane changing and overtaking. In this regard they are distinct from the models outlined in section A9.2 which use an aggregate representation of traffic where all vehicles exhibit uniform behaviour. Micro-simulation packages do not yet have the ability to optimise traffic signal settings, therefore software such as TRANSYT and LinSig are commonly used in conjunction with micro-simulation modelling.

When compared to deterministic models the finer resolution and stochastic approach of micro-simulation software allows better representation of driver and therefore network behaviour. They are the only tools capable of representing complex traffic problems in an offline environment, for example the impact of parking or network incidents. In addition most micro-simulation packages are capable of generating graphics which animate individual vehicles within a network. As a result micro-simulation modelling can provide an excellent visual aid when presenting complex traffic phenomena to a non-engineering audience.

Micro-simulation models are useful when modelling heavily congested conditions where a network suffers poor performance due to excess queuing from adjoining junctions. In networks where significant congestion is expected, micro-simulation models are likely to accompany an empirical model outlined in section A9.2. The boundary of a micro-simulation model should encompass the extent of the impact of the scheme so may extend further than the boundaries of any accompanying empirical model.

The most widely used traffic micro-simulation software within London are VISSIM[23] and S-Paramics[24], and to a lesser extent AIMSUN[25].

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23 **http://www.ptvag.com**

24 **http://www.sias.com**

25 **http://www.aimsun.com**

TD currently has most of its modelling expertise concentrated in VISSIM. To ensure that analysis, audit and impact assessment can be carried out as quickly as possible TD recommends VISSIM when consultants are building micro-simulation models for TfL Streets.

TD can accept micro-simulation models developed using S-Paramics or AIMSUN; however there is not sufficient expert familiarity within TD NP to enable internal model audits and assessment.

- **VISSIM**

VISSIM, developed by PTV AG, specifically models traffic in urban areas. Vehicles are controlled by psycho-physical parameters defined within a complex traffic model. The parameters controlling vehicle behaviour are verified by PTV using calibrated research conducted at the University of Karlsruhe. VISSIM allows a modeller to implement complex, dynamic forms of signal control, replicating equipment from different manufacturers, and can simulate pedestrian characteristics according to a dedicated social forces behavioural model. VISSIM is a multipurpose simulator with a wide range of applications.

The modelling of individual vehicles has allowed VISSIM to become a proxy for real-world scenarios. This has been formalised through the development of an interface between London's traffic control system and VISSIM[26] which allows 'faster than real time' offline testing of traffic management measures.

9.4 Assignment Models

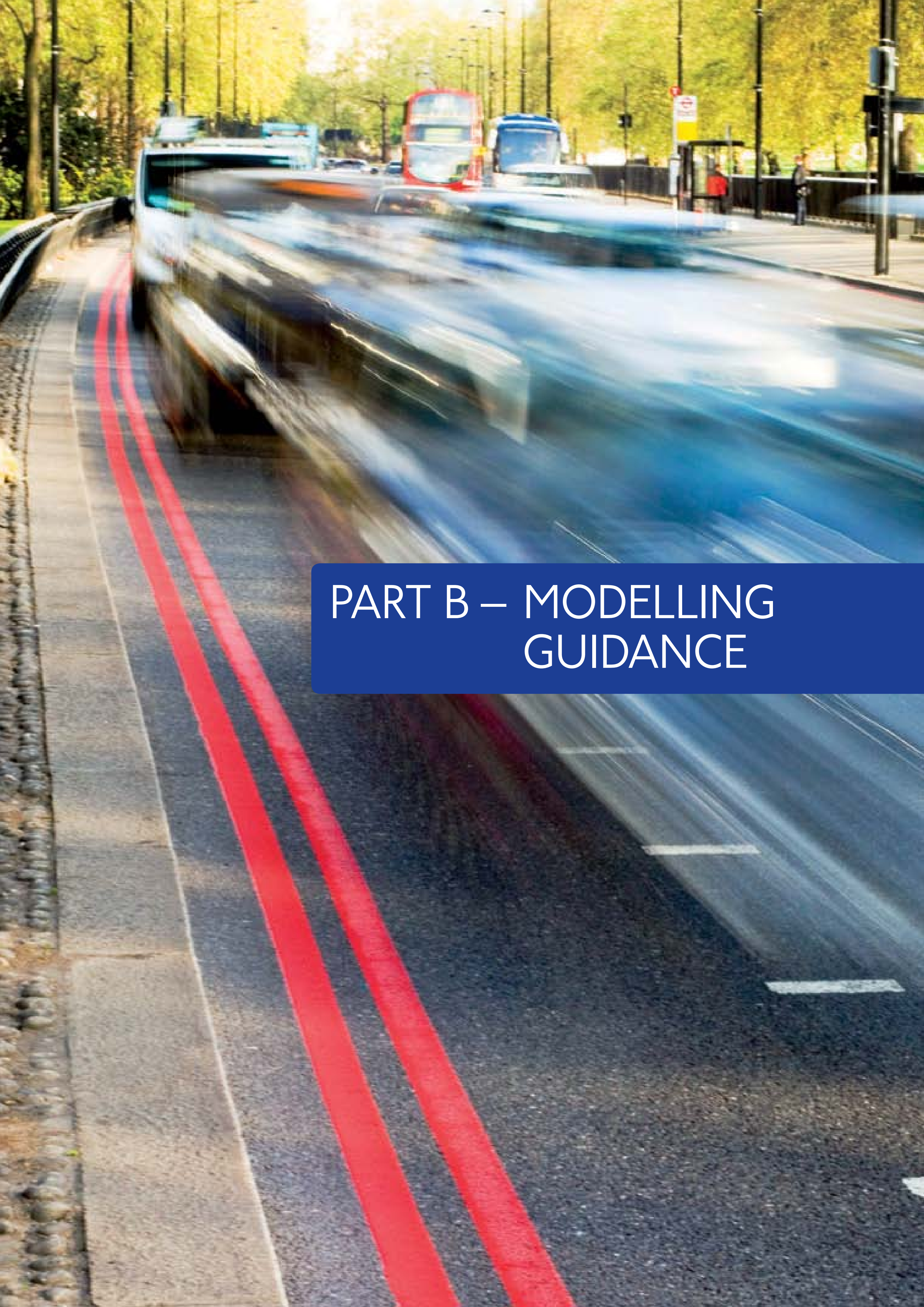
For schemes with considerable or wide-reaching network impacts a highway traffic assignment model can be used in conjunction with the modelling packages outlined in sections A9.2 and A9.3. It is normal for successive iterations to be required with local area models in order to assess the impact of a scheme on traffic volumes and driver route choice (see section A4.3).

VISUM[23] and SATURN[27] are the two packages used by TfL for highway traffic assignment modelling in London. VISUM is developed by PTV AG as a system for travel demand modelling, transportation planning and network data management. It is principally designed for multi-modal analysis which integrates modes of transportation into a single network model. SATURN is a suite of programs developed by the Institute for Transport Studies at the University of Leeds. It is a combination of network analysis programs that combine traffic simulation and traffic assignment to analyse the impact of traffic management on a regional, sub-regional and local scale.

A consistent base assignment model should be used for major scheme assessment in London. TfL has produced a set of sub-regional and central London SATURN models which are specifically designed for this purpose. Scheme sponsors and their consultants should contact TfL Policy Analysis for further information.

26 Cottman N, Giszczak A & Jackman G, *Desktop traffic control for London: developing UTC-VISSIM interface*, TEC Magazine, January 2009, pp41-45.

27 **http://www.saturnsoftware.co.uk**



PART B – MODELLING GUIDANCE

Part B – Modelling Guidance Contributors

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1 Introduction

TfL Streets Traffic Directorate (TD) is dependent on comprehensive modelling and supporting information from clients (including Boroughs and TfL departments) and consultants in order to effectively design, assess, implement and operate traffic schemes.

Appropriate, comprehensive and accurate modelling is necessary to ensure traffic schemes are:

- Assessed for impacts and benefits;
- Effectively designed to satisfy an objective;
- Clarified to avoid confusion or misinterpretation of the design; and
- Effectively and efficiently implemented and operated.

Part B of the Traffic Modelling Guidelines contains technical advice relating to modelling best practice. The first chapter entitled 'Modelling Principles' covers general topics which are common to all types of traffic model. It is recommended that all model developers producing a traffic model within the London area familiarise themselves with the Modelling Principles chapter prior to commencing model development and irrespective of the particular software they intend to use.

Part B of the Traffic Modelling Guidelines assumes the reader has an awareness of basic traffic engineering principles, covering traffic signal control, traffic flows and traffic surveys. Specific concepts and terminology that should be understood include phase minima, phase intergreens, phase delays, stage minima, interstage design, cycle time, offset, saturation flow, degree of saturation (DoS), stopline flows, manual classified counts and demand flows.

This level of awareness would typically come from introductory courses to traffic signals and industry-standard software packages, combined with experience in the traffic engineering/transport planning field.

The remainder of Part B is organised into chapters appropriate to different types of modelling software. The model developer can refer to individual chapters for relevant guidance on the modelling software being used for a specific project. If there are any specialist competencies relating to particular modelling software, these will be stated in the chapter for that package.

2 Modelling Principles

This chapter contains key information which should be read and understood by anyone undertaking traffic modelling.

The key areas that will be covered include:

- Model Definitions;
- Model Auditing Process;
- Network Familiarisation;
- Data Acquisition;
- Model Development;
- Proposed Model Optimisation; and
- Model Reports.

All model developers are encouraged to familiarise themselves with Part A of the Traffic Modelling Guidelines to ensure that the considerations outlined there will be met by any proposed model.

2.1 Model Definitions

Before building a traffic model it is appropriate to define what is meant by the term 'model' in its most general form:

> *"A model can be defined as a simplified representation of a part of the real world … which concentrates on certain elements considered important for its analysis from a particular point of view."*[28]

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28 Ortúzar J de D & Willumsen L G, *Modelling Transport*, 3rd Ed., Ch1, Wiley, London, 2001, p2.

It is important to be aware of the simplifications that are made in creating a model and to understand whether they have any significance for the intended analyses. Simplifications can be made by the modeller, either deliberately or inadvertently, during model development or calibration, or can be inherent to the particular choice of modelling software used for a project.

2.1.1 Model Scope

The development of a clear brief can prevent ambiguity and increase the likelihood of producing fit for purpose traffic models. It is important to define the intended purpose and therefore scope for which the traffic model is to be developed. The model developer should be made fully aware of this purpose in order to ensure that the final modelling meets the required criteria.

A purpose statement is developed during Stage 1 of the Model Auditing Process (MAP), as discussed in B2.2, to ensure all parties have agreed the scope of the modelling requirements associated with a proposal. The scope of the model will therefore determine which modelling outputs are required from a proposal. A base, proposal and on-street timing traffic model may be created when advancing a proposal from initial design to final on-street implementation (as discussed in section B2.5). It may also be necessary to establish consensus regarding a preferred optimisation strategy and the software required to complete any agreed modelling methodology.

The scope of the traffic model as defined in MAP Stage 1 should be clearly stated in accompanying reports and in any discussion or reference to results obtained from the model. The developer should also relate decisions made in the model's development process to the requirements of the model, as defined by its purpose.

2.1.2 Base Model

A base model is a model that has been demonstrated to accurately recreate traffic conditions as observed and measured on-street. It should be suitable for use in analysing current network performance and as a benchmark against which other modelling scenarios can be tested.

2.1.3 Proposed Model

A proposed model is a validated base model that has been modified to take account of proposed network changes. These changes can include physical layout, signal timings or predicted developments in traffic demand. By comparing proposed modelling to the original validated base model, the impact of the proposed changes can be determined, allowing informed decisions to be taken based on those impacts.

A proposed model may also be modified to verify the signal timings required for on-street implementation. Where required by project scope, the modified model will indicate exactly how the signalised facility will operate in a microprocessor signal controller under local or central control (see B2.4.9).

2.2 Model Auditing Process

Traffic model development is a complex task that can be completed in a variety of ways, and the process of auditing a model can also therefore be challenging. The Model Auditing Process (MAP)[29] has been created by TD NP to simplify this process by providing a structured framework which leads all interested parties through model development, submission and auditing.

MAP contains six stages, which outline traffic model development and auditing from initial scoping of the base model through to submission of the Traffic Signals Supplementary Report (TSSR) to the TD Forward Planning Team (FPT). It defines each model auditing step, assigns key roles, encourages communication and provides standardised auditing check sheets.

The primary objective of MAP is to ensure that traffic models submitted to TD for audit are developed, calibrated and validated to an appropriate standard. This ensures that TD NP is able to provide advice to TD FPT based on accurate and robust modelling.

MAP applies in all circumstances where FPT requires traffic modelling to assess impacts on the Transport for London Road Network (TLRN) or the Strategic Road Network (SRN). However, where a Borough is the promoter of a scheme that does not impact on the TLRN or the SRN the use of MAP is only advisory. All traffic models commissioned by TfL Streets and submitted to TD are audited in accordance with MAP.

MAP was implemented in April 2008 and continues to be reviewed and updated. MAP documentation is available, without charge, from the TfL website[30].

MAP is designed to give a common structure for all model submissions. However, for each modelling package the details and consequently the checks are different. Two software-specific MAPs are currently available, for TRANSYT (TMAP) and VISSIM (VMAP). However, a similarly structured six-stage approach can be beneficial when applied to any type of modelling software.

The six stages established by MAP are:

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

29 *TD Model Auditing Process: Traffic Schemes in London Urban Networks*, v2.2, Traffic Directorate, Transport for London, 2010.

30 **http://tfl.gov.uk/streetspublications**

Each stage has unique requirements, as outlined in the documents, however the administration process for dealing with the submission and the communication associated with each stage remains the same.

MAP also defines six key roles:

- **Promoter (P):** The person responsible for delivering and project managing the proposal. The client for a scheme;
- **Design Engineer (DE):** The engineer responsible for creating the modelling for the Promoter. Normally a consultant traffic engineer engaged by the scheme Promoter;
- **Checking Engineer (CE):** The engineer responsible for checking and signing off the Design Engineer's work as 'fit for purpose' for the Promoter. This is typically a senior consultant traffic engineer engaged by the scheme promoter;
- **TD Signals Auditing Engineer (SAE):** The engineer responsible for checking and safety approving the signal infrastructure elements of the proposal. The role is usually undertaken by an experienced signals engineer from within TD TI;
- **TD Model Auditing Engineer (MAE):** The engineer responsible for auditing the modelling and assessing the network impact of the scheme. A function usually filled by an experienced signals engineer from within TD NP; and
- **TD Network Assurance Engineer (NAE):** The engineer responsible for assessment, then approval/rejection of the Promoter's proposal (under the Traffic Management Act). A responsibility fulfilled by an experienced FPT engineer from within TD.

For MAP Stages 2, 3 and 5, there are check sheets to be signed off by the DE, the CE and the TD NP MAE.

The following key points should be noted:

- All model submissions should be version controlled;
- All model submissions should be internally audited by the CE prior to submission; and
- All formal correspondence and submissions to TD should be sent to the TD MAP Coordinator (**TDNPModelling@TfL.gov.uk**).

2.2.1 Use of Approved TfL Models

Models which have been audited and approved by TfL are often used by third parties. This practice is generally encouraged as it ensures consistency and reduces cost. The use of TfL-approved models must meet the following criteria:

- Permission is given by the developers of the original model for its use;
- The party requesting the use of the model contacts TD and obtains permission in writing;
- The party requesting the approved models accepts that the models supplied were considered fit for purpose when they were produced;
- Any TfL-approved model which is subsequently altered is no longer considered a TfL approved model; and

- The model developer accepts responsibility to ensure that the modelling they produce is fit for purpose.

2.3 Network Familiarisation

Before commencing any modelling work or measurement of site data, it is important for the modeller to familiarise themselves with the area to be modelled. It is useful to identify the following information:

- TfL site number(s). All requests should be directed to the TfL TD Site Data Manager via **SFMdatamanagement@TfL.gov.uk**;
- UTC group/region number (if applicable, obtained from TD NP);
- Time period(s) under consideration; and
- Date(s) when traffic flow data was collected, if available.

The following section details some initial steps that should be taken by the modeller in order to familiarise themselves with the area to be modelled.

2.3.1 Model Boundary

A traffic model should assess the full impact of a scheme on all road users over the impacted area. In general the model boundary should encompass the area within which traffic flows, journey times or delays will be significantly affected by the implementation of the scheme or proposed intervention. This should be agreed during MAP stage 1 for TRANSYT and VISSIM models, as described in B2.2.

The impact of a 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 TD. For guidance the model boundary should include junctions that meet any of the following criteria:

- Traffic flows are expected to change significantly as a result of the proposal;
- Include proposed physical changes to the road network;
- Include proposed changes to operation of traffic control; and
- Are expected to suffer exit-blocking as a result of the proposal or changes to local traffic control strategy.

If the model area is part of a CLF or UTC group with a proposed change in cycle time then the whole operational group must be included in any modelling. If there is no proposed change to cycle time then the whole group does not have to be included provided none of the above criteria are met by adjacent junctions to the proposal.

> It is recommended that Stage 1 meetings occur prior to the scheme being registered on the TD Workbook. This will ensure that all TD requirements are captured by the Promoter and the Design Engineers prior to development of the scheme design.

Where the following issues are deemed important to the client it may be necessary to consider use of a highway assignment model, alongside traditional traffic modelling:

- Routes currently being used, or likely to be used in the future, by traffic will be affected by the scheme;
- The scheme will provide significant relief to areas;
- The scheme will generate extra traffic in areas that may be significantly affected;
- The impact of changes in traffic levels, on both existing and new or improved roads in the area, needs to be assessed; and
- Economic benefits are to be assessed over the area impacted by the scheme.

2.3.2 Site Paperwork

Once model boundaries have been defined and a list of TfL site numbers has been obtained, the following paperwork should be consulted for all signalised facilities:

- Current TfL Controller Specifications and Signal Timing Sheets, which detail phasing, method of control, intergreens, phase minimums and phase delays along with other pertinent information relating to the site;
- Site Layout Drawings (SLDs), detailing junction layout, lane markings and site equipment; and where appropriate
- SCOOT Link Diagrams, showing link and node structure for SCOOT regions.

Detailed drawings, maps and aerial photographs can be used to determine site layout. However, a site visit must be carried out to confirm the accuracy of any material used.

2.3.3 Online Data Sources

The internet provides a useful resource for mapping and aerial photography that modellers can refer to during the initial stages of network familiarisation. Websites commonly used for this purpose include:

- 192.com[31],
- Google Maps[32],
- Microsoft Live Maps[33],
- MultiMap[34], and
- Seety[35].

Of the aerial photography options available, 192.com's 'Super Zoom' currently provides the highest resolution imagery of central London. In cases where aerial photographs are either obstructed or unclear, the 'Bird's Eye' option provided by Microsoft Live Maps shows oblique images to give an alternative view.

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31 **http://www.192.com/places/**
32 **http://maps.google.co.uk**
33 **http://www.bing.com/maps/**
34 **http://www.multimap.com**
35 **http://www.seety.co.uk**

One of the most useful online tools comes in the form of street-level panorama photography, showing a driver's eye view of the road network using imagery taken with 360° cameras. Examples of these include Google Maps', 'Streetview' and Seety.

Using online data sources modellers can quickly check vast amounts of data during model development, from lane markings and parking restrictions to the specific details of road geometry or signage. However, online data sources should not be viewed as an alternative to site visits as material may be out of date and not representative of current on-street conditions. Instead, they offer useful supplemental information which can be confirmed later during site observations.

2.4 Data Acquisition

Once familiar with the modelled network it is necessary to collect the relevant information required to generate an accurate traffic model. Without accurate data a model cannot be correctly developed, calibrated or validated. A common cause of inaccurate data is a lack of understanding and experience on behalf of a person conducting a survey. On-site measurement should be conducted by an experienced traffic engineer who possesses a thorough understanding of modelling concepts and accepted survey methods, as well as experience of developing traffic models.

2.4.1 Typical Traffic Conditions

Where data needs to be collected from site, either during general site visits or traffic surveys, the modeller must ensure that network conditions and traffic signals are operating typically and there are no other unusual activities or travel patterns. This includes, but is not limited to:

- Day of week behaviour (e.g. avoiding Monday mornings and Friday evenings);
- School holidays;
- Roadworks;
- Temporary road closures;
- Demonstrations;
- Festivals;
- Traffic incidents;
- Temporary loss of UTC control (e.g. local control); and
- Temporary use of atypical (e.g. UTC contingency) timing plans and strategies.

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; and
- Late evening where heavily trafficked conditions occur.

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.

When determining a programme for traffic surveys and other site data collection, the modeller should consult with the TfL London Streets Traffic Control Centre (LSTCC) to check that normal traffic control conditions are expected during the planned times for the traffic survey/site visit. This should also be confirmed once on-site. Contingency dates should be set aside in case the scheduled survey has to be cancelled.

The LSTCC information desk can be contacted on 020 3054 3096, or via email at **LSTCCinformationdesk@TfL.gov.uk**.

2.4.2 Site Visits

All models are developed using calibration data, which needs to be collected in the form of site observations and on-street parameter measurement. The quality of the final model, and any analysis derived from it, depends on the data used during model development. The consistent collection of data is paramount in ensuring the accuracy of any traffic model.

Data on its own does not provide enough information to develop an accurate model. The correct interpretation of the data requires a thorough understanding of on-site conditions. This understanding can only be acquired through visiting the site. The engineer developing the model should personally visit the site during each period for which a model is being developed. These site visits should include the collection of some of the more complex information which can only be undertaken by an engineer with the appropriate knowledge and experience.

As described in sections B2.3.2 and B2.3.3, it is important to verify the accuracy of any drawings or aerial photography used during model development, to ensure their content accurately represents current site layout and appearance.

Site-specific parameters should also be recorded for all periods of the day for which the models are being prepared. Common examples of data that can be noted or measured during site visits are:

- Date, time of day and day of week;
- Junction/network layout;
- Link lengths, lane widths and pedestrian crossing distances;
- Lane/road markings and usage;
- Cruise times;
- Saturation flows;
- Give-way behaviour;
- Vehicle and/or pedestrian spot counts;
- Right-turner storage and blocking effects;
- Flare lengths and usage;

- Vehicle usage of the flashing amber period at Pelican crossings;
- Fanning and funnelling;
- Exit-blocking;
- Bus lanes, hours of operation, bus stop locations and bus stop dwell times;
- Car parks, street parking and interference during parking manoeuvres;
- Restrictions on the network (parking/stopping/loading, etc);
- Speed limits;
- Roadworks and other incidents, and their impact;
- Degree of saturation;
- Journey times (for both private and public transport); and
- Queue lengths (if required).

Whilst many of these parameters can be measured in quantifiable terms, it is also important to record general site observations that capture more subtle behaviour exhibited within the study area. It can be useful to note where traffic behaviour does not reflect street markings or the intended geometric design of a junction, for example where ahead moving vehicles use a dedicated left-turn lane.

When measuring data it is necessary to obtain a sufficient number of measurements to give confidence that average values are representative. If practical an average of ten measurements may typically be used. In some cases fewer measurements may be appropriate (e.g. when recording link lengths and crossing distances), and in other cases a higher number of readings may be required, for example where a large variation in values is obtained. Many parameters are time dependent, and should therefore be recorded for each period being modelled, such as effective flare usage which can vary at a site according to differing traffic patterns.

2.4.3 Traffic Count Surveys

It is advisable that TD NP is contacted before commencing road traffic counts to establish current best practice for data collection, and to ensure data formatting complies with TfL requirements.

> The time and duration of the peak period to be modelled will be determined from the survey count data. This should represent the time within the survey period during which the largest total amount of traffic was observed. A modelled peak period is typically one hour, however longer peaks can be used if appropriate.

Classified turning counts should be obtained at each junction, or in the case of a network with complex route choice an Origin-Destination (O/D) survey may be more appropriate. The chosen approach will depend on the road network being modelled and type of software being used for the project. Traffic surveys can be performed on-site by manual counters, using fixed location video cameras or via Automatic Number Plate Recognition (ANPR) systems. Wherever possible, traffic counts should be recorded on the same day at all modelled junctions and for all modelled periods.

In some cases it may be acceptable to use flow-factoring techniques, based on flows recorded during another representative peak, but authorisation should be sought from TD NP MAE before applying this technique.

Site visits should be carried out during traffic count surveys to collect pertinent calibration and validation data and ensure site conditions remain typical. These visits are important as journey time, degree of saturation and queue length surveys should ideally be conducted while traffic counts are taking place. Multiple factors, such as traffic management, may have a bearing on survey results and it is important that these are identified in addition to the usual weather and incident reports provided by survey companies.

Classified turning count surveys have inherent limitations. Before they are used in a model, a check must be made to see whether traffic leaving one junction arrives at neighbouring junctions. If there is a discrepancy of more than five 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 (e.g. side roads, car park entry and exits) that were not captured in the original survey. If sinks or sources are found, 15-minute spot counts should be conducted to estimate hourly flow rates. Where a discrepancy exists and no sinks or sources are discovered, a 15-minute spot count can be conducted to compare with surveyed flows to see if the original counts are reasonable. To get an accurate spot count, it is recommended that the flow is recorded over a whole number of completed cycles.

Analysis of traffic flows across the network as a whole may highlight a particular count site as being in error, for example, if flows at neighbouring survey sites are inexact by a similar value. Where a manual counting error appears to have been made, a general rule is to take the larger flow count from adjacent survey sites as being accurate, as it is more common for errors to result in under-counting than over-counting. This also represents the worst case as far as the network is concerned, as the largest observed flow will be modelled.

The TD Performance and Research team (**trafficdata@TfL.gov.uk**) maintain additional traffic count data for TfL. Sources of data include:

- TfL's 'Ad-Hoc' Count Database, containing counts performed by the TfL Traffic Survey Team and other stakeholders;
- TfL's Cordon and Screenline data, part of an ongoing programme of surveys on the central, inner and boundary cordons and the Thames, northern, peripheral and radial screenlines; and
- TfL's permanent automatic traffic and pedal cycle counter sites.

2.4.3.1 Passenger Car Unit

Traffic is composed of various types of vehicles, the range and relative composition of which can vary from location to location. Traffic modelling software frequently utilises a common unit, known as the Passenger Car Unit (PCU), to represent general traffic. Common vehicle types are assigned a conversion factor so that an equivalent PCU value can be generated from classified vehicle data collected as described in B2.4.3. Typical PCU values used for different vehicle types are shown in Table 1.

Table 1: Passenger Car Unit (PCU) values for various vehicle types.

Vehicle Type	PCU Value
Pedal Cycle	0.2
Motor Cycle	0.4
Passenger Car	1.0
Light Goods Vehicle (LGV)	1.0
Medium Goods Vehicle (MGV)	1.5
Buses & Coaches	2.0
Heavy Goods Vehicle (HGV)	2.3
Articulated Buses	*3.2**

* *Recent research conducted for TfL has suggested this to be an appropriate PCU value for articulated buses*[36].

Where cyclists are present, their volume can have an impact on the calibration and validation of traffic models. As the volume of cyclists change, their impact on traffic behaviour varies in a non-linear manner. It is not appropriate to assign a common PCU value to cyclists where a significant proportion of cyclists and powered two-wheelers are present, as where their volume exceeds approximately 20% of the total volume on any one approach this may have a disproportional effect on modelling results[37].

2.4.4 Private Transport Surveys

Vehicle surveys are needed to capture specific data for calibration and validation purposes, to aid in base model development. This section details some of the information that may be required.

2.4.4.1 Cruise Times

Cruise times reflect the typical un-delayed time taken for a vehicle in the middle of a platoon to travel from stopline to stopline as if there were no traffic signals causing loss of speed.

It may prove difficult to obtain accurate free-flow cruise times in congested conditions. If congestion prevents data collection it is advisable to measure free-flow cruise times outside of peak hours. An alternative approach is to measure the cruise time for a free-flowing section on each approach, and extrapolate a value for the whole link distance, based on the relative lengths of the free-flowing and congested sections. If persistent congestion prevents cruise time measurement for a particular link at all times, it is

36 *Optimising Capacity – PCU Factors for Different Vehicle Types*, Draft Research Report. Transport for London, 2009.

37 *Mixed Traffic Conditions in Parliament Square – Cyclists Impact Assessment Report*, London Cycling Centre of Excellence, Transport for London, July 2008.

acceptable to measure cruise times for vehicles travelling in the opposite direction but this should be noted in accompanying technical reports.

Full link measurements cannot be made when the downstream stopline is not visible (e.g. due to a bend or long link). In this case the measurement can be divided into segments using an arbitrary reference point, with segment journey times summed to obtain a total journey time for the link as a whole, or two surveyors can collaborate to chose a particular vehicle and communicate progress along the link between stoplines. It is recommended that ten typical readings are taken to obtain a mean average.

2.4.4.2 Journey Times

All journey times should be collected under 'normal' network conditions free from incidents and events. Surveying should also take place on a neutral day, in order to capture typical traffic behaviour and levels of congestion. This is described further in section B2.4.1.

> If private transport journey time measurements are required, e.g. for micro-simulation validation purposes, these should be performed using the 'floating car' technique.

The 'floating car' technique involves one or more survey cars driving along prescribed routes within the modelled area and recording travel times between pre-defined points. These points are typically, though not exclusively, signalised stoplines or give-way road markings. The survey car(s) should attempt to balance the number of vehicles overtaking with those being overtaken, while remaining within the speed limit. Where stoplines are used as a datum, segment journey time measurements should begin and end immediately after crossing the stopline. These segmented journey times provide valuable information with respect to signal coordination and queue delay which can become useful during later model development.

Multiple repeat journey time observations should be collected for each route, during each peak period. 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. Typically at least six repeated observations are necessary in order to derive a statistically reliable estimate of average journey time; however this depends on the variability of journey times along the route. A description of how the required number of observations is calculated from the desired level of accuracy can be found in the DfT's Cost Benefit Analysis (COBA) manual (i.e. DMRB Vol. 13)[38]. Collecting multiple repeated journey time observations also allows an analysis of journey time variability (range, maximum, minimum and standard deviation). This information is useful to compare against model outputs during base model validation.

38 *Design Manual for Roads and Bridges*, Volume 13, Section 1, Part 5, Chapter 11, Department for Transport, 2002.

2.4.4.3 Queue Lengths

Queue length data can be useful for model calibration at locations where queues persist from one signal cycle to the next. Surveyed measurements are normally taken at a consistent point in the signal cycle (e.g. at the start of green), specified for each traffic lane and measured in metres or PCUs.

The level of accuracy in queue measurement surveys can often lower than for other surveys as the definition of a queue can be ambiguous as well as difficult to identify.

However, to try and collect maximum queue length data on-street, it is best to stand at the back of the queue at the start of green. Considering the case where vehicles will start discharging at the front of the queue and vehicles are joining the back of the discharging queue, the maximum length of the queue occurs at the point where an arriving vehicle is no longer delayed by the back of the discharging queue. If there are no arriving vehicles, then the queue length remains the queue at the start of green.

2.4.5 Flared Approaches

A flare represents a lane at a stopline that is fully used for only a proportion of the green time, even during fully saturated conditions. A flare therefore only contributes to stopline capacity for a limited period at the start of green, after which it provides no further benefit.

A flare can be physical (e.g. increased road space due to widening of the carriageway before a stopline), or effective (e.g. termination of a bus lane or parking area before the stopline). Flares are a common source of modelling error, therefore consideration should be given to if and how they should be modelled.

Flare length utilisation must be considered according to the proportion of vehicles using the flare, and effective flare lengths should be entered into deterministic traffic models rather than physical lengths. This data must be collected on-site, as identified in section B2.4.2. Only in circumstances where data cannot be collected on-site should the JCT software LinSat be used to estimate effective flare length usage. The use of LinSat should be highlighted in any accompanying model reports.

2.4.6 Non-Green and Flashing Amber

The time used by traffic during non-green or flashing amber periods can influence road capacity and adjustment for this phenomenon should therefore be a requirement during model calibration. Additional road capacity created by aggressive vehicle behaviour can be recreated within submitted traffic modelling but must be identified for audit.

Non-green periods should be accounted for if vehicles are observed on-site to behave aggressively at the stopline, e.g. by accelerating during the starting amber period or crossing a stopline after the start of red. Site observations should record the total time (in seconds) utilised by traffic during non-green periods for each peak period. For Pelican crossings, traffic usage during the flashing amber period should also be recorded (in seconds) during site observations for each peak period being modelled. It is recommended that ten readings are taken on-site to obtain a mean average.

2.4.7 Saturation Flow

Saturation flow represents a key measurement of on-street performance and thus the values used within a model must accurately reflect the built environment.

Saturation flow, measured in PCU/hr, can be defined as:

> *"…the maximum flow, expressed in passenger car units (sic), that can be discharged from a traffic lane when there is a continuous green indication and a continuous queue on the approach."* [39]

Saturation flow is an expression of the maximum capacity of a link as predominantly determined by junction characteristics (geometry, layout, turning radii, visibility etc). The saturation flow input for a model should generally not be altered between models or modelled periods unless physical characteristics are modified, such as changes within a proposed model. Saturation flows should only be altered for each time period where a lane shares more than one turning movement, and site observations have noted that flow patterns vary significantly across the day. Saturation flows are normally required for each individual lane that is modelled, although multiple lanes can be combined into a single measurement if they perform identically in terms of flow, vehicle destination and queue behaviour.

Where fully saturated traffic appears to discharge at a rate less than the saturation flow (e.g. due to driver behaviour or exit-blocking), this should not be accounted for by changing the saturation flow in a model. Instead, it is recommended that Underutilised Green Time (UGT) is used to quantify this behaviour, as explained in section B2.4.8.1.

It is important that saturation flows are measured accurately. Incorrect saturation flows represent a common source of error which can cause delay during model auditing. It is recommended that a minimum of ten typical readings are taken to obtain a mean average, and that the minimum length of each measurement should be 12 seconds[40].

Measurements should be conducted using vehicles discharging across the stopline in free-flow and thus unaffected by downstream interference such as congestion or exit-blocking. Conditions need to be sufficiently busy that the link is saturated for an adequate period to allow measurement. The surveyor should be able to recognise the end of saturated conditions during each cycle. In some cases, due to insufficient flow or short green periods, it will not be possible to measure a minimum of 12 seconds of saturated conditions at any time of day. In these circumstances shorter measurements can still be recorded but should be identified in accompanying reports for the TD NP MAE, and their validity should be scrutinised by the CE.

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39 Salter R J & Hounsell N B, *Highway Traffic Analysis and Design*, 3rd Ed, Macmillan, 1996, p292.

40 Binning J, *Traffic Software News*, TRL, September 2007, No. 43, p2.

Saturation flow measurements should not include periods of 'lost time' at the start and end of green, as these represent time during which vehicles are accelerating or decelerating and therefore not moving at saturation flow. 'Lost time' parameters can be calculated, but it is unlikely exact values will be known unless recorded using a dedicated survey, it is therefore acceptable to use a default of two seconds start lost time and no end lost time. A common technique to account for start lost time is to ignore the first two vehicles to cross a stopline before recording saturation flow measurements. This prevents accelerating vehicles being counted towards measurements and therefore underestimation of the saturation flow.

Situations may occur where satisfactory saturation flow measurement is not possible, for example due to insufficient traffic flows, green time or queuing. These should be assessed on a case by case basis, and identified along with an explanation on the method used to estimate saturation flows. An example method for estimating saturation flow using RR67 is explained in B2.4.7.1.

2.4.7.1 Use of Calculation Formula RR67

The prediction of saturation flows using a standard formula was outlined in TRL Research Report 67 (RR67) by Kimber *et al* through the classification of empirical data surveyed over twenty years ago at various UK sites[41]. RR67 allows the estimation of saturation flows based on geometric data such as vehicle turning radii, lane width and road gradient. Data used in the development of RR67 was restricted to sites which were classified as 'good' or 'average' in terms of junction performance by Webster and Cobbe [42]. Given the numerous sources of interference for traffic in London, such as heavy pedestrian movements, poor visibility and parked vehicles, many junctions would not meet either of these classifications and thus use of the RR67 formula can result in the over prediction of saturation flow at signalised junctions within London.

The use of RR67 can remove the need to measure all saturated lane groups within a network (i.e. non-critical approaches). Similarly saturation flow estimates can be derived from RR67 and applied where site measurement is not possible for reasons as discussed in B2.4.7.

However, where RR67 is applied it is necessary to verify the applicability of the estimated value against measured data. A factor should be calculated that accounts for local junction characteristics as compared to the 'typical' junction inherently described by RR67. This factor should be generated by comparing the RR67 predicted saturation flow against measured values from a lane group with similar physical or lane usage characteristics. This adjustment factor should be applied to predicted values on approaches where measurement was not possible or practical.

RR67 adjusted saturation flows should be highlighted in accompanying reports for the TD NP MAE and audited by the CE during model calibration.

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41 Kimber R M, Macdonald M & Hounsell N B, *The Prediction of Saturation Flows for Road Junctions Controlled by Traffic Signals*, Transport and Road Research Laboratory, Department of Transport, Research Report 67, 1986.

42 Webster F V & Cobbe B M, *Traffic Signals*, HMSO, Road Research Technical Paper No. 56, 1966.

2.4.8 Degree of Saturation

Degree of Saturation (DoS) is a key parameter for validating traffic models. It is advisable that all traffic engineers have a thorough understanding of DoS and how to accurately measure it on-site. Intrinsic to this understanding is knowledge of the different factors that can influence DoS, both on-site and in a model. This subsection describes the methodology recommended by TfL for measuring DoS. The method is designed to account for Underutilised Green Time (UGT), as defined in section B2.4.8.1, which can be calculated from DoS measurements.

A DoS survey should be conducted on all critical approaches for each modelled period. In order to achieve an overall measurement that is representative, data sampling should be distributed across the whole of each period during which DoS is being measured. As described in B2.4.7, multiple lanes can be combined into a single measurement if they behave identically in terms of flows and queuing.

To calculate DoS the surveyor is required to measure the period of full traffic demand. Recognising full traffic demand can require experience as at times a gap may develop between vehicles even though full demand is still present, for example where slow moving traffic approaches a stopline but individual vehicles accelerate at different speeds.

The surveyor is required to record the time from the beginning of green until the end of full demand, during which they record the number of PCUs that cross the stopline. The end of full demand occurs when there is no further traffic queuing or flowing at the stopline across all lanes being measured. The surveyor then records the number of PCUs that cross the stopline during any subsequent period of low demand. The number of PCUs must be recorded separately during each period of differing demand type. Finally the total length of the green period should be recorded.

In summary the following information should be recorded:

- Time at start of green;
- Time at start of full demand (if different from start of green);
- Number of PCUs crossing stopline during full demand;
- Time at end of full demand;
- Number of PCUs crossing stopline during low demand; and
- Time at end of green.

This process should be repeated ten times in order to obtain a mean average suitable for model validation. However, for sites which experience large variations in flow it may be necessary to record more samples to generate a representative value.

2.4.8.1 Underutilised Green Time

Underutilised Green Time (UGT) corresponds to the number of seconds of green time within a signal cycle where saturation flow is not achieved despite the presence of full demand. Full demand is defined as occurring when traffic is passing or attempting to pass the stopline during a green period. UGT is measured in seconds per cycle and is calculated from data recorded during DoS measurement.

UGT is comprised of two elements:

- ‘Wasted Green’, which describes the period of a cycle during which an approach experiencing full demand receives a green signal but traffic is unable to progress across the stopline, for example due to downstream exit-blocking; and
- ‘Sub Saturation Flow’, which describes the period of a cycle during which an approach receiving a green signal does not fully utilise the available capacity, i.e. for vehicles to proceed at saturation flow. This effect can be caused by a number of factors such as driver behaviour, signal offsets or downstream congestion.

At times traffic experiencing sub saturation flow may only be travelling marginally slower than would be the case during unrestricted saturation flow. This may not be noticeable to an on-street observer but its impact will be captured by UGT during data processing. UGT is calculated to quantify situations where congestion-related issues prevent fully saturated discharge. It is derived in a form that can be directly applied to available green time in traffic models such as TRANSYT and LinSig by utilising dummy staging, phase lags and/or bonus green.

If a negative UGT value is encountered it may indicate that the initial saturation flow measurement was inadequate and that further measurements are required. A negative UGT value highlights traffic that has been observed to discharge at a rate greater than the measured maximum saturation flow during a DoS survey.

Figure 2 illustrates a flow profile measured on-street for a link in two different scenarios. The blue curve shows a flow profile for a stopline during non-congested conditions. The orange curve shows a flow profile for the same stopline, but under congested conditions. The shaded area between the curves therefore represents the reduction in flow across the stopline due to congestion.

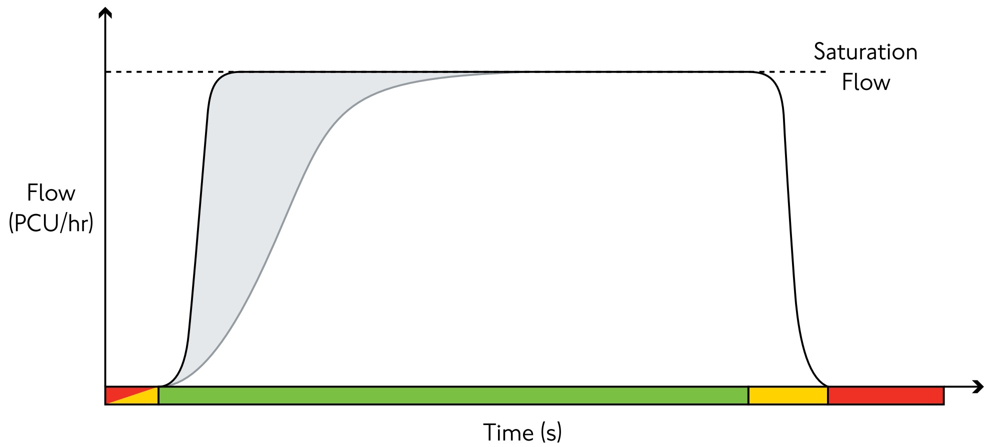

Figure 2: Flow profiles showing ‘normal’ (blue) and ‘congested’ (orange) conditions.

Figure 3 illustrates how the shaded area, equal to that in Figure 2, represents the difference in capacity as accounted for by UGT, i.e. the time period during which full saturation flow was not achieved. It also illustrates how these scenarios will be modelled within deterministic traffic models such as TRANSYT or LinSig. UGT calculations are unable to discriminate between time periods where vehicles are 'slow moving' or where vehicles are stationary. This imitates deterministic traffic modelling software such as TRANSYT and LinSig where vehicles are also assumed to be either stopped or moving at a saturated rate of discharge.

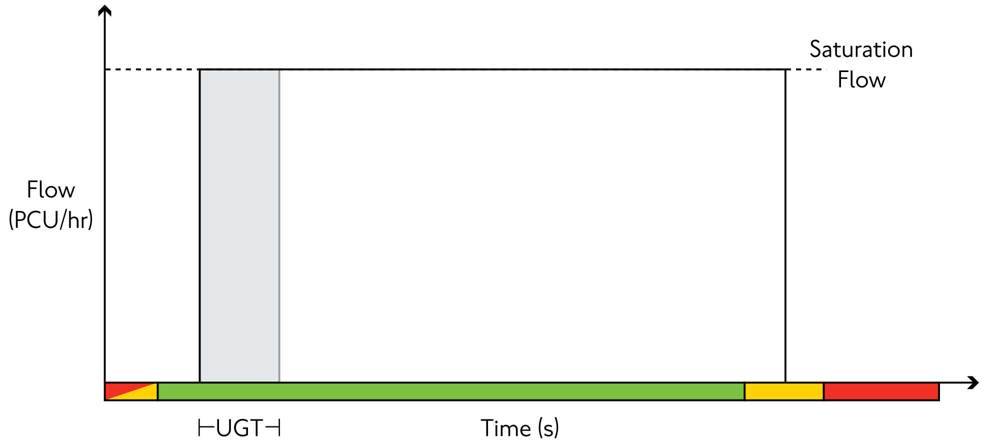

Figure 3: Congested conditions as modelled in LinSig or TRANSYT with UGT.

It is advisable to apply UGT to model the effects of congestion, as this technique avoids the need for a modeller to iteratively adjust the saturation flow in a model during calibration, and provides quantifiable evidence to justify the approach taken. Whilst it is possible to reduce saturation flows to achieve an effect analogous to the application of UGT (see Figure 4), it is theoretically unsound as the applied saturation flow no longer represents the maximum rate of discharge across a stopline.

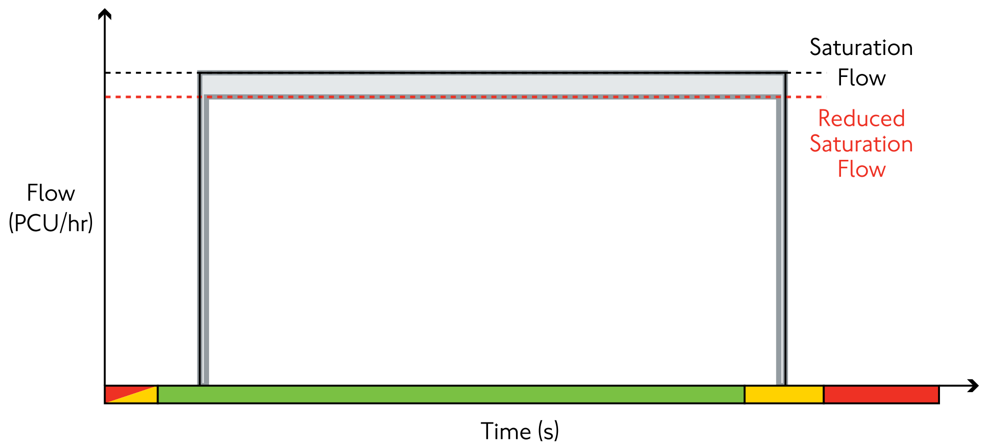

Figure 4: Incorrectly reduced saturation flow analogous to UGT applied in Figure 3.

For further details on the calculation of UGT values using data recorded during DoS measurements, refer to Appendix I.

2.4.9 Signal Timings

Traffic modelling relies heavily on the accuracy of signal timings to correctly represent capacity at signalised intersections. This section briefly describes how signal timing data should be extracted to accurately reflect on-street conditions.

> Signal timing data must be captured at the same time as other traffic surveys and should therefore be recorded for each modelled period.

In general terms the control of traffic signals can be split into two groups, Urban Traffic Control (UTC) and non-UTC. UTC coordinates the operation of junctions over an area through use of timing plans implemented by a central computer. Non-UTC signals operate under local control, where timings are stored locally on each controller and activated according to a pre-defined timetable.

UTC traffic signal control can be further classified into fixed time and SCOOT:

- **Fixed time** – These facilities operate via set plans which change by time of day. Traffic and pedestrian stages within these junctions can be demand-dependent, i.e. if there is no demand then the stage will not run on-street; and
- **SCOOT** – These facilities operate via an adaptive system which uses an algorithm to constantly optimise the green split, junction offset and group cycle time based on current local traffic demand. Stages at SCOOT sites can be demand-dependent.

Furthermore, System Activated Strategy Selection (SASS) or selective vehicle detection (SVD) bus priority are dynamic signal control methods applied within the UTC system for traffic management on the TLRN. When in operation they will vary signal timings across a modelled period. Engineers should identify whether SASS or SVD bus priority is present during network familiarisation. If they are active then it is advised that TD NP be consulted to determine the best approach to capturing average signal timings for modelling purposes.

2.4.9.1 UTC Junctions

The primary function of the UTC system is to transmit stage change events via timing plans to on-street controllers which then adjust the amount of available red and green time. The UTC signal timing plan communicates the required stage combination to be operated within the controller. To do this UTC sends a request to the controller to change stage (force bit), and once the stage change has occurred UTC then receives a confirmation from the controller (reply bit). All signal timing plans follow a uniform format which specifies the target controller, the plan number, cycle time, and stage change event times. Closely associated junctions are often grouped together within UTC timing plans (multinodes) to maintain critical safety offsets, for example where parallel pedestrian streams are positioned on the exit to a junction.

> The current process used by TD to extract 'on-street' signal timings from UTC requires a skilled resource. It is not possible for these guidelines to detail the process required to manually calculate and audit derived signal timings. The exact approach necessitates prior knowledge of the UTC control type used to operate the signalised intersection.

Fixed time signal timings can be extracted directly from UTC as these facilities operate using a constant cycle time with a repeatable sequence of stages and stage lengths. The interpretation of force and reply bit information can therefore be conducted once demand-dependent stage data has been captured, as described in section B2.4.9.3. Once all data has been collated it is necessary for the modeller to translate the stage sequence as defined by the signal timing plan to understand where time has been allocated within an average cycle.

UTC timing plans must not be interpreted directly when SCOOT is in operation. SCOOT is an adaptive system which optimises signal timings, meaning stage durations and cycle times fluctuate during the modelled period. It is therefore necessary to generate an average timing plan for each SCOOT junction or region.

To create an average plan it is necessary to log dedicated SCOOT messages during the modelled period. The collation of information concerning three variable elements (cycle time, stage length and offset) should provide an average timing plan suitable for modelling purposes. However, multinode relationships may exist within SCOOT to fix stage durations and offsets between separate nodes. Modellers should also be aware that the stage lengths recorded and displayed within SCOOT are the lengths of SCOOT stages rather than UTC stages. For this reason it is a prerequisite to analyse UTC signal timing plans to reconcile differences between UTC and SCOOT staging prior to extracting average SCOOT signal timings.

SCOOT has the capability to vary group cycle times which can allow individual facilities the opportunity to double cycle within the operational group. Before collating cycle time information it is necessary to establish whether any signalised facilities were single or double cycling during the modelled period. The modeller can then determine the average cycle time for each SCOOT node. The average UTC stage lengths should then be calculated in proportion to the defined cycle time. Average UTC stage to UTC stage offsets are then calculated and applied to each node according to SCOOT relationships defined within the UTC database.

2.4.9.2 Non-UTC Junctions

Non-UTC signal sites are operated by the junction controller rather than a centralised system. These facilities are controlled using Cableless Linking Facility (CLF), Microprocessor Optimised Vehicle Activation (MOVA) or Vehicle Actuation (VA).

CLF-controlled sites operate using timing plans stored locally within the controller. CLF control plans are detailed on Signal Timing Sheets, which should be collated for all sites during network familiarisation. CLF plans are analogous to fixed time UTC plans, making it is possible to extract average signal timings using a similar method to that described in B2.4.9.1. It is advisable to check the accuracy of CLF timings derived from Signal Timing Sheets with TD NP, to confirm they are up to date and as running on-street.

MOVA and VA allocate signal times to different traffic movements between preset minimum and maximum limits. Vehicles detected by the controller during a green phase extend the green period until a gap exceeding a critical value is found or the maximum is reached. MOVA and VA signal timings are not based on structured plans, meaning average timings will need to be observed on-street.

2.4.9.3 Demand-Dependent Stages

A signal controller registers the presence of on-street demand, when activated by vehicle detectors or pedestrian push-buttons, and ensures that the relevant demand-dependent stage will be called at the next available opportunity. An opportunity for demand to be enabled is determined by the stage sequence embedded within the controller logic (VA, MOVA) or signal timing plan (UTC, CLF). The number of opportunities available for a demand-dependent stage at UTC or CLF-controlled sites is broadly based on the signal timing plan structure and overall junction cycle time. When a demand-dependent stage does not appear within a cycle the unallocated time will either be provided to the stage already in operation, the next stage in the sequence, shared between both stages or allocated to an alternative stage.

TfL Streets' UTC system monitors the behaviour of stage demands at UTC-controlled sites, where the confirmed appearance of demand-dependent stages are recorded. These data can be analysed at a 15-minute resolution within a 24 hour period. The monitored counts provide the number of demand-dependent opportunities against the number of actual appearances. Counting occurs under both fixed time and SCOOT control but it is not possible to query split time periods or multiple dates. It is worth noting that the number of available stage opportunities may be variable under UTC SCOOT control when a node is free to single or double cycle. Advice from TD NP should be sought if a node has the potential to single and double cycle within one monitoring period as additional cycle time data will need to be captured to calculate the correct number of available stage opportunities.

Demand-dependent stage frequency data for UTC sites can be requested from the TD Data and Legal Requests team (**TDDataLegalRequests@TfL.gov.uk**). Demand-dependency data is not available for sites under local control and will have to be measured on-site.

2.4.9.4 Pedestrian Facilities

Pedestrian demand is not usually measured during traffic surveys for TfL. When examining UTC facilities an appropriate proxy is the appearance of pedestrian stages, either as a pedestrian stream at a junction or an isolated crossing. The frequency of appearance can be obtained from UTC via demand-dependency data as described in section B2.4.9.3. This data can be used to infer the appearance of a pedestrian stage at a defined frequency across the modelled period. This data can be interpreted directly at Pelican crossings where pedestrian stages operate using fixed minima as specified on Signal Timing Sheets.

Toucan and Puffin crossings operate with on-crossing detectors, which allow pedestrian-to-traffic intergreens to vary between minimum and maximum values. The presence of these facilities should be determined during network familiarisation. Where they are operational it is necessary to gather information during traffic count surveys so actual timings can be interpreted to determine average stage and interstage durations.

Engineers should be aware that some pedestrian crossing facilities can be operated using UTC timing plans with force bits (as described in B2.4.9.1). In those situations it is possible for pedestrian stages to operate for longer than their minima. It is the responsibility of the model developer to analyse the timing plans on all pedestrian crossing facilities to understand the adopted UTC control method.

2.4.10 Public Transport Surveys

The proposed scope of a traffic model will determine the level of detail required for public transport modelling, and should be evaluated through discussion with the scheme sponsor (see section A2.5). Essentially the modeller should be aware of all fixed public transport stopping points and routes traversing the modelled area during the period of study, including any rail replacement services that may be in operation. Public transport route maps[43] and timetables[44] are available from TfL. This material should be used to verify routes and stop locations, although data must be confirmed on-street before use in any modelling.

2.4.10.1 Bus Route Frequencies

Bus route service frequencies should be calculated per route from published timetables, for each period being modelled. Timetabled bus routes should be modelled separately from general traffic and therefore deducted from classified traffic survey counts. Any buses remaining after timetabled fixed routes have been deducted may be private coaches and 'out of service' buses. Where buses terminate within the modelled area site observations should record the route taken between bus route start and end points as this information is not published. Any significant discrepancies between scheduled and counted buses should be investigated.

2.4.10.2 Bus Journey Times

Bus journey time surveys should distinguish between in-motion journey time and stationary dwell time. This will separate the delay in journey times associated with difficulties in reaching and departing stop locations rather than including this delay as part of the bus dwell time.

Multiple repeat journey time observations should be collected for each route, during each peak period. 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. Where more than one public transport service follows the same route it is useful to undertake multiple journey time measurements for each service to derive a service-specific average journey time.

2.4.10.3 Bus Stop Usage and Dwell Times

Bus stop usage should be examined during site visits because the layout of a stop, as indicated on-site drawings, is not always indicative of how it is used on street. It is useful to consider the interaction with general traffic that occurs when a bus is waiting at a stop, for example the modeller can observe whether approaching traffic can pass a stationary bus or whether they give-way to oncoming vehicles. This can have an impact on road capacity, and hence journey time validation, for both private and public transport.

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43 **http://www.tfl.gov.uk/maps/**

44 **http://www.tfl.gov.uk/timetables/**

Similarly in order to accurately replicate bus journey times it is important to account for the dwell times of routes using the stop. The dwell time can include passengers alighting, buses waiting due to driver rest stops, driver changeovers and extended layovers used to regulate a timetabled bus service. Bus stop dwell times should be measured on-street, for each period being modelled. Measurements should commence once the service has stopped and end once the service is ready to depart (e.g. when a bus service has closed its doors).

The level of required detail will vary according to the model's purpose and the importance of accurate public transport representation. Where a high level of detail is required, dwell times should be measured for each bus route at every bus stop. Default values should not be used within micro-simulation modelling.

2.4.10.4 Bus Lane Usage

The distance at which a bus lane terminates before a junction should be observed during network familiarisation. Bus lanes influence the amount of available road space for general traffic. The methodology used to model bus lanes will vary according to the software platform and should be examined on a site by site basis. Modellers may also find it useful to note the frequency and volume of buses, cyclists, motorcyclists and taxis using a bus lane especially as within London the hours of bus lane operation can vary by day of week.

2.5 Model Development

Traffic models are developed to understand how a transport network may react to proposed change. To do this a traffic model is created which represents the existing situation. This model provides the benchmark against which any proposal will be compared. By comparing results between the existing and proposed situation an informed decision can be taken on whether to proceed with the proposal based on the impact it will have on the existing network.

Traffic models can be developed once the network familiarisation and data acquisition stages have been completed. Traffic model development often follows a defined sequence to create a common audit trail between model versions (see Figure 5). Generally an initial skeleton model is refined until fully calibrated and validated to produce an audited base model which is eventually developed into a proposed model. However, it is the responsibility of the model developer to generate a robust methodology that generates accurate fit for purpose modelling applicable to MAP, as described in B2.2.

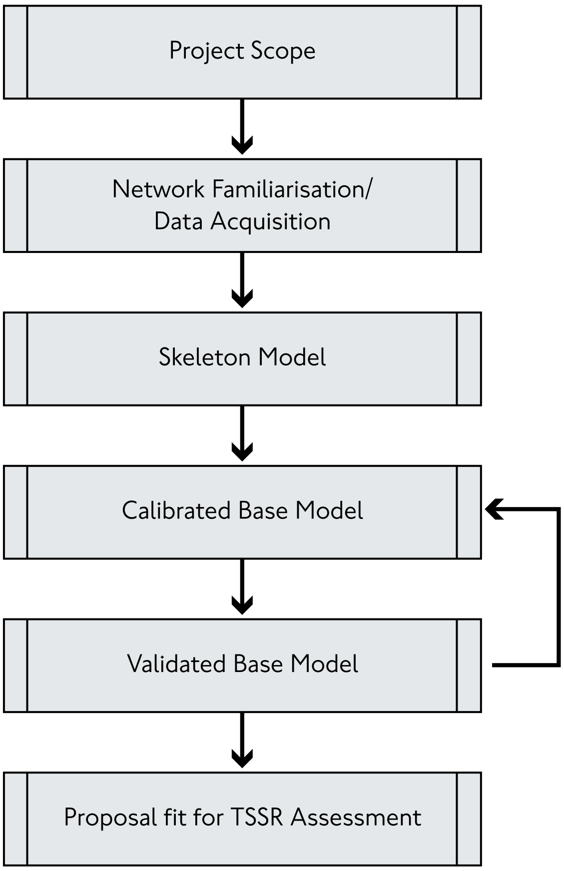

Figure 5: Schematic diagram outlining a generalised approach to traffic model development for TfL.

Accurate traffic modelling can better inform decision making and aid the development of optimal solutions. The following subsection will define different stages of traffic model development, their common use, and factors which require consideration during the development of a scheme proposal.

The exact nature of the required modelling elements will be defined by the scope as agreed during MAP Stage 1. The agreed purpose of the modelling will determine whether it is necessary to produce base, proposal and/or final signal timing models.

2.5.1 Versions of Modelling Software

Developers frequently release new versions of their software, either to introduce new features or to address specific software issues. Modellers should be aware of the software available and consider which version is the most appropriate to use for the model(s) being developed. Although it may seem probable, it is not always the case that the most recently released version of the software is the most appropriate one to use, even for development of entirely new models.

It is the responsibility of the modeller to determine the most appropriate version to use before commencing any modelling work. If a model is to be audited by TD according to MAP, it is important to consult with TD NP to confirm the software version currently available within TfL prior to commencing model development.

Under no circumstances should software versions change between the calibration of a base model and the production of a proposed model. Even with identical inputs, it is common for different software versions to produce different results. It will invalidate a previously validated model if it is used in a software version different from the one in which it was originally developed.

2.5.2 Base Model Calibration

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

Calibration describes the process of placing verifiable data into a traffic model to replicate observed street conditions. All input data for calibration should be auditable, such as signal timings and on-street measurements (e.g. lane distance, cruise times, saturation flows). It is usual for this information to have been collected from on-street measurements as described in section B2.4. Calibration may require the adjustment of model parameters to recreate observed behaviour, for this reason the calibration process should be applied to each period being modelled.

MAP Stage 2, described in B2.2, defines the requirements necessary to generate a calibrated model for both TRANSYT and VISSIM. It is advisable that a similar structured approach be adopted when using other traffic modelling software.

2.5.3 Base Model Validation

Validation is the process of comparing model output against independently measured data that was not used during the calibration process. The purpose of validation is to verify that a model has been correctly calibrated and is therefore capable of producing valid predictions for proposed scenarios.

As the overarching aim of validation is to produce a model that is fit for purpose, as described in B2.1.1, it is necessary to choose validation parameters that are relevant to the purpose of the model. The model developer should therefore identify suitable validation parameters at an early stage of model development and ensure they are recorded at the appropriate time (i.e. to coincide with site visits or traffic surveys). Ideally the modeller should be actively involved with on-site data collection, to be satisfied that street conditions represent those which are to be replicated in the traffic model. Common validation parameters such as degree of saturation and journey times are used to show confidence that calibrated model results accurately reflect observed on-street behaviour.

Validation criteria are used to demonstrate that the modelled results fall within an acceptable tolerance of measured data. These criteria vary according to the modelling software used, and are detailed both in MAP and relevant software chapters contained within these guidelines. If a model fails to validate it is often an indication that poor data collection practices were adopted or that further calibration is required. Results for the validation exercise must be taken from a model version which accounts for measured demand-dependency (see 2.4.9.3). Validated TRANSYT and VISSIM models are submitted during MAP Stage 3, as described in B2.2.

At the model validation stage any degrees of saturation produced by a model using stopline traffic flows should generally not rise above 100 percent. If instead they represent true traffic demand, as determined from an assignment model or survey well upstream of any queue, then the degree of saturation may exceed 100%. If this is the case validation should focus on comparing the capacity of the link in the model against site-measured spot counts.

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

- The measured flow data for a particular link is inaccurate, or has been entered into the model incorrectly;
- The saturation flow is too low;
- Signal timings have been entered incorrectly; or
- One or more demand-dependent stages have not been modelled correctly.

2.5.4 Proposed Model Development

The scope of a scheme proposal can vary from a minor adjustment of timings at a single site to a complete redesign of junctions, layouts and methods of control across a wide area. Traffic modelling must be generated at an appropriate scale to be considered fit for purpose. The scale of a proposal will also determine the most suitable modelling platform necessary to produce robust estimates of performance, for example small schemes may focus upon the quality of junction design, capacity, operational safety, needs of all road users, journey time reliability in the local network and emissions whereas larger schemes may examine wider network capacity, network stability, pollution, journey time reliability, demand management measures, and traffic re-assignment.

Proposed models are modified versions of validated and approved base models, as illustrated in Figure 6. Any changes to the base model should be limited to the minimum required to represent the proposed changes. When producing models of a proposed scheme it is essential that the model accurately reflects any changes which form part of the scheme, which should be discussed and agreed during MAP Stage 4 as described in B2.2. Care should be taken to ensure new or estimated data are verified with confidence before being introduced into the model.

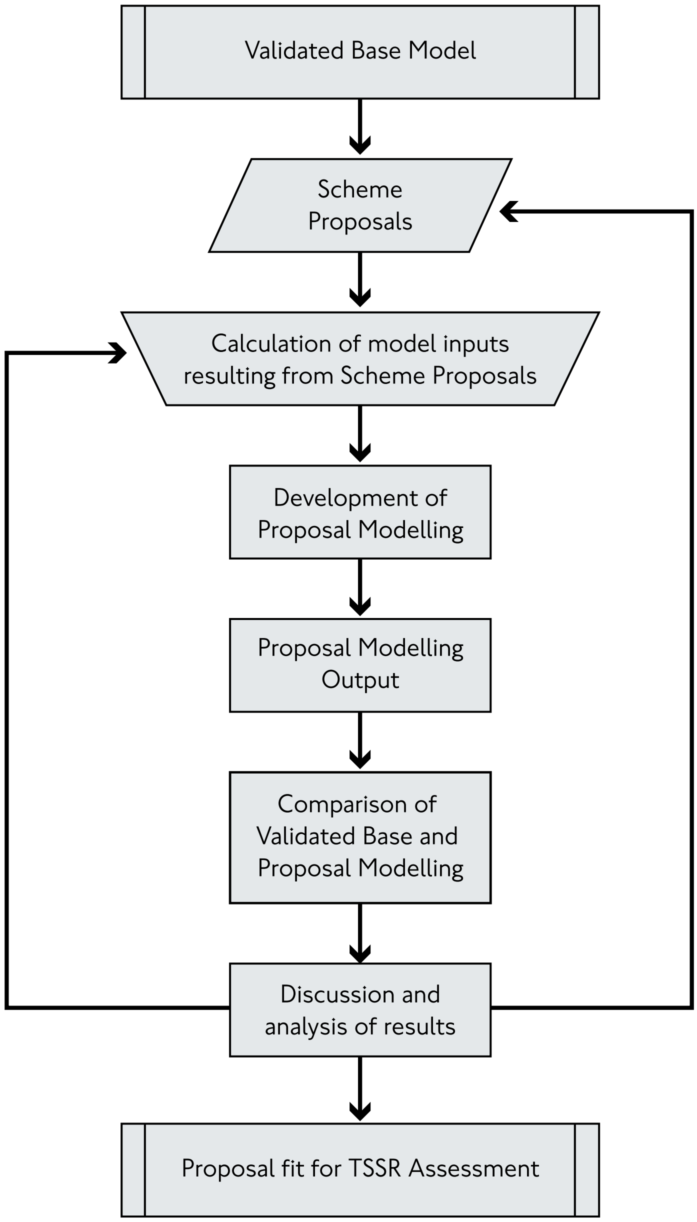

Figure 6: Development and evaluation of a proposed traffic model for TfL.

Every proposal is unique and it is beyond the scope of this document to list all the parameters that may need adjustment. It is the responsibility of the modelling engineer to determine the changes that are required and to justify any applied methodology. Proposed changes that may need to be accounted for within a traffic model include:

- Physical road layout and geometry;
- Lane markings and usage;
- Saturation flows;

- Methods of control at signalised junctions;
- Signal timings;
- Signal staging;
- Signal hardware;
- Traffic flows;
- Traffic compositions;
- Effective flare usage; and
- Demand-dependent stage frequencies.

When producing a proposed model it is important to consider the traffic management objectives of the scheme. Whilst overall network performance measures should be considered, these should not override considerations detailed in Part A such as local policy requirements or the Mayor's Transport Strategy 2010.

TD will use modelling output and analysis to make an assessment of the likely impacts of the scheme, and give recommendations to TfL Network Assurance Team via a Traffic Signal Supplementary Report (TSSR). A scheme designer should therefore understand the impact of all changes made to the base model.

2.5.4.1 Changes to Junction Design

Modifications to junction design or method of control may typically require a recalculation of phase minimums and phase intergreens. For this purpose reference should be made to TfL SQA-0064 which details pedestrian minimum and intergreen timings for pedestrian crossing facilities, including pedestrian crossings at signalised junctions. Calculation of phase intergreens for traffic must be undertaken in accordance with DfT guidelines[45], as referred to in DMRB[46].

Layout changes within a proposed design may also impact saturation flows. Where existing saturation flows are affected by new issues such as pedestrian movements or parking, the impact of these should be accounted for in saturation flow values used within the proposal modelling. To do this saturation flows should be estimated using RR67 for the base model geometry (see section B2.4.7.1). The difference between the measured value in the base model and the estimated RR67 value should be factorised and an adjustment applied to the saturation flow used within any proposed modelling for that junction approach.

It is recommended that changes to geometric inputs are assessed by processing a version of the proposed model incorporating just these changes, before applying changes to signal timings or traffic flows. This will allow the modeller to gain a rudimentary estimate of the impact of physical design changes on the performance of the study area.

45 *General Principles of Traffic Control by Light Signals*, TAL 1/06, Part 4, Department for Transport, 2006.

46 *Design Manual for Roads and Bridges*, Volume 8, Section 1, TA16/07, Highways Agency, 2007.

A proposed model should supply junction design information to a level of detail that allows the production of a Controller Specification. In order to reconcile phase-based signal design with stage based minima and interstage design it is recommended to use LinSig or OSCADY PRO and to supply these models with any submitted proposal. Inclusion of these controller models within a proposal provides a clear indication of how stage minimums and interstage designs were calculated and optimised.

Where critical offsets exist within a base model, such as within SCOOT multinodes, it is vital that these are coded accurately. Any fixed relationships should be audited by a checking engineer to ensure correct groupings are carried forward into any proposal.

Consideration should always be given to pedestrian linking during junction design. Pedestrian movement can be progressed through a junction by linking pedestrian phases, for example by using an associated parallel stage stream pedestrian crossing. Pedestrian considerations are outlined in Part A but designers should be mindful of optimising phasing and interstage design to maximise an opportunity for pedestrians to move smoothly through the network.

2.5.4.2 Changes to Traffic Flow

Proposed modelling should represent any significant changes to traffic flows or flow patterns which are expected to occur as a result of a proposal. Effective flare usage should be estimated based on the proposed flow changes using JCT's LinSat software. Where flows are unchanged, flare usage should not be changed from the calibrated values held within the validated base model.

2.5.4.3 Demand Dependency Adjustments

The validated base model on which the proposed model is based is likely to have been calibrated with demand-dependent stages appearing for only a proportion of the total cycles modelled. This will have been based on observed data and may be modelled using 'bonus greens', dummy stages or reduced stage lengths.

If the cycle time is changed in the proposed model then the number of demand-dependent stage appearances may need to be adjusted to account for the change to the total number of cycles per hour that will be modelled. Similarly, if the cycle time does not change but demand (either pedestrian or vehicular) is expected to change then consideration should be given to whether the frequency of demand-dependent stage appearances will need to be adjusted.

Allowances for demand dependency should generally be included during all full optimisation steps, as the model represents actual observed on-street capacity. Only when controller timings are to be produced should demand-dependency adjustments be removed, in order to generate optimum offsets for when demand-dependent stages appear.

2.6 Proposed Model Optimisation

In networks operating below capacity it is useful to coordinate the movement of traffic to enable efficient use of a network's geometric layout. The control of vehicles in a road network is usually promoted through efficiently linked traffic signal settings optimised for current levels of vehicle demand.

All signalised proposals should therefore undergo optimisation to ensure that the signal timings produced are the optimum timings for the demand scenario being modelled. This can be achieved through use of appropriate software to generate proposed timings or through analysis of timings in a micro-simulation environment. Micro-simulation packages do not yet have the ability to optimise traffic signal settings.

The software used for an optimisation will be dependent on the predicted level of saturation within the network. Aggregated behaviour models such as TRANSYT are appropriate for under-saturated networks, but for over-saturated networks a micro-simulation model like VISSIM is usually required, but in conjunction with a model suitable for initial signal optimisation.

The process to be followed when optimising a proposed traffic model depends on the modelling scope identified during MAP Stage 1, while the objective of the project determines the modelling outputs required during MAP Stage 5. Figure 7 demonstrates a generalised approach to model optimisation, containing each of the three main stages of optimisation that may be required:

- Phase One – Initial Optimisation, used to enhance signal timings after the major design decisions have been made within a proposal;
- Phase Two – Fine Tuning & Impact Assessment, used to hone signal timings which maximise performance within the proposal prior to impact assessment against the base; and
- Phase Three – On-Street Controller Timings, an optional stage based on model scope used to derive signal timings fit for direct implementation onto the street.

These optimisation phases are described in further detail below and flow diagrams are provided in Appendix II, to form a generalised framework within which the modeller can use engineering judgement to maximise the performance of a proposal relative to project scope.

The diagrams within Appendix II also highlight how the optimisation process can align with MAP, as introduced in B2.2. The most significant milestone dictates that final versions of proposed TRANSYT and VISSIM models are submitted during MAP Stage 5.

2.6.1 Initial Optimisation

The initial stage of model optimisation provides an opportunity to assess the performance of a proposal after major design decisions have been implemented, such as those outlined in B2.5.4. The initial optimised signal settings are usually automatically generated through an optimisation algorithm such as those employed within LinSig, OSCADY PRO and TRANSYT to reduce delay or increase capacity.

Major design decisions made during proposal development will broadly determine whether it is necessary to influence a software optimiser with weightings and penalties. These can be applied to encourage the optimiser algorithm to produce signal timings which reduce delay or limit queues in particular parts of the proposal.

During the initial stages of optimisation it is essential to analyse the impact of signal optimisation by considering modelled queue lengths, platoon progression and overall network or junction performance. This safeguard should enable a modeller to assess whether the fundamental aspects of the design and signal strategy are acceptable. An optimised proposal should only move into the fine tuning stage once the basic performance of the model is fit for purpose. The following subsections highlight issues which may be influential when determining whether a model can progress to a more detailed signal strategy stage.

2.6.1.1 Underutilised Green Time (UGT)

Underutilised Green Time may be present in a validated base model, representing lost time as a result of driver behaviour, localised junction characteristics or due to congestion and exit-blocking (as described in B2.4.8.1). Where UGT is modelled, it will have been based on site-gathered data and may be represented as negative phase lags or dummy stages.

> UGT adjustments should only be modified if the cause of the original UGT present in the validated base model is expected to change, for example if optimised splits or offsets are expected to reduce the onset of exit-blocking and congestion, or if physical layout changes are expected to influence the local characteristics and/or driver behaviour responsible for UGT.

UGT adjustment should be removed prior to initial full optimisation, and only re-applied when proposal impacts are to be assessed during fine tuning, prior to a final offset optimisation. If a model that has been used for a proposal impact assessment is subsequently used to generate on-street controller signal timings, the UGT adjustments should first be removed.

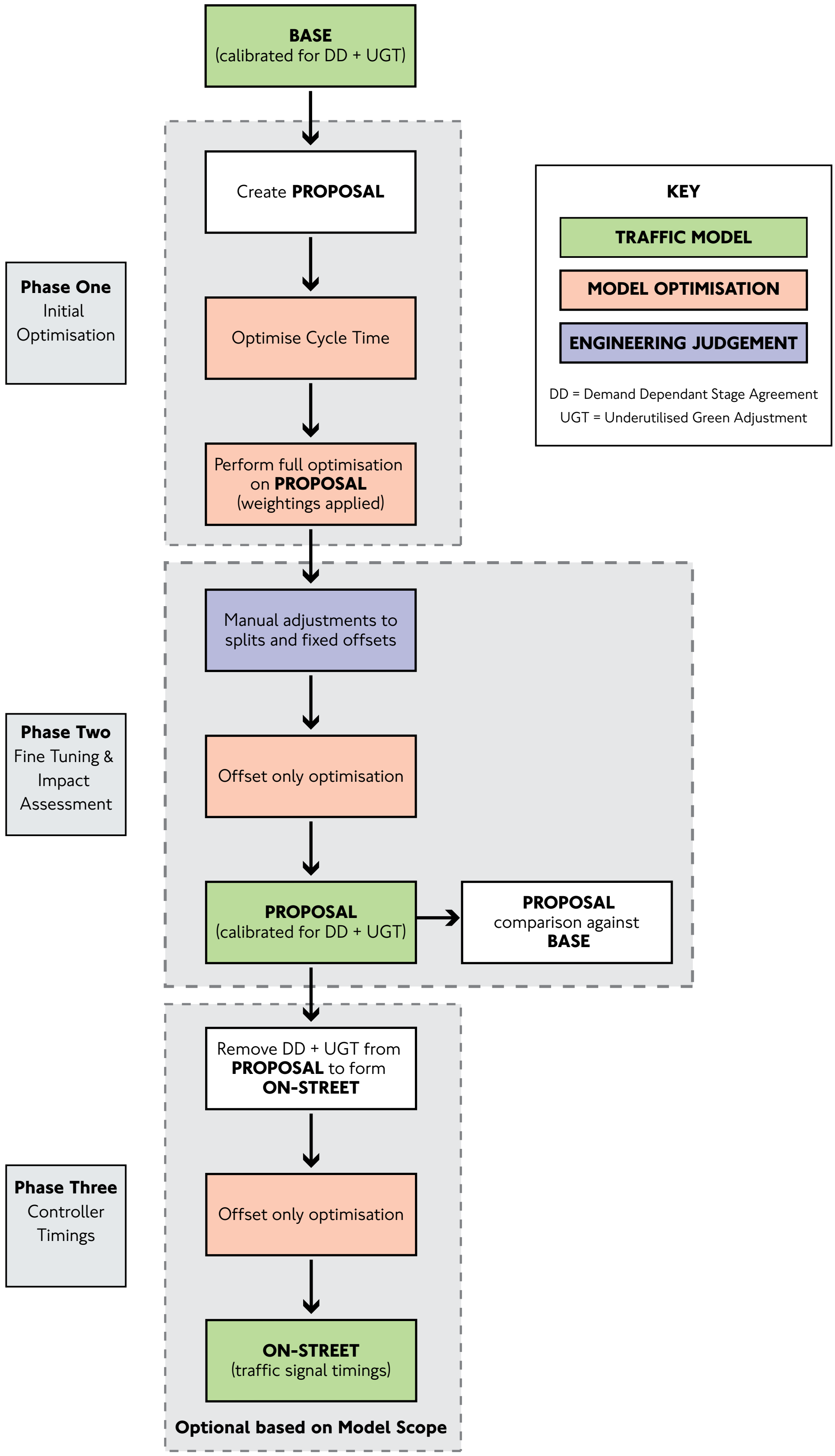

Figure 7: Overview of a proposed approach to traffic model optimisation.

2.6.1.2 Junction Storage Effects

Storage in front of stoplines for opposed turners are frequently modelled as ‘bonus’ green, in order to account for vehicles clearing during the intergreen period. Where storage bonuses have been modelled, they should not be removed from any optimisation steps unless physical layout or staging changes within a proposal prevent the storage in front of the stopline from being used.

2.6.1.3 Cycle Time Optimisation

Scheme designers should chose an optimum cycle time that balances road traffic demand with pedestrian delay. If a change to cycle time is under consideration then it is important to understand its impact upon delay to pedestrians, linking to other signals and the overarching objectives outlined in the Mayor’s Transport Strategy 2010.

The entire UTC control group should be modelled where a cycle time change is anticipated for a proposed scheme. Only SCOOT compatible cycle[47] times should be considered, even in UTC fixed time and non-UTC areas.

Cycle times should be kept as low as practically reasonable to minimise pedestrian delay, and ideally pedestrian waiting times should not exceed 83 seconds. The lowest UTC-compatible cycle time is 32 seconds. SCOOT nodes require an additional 4 seconds over and above the summation of SCOOT stage minima, meaning cycle times of lower than 64 seconds prohibit SCOOT double cycling.

Pelican sites should be designed to double cycle where appropriate. Designers can explore the possibility of increasing a junction cycle time to produce pedestrian benefits at other sites within the group. An increase in cycle time can facilitate double cycling, asymmetrical double greening or allow the provision of an extra stage that directly benefits pedestrians. Similarly a proposed cycle time increase at one junction, in order to accommodate a proposed pedestrian facility, should not have a detrimental effect on other facilities within the operational group. This may create additional delay to pedestrians and result in net disbenefit across the operational group.

2.6.1.4 Junction Performance

It is useful to be aware of the relationship between traffic delay and DoS in order to best optimise junction performance during proposal development. The relationship illustrated within Figure 8 strengthens the considerations outlined in Part A, which highlight the role stable network performance can play in maintaining journey time reliability. Engineers should be mindful that delay begins to increase exponentially above approximately 85% DoS. At junctions operating close to zero Practical Reserve Capacity (PRC), corresponding to approximately 90% DoS, small reductions in capacity can result in a significant increase in delay. For this reason a DoS of 90% represents an upper limit of practical capacity for signalised junctions. Unsignalised junctions typically have a lower practical capacity limit, with DoS in the range 80-85%. Junction capacity relationships are important when designing schemes in order to ensure that new proposals perform capably within the existing network.

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47 Allowable SCOOT compatible cycle times, in seconds, are: 32, 36, 40, 44, 48, 52, 56, 60, 64, 72, 80, 88, 96, 112 and 120.

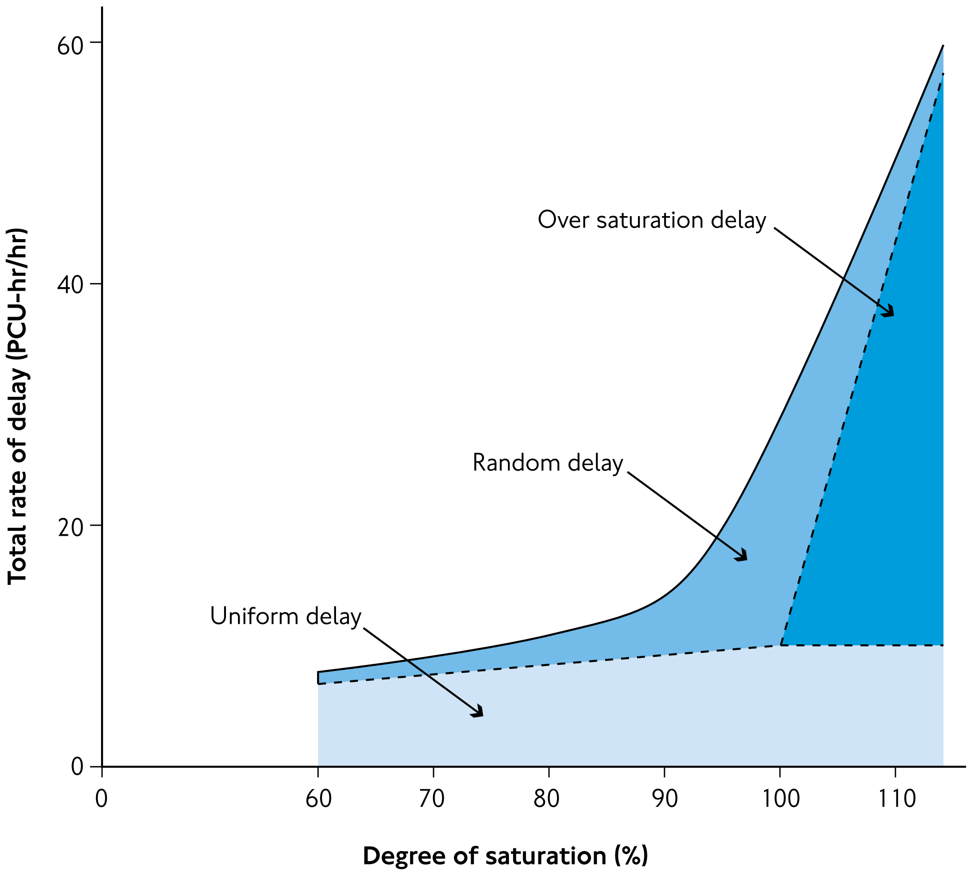

Figure 8: Relationship between junction delay and degree of saturation.

2.6.2 Optimisation Fine Tuning

The fine tuning stage of optimisation allows a modeller to manually influence the initial settings automatically generated by a software algorithm. It is at this stage where engineering judgement can maximise an opportunity to fully utilise the proposed design. The major design decisions have been completed and acknowledged as fit for purpose so this stage of the process evaluates how minor modifications to the proposal can maximise network performance relative to the base. The following subsections outline a few approaches to fine tuning which can be employed to generate an operable signal strategy.

2.6.2.1 Balancing the Network

A modeller can seek to achieve more balanced loading of the network if model output indicates that queue storage problems are apparent after initial optimisation. The available network capacity can be manually adjusted (e.g. through changes to green splits) during fine tuning, with the model then undergoing offset only optimisation to ensure good platoon progression but with a fixed network capacity.

Fixed relationship junction groups should not be changed from a validated base model without prior consultation with TD NP as these permanent offsets may be a prerequisite for any proposed timing plan.

2.6.2.2 Utilisation of Network Capacity

A modeller may decide it is more efficient for a proposal to contain fixed signal offsets to prevent cyclical problems caused by fanning, funnelling or exit-blocking. Within certain network layouts the use of a fixed offset can encourage drivers to fully utilise available capacity.

Under utilisation of upstream lanes can result from traffic funnelling over a short distance, e.g. due to a reduction of lanes for general traffic on the exit to a junction. The potential impact of traffic funnelling should be reflected in the upstream link structure of the model through the introduction of flares or by reducing the saturation flow assumption. Modellers should be aware of fanning when assessing the grouping of nodes. Fanning into a wider carriageway may prevent downstream links from fully contributing towards stopline capacity. Where this is the case a modeller should manually apply a fixed offset to ensure full lane saturation by only allowing platoon progression once all lane storage has been utilised. Fanning may prevent downstream lanes from contributing to capacity where it is not possible to fix the offset, in this case reduced upstream saturation flows should be applied to the downstream links.

Once the modeller is satisfied with the operation of internal links a manual optimisation can be performed. The modeller may decide to audit cyclic flow profiles to ensure appropriate front and back end platoon coordination exists between closely associated links. This analysis should confirm whether the proposed traffic control strategy of fixed groupings is being implemented properly and provides an opportunity to further fine tune offsets and promote efficient lane utilisation, platoon compression etc.

2.6.2.3 Protecting the Network

Where a proposed network is operating close to its limit of practical capacity it may be necessary to protect the network from unexpected traffic fluctuations. The modeller can mitigate this risk by manually adjusting green times to saturate any under-saturated external (entry) links. This strategy can be used to prevent internal links becoming overwhelmed with traffic that cannot be stored within the network. Over-saturated internal links can lead to high levels of unpredictable delay and poor journey time reliability within a proposal.

2.6.3 Proposal Evaluation & Impact Assessment

As any proposal is a forecast there is no observable data to validate against model output. Validation of a proposed model is therefore accomplished by analysis of the approach taken by the model developer and output results from the proposed model.

Figure 6 illustrates the iterative process of using proposed model results to analyse the predicted impact of scheme proposals on the network. Modelling and/or scheme proposals can then be updated and reassessed as necessary, depending on the impacts predicted.

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

- Degrees of saturation;
- Link capacities (PCU/hour);
- Junction practical reserve capacity;
- Maximum average queue lengths;
- Cyclic flow profiles (CFP) for critical links (short/highly saturated);
- Percentage green per junction wasted due to exit-blocking;
- Average delay per vehicle per link;
- Average delay per bus per link;
- Percentage of buses per route waiting more than one cycle to clear nodes;
- Mean travel time and standard deviation for private and public transport along pre-defined routes; and
- Mean pedestrian travel time along pre-defined routes.

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 TD NP and other key stakeholders, e.g. FPT and the local Boroughs, before they are produced.

2.7 Model Reports

Reporting should reflect the logical approach taken by a modeller to resolve the complex and iterative nature of traffic modelling. It should emphasise the sound engineering principles adopted during model development. Without accurate reporting the model development process is hindered by a lack of historical information. The following subsections outline an approach to model reporting which should allow a third party to accurately comprehend the decisions made during the development process from network familiarisation through to proposal evaluation.

A traffic model may be developed over a period of months or even years by a number of different engineers. While developing a model the engineer should retain detailed notes that include a record of all assumptions and modelling decisions. These notes should be kept for future reference, and can form the basis for subsequent reporting.

It is the responsibility of the engineer and the scheme sponsor to ensure that all reporting is accurate, thorough and sufficient, and that submitted documents are fit for purpose to adequately support accompanying models.

2.7.1 Calibration Report

A calibration report should present all relevant survey data and include a history of model development.

Model auditing will rely on the report to explain how the model has been calibrated. For this reason the calibration report should focus on presenting traffic model inputs and detailing how the model has been developed to ensure that it represents existing conditions. In particular, the following should be included:

- The stated purpose of the model;
- A list of all TfL-referenced sites in the model, with addresses and where required a note detailing any operational relationships (e.g. UTC multinodes and subgroups);
- Clear notes on site observations and measurements, covering both the physical network and observed vehicle behaviour. Where behaviour is specific to a particular time of day, this should be noted along with how it has been accounted for in the model;
- Site data highlighting measured saturation flows, cruise times and effective flare lengths;
- Table of saturation flows for each link in the network, indicating whether values have been measured on-site or calculated. If calculated (e.g. using RR67) a justification describing why measurement was not possible; and
- Description detailing the extraction method used to obtain signal timings, including source of data (e.g. fixed time UTC plans, CLF timings, or average timings representing SCOOT operation).

Specific calibration reporting requirements for TRANSYT and VISSIM are detailed in MAP Stage 2, as described in B2.2.

2.7.2 Validation Report

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

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

- Details of traffic flows used, when they were recorded and who recorded them and how the peak hour was chosen;
- Demand-dependency calculations, including source data and how demand-dependency has been accounted for in the model;
- Validation data, such as vehicle journey times or DoS;
- Relevant site observations not already included in the calibration report, such as give-way behaviour, exit-blocking, flare/non-green usage, parking/loading and bottleneck details; and

- Evidence of validation, comparing modelled results to on-street observations and measurements. Any discrepancies should be analysed and discussed.

Specific validation reporting requirements for TRANSYT and VISSIM are detailed in MAP Stage 3, as described in B2.2.

2.7.3 Proposal Report

The report accompanying any proposed model must give a full description of the proposed scheme and any expected scheme impacts (e.g. any expected changes in demand). The modifications made to the validated base model to develop the proposed model should all be based on these key details. All changes made in order to develop the proposed model should be documented by the modeller, along with the reasoning behind them. Specific items that could therefore be included in the proposal report are:

- Scheme summary;
- Scheme objectives/problem;
- Proposed traffic management strategy;
- Evaluation of proposal results;
- Conclusions and recommendations;
- Design summary sheets;
- Model source data;
- Modelling assumptions;
- Electronic copies of model input file;
- Electronic copies of skeleton LinSig stage/interstage diagrams; and
- Model audit trail with full version control.

Results of the proposed model should be compared to the validated base model. This should be done for all modelled periods to demonstrate the impact of the proposals on the network. The proposal report should include a discussion of results. It is useful to include a section detailing the impact of any geometric changes as this enables TD to make informed decisions about preferred design options. Version control should be applied to all design documents to avoid ambiguity thus ensuring all parties are aware of the current design status for each proposed model.

All data presented with the validated and approved base models should be presented within the proposal. TD will use modelling output and analysis to make an assessment of the likely impacts of the scheme. Data provided with the base and proposed model submissions will be considered when producing the TSSR, therefore it is in the scheme sponsor's interest to ensure proposed model submissions are provided with detailed analysis.

Specific proposal reporting requirements for TRANSYT and VISSIM are detailed in MAP Stage 5, as described in B2.2.

3 LinSig Modelling

3.1 Introduction

This section is designed to assist experienced practitioners when building LinSig models of London's road network. It is useful to have read the guidance in B2: Modelling Principles prior to reading this section.

LinSig, developed by JCT Consultancy Ltd (JCT)[48] , can be used for detailed junction design, assessment of scheme proposals and the creation of skeleton models for checking against junction Controller Specifications. It combines geometric layout, traffic and controller modelling to ensure that LinSig accurately reflects the way existing junctions work, and how any design proposals would operate if implemented.

In terms of optimisation of junction performance, LinSig allows the modeller to maximise the efficiency of interstage design and is capable of optimising signal timings to either minimise delay or maximise Practical Reserve Capacity (PRC). Additionally, LinSig has a cycle time optimiser, which allows selection of an optimum cycle time by showing how delay and PRC vary against cycle time increments.

LinSig has traditionally been used for the design and assessment of isolated signalised junctions, and is used by the majority of UK Highway Authorities, consultants and traffic engineers for this purpose. Since version 2 it has also been capable of modelling small networks, typically representing closely associated junctions and pedestrian

48 **http://www.jctconsultancy.co.uk**

streams running off a single controller. LinSig version 3 is now capable of modelling multiple controllers and therefore larger networks.

3.2 LinSig Version 3

LinSig version 3 offers the possibility of modelling large networks traditionally associated with TRANSYT, however it is not yet widely deployed or used within TD NP for this purpose. An evaluation of LinSig version 3 is being carried out by TD NP to produce an updated MAP. It is expected that the content of this chapter will evolve as more experience is gained modelling large networks in LinSig. The remainder of this chapter is written in relation to LinSig version 2, although much of what is written may still be of relevance to version 3.

Network models completed in LinSig version 3 are not currently accepted by TfL and will not be audited by TD. This situation will be reviewed once MAP has been updated to include LinSig.

3.3 Appropriate Use of LinSig

This section describes some of the circumstances when it would be most appropriate to develop a LinSig traffic model.

LinSig should only be used to model isolated signalised junctions, or small groups of signalised junctions. The applicability of LinSig for modelling multiple junctions should not be determined from the physical distance between intersections, but from traffic behaviour between neighbouring junctions and whether they are controlled by a single controller. The junction(s) to be modelled should be discussed and agreed during TMAP Stage 1 as described in B2.3.1.

It is possible to model priority intersections within a LinSig model but this is only appropriate where they form part of a larger signalised junction.

3.3.1 Skeleton Models

LinSig models do not have to include any modelling of traffic flows when used solely for the purpose of assessing the phase-stage relationship at a junction. These skeleton models are effectively a ‘control data only’ representation of the controller. A LinSig skeleton model can be used to assess phase or stage minima and interstage durations. Within a skeleton model the stage sequence should be based on current UTC or CLF timing plans. To get a true picture of the stage minima information it is necessary to reduce LinSig to the minimum cycle time.

Skeleton LinSig models are best used to augment junction analysis, for example when full modelling (including flows) will be conducted separately in TRANSYT or VISSIM.

TD NP recommends that individual LinSig skeleton models are prepared for all junctions within TRANSYT and VISSIM models. This will benefit both modeller and auditor, as it ensures accurate representation of phases, phase minimums, stages, stage sequence, phase delays and intergreens.

The JCT software package TranEd includes a useful function which allows phase/link conversion for TRANSYT. However TranEd does not negate the usefulness of LinSig as an auditing tool, for example, LinSig will allow the correct phase-stage representation of parallel stage streams in separate nodes.

3.3.2 Isolated Junctions / Multiple Streams with Single Controller

LinSig is suited to modelling junctions which are sufficiently isolated from other signalised junctions that coordination to upstream/downstream intersections is not a requirement.

It can also be used to model a small traffic signal group consisting of multiple streams controlled by a single controller. When modelling small networks LinSig is not capable of modelling the causal reasons for poor network performance but can model the effect of exit-blocking upon a junction where input data is manually adjusted (see B3.6.9). However, under these circumstances consideration should be given to using micro-simulation modelling, for example, to model both the cause and effect of pan-network exit-blocking.

3.3.3 Networks

LinSig is not currently recommended for building large networks (see B3.2).

3.3.4 Proposed Design Changes

LinSig can accurately represent controller behaviour by taking into account the features and constraints of specific controlling equipment. For this reason LinSig models should be produced to allow auditing of proposed changes to a junction's method of control. The provision of a LinSig model ensures that TD can assess the proposal with confidence, knowing that they are modelled accurately, and appear as they would operate if implemented on-street.

LinSig models are often sufficient for local schemes such as carriageway closures, changes to junction method of control or signal timing revisions. However, LinSig is often unable to provide suitable representation where more complex situations exist such as vehicle merging, junction exit-blocking or the dynamic operation of demand-dependent stages. In such cases other modelling software may be more appropriate.

3.4 LinSig Modelling Approach

LinSig can optimise signal timings using two different objectives, by maximising Practical Reserve Capacity (PRC) or minimising total network delay. These criteria may lead to similar results but the choice of method should be determined by the modeller based on the design objectives agreed during MAP Stage 1.

LinSig selects initial signal timings using a simple analytical junction model to calculate optimal green splits. This initial simulation excludes many aspects of the full model, but uses more than one variant to ensure final settings are not overly dependent on a single estimate of initial signal settings. LinSig then uses a hybrid strategy based on a combination of traditional optimisation methods to determine where changes to initial green splits and offsets could potentially improve network performance. The traffic model then reruns using the potentially improved signal timings. If it is shown that these timings were better than previous results LinSig uses these timings to try and predict further improvements. LinSig monitors progress to target optimisation effort at the areas where most improvements are likely to be realised.

LinSig does not run the optimisation process for a fixed number of iterations. JCT feel a fixed approach can risk the optimiser terminating early with complex networks, leading to signal timings that do not represent optimal network performance. LinSig instead varies the number of iterations according to the complexity of the network and other issues such as the level of traffic in the network. LinSig will let the optimiser continue where significant improvements are gained with a relatively minor extension of the run time. When the optimiser fails to achieve improvements within an acceptable time the optimisation process will terminate.

3.5 Program Settings

The LinSig program settings for a model can be completed as detailed below.

3.5.1 Junction Details

The 'Junction Details' section should be completed to aid model auditing by including the location of the junction(s), the purpose of the model and the information source used to build the model. Useful information could include:

- TfL site reference;
- Scheme title;
- Location (e.g. identification of intersecting roads);
- Time period being modelled; and
- Whether a base or proposed model.

For TfL modelling it is compulsory that the source of the controller data used to build the model is specified:

- Details of controller data source (e.g. Signal Timing Sheet issue number and/or Controller Specification issue number).

3.5.2 Controller Details

For an existing junction, the controller type should reflect the manufacturer of the hardware that is on-street, as identified in the Controller Specification and/or Signal Timing Sheet. For a proposed junction that does not currently exist and for which the hardware to be used is not known, the controller type should be set to 'generic'.

It is important that when modelling existing junctions, the phase minimum type is set to 'controller phase minimums' and not 'street phase minimums'.

3.6 Model Build

The following section describes some of the steps involved in building a LinSig model and identifies issues requiring consideration.

Prior to building a model in LinSig the following information should already have been obtained, as identified in sections B2.3 and B2.4:

- Site Layout Drawings and SCOOT Link Diagram (if applicable);
- TfL Controller Specifications and Signal Timing Sheets;
- Site-measured values for link length, cruise time, flare usage and saturation flow. Where measurement has not been possible, estimates should be used with appropriate justification (e.g. RR67 for saturation flows or extrapolated cruise times if conditions are permanently congested);
- Stopline traffic flows by turning movement;
- Determination of average signal timings, either from the UTC system or site measurement; and
- Site observation of traffic behaviour, particularly lane usage and effective flare length.

3.6.1 LinSig Model Structure

The modelled network within LinSig is displayed in the Junction Layout view, and is represented as a collection of arms, links and lanes. Creating a suitable link and lane structure is one of the most important aspects of building a LinSig model, as it determines how traffic behaviour will be replicated in the final model.

A diagram showing an example junction in LinSig's Junction Layout view is shown in Figure 9.

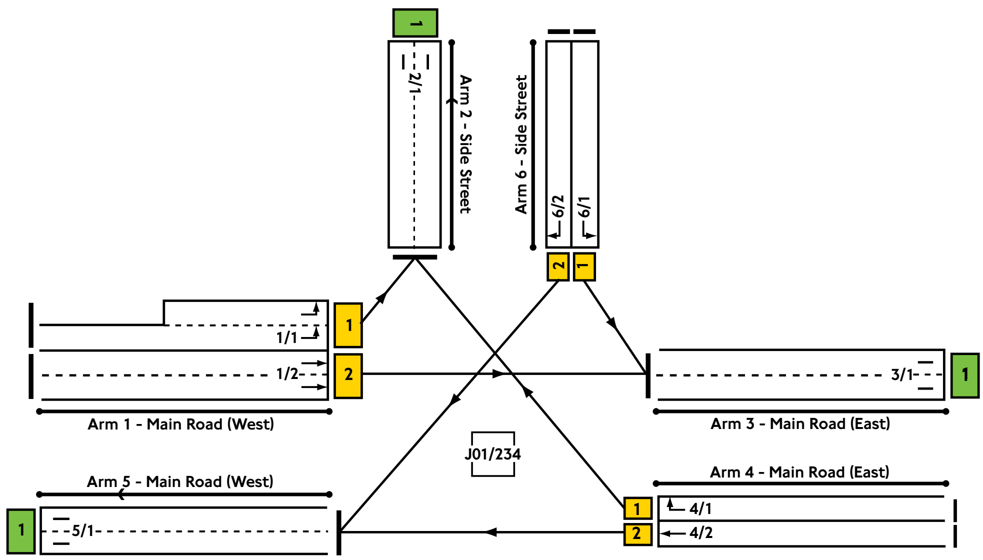

Figure 9: Example junction showing arms, links and lanes in LinSig.

An arm represents a one-way section of road within the modelled network, which should therefore contain at least one link and one lane. Arms play no specific part in the modelling process, but allow individual groups of links and lanes to be graphically manipulated as a single entity. Similarly, arm groups can be created which allow multiple arms to be manipulated as a single entity, for example allowing separate manipulation of all arms at a junction from the arms associated with a stream. It is important from an auditing point of view that each approach arm is correctly labelled with the relevant street name (or similar) as the link numbering system within LinSig is arbitrary. Where arm groups are used these should also be labelled to describe what they are intended to represent, for example using a junction or stream site reference number.

A link consists of a group of lanes within an arm, representing an independent stream of traffic passing through the arm that does not impact or interact with other traffic streams on the same arm. A link must always contain at least one lane, and all lanes within the link must share the same green signal (i.e. signal phase). All traffic flows and queuing within a link is assumed to be equally distributed across all full lanes within that link, therefore consideration should be given to whether it is appropriate to group adjacent lanes within the same link. Once all links have been defined, link connectors should be added between upstream and downstream links to represent all possible traffic movements.

Each lane that exists, or is seen to function as a separate lane during on-street observation, must be modelled as a separate lane within a modelled link. A lane is defined as either infinitely long or short. A long lane extends sufficiently far back towards the upstream junction that it always behaves as a dedicated lane over the available green time, whereas a short lane represents a flare, only contributing as a full lane for a portion of the available green time. Short lanes must be grouped in a link together with at least one adjacent long lane that it will interact with.

Any link within the LinSig model that does not have a link connector leaving the link will be treated as an exit link. Pedestrian phases are not represented as links within the Junction Layout View in LinSig 2, although for auditing purposes they must still be included within the controller model and any associated staging.

3.6.2 Traffic Flows

Traffic flows are assigned to routes using a zone-based origin-destination (O/D) matrix within LinSig, with individual entry and exit arms assigned to the different zones. Traffic flow data for LinSig models should be fully classified turning count data, converted to equivalent PCU values (see B2.4.3.1).

For a small group of closely associated junctions an O/D survey should ideally be used if a single junction turning count survey is not suitable. However where this is not possible separate junction turning count surveys should be used and converted into a combined O/D format, utilising manual flow smoothing as detailed in section B2.4.3.

3.6.3 Routing / Lane Usage

When flows have been entered into LinSig, they are assigned to routes based on all possible zone-to-zone routes available in the model. Where choices of route are available (e.g. due to links with mixed lane usage), LinSig uses a flow balancing technique to ensure equal flows are assigned across all lanes on individual junction entry links. The modeller should ensure traffic flows have been assigned correctly where multiple route choices are available. If necessary, based on site observation, flows on specific routes may need be manually 'locked' using the 'Traffic Flows View' to get correct link/lane usage before allowing LinSig to allocate flows along other permitted routes.

If circular routes are possible within a model, typically for roundabouts but also with closely associated junctions, these routes must be manually checked in the 'Route List' of the 'Traffic Flows View'. If unrealistic routes are generated, i.e. those that are not observed on-street, these should be removed using the 'Edit Permitted Routes' feature. This is similar to the process followed when using another JCT product called FlowRound.

3.6.4 Saturation Flows

Saturation flows should be measured on-street for all critical links, as described in B2.4.7. Saturation flows for links in LinSig are determined from the contribution of all lanes within the link, therefore saturation flows should be directly entered for each lane included in the LinSig model. Where on-site measurement is not possible, RR67 values (described in B2.4.7.1) can be manually calculated and directly entered into the model, or alternatively geometric parameters can be entered into LinSig (lane width, gradient and turning radius) from which RR67 values will be calculated automatically.

Any link within the LinSig model that does not have a link connector leaving the link will be treated as an exit link. If saturation flows are directly specified for these links they should be suitably high (e.g. 8000 PCU/hr) so that artificial and unintended queuing does not occur on the exit of the network, which may be the case if default values are used or if the exit link contains an insufficient number of lanes. A recommended alternative is to specify all exit links as being 'unconstrained (infinite saturation flow)' to ensure traffic will incur zero delay when exiting the junction. Where queuing is observed on a downstream exit from a modelled junction then the modelling approach and use of LinSig should be re-assessed.

> Saturation flows are required for each lane or identically performing group of lanes within the model.

3.6.5 Flare Usage

Flare usage, when applicable, should be included as described in B2.4.5, and entered directly into the model for each period being modelled. It is recommended that modelled flare usage should be within 10% of observed flare usage.

> Physical flare length in LinSig 2 models is for graphical and reporting purposes. The average effective flare usage should be calculated from site measurements and entered into the model.

LinSat should be used to estimate flare usage where site measurement is not possible. Typically LinSat should be used only for proposed models but may be applicable to other situations which should be clearly noted in accompanying reports.

3.6.6 Priority Give-Way Parameters

For priority movements that give-way, the LinSig model requires entry of two essential parameters:

- 'Maximum Flow while Giving Way', which describes the maximum flow rate of traffic in the absence of an opposing flow, but while still giving way to the opposing movement. This is often called the intercept, as it represents the intercept with the y axis when the flow giving way (y axis) is plotted against the opposing flow (x axis). It is measured in PCU/hr; and
- Give-way coefficient, which describes the assumed linear gradient relating how the flow giving way decreases as the opposing flow increases.

JCT recommend the use of standard give-way parameters for different types of opposed movements, such as an intercept of 1440 PCU/hr and slope of 1.09 for opposed right-turns at signalised junctions and an intercept of 715 PCU/hr and slope of 0.22 for give-way-controlled left-turns[49].

3.6.7 Opposed Right-Turning Vehicles

The ability to accurately model right-turning vehicles requires careful site observation and entry of LinSig parameters. Particular attention should be paid to recording and calibrating:

- Storage in front of the stopline;
- Non-blocking storage;
- Maximum number of turners in intergreen (which may be less than the storage in front of the stopline); and
- Right-turn factor.

The right-turn factor controls the amount of bonus capacity available due to storage in front of the stopline. Its default value is 0.5 and should not be changed unless observed on-site. Any amendment should be reported and supported by site data.

For opposed right-turns which are subsequently unopposed (i.e. indicative arrows), it is imperative to set the 'Saturation flow when opposing traffic is stopped' to the appropriate link saturation flow. This can be important where a lane contains a mixture of opposed and unopposed movements that can lead to the obstruction of unopposed movements. For right-turns which remain opposed at all times, this should be set to the maximum flow while giving way (as entered in the give-way parameters).

3.6.8 Demand-Dependent Stages

The frequency of demand-dependent stage appearance should be measured directly from the UTC system, or through on-street observation in the case of VA sites, as described in B2.4.9.3.

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49 Moore P, Simmonite B & Reid D, *LinSig Version 2 User Guide & Reference*, JCT Consultancy Ltd, V2.4A, Ch 4, 2007, pp144-145.

In LinSig, it is possible to account for demand-dependent stage appearance by running the stage sequence for multiple cycle lengths with the demand-dependent stage appearing only once in the total sequence.

3.6.9 Exit-blocking

Exit-blocking can be accounted for in a LinSig base model through the use of dummy stages, where exit-blocked phases are removed to replicate lost capacity. The application of this technique needs to be supported by site observation and empirical data such as Underutilised Green Time (UGT) measurements.

It is important to note that the cause of exit-blocking cannot be modelled in LinSig. Where endemic exit-blocking exists within a network, consideration should be given to applying micro-simulation modelling which can represent both the cause and effect of exit-blocking.

3.7 LinSig Output

LinSig offers a variety of output features that can aid in the analysis and reporting of model performance, which are detailed in this section.

3.7.1 Link Results

The link results view allows data and performance statistics to be displayed for every link in the model. The exact data that is displayed is user-customisable, but can contain a mixture of input data (flows, saturation flows, phase letters, link green times etc) and output data (DoS, delay and queue information).

As well as identifying performance parameters for individual links, the link results view also displays PRC and delay information for streams or the entire model. Results for individual links can also be further broken down into specific routes through individual links.

3.7.2 Cyclic Flow Profile and Uniform Queue Graphs

Cyclic Flow Profile (CFP) graphs show traffic flow arrival and discharge patterns for a particular stopline during a typical cycle. These can be plotted for either individual links or for whole routes. Where CFPs are plotted for an individual link they can be set up to show either arrival and/or discharge flows, and can be further broken down into flows associated with individual routes. Where a whole route is plotted, multiple CFP graphs are provided at all stoplines along the route, allowing analysis or platoon progression along the route selected.

Uniform queue graphs can also be plotted for individual links. These show the uniform component of a queue, not including random and oversaturated queue components.

When a link has a DoS less than 80% the uniform queue is an accurate representation of the average queue on a link, however when operating above 90% the random and oversaturated queue components become more critical and the uniform queue graph should not be relied on to predict queue storage issues.

3.7.3 Report Builder

The Report Builder allows various LinSig modelling information to be extracted and presented in a customisable manner, either for direct analysis or further editing in word processing software. Such information can include graphical views of almost any of the LinSig program views (junction layout, stage views/sequences, signal timings, interstage timings etc) or data in tabular form such as input data or model performance statistics.

3.8 LinSig Calibration Requirements

A calibrated LinSig base model is defined as being a model which has the correct geometric and signal timing inputs, but does not contain flows or signal timing adjustments for demand-dependency or exit-blocking.

The purpose of the calibrated model is to allow the developer and any model auditor to assess the model structure and arrangement. At this stage it may be possible to identify any issues relating to the development of the model. The model developer should therefore ensure that a copy of the calibrated model is kept on file for future reference.

There is no Model Auditing Process (MAP) specific to LinSig modelling. It is advised that modelling should follow a similarly structured auditing process to that used for TRANSYT development (TMAP).

3.9 LinSig Validation Requirements

It is essential that a base scenario LinSig model is validated against the existing network using current signal timings, as described in B2.5.3.

A validated LinSig base model is normally identical to the calibrated model, but includes traffic flows and accounts for any measured demand-dependency or exit-blocking.

The following can be used as validation criteria:

- Degrees of saturation within 5% of observed values; and
- Average queue lengths at the start of green approximately equal to observed values.

If modelled flows are based on surveyed stopline turning counts then degrees of saturation at those stoplines should not exceed 100%, as explained in B2.5.3. If any link has a degree of saturation above 100% it should be investigated before proceeding, as it is usually a sign that the model is seriously in error.

3.10 Developing Proposed Models

Proposed models should be based on a validated base model. The base model should be modified to fully describe the proposed scenario, as described in B2.5.4.

Where flows are predicted to change following implementation of a scheme, flare usage should be estimated using LinSat. Flare usage should be presented as in the validated base model when flows are not predicted to change. Where timings at an existing site are not compliant with SQA-0064 requirements, proposed modelling reports should include results with 'existing' and 'existing plus SQA-0064 timings'.

3.10.1 Cycle Time Optimisation

The Cycle Time Optimisation view can be used to assess the optimum cycle time for a LinSig model. This feature plots PRC and delay results for a model against cycle time, for a range of cycle times and cycle time increments specified.

The most appropriate cycle time must be chosen by the modeller and manually applied in the LinSig model. Section B2.6.1.3 provides guidance on available cycle times and important considerations which may influence the choice of cycle time.

3.10.2 Signal Timing Optimisation

Signal Timings in LinSig can be optimised either for minimum delay or maximum PRC, depending on which is considered the most appropriate methodology during the initial determination of model scope. The generic procedure for optimising a traffic model is discussed in section B2.6. During the initial optimisation phase, signal timings within LinSig can be influenced if desired through the following link parameters:

- Excess Queue Limit (PCU) – this is used to specify the acceptable limit for a queue on a particular link, accounting for limited storage space on the link that may lead to blocking back to upstream links. If the queue extends beyond this limit LinSig will attempt to adjust timings to reduce the queue;
- Degree of Saturation Weighting (%) – this value is only used when optimising for PRC, and determines the aggressiveness LinSig will use in reducing the average excess queue where an excess queue limit has been applied; and
- Delay Weighting (PCU Hr) – this serves the same purpose as the Degree of Saturation Weighting, but is used when optimising timings for delay rather than PRC.

3.11 Additional LinSig Modelling Issues

3.11.1 Sliver Queues

Due to the simplified mathematical nature of a deterministic software model, behaviour can sometimes occur that whilst mathematically correct does not actually happen in the real world due to driver behaviour. An example of this within LinSig is the formation of 'sliver queues'.

A sliver queue occurs when vehicles are approaching the back of a discharging queue of traffic. In practice, drivers will typically regulate their speed if they see a queued vehicle in front of them is about to accelerate, whereas in LinSig they are assumed to progress at free-flow speed until they join the back of the stationary queue. This can lead to successive vehicles joining the back of a modelled queue which leads to excessive and unrepresentative queuing behaviour. A modeller can set a 'de-sliver threshold' (in PCUs) in order to prevent the formation of sliver queues. This value is the minimum queue that will actually form on-street meaning LinSig regards anything less than this value as a sliver queue.

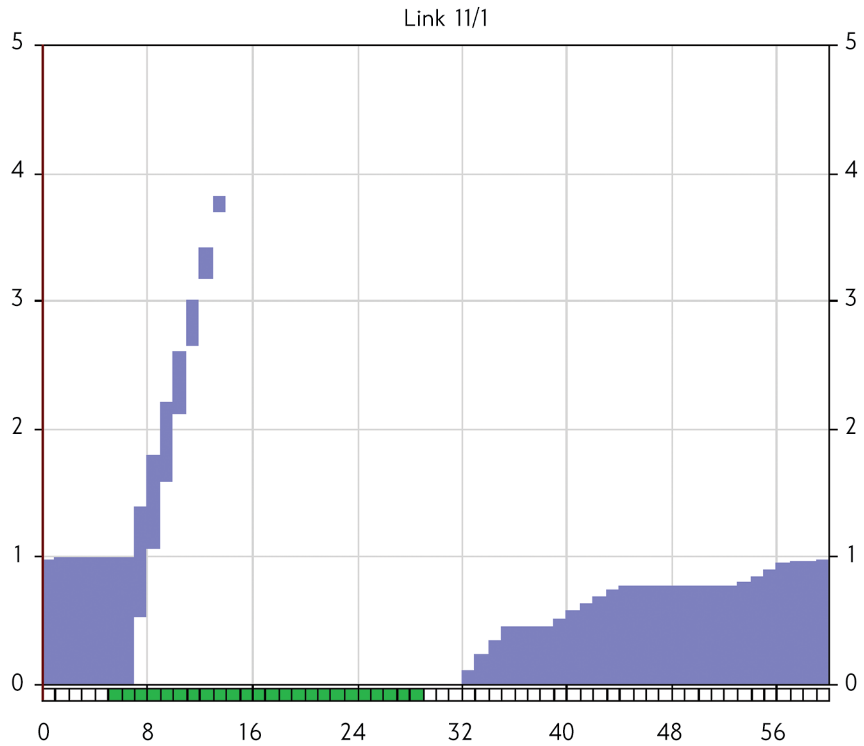

Figure 10: Formation of a sliver queue in a LinSig uniform queue graph.

A modeller can recognise the formation of a sliver queue by examining the LinSig queue data or a uniform queue graph. As Figure 10 illustrates, the data will highlight a small amount of traffic in the queue relative to the total queue length. Figure 11 shows the same link with a de-sliver threshold of 1.0 PCU applied.

Where a sliver queue has been identified it is acceptable to enter a de-sliver threshold value of no more than one PCU. It is recommended that values of less than one PCU are used to achieve the desired effect. Where this function has been used it should be clearly stated within the accompanying model report.

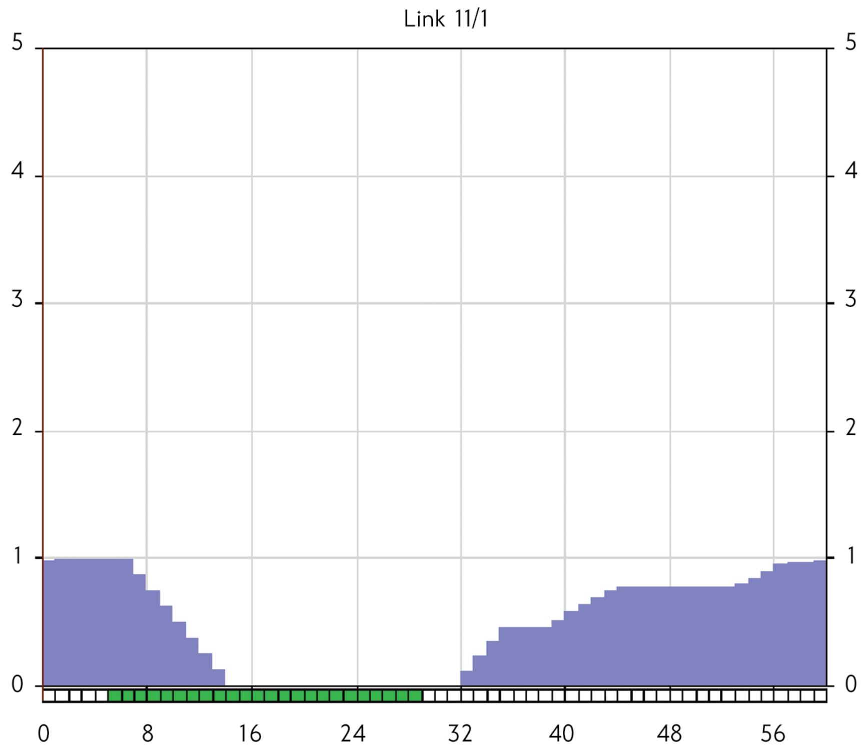

Figure 11: The same queue as Figure 10 with a de-sliver threshold of 1.0 PCU.

4 TRANSYT Modelling

4.1 Introduction

This section is designed to assist practitioners when building TRANSYT models of road networks located in London. It should be read in conjunction with the guidance contained in B2: Modelling Principles.

Whilst this section outlines the modelling requirements of TfL in respect of TRANSYT modelling there will be cases where local conditions or project requirements dictate the use of methods which may be different to those outlined. For more detailed explanations of specific TRANSYT features it is advisable to consult the ‘Help Tips’ function of TRANSYT.

4.1.1 TRANSYT 13

At the time of publishing the latest version of TRANSYT is version 13. This version contains a number of changes to previous versions, the most significant of which is the addition of a new traffic model, referred to as the Cell Transmission Model (CTM). The intention of CTM is to enable more accurate modelling of queuing behaviour at a stopline.

TRANSYT CTM functionality has not been fully evaluated by TD NP. Hence at the time of publishing TfL are not accepting models developed in TRANSYT 13 that use CTM. Any modelling developed for TfL in TRANSYT 13 should therefore make use of the traditional Platoon Dispersion Model (PDM) methodology.

The remainder of this chapter is written in relation to TRANSYT version 12, although much of what is written will still be of relevance to version 13.

4.1.2 TranEd

It is common practice for TRANSYT 12 and earlier models to be built using TranEd, a JCT software product that provides a graphical interface allowing translation of controller phase information into TRANSYT stage data. The TranEd interface allows the TRANSYT link diagram to be coded graphically as part of the input file. The information contained in this chapter applies equally to both products as the underlying functionality of TranEd is provided by TRANSYT. No preference for either software is expressed or implied within these guidelines.

4.1.3 Appropriate Use of TRANSYT

TRANSYT, produced by TRL, is widely used for modelling signalised networks within the UK. It is capable of developing optimum signal settings for representative traffic conditions within a network. The development of these settings requires average traffic data to be collected and analysed for each modelled period and placed into an abstract network of links and nodes. Using this structure TRANSYT can be used to optimise signal settings on a wide variety of networks.

The applicability of TRANSYT does not depend upon the physical distance between junctions but on the behaviour of traffic between neighbouring intersections. TRANSYT can only produce optimised timings to progress platoons of traffic through a network. Vehicle platooning can be affected not just by distance travelled but friction caused by parked cars, road widths, bends or minor sinks/sources. However the longer the distance between intersections the greater amount of platoon dispersion with an associated reduction in the potential benefits to be gained through traffic signal coordination.

It is possible to model priority junctions within a TRANSYT model but this is only appropriate where these junctions form part of a larger network comprised of signalised junctions. TRANSYT should only be used to model signalised junctions which operate with a common cycle time or fractions of a common cycle time, i.e. double, triple or quadruple cycling. It is normally only practical to model one CLF or UTC group within a single model. If it is determined that a proposal will influence traffic conditions in more than one region then it may be necessary to create two or more models to be run separately to represent the complete zone of influence. The area to be modelled should be discussed and agreed during TMAP Stage 1 as described in B2.3.1.

4.2 TRANSYT Modelling Approach

TRANSYT is a mathematical model used to produce timing plans for signal-controlled junctions where it is believed benefits may accrue if different junctions are linked. TRANSYT does not model individual vehicles and can only approximate actual traffic behaviour and as such signal timing output is never directly applied onto the street. TRANSYT's traffic model ignores any queues and delays before the start of the modelled period and assumes that flows are constant by considering the pattern of vehicle arrival and departure over one typical cycle.

TRANSYT contains two main components – a traffic model and a signal optimiser. The traffic model predicts a Performance Index (PI) for a network based on a fixed signal timing plan and set of average traffic flows. The PI is a measure of the overall cost associated with congestion and is a weighted combination of total vehicle delay and stops experienced by traffic within the modelled network. The signal optimisation component within TRANSYT modifies signal timings and assesses whether those adjustments have reduced the PI. This iterative process is illustrated within Figure 12.

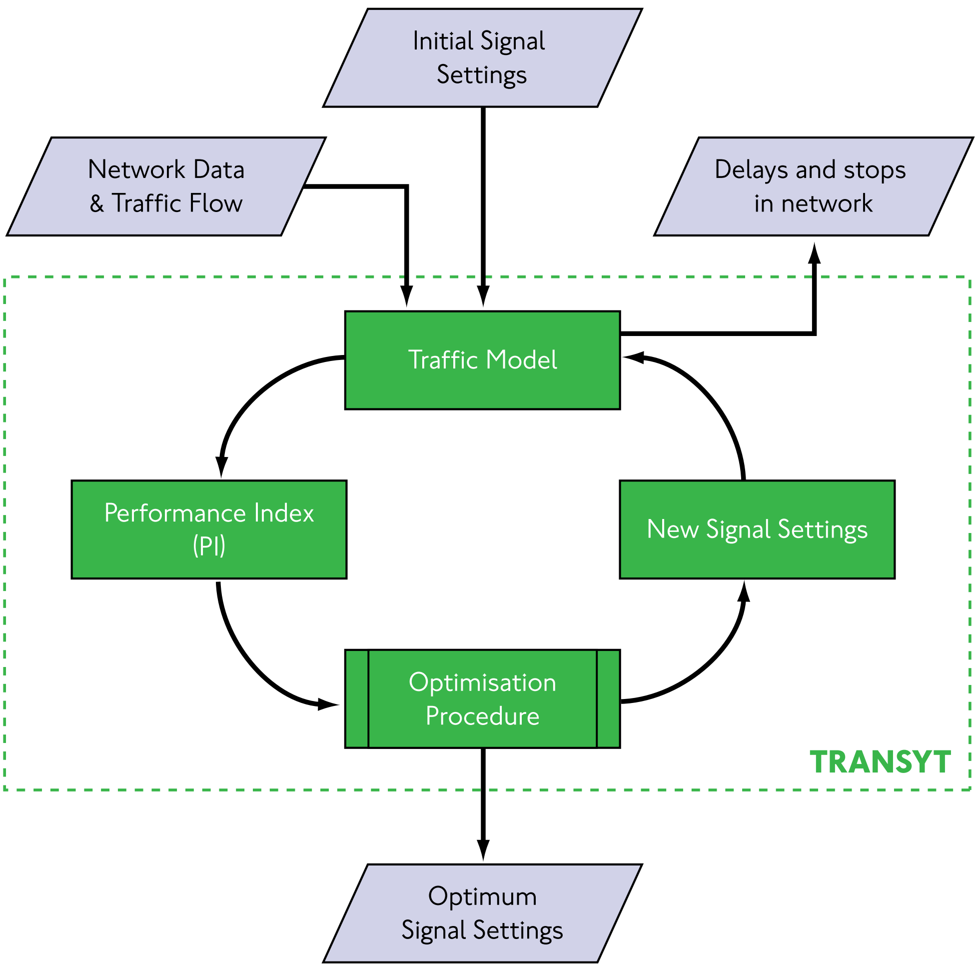

Figure 12: The TRANSYT optimisation process, adapted from Binning et al[50].

50 Binning J C, Crabtree M & Burtenshaw G, *TRANSYT 12* User Guide, Application Guide 48 (Issue C), TRL, 2005.

TRANSYT simulates the arrival and departure patterns of vehicles at stoplines throughout the model network. It uses these patterns known as cyclic flow profiles to determine vehicle stop and delay. TRANSYT assumes that during green queued vehicles discharge at a rate determined by saturation flow until a queue has dissipated. Vehicles discharge at the rate of arrival if they reach a stopline after a queue has disappeared. TRANSYT attempts to offset the arrival of platooned vehicles to minimise the network-wide weighted sum of traffic delays and stops.

The software contains a simplified queuing model which means TRANSYT cannot implicitly detect spatial phenomena such as cross junction exit-blocking, however modelling techniques can be applied to overcome this limitation and they are detailed in section B4.4.

4.2.1 Program Settings

TRANSYT program settings need to be specified before commencing model development. Default values for stop and delay should be defined within the model file, and for TfL models these should be:

- Monetary value of delay = 1420 pence per PCU-hour; and
- Monetary value of 100 stops = 260 pence.

Particular attention should also be paid to the following general settings which influence the TRANSYT traffic model and signal optimiser:

- Number of Steps in Cycle – this should typically be equal to the cycle time;
- Simulated Time – this represents the period in minutes over which the modelled flows are assumed to exist. This is commonly set to 60, as a peak hour is modelled using hourly flow rates. However, if peak flow conditions exist for two hours on-street, even though only one hour is being modelled by TRANSYT, the simulated time value should be set to 120. This allows accurate calculation of queues and vehicle delay. The default value in TRANSYT is 120s whilst TranEd is 60s;
- Start/End Effective Green Displacements – these represent the period after the beginning of green before vehicles discharge, and after the end of green before vehicles cease to cross the stopline. These should not be changed from default values unless a specific survey is conducted for each stopline within a modelled area;
- Flow Scaling Factor – this should be unchanged from the default value unless modelling a change in flow volume (e.g. looking at predicted increase/decrease in demand or using a 'flow-factoring' technique to model a peak for which specific flow data are not available);
- EQUISAT – for a base model this should be disabled in order to maintain existing timing settings. EQUISAT can be enabled during the optimisation process for proposed modelling;
- Cruise Times/Speeds – this should be set to use cruise times, as measured on-street and detailed in section B2.4.4.1;
- Cruise Time/Speed Scaling Factor – this should remain unchanged from default unless specifically required for a particular purpose (e.g. a proposed change in speed limit); and

- Level of Optimisation – for a base model, this should be set to 'No Optimisation'. This will provide performance results based on existing timings in the model. Offset and green times/offset optimisation should be used during the optimisation process for proposed modelling.

4.3 Model Build

Prior to building a model in TRANSYT the following information should already have been obtained, as identified in sections B2.3 and B2.4:

- Site Layout Drawings and SCOOT Link Diagram (if applicable);
- TfL Controller Specifications and Signal Timing Sheets;
- Site-measured values for link length, cruise time, flare usage and saturation flow. Where measurement has not been possible, estimates should be used with appropriate justification (e.g. RR67 for saturation flows or extrapolated cruise times if conditions are permanently congested);
- Stopline traffic flows by turning movement;
- Determination of average signal timings, either from the UTC system or site measurement; and
- Site observation of traffic behaviour, particularly lane usage and effective flare length.

In addition to collecting the above data, skeleton LinSig models should be produced for all junctions to be modelled in TRANSYT, as detailed in section B3.3.1. These will ensure signal timings are accurately represented, particularly when modelling stage and interstage relationships between phases in LinSig and links in TRANSYT.

4.3.1 TRANSYT Network Structure

TRANSYT requires an abstract translation of the road network in order to represent the relationships observed on-street. It uses a series of nodes and links to model intersections and the interconnecting carriageway. The structure of a node and links within TRANSYT determines its ability to accurately represent the traffic network. Network data must be specified on these elements in order for the TRANSYT traffic model to generate optimised timings via estimates of network PI.

A node represents an intersection and can be either signal-controlled or an unsignalised priority give-way. Nodes should not be used to represent physical phenomena within the carriageway such as road narrowing or widening.

A link represents a one-way traffic stream to or from a node, and can contain one or more physical lanes. Multiple lanes can be grouped together within a single link only if they behave identically, that is:

- Flows must be distributed equally across all lanes;
- All lanes must queue evenly;
- All lanes must contain same movements; and
- All lanes must share a common method of control.

Where multiple lanes exist that do not behave identically they must be treated as separate links, even if they share the same destination, and the traffic flow on each link proportioned according to observed lane usage.

TRANSYT has two main types of link – major and minor. Major links represent all traffic at a stopline, while minor links can share a stopline with major links to generate a cyclic flow profile for a particular vehicle group. The minor link occupies the same physical road space as the major link, but represents only a proportion of the flow and queue on the major link. Minor links therefore facilitate analysis of vehicle progression through the network by distinguishing between platoons from different sources where in reality they form a single queue at the stopline. Up to eight separate minor classes may be disaggregated from any major link.

It is important to note that the choice of which link is the major and minor link is arbitrary as they share all input data and thus have no effect on model output. For this reason model output values from major and minor links should not be summed as by nature there is only one value for DoS and queue length. The use of TRANSYT shared links can be helpful where complex travel patterns occur, such as on signalised roundabouts. Here it is desirable to optimise offsets between entry and circulating traffic so that excessive queuing does not occur on internal links with limited storage capacity, which would interfere with efficient operation of the roundabout. It is also possible to model bus movements with shared links, unless there is a dedicated bus lane which should be modelled with a discrete link.

Major and minor TRANSYT link types are further sub-classified by how they operate on-street. Links can be classed as signalised, priority (non-signalised give-way), bottleneck, exit, or pedestrian:

- Signalised links (for example link 6611 in Figure 13) represent individual traffic streams that are controlled by one or more signalised traffic phases at a junction;
- Priority links represent traffic streams that are controlled by giving way to an opposing flow. They can either be pure give-way links, modelled as green all the time and only controlled by the opposing flow, or signalised and therefore obeying signal control in addition to giving way to other traffic (as demonstrated by link 6610 in Figure 13, which represents a signalised opposed right-turn);
- Bottleneck links attempt to represent behaviour which occurs mid-link between intersections, for example:
  - Where platoons progress through a narrowed carriageway;
  - To restrict entry to additional downstream lanes during carriageway fanning; or
  - Due to localised influences such as right-turn bays, loading bays, frequently used bus stops, start of bus lanes or uncontrolled pedestrian crossings;
- Exit links can be used to represent traffic leaving the network (as shown by link 6699 in Figure 13). Bottleneck links should be used for this purpose using an artificially high saturation flow, typically 8000 PCU/hr, to avoid the creation of unintended and unrealistic queues. If queuing does exist on-street from a downstream intersection outside the modelled network then the modelling approach and use of TRANSYT should be re-assessed; and

- Pedestrian links represent pedestrian movements controlled by signalised pedestrian phases. Each individual pedestrian phase should be modelled as a separate link, especially where they run in parallel with traffic phases (as shown by links 6650, 6651, 6652 and 6653 in Figure 13). Pedestrian links should use proxy flows, link lengths and saturation flows. All round pedestrian stages may be modelled as a single link even though there are several phases that run in that stage. However, if this approach is employed the modeller should ensure that the largest clearance period is used to determine the stage minima, and that appropriate start and end lags are calculated correctly using a skeleton LinSig model.

4.3.2 TRANSYT Labelling Convention

The node and link numbering system used during model development should reflect set conventions to allow clear assessment of model output during audit and proposal optimisation. The numbering system outlined in the next section is demonstrated in Figure 13.

TRANSYT (up to version 12) has a maximum link number of 32767. Therefore in the case where a node number is 327 or higher, the model developer must decide on an alternative link numbering convention for the node and highlight this change within the calibration report.

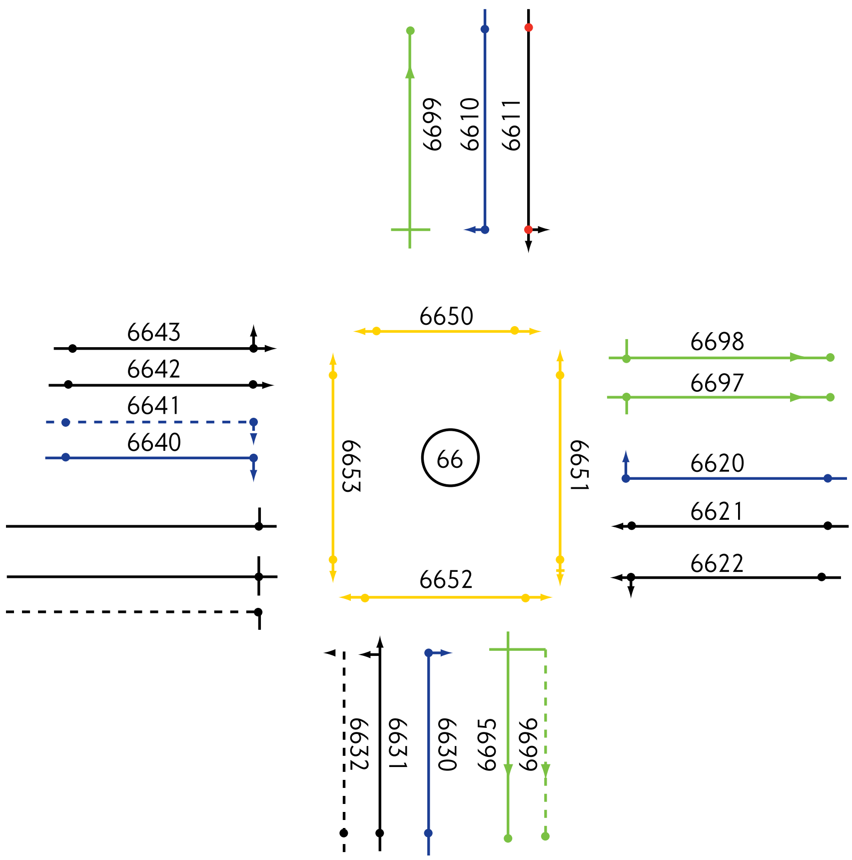

Figure 13: TRANSYT node and link labelling system (shown for J05/066).

4.3.2.1 Node Numbering

For signalised intersections the TfL junction number short code should be used to label the node without the group or region number, for example junction 05/000066 becomes J05/066 and hence TRANSYT node 66. The borough code (e.g. 05/XXX) should not be used to reference nodes within TRANSYT. Non-signalised nodes should be numbered using a unique number starting from ten and rising upwards in units of ten for additional nodes.

4.3.2.2 Traffic Link Numbering

The traffic link label should be constructed from the digits of the node number (e.g. 66) followed by a two digit number starting from ten.

Link numbering for traffic links should be applied in a clockwise direction, starting from an arbitrary reference direction that remains consistent throughout the model (e.g. southbound links). As illustrated within Figure 13 link numbers should begin with the offside link of the reference direction, here 6610, and increase in units of one until the nearside link, 6611, is reached. The next junction arm in the clockwise direction is then labelled with the node number and a two digit number starting from 20. The same numbering process then applies, from offside (6620) to nearside (6622). This is repeated for each link moving in a clockwise direction around the node until all approaches have been labelled. Shared minor links should be labelled using the same technique as the associated major link.

4.3.2.3 Pedestrian Link Numbering

Pedestrian links should be labelled in a similar manner to signalised traffic links, following on from the last traffic link to be labelled. For example within Figure 13 the last traffic label was 6643, so the pedestrian link numbering starts from 6650. Beginning at an arbitrary reference link (i.e. pedestrians crossing the southbound traffic movement), the first pedestrian phase is labelled with subsequent pedestrian links being labelled in a clockwise manner around the node, with link numbers incremented in units of one. The next pedestrian link would be therefore be labelled 6651, until all pedestrian links have been labelled.

4.3.2.4 Exit Link Numbering

Exit links from the network should be labelled with the node number suffixed by two digits starting from 99. Working clockwise, starting from the same junction reference point as used for other traffic links, the link numbers should descend in units of one. The first exit link in the example illustrated by Figure 13 is therefore 6699, followed by 6698 until 6695.

4.3.2.5 Priority Link Numbering

Give-way links use the same methodology as signalised links, with labelling commencing with the associated node number and then a unique two digit number starting with 10, rising in increments of one on the same arm and ten for other arms.

4.3.3 Node Input Data

Nodes, and the level of input detail required to describe their behaviour, can be classed according to whether or not they are signal-controlled. Non-signalised priority nodes are treated as a separate node type in TranEd.

4.3.3.1 Signalised Nodes

For each signalised node in the network, the following data needs to be entered:

- Number of stages; and
- Whether the node double cycles.

Then for each defined stage at every node, the following input parameters are specified:

- Time of change to current stage (derived from the average signal timings);
- Interstage between previous and current stages; and
- Minimum stage green time.

As described in B3.3.1, skeleton LinSig models should be used to ensure that node signal timings are accurately represented in TRANSYT.

4.3.3.2 Non-Signalised Nodes

Priority give-way junctions in TRANSYT are modelled as 'virtual' signal-controlled junctions with stoplines at intersection give-ways. Give-way coefficients determine gap-seeking behaviour and depend on the following:

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

Give-way coefficients, and how they differ according to the geometric characteristics of an intersection, are described in detail in the appendix of TRL report LR 888[51]. These are entered in the link data for the give-way link concerned.

4.3.4 Link Input Data

The link input data required by TRANSYT varies according to the link type and how it is to be modelled.

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51 Vincent R A, Mitchell A I & Robertson D I, *User Guide to TRANSYT Version 8*, Report LR 888, TRL, 1980.

4.3.4.1 Major Links

All TRANSYT links are created by default as major links. Essential data that needs to be entered for each major link includes:

- Cruise times – representing the un-delayed time for a platoon to travel from the upstream stopline to the current link's stopline;
- Link lengths – as measured on-street with a measuring wheel (measurements from mapping or aerial photography is not appropriate);
- Saturation flow – as derived from on-street measured values, or estimated (e.g. using RR67) where this is not possible (not required for pure give-way links);
- Total flow across the current link's stopline; and
- Contributing flows from upstream links.

Cruise times represent a critical input parameter in TRANSYT, as they will be used to calculate optimum offsets during any optimisation. If cruise times are underestimated, the green signal will come in too early and the backend of a platoon may fail to clear the stopline. In contrast if cruise times are overestimated, the green signal will come in too late and result in the bulk of the platoon arriving on a red signal. Note that if prompted for cruise speeds rather than cruise times, program settings should be checked to ensure that cruise time entry has been enabled (see section B4.2.1). Cruise speed will always need to be entered on a bus link (see section B4.5).

For each upstream link that is defined, the modeller must specify an entry flow from that link (in PCU/hr), together with a cruise time to the current link's stopline. The total flow across the current link's stopline should also be entered (in PCU/hr).

A uniform flow can be specified to represent a source or sink along the link that has not been explicitly modelled as an entry or exit from the network. This is an additional flow that is either added or removed from the link with a uniform arrival profile.

4.3.4.2 Minor Links

Minor links in the network need to be associated with a major link. Since a minor link occupies the same physical road space as the major link the majority of key variables are inherited from the major link. Modellers should be aware that in the TRANSYT input file the saturation flow quoted for a minor link will instead be a reference to the associated major link.

The following minor link values are specified independently from major links:

- Total flow across the shared stopline (representing a particular vehicle group of interest); and
- Uniform flows (representing sources or sinks for the vehicle group of interest).

4.3.4.3 Signal-Controlled Links

For signal-controlled links, the following values need to be entered:

- Signalised node controlling the link;
- Number of link green periods per cycle;
- Stages the link starts and ends in; and
- Start and end lag times, representing the period after the stage start and end times that the link commences and terminates green.

As described in B3.3.1, skeleton LinSig models should be used to ensure that link signal timings are accurately represented in TRANSYT, particularly with respect to start lags, end lags and phase delays. If using TranEd, the 'Phase Intergreen Converter Tool' can be used to accurately generate TRANSYT start and end lags from phase intergreens. Phase lettering used in the TranEd intergreen converter tool should match those shown on TfL Controller Specifications and Signal Timing Sheets.

4.3.4.4 Bottleneck Links

Bottleneck links are effectively treated as permanently green where traffic throughput is solely determined by a specified saturation flow. Bottleneck links should be applied with caution within a network and only where site observations deem it necessary to model mid-link phenomena and its impact on signal coordination.

The correct capacity for a bottleneck can be assessed by conducting a fifteen minute traffic spot count for each modelled period where on-street bottlenecks have been observed to result in mid-link delay or queuing. If the model contains unrealistic queuing originating from a bottleneck link the saturation flow can be set to an artificially high value, but this must be explicitly stated and justified in the calibration report.

Where bottleneck links are used, it is important to ensure that any queuing traffic does not extend beyond the link's storage capacity. Where this occurs, upstream link signal timings will need to be adjusted, as described in B4.4.2. If the bottleneck link is less than 50m in length, any queue should not extend beyond two-thirds of the link length.

4.3.4.5 Give-Way Links

For links that give-way to opposed movements, up to two opposing links can be specified. For each opposed link it is necessary to specify:

- Which link(s) oppose the give-way link;
- The maximum flow at the give-way line;
- Give-way coefficients – for each opposing link, describing the assumed linear gradient relating how the flow giving way decreases as the opposing flow increases; and
- Where more than one opposing link is specified, a percentage needs to be entered to describe the proportion of vehicles giving way to the first link only.

Standard values are typically used for give-way coefficients, representing commonly encountered give-way scenarios. It is also possible to use PICADY to manually calculate give-way coefficients based on junction geometry, or ARCADY can be used for give-way links at roundabouts. Alternatively measured on-site data can be used to plot various opposing and opposed flow rates, from which the intercept and slope can be measured. These values can then be entered into TRANSYT as capacity and slope parameters.

4.3.4.6 Flared Approaches

If a link contains a flare, either physical in nature or as a result of the termination of a bus lane or presence of on-street parking, the following data needs to be entered for the flared link:

- Number of flares;
- Saturation flow for each flare; and
- Average utilisation of the flare.

As described in B2.4.5, flare utilisation should be determined from site-based measurement, for each period being modelled. Only where site measurement is not possible should alternative estimation techniques be used, such as use of JCT's LinSat [52] software or TRANSYT's QueProb[53] feature.

4.3.4.7 Pedestrian Links

Pedestrian links should be placed in the model wherever there are signalised or significant priority crossings. Since TRANSYT cannot model the complexities of priority crossings, their impact should be accounted for through use of dummy signalised staging in order to quantify their impact on capacity.

When entering link data for pedestrian links it is common to use standard values, such as saturation flows of 10000 PCU/hr and dummy flows of 10 PCU. Link lengths can be entered from site-measured crossing distances, and cruise times calculated by dividing link length by an average pedestrian walking speed of 1.2 m/s. Pedestrian links should be specified as bottleneck links, with stop and delay weightings set to -9999 in order that they do not affect values for network PI.

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52 LinSat is freely available from the JCT website, via **http://www.jctconsultancy.co.uk/Software/LinSat/linsat.php**

53 QueProb is accessed from within TRANSYT on the link data input screen for flared approaches

4.3.4.8 Entry and Exit Links

Since entry and exit links do not have modelled upstream and downstream stoplines, their link lengths and cruise times are arbitrary. It is common to use standard values of 200m for link lengths and 18s for cruise times, based on an average speed of 40kph (~25mph), though the cruise time can be adjusted if observed vehicle speeds are significantly different.

Exit links should have their stop and delay weightings set to -9999, as was the case with pedestrian links, so that they do not affect the overall network PI. The saturation flow for exit links should be set to 8000 PCU/hr, as explained in B4.3.1.

4.4 Modelling Techniques

The previous section specified the input requirements for TRANSYT, however it is not always obvious what these values should be or how they should be used. This section provides some basic guidance on appropriate techniques that can be applied with engineering judgement to better model particular scenarios within a base or proposal.

4.4.1 Flow Smoothing

It is not a requirement in TRANSYT for the total flow on a link (the output flow) to exactly match the sum of the contributing flows (the input flows). If the total flow is different from the flow inputs on a link, TRANSYT assumes that the total flow is accurate and will therefore proportionally increase or decrease the upstream flow values in order to achieve the total link flow entered. This methodology works reasonably where link input flows are roughly equal to the output flows. However where there is a significant link flow discrepancy it can lead to inaccurate modelling and result in downstream flows that are in excess of upstream stopline saturation flows. To prevent this, it is desirable to ensure surveyed flows are consistent before entering values into TRANSYT. It is not acceptable to combine flow surveys from different peak periods into the same model.

Most TRANSYT models are built using stopline flows from classified traffic count surveys. If a model is to be built using flows from an origin-destination (O/D) survey these will need to be converted into link based flows for entry into TRANSYT. This requires the creation of a lane-flow diagram based on network layout. This can be completed manually or by using bespoke software such as JCT's FlowRound[54]. Section B2.4.3 highlights basic guidance for reconciling surveyed traffic flow differences within a modelled network.

54 FlowRound (**http://www.jctconsultancy.co.uk/Software/FlowRound/flowround.php**) is a tool for analysing traffic lane movements on signalised and unsignalised roundabouts.

4.4.2 Adjustment of Start and End Lags

Start lags and eng lags control when a link commences and terminates green, relative to stage change timings. These should be set according to link intergreen requirements and must also take account of any phase delays that are present. Situations where it may be appropriate to modify start and end lags include:

- Demand-dependency (see B4.4.3);
- Accounting for exit-blocking/Underutilised Green Time (see B4.4.4);
- Modelling bus set-backs (see B4.5);
- 'Bonus' storage effects (e.g. storage in front of a stopline for opposed right-turners which clear in the intergreen, and indicative arrows);
- Aggressive driver behaviour at particular junctions, resulting in usage of the starting amber and red periods; and
- Vehicle usage of flashing amber periods at Pelican crossings.

This list is not exhaustive and other situations may be encountered where start and end lag adjustment is appropriate. It is up to the modeller to justify any decisions taken, and to fully report on all adjustments. This is particularly important where multiple adjustments are made on the same link, as it can become impossible to audit signal timings if modifications are not well documented.

Where TranEd is used, start and end lag adjustments should be made using 'bonus green', which allows modelling adjustments to be separated from timings dictated by interstage design, such as link delays and intergreens.

4.4.3 Demand-Dependency

TRANSYT simulates only one typical cycle and as such it is not possible to explicitly model demand-dependency. For this reason the appearance of demand-dependent stages are modelled by manipulating signal timings. There are two methods commonly used:

- A dummy stage can be used in place of the demand-dependent stage in the stage sequence, with its stage length reduced proportionally to the frequency of demand observed. The timing of the dummy stage appearance should then be adjusted to take account of how the time is shared between the preceding and following stages in the event of non-appearance of the demand-dependent stage (see B2.4.9.3). The dummy stage method is discouraged as proposed models are required to have all stages modelled with controller minimum stage lengths in order to optimise junction performance and distribute spare green time; or
- The manipulation of link start and end lags, to account for the extra green time given to other stages when a demand-dependent stage does not appear. In TranEd, this is specified as bonus green and implemented on the node rather than the link. Bonus green usage is preferred as modelling adjustments can be separated from interstage design. There is a limitation on how much bonus green can be applied as links cannot be active in stages that they are not assigned to in the junction method of control.

Demand-dependent stage frequency can significantly affect the amount of green time that links receive, and can vary by time of day. It is recommended that the modeller ensures all modelled adjustments result in appropriate green times. For example, if a junction has been modelled with a pedestrian stage being activated every cycle, when in reality it is only called 50% of the time, then the model is likely to underestimate the capacity available to one or more movements.

4.4.4 Exit-Blocking / Underutilised Green Time

TRANSYT stores queues vertically and thus has difficulty considering the impact of queuing from the stopline. TRANSYT cannot automatically predict the effect on adjacent or upstream links if a queue extends beyond a link's storage capacity. Wasted green due to exit-blocking can be quantified through on-site measurement of Underutilised Green Time (UGT). UGT accounts for both wasted green due to exit-blocking, during which traffic is stationary, and sub-saturated flow, during which traffic is slow moving due to downstream queuing and congestion.

To account for blocking back the traffic modeller has to manually apply effective lost time to the relevant TRANSYT link start and end lags, as explained in section B4.4.2. The manipulation of link signal timings to account for exit-blocking should be stated within the model validation report.

4.4.5 Opposed Right-Turn Movements at Signals

Where right-turning movements are opposed at signalised junctions, the following factors need to be considered:

- The amount of opposed vehicles that turn during gaps in the opposing flow(s);
- The amount of opposed vehicles that turn during the interstage period;
- The link(s) opposing the opposed flow; and
- Whether right-turning vehicles share lanes with other movements that are blocked.

The numbers of right-turners that are able to make use of gaps in the opposing flow(s) are determined by the give-way parameters referred to in B4.3.4.5, i.e. the maximum flow while giving way (the intercept) and the give-way (slope) coefficients that determine how an opposed flow varies with its opposing flow. The give-way parameters can be calculated using PICADY, or alternatively it is common to assume the following suggested values[55]:

- Maximum flow of 1000 PCU/hr; and
- Give-way coefficient of 50.

These values should be considered a starting point, which can be modified if justified by more accurate data (e.g. site-based measurements).

The number of opposed turners that turn during the intergreen period can be accounted for by adding a 'bonus effect' to the signal timings. This is achieved by increasing the

55 Crabtree M, *Traffic Software News*, TRL, December 2001, No. 20, p2.

end lag for the opposed link, or in the case of TranEd by the addition of bonus green, as discussed in B4.4.2. The additional time added should be long enough to clear the number of vehicles that are able to store in front of the stopline. It is common to add two seconds per vehicle for opposed movements that do not have an unopposed period, and one second per vehicle if an unopposed period follows (i.e. an early cut off for an indicative arrow stage).

The links opposing the opposed flow are usually evident. It is important to be aware of the limitations of TRANSYT, which is only able to consider two opposing links that cannot be separate lanes of the same opposing movement, for instance where an opposed right-turn gives way to multiple lanes of traffic in the other direction. In this situation multiple opposing links should be combined into a dummy link so that a single opposing link can be specified in the opposed link give-way parameters. If it is desirable to keep the flows distinct in the combined dummy link, shared links can be used to separate the flows. TRANSYT cannot model a mutually opposed link, i.e. a link that is opposed cannot itself be specified as opposing another link. As a workaround when mutually opposed movements occur, the saturation flow for one link, usually the one with the lower opposed flow, can be manually adjusted to account for its actual capacity and the other specified as the opposed link.

Where an opposed right-turn movement shares a single lane with an unopposed ahead movement, this can lead to interference and blocking. This is modelled in TRANSYT by specifying a proportion of the opposed flow as giving way to nothing (the ahead movement), while the remainder (the opposed right-turn) gives way to the opposing link. This combines the effect of right-turners giving way and the ahead movement discharging at the link's saturation flow. It does not account for any vehicles entering the junction without blocking the ahead movement and may therefore slightly underestimate capacity.

If an opposed right-turn movement shares a lane with unopposed ahead traffic, but a separate ahead lane also exists, then an allowance should be made for the likelihood of right-turners blocking the shared lane. This reduction in ahead capacity can be achieved in TRANSYT through modification of the saturation flow if the ahead lane is modelled as a single link, or through separating the ahead movement into separate links and allocating flows according to observed lane usage for each modelled period. If a right-turn bay exists that allows some storage of right-turning traffic separate from any ahead lanes, the modelling approach taken depends on whether right-turn traffic will queue back and block the adjacent ahead lane or not. If blocking back does not occur, the right-turn and ahead lanes should be modelled as separate links, however the capacity of the adjacent ahead lane can be reduced to account for the effect of slowing right-turning traffic. If blocking back occurs, the right-turn bay and adjacent ahead lane should be modelled as a single link using the give-way parameters detailed previously, with a proportion of the flow opposed by nothing and the remainder opposed by a specific link.

4.4.5.1 Stop and Delay Weightings

Stop and delay weightings are used to apply penalties to stops and delays on links by increasing their cost within the PI calculation used for optimisation. Weighting values are entered as percentages which are directly applied to the cost of specified links when calculating the cost of stops and delays across the network as a whole. A value below 100% therefore reduces the cost of stops and/or delays on a link and a value above 100% increases the cost.

Since TRANSYT will always attempt to minimise the overall network cost (in terms of the PI), these weighting values determine the amount of effort TRANSYT will put into minimising stops and/or delays on the particular link relative to costs elsewhere in the model. Weightings of less than 100% are therefore likely to increase the number of stops and/or delays on the link if this leads to a reduction in cost elsewhere in the model.

It should be noted that the default value of 0 in TRANSYT 12 and earlier versions is the same as 100, representing a weighting of 100%. In TRANSYT 13 however, a value of 0 represents a weighting of 0% and 100 represents 100%. In TRANSYT 12 and earlier versions, a weighting of 0% is specified as -9999.

4.4.5.2 Queue Limits

Queue limit penalties can be imposed in order to discourage the formation of queues on links during the TRANSYT optimisation process. In a similar manner to stop and delay weightings, this penalty imposes an additional cost on network PI when the queue on a link extends past a user-defined or calculated value. The two values required for a queue limit are:

- Queue length limit for the link (in PCUs); and
- The penalty to be applied when the average Mean Maximum Queue (MMQ) on a link exceeds the specified queue limit, in pence.

Queue limits can be useful to prevent the formation of disruptive queues on circulating links within a gyratory, or on short internal links where queuing can cause wasted capacity within a junction.

It is important for a modeller to be aware what MMQ represents in TRANSYT when deciding on the selection of an appropriate queue limit value. The MMQ is not the queue at the end of red, but rather the position reached by the back of the queue as the queue is discharging during green, i.e. the point at which newly arrived traffic is not delayed before progressing across the stopline. The MMQ is therefore the mean number of PCUs which have queued up to the time when the queue finally clears the stopline. As discussed in section B4.2 the simplified queuing model within TRANSYT is not realistic. Consequently the time at which the maximum queue occurs is later in TRANSYT than on-street. The MMQ value will statistically be exceeded in 50% of cycles during the period being modelled. Similarly for over-saturated links the MMQ will be the mean of a queue that is increasing over the modelled period. This means that the queue on-street at the end of the period being modelled can be up to twice the MMQ provided in the model output.

When specifying a suitable queue length limit it is necessary to make an allowance for queue length variation above the MMQ, so that the queue on-street will never exceed the maximum allowable value as determined by junction layout. A queue limit of half to two-thirds of the actual storage capacity of a link is often used, so that the link not only accommodates the MMQ, but also has sufficient extra storage space for more extreme queues that may develop.

4.5 Public Transport

Buses should be modelled using minor links where they share the carriageway with general traffic, and major links where they are segregated in dedicated bus lanes. This link structure allows public transport delay and optimisation to be assessed separately from general traffic. Whichever link type is used, the links should be specified as dedicated bus links.

Bus links require the entry of two link parameters:

- Bus link cruise speed, in km/hr (regardless of whether cruise speeds or cruise times are specified in the TRANSYT program options); and
- The time stationary on each link, representing the dwell time at a bus stop along the link.

If no bus stops are present on the link then the stationary time should be left as zero. If more than one bus stop occurs on a link the stationary time should represent the sum of all bus stop dwell times, with an additional contribution representing acceleration and deceleration periods at the additional bus stops (TRANSYT already accounts bus acceleration and deceleration for the first bus stop). Bus dwell times can be as surveyed on-street, or in some cases it may be appropriate to use estimated default values.

If bus lanes do not extend all the way to the stopline, a bus set-back is created which allows general traffic to use the short lane in front of the bus lane (e.g. for left-turning vehicles). This should be modelled as a stopline flare, with the bus link start lag increased by the time taken for buses to travel from the end of the 'effective' bus lane to the signal stopline. The bus set-back start lag should be measured for each modelled period as it may vary according to time of day.

As TRANSYT is based on average signal timings during a typical cycle, dynamic control strategies like SVD Bus Priority cannot be explicitly modelled. Instead their effect can only be represented by the average signal timings within the model.

4.6 Calibrated TRANSYT Base Model

A calibrated TRANSYT base model is defined as being a model which has correct link structure and geometric input data, and is submitted during TMAP Stage 2 as identified in B2.2. It should contain representative signal timings for the modelled period with no demand-dependent stage adjustments. The model should be accompanied with a technical note as detailed in section B2.7.1. This should state the purpose of the model, the modelled period, TRANSYT version number and study area.

The purpose of the calibrated model is to allow the developer and any model auditor to assess model structure and the correctness of initial input data. At this stage it is possible to identify issues which may hinder future development of the model. For this reason the calibrated model should be accompanied with tabulated data that clearly emphasises model inputs and how they were derived from measured sources.

4.7 Validated TRANSYT Base Model

The validation of a calibrated model can only occur once traffic flows have been introduced in to the TRANSYT model. A validated base model, submitted during TMAP Stage 3, should not contain traffic flow discrepancies unless previously agreed with TD NP.

Where there is a discrepancy in traffic flows the modeller should examine the raw flow data used for modelling. It may be necessary for the model developer to adjust modelling inputs from the calibrated model in order to validate against on-site surveyed conditions. However it is not acceptable to progressively adjust model inputs to achieve validation. Any changes should be justifiable, based on sound engineering principles and documented in accompanying validation reports.

Base TRANSYT models should not show results for DoS over 100%. TRANSYT uses stopline traffic counts rather than demand flow. All traffic should clear the stopline within TRANSYT, therefore if a model has a DoS over 100% then discrepancies may exist for one or more of the following parameters: saturation flow, link structure, green time and/or stopline flow.

Excess queues are highlighted in the TRANSYT output file. Actual queue lengths will often vary around an average value, making it difficult to rely on modelled queue lengths for validation purposes. Queues will increase exponentially as network performance verges towards 100% DoS, making it difficult to compare modelled and measured values. However, if excess queues are flagged in a model, indicating that the queue length on a link exceeds its length, the modeller should assess whether green times, offsets, saturation flows and traffic flows are correct for the link. If these parameters have been correctly modelled, the modeller may consider an adjustment of start and/or end lags on relevant links to remove excess queues, as carried out when accounting for exit-blocking (see B4.4.4).

Model output should be compared with survey data for the corresponding on-site links in order to validate the calibrated model. The following criteria, reproduced from MAP v2.2, should be used to indicate validation of base TRANSYT models:

- Degrees of saturation within 5% of observed values;
- Degree of saturation for links upstream of pedestrian crossings within 10% of observed values; and
- Observed Cyclic Flow Profiles (CFP) for critical links showing similar peaks, dispersion and spacing.

4.8 Developing Proposed Models

Proposed TRANSYT models should be created from a validated base model modified to describe the proposed scenario. Optimised signal timings for the proposed situation should then be produced and analysed following the pathway outlined in B2.6. Network performance based on these new timings can be assessed within TRANSYT or using third party modelling software.

During scheme design, model output should be used to assess the scheme's effectiveness and if necessary consider suitable design changes prior to full re-optimisation, as described in B2.6.2. Two further inputs instruct TRANSYT how signalised nodes should be optimised:

- Order of optimisation – this notifies TRANSYT of the node order to be used during the hill climb optimisation process; and
- Node Grouping – this facility allows fixed offsets between nodes to be maintained (e.g. for critical offsets within a UTC multinode or CLF subgroup). Offsets for the group are optimised together rather than for individual nodes.

Where flows are predicted to change following implementation of a scheme, effective flare length should be estimated using LinSat. Where timings at an existing site are not compliant with SQA-0064 requirements, proposed modelling should include results with 'existing' and 'existing plus SQA-0064' timings. Cruise times should not be changed to reflect a proposal that is expected to reduce queuing and delay as cruise times represent free-flow conditions. However, cruise times should be re-measured if proposals are expected to involve changes that impact on cruise speed, such as a reduction in parked vehicles, introduction of speed reduction features or stopline-to-stopline distances being changed.

It is recommended to include proposed skeleton LinSig models with any TRANSYT submission for auditing purposes. Both models should be supplied with LinSig phase/TRANSYT link relationships detailed for any new proposals.

4.8.1 Modifying Network Structure

Any nodes representing proposed signalised junctions should be numbered using a single digit starting at one, rising in increments of one. Where existing nodes or links are converted in type, i.e. from non-signalised to signalised, care should be taken to ensure existing data is maintained where applicable. Modellers should ensure new links are furnished with appropriate data for each link type, with special attention paid to the effective length of flared approaches and the impact of these on traffic distribution at the stopline.

> Existing link and node numbering within a validated base model should not be changed within a proposed model. New links should be added using the most appropriate numbering convention and highlighted within the proposal report.

When modelling new proposals the treatment of 'funnelling' and 'fanning' traffic can become a source of possible error. 'Funnelling' occurs when a greater number of lanes at one signal-controlled stopline exit into a fewer number of lanes downstream, while 'fanning' represents the opposite scenario, where fewer lanes upstream flow into more lanes downstream. This behaviour should be reflected in the link structure of the model where funnelling forces lanes of continuous length to behave like flares or with modified capacity where fanning results in underutilisation of upstream stoplines.

4.9 TRANSYT Network Optimisation

TRANSYT is a tool that represents a simplified version of reality based on a series of approximations. These approximations can be influenced in order to generate robust signal timings but there will always be real-world situations where the choice of the most appropriate methodology requires engineering judgement. A generic workflow for traffic model optimisation has been outlined in section B2.6 and Appendix II to provide a framework for the following section.

4.9.1 Cycle Time Optimisation

TRANSYT can provide an indication of the most appropriate cycle time for a traffic network via an internal cycle time optimiser (CYOP). CYOP is a guidance tool which models each node as a distinct entity using timings which give equal DoS to critical approaches. TRANSYT v12 and earlier versions disregard the influence of any applied grouping, weighting or penalties but later versions run CYOP with full optimisation that includes network weightings. TRANSYT calculates the PI for a node over a series of cycle times. It highlights where a common cycle time may force a link to exceed 90% DoS and recommends where double cycling may be beneficial. When using CYOP engineers should be mindful of junction delay as mentioned in section B2.6.1.4.

TRANSYT can also create a histogram which plots cycle time against total network delay to illustrate network performance at different cycle times based on full optimisation, i.e. to include the influence of coordination and weightings. This cycle time graph can complement the CYOP approach as it will not produce double cycling recommendations. TranEd allows further graphical display options, plotting PI, delay and/or the maximum degree of saturation against a range of cycle times, by performing multiple TRANSYT runs.

The most appropriate cycle time for the region must be chosen by the modeller and manually applied to any proposed model along with a proportional alteration to any UGT or demand dependency adjustment. Section B2.6.1.3 provides guidance on available cycle times and important considerations which may influence choice. Modellers are reminded to specify in a proposal report the chosen cycle time and whether double, triple or quadruple cycling nodes have been generated or removed.

4.9.2 Signal Timing Optimisation

TRANSYT requires a set of signal timings for every signal-controlled node prior to beginning optimisation, for a proposed model these initial timings should be derived from the validated base model. A modeller can use EQUISAT to overwrite specified signal settings, which will allow TRANSYT to calculate initial signal timings based on equalised DoS on the critical conflicting links at each node.

TRANSYT hill climb optimisation is influenced by which stage occurs first in the signal cycle (as illustrated in Figure 12). As the initial start stage may change during optimisation, derived timings may not be exactly the same as those produced by a previous calculation. Modellers should also be aware that this effect can generate two repeated results when running back to back TRANSYT optimisations. In this situation EQUISAT should only be run during the initial optimisation to balance the network with subsequent iterations utilising already optimised timings for the next simulation run.

Simplifications within the TRANSYT traffic model may mean it does not accurately predict the performance of networks operating close to capacity. As a result, after an initial signal optimisation, the modeller should study output such as the traffic profiles and queue graphs. It is possible to use this information to establish when in the cycle different links are likely to suffer from exit-blocking or poor performance. Once the reasons for a loss of capacity are known new stages in the method of control can be considered and full optimisation can be repeated. In order for a proposal to consider all underlying traffic management requirements within a proposal it may be necessary for the modeller to influence TRANSYT during initial optimisation with appropriate delay, stop and excess queue penalty weightings. They may also find it beneficial to reiterate the hill climb optimisation process by repeating the node list so that each node is optimised twice within the same model cycle.

It is important at all stages of optimisation to assess model output to ensure proposed signal timings are fit for purpose relative to the scope of the project and overarching considerations, as outlined in Part A.

4.10 TRANSYT Output

TRANSYT can deliver a number of outputs that provide a modeller insight into model results. These allow analyses of optimised signal timings and their potential impact on-street such as required during proposal fine tuning (phase two within Figure 7).

It is possible to define specific routes through a TRANSYT network to examine performance statistics for a particular pathway or vehicle type. The following subsection will outline examples of TRANSYT output which provide insight into stopline queuing, network performance, etc. It will not provide interpretative guidance as this should be developed on a case-by-case basis under advice from experienced TRANSYT practitioners.

4.10.1 .PRT File

TRANSYT is a mathematical model which requires fixed format numerical data to understand input information. All input information is held within the .PRT file. The .PRT file is only available to the modeller after an optimisation cycle has been completed and will display the TRANSYT program version which determines the exact format of input and output data. The .PRT file is the master record which should be referenced when auditing data inputted into a TRANSYT model. TMAP Stages 2 and 3 specify how the .PRT file should be examined during a model audit to extract information relating to optimisation settings, cycle times, traffic flows, saturation flow, mean cruise time, green start and end time.

The .PRT also provides numerical output which is of use to a modeller when assessing a proposed set of signal timings. It provides the intermediate and final settings produced during optimisation alongside link predictions for DoS, MMQ (see B4.4.5.2), PI, average excess queue and the separate components of delay (see Figure 8). The .PRT file also displays network data such as total distance travelled, total monetary value for stops and delay, mean journey speed and total network PI. These data should not be used in isolation to assess the merit of proposed signal timings.

The .PRT file can be used to identify sources of poor optimisation or network performance. TRANSYT aids the interpretation of the .PRT by flagging potentially problematic links using symbols. TRANSYT will produce a (**<**) symbol to indicate that flow into that link has been reduced by more than ten percent. This may indicate that an upstream node has become over-saturated and starved the downstream network of demand flow. In this case a modeller can trace upstream from the link being starved to identify the flow bottleneck as TRANSYT output for starved links will not validate against measured data.

TRANSYT utilises a (**+**) symbol to denote where an excess queue has formed in the model. This may indicate that queue lengths have exceeded storage capacity on the link and signal timings may generate blocking back on-street. Modellers can examine links where this symbol is present to check signal offsets are not generating artificial queues and to ensure that adequate stacking capacity exists on the link. TRANSYT calculates link storage capacity as a function of link length and saturation flow. This value can be overwritten by a user defined queue limit as detailed in section B4.4.5.2. To estimate an average excess queue the MMQ of a link is checked against the queue limit/link capacity during each step of the cycle. If the limit is exceeded for a time step the excess queue is noted to generate an average excess queue value which accounts for the duration of time during which blocking back may have occurred.

4.10.2 Graphical Output

TRANSYT can produce histograms to illustrate queuing behaviour by plotting the number of PCUs in a queue against time in the cycle. This queue graph shows the rate of discharge from the front of the queue during green and the distance of the back of the queue from the stopline throughout the cycle. TRANSYT forms queues based on three components of delay – uniform, random and over-saturation.

TRANSYT queue graphs display only the uniform component so should not be used instead of excess queue calculations to predict where queue storage problems may occur. The facility remains useful as it can highlight queuing occurring during green periods, i.e. where flow along a link is greater than saturation flow.

Cyclic flow profiles (CFP) are histograms of traffic flow rate (PCU/hr) across a signal-controlled stopline at different moments through the length of a signal cycle, as shown in Figure 14. CFPs are useful for assessing offset progression between stoplines as the timing of platoon arrival and queue discharge can be compared between linked histograms. A modeller can understand the different profiles of movement within a CFP to derive the amount of spare capacity available at a stopline for different points within the signal cycle. For example, areas of the CFP in Figure 14 use the following colour key:

- Dark green – previously delayed vehicles discharging from a queue;
- Light green – vehicles arriving during a green signal; and
- Red – vehicles arriving during a red signal.

The CFP also provides an indication of the Mean Modulus of Error (MME) for each link. MME is a measure of how bunched a travelling platoon is as it progresses along a link, and is an important parameter when deciding whether a particular link should be coordinated with an upstream link. A higher value for MME indicates there are potential benefits to linking signal timings, as platoons remain clearly defined and are therefore more likely to benefit from offset progression. MME is a theoretical concept because TRANSYT can only model platoon dispersion due to different speeds and not mid-link friction caused by parking, loading and minor sinks or sources. A value for MME higher than 0.3 suggests stopline coordination may be effective whilst a value of zero indicates a uniform arrival pattern.

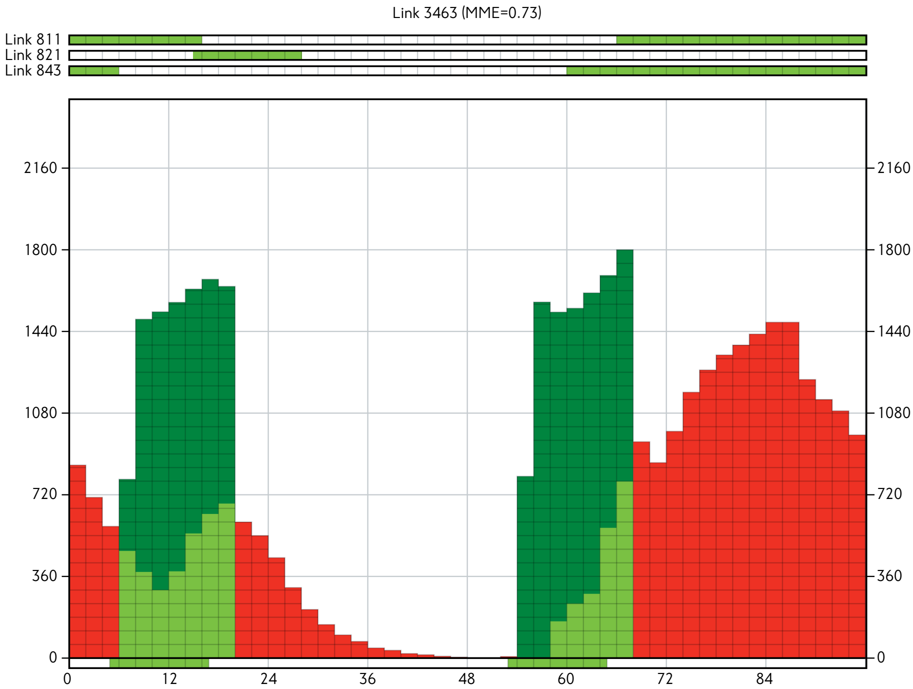

Figure 14: Cyclic Flow Profile graph, as shown in TranEd.

A PI graph can be used to indicate the likely change in link PI following a change in the offset between the displayed node and an upstream node. The histogram plots the PI for a link against the offset-difference, where the initial PI is the value at the start of red. The graph illustrates how PI may vary if the offset-difference was altered by an amount varying between zero and the user defined cycle time. Generally the lower the PI the better the coordination between associated signalised stoplines.

A time-distance diagram allows the modeller to modify signal offsets to provide priority to a particular route by minimising stops and delay. The diagram illustrates the progression of a platoon along a complete route. This can be a useful feature when assessing the output of a proposal to check front and back end progression along a critical route.

5 VISSIM Modelling

5.1 Introduction

This section is designed to assist experienced practitioners when building VISSIM models of London's road network. It is important therefore to have read the guidance in B2: Modelling Principles prior to reading this section.

This section outlines the approach of TfL in respect of VISSIM micro-simulation modelling. However there will be cases where local conditions or project requirements dictate the use of methods which may be different to those outlined. In these situations, TD should be consulted on the methodology where modelling is being undertaken for, or for approval by, TfL.

5.1.1 Appropriate Use of VISSIM

VISSIM should be used appropriately to complement analyses provided by traditional traffic optimisation and design tools such as TRANSYT and LinSig. Some examples of where it is appropriate to develop VISSIM models:

- Where over-saturated conditions exist, and particularly where exit-blocking occurs, or where queues interact with other facilities;
- Where network infrastructure changes dynamically throughout the modelled period (e.g. VA or SCOOT signal control, demand-dependency, bus priority at signals);

- Where accurate journey time prediction is important as an improvement measure (e.g. bus priority scheme); and
- Where it is necessary to visually demonstrate the operation of a scheme, traffic management technique or control strategy for use in a stakeholder consultation or Public Inquiry.

5.2 Developing Base Models

General guidance on base model development is provided in B2: Modelling Principles. This section provides specific guidance for building base models using VISSIM.

5.2.1 Model Boundaries

VISSIM is able to model adjacent CLF or UTC groups operating different cycle times. It can therefore assess the impact of scheme proposals which cover two or more traffic control groups. Where blocking back from one group impacts traffic upstream, VISSIM can be used to predict the magnitude and frequency of any operational issues and test proposals for mitigation.

When deciding on the VISSIM model boundary the modeller should consider the length of external links (i.e. where vehicles are loaded onto the network). Links must be designed such that there is sufficient capacity for all vehicles to be loaded into the network within the modelled time period, in all scenarios. There are two reasons this should be done:

- To ensure that any upstream blocking back effects can be easily identified (visually) and mitigated; and
- To ensure that when measuring scheme performance parameters (e.g. journey time, delay, queue length, average speed) all vehicles are included. If some vehicles are not successfully loaded into the network, the modeller will produce a biased result which may underestimate the capacity impacts of the scheme.

5.2.2 Model Time Periods

VISSIM is not constrained to modelling a single peak hour period. For a broader assessment it is possible to create models which cover three or more hours, this is beneficial for an assessment of traffic during the shoulders of a peak period.

VISSIM models must include warm-up and cool-down periods (see B5.3.1.2), in addition to the analysis period. The extent of the warm-up period will depend on the network size and congestion level. Typically a warm-up period of 15 to 30 minutes will be sufficient. Therefore VISSIM models with a single hour of analysis will typically cover 1.5 hours as a minimum.

5.2.3 Data Collection

Prior to building a model in VISSIM the following information should already have been obtained, as identified in sections B2.3 and B2.4:

- Network layout (e.g. OS mapping, aerial photography);
- Familiarity with site operation and driver behaviour;
- Traffic flows and turning proportions;
- Traffic flow compositions (i.e. according to vehicle classifications);
- Bus frequencies;
- Bus stop locations;
- Bus stop dwell times;
- Signal timings and controller logic;
- Saturation flows;
- Vehicle journey times;
- Queue lengths;
- Mandatory speed limits; and
- Parking and loading.

The following data may also be needed, depending on the purpose of the model:

- Origin-destination surveys;
- Speed and acceleration profiles;
- Bus boarding and alighting survey;
- Pedestrian flows; and
- Bus occupancy survey.

In addition to collecting the above data, skeleton LinSig models should be produced for all junctions to be modelled in VISSIM, as detailed in section B3.3.1. This will ensure signal timings are accurately represented, particularly when modelling stage and interstage relationships.

The remainder of this introductory section provides specific guidance on the collection of some of the above data as necessary for the preparation of VISSIM models.

5.2.4 Site Observation

Micro-simulation models are able to simulate complex interactions between road users and their environment. It is therefore essential that behaviour such as blocking back, lane changing, parking and queuing, which can significantly affect model results, is understood from site visits in order that it can be accurately replicated in the model.

5.2.5 Network Layout

Background drawings on which the VISSIM traffic network is built should be of sufficient detail and accuracy to give information on relevant network elements such as signal stoplines, give-ways, bus stop locations and lane marking arrangements. Before network build begins it is essential that the background datum is scaled correctly. As an additional safeguard it is suggested that a scale marker is included on the background which should be at least 100m in length.

Aerial photographs and detailed topographical drawings may be used to supplement Site Layout Drawings, but they should not be used in isolation for building the traffic network.

Finally, as described in B2.3.2 and B2.3.3, it cannot be assumed that drawings and aerial photographs are up to date and accurate. Therefore it is necessary to check layout details during site visits to confirm their accuracy.

5.2.6 Traffic Flows and Turning Proportions

Traffic flows and turning proportions are usually determined through fully classified turning counts and/or origin-destination (O/D) surveys covering each modelled period.

Turning proportions (i.e. routing decisions) can be applied to groups of vehicles where similar turning proportions are shared across different vehicle types. However for checking and auditing purposes it is desirable to minimise the number of routing decisions within the model.

Section B2.4.3 highlights recommended methods for reconciling surveyed traffic flow differences within a modelled network.

5.2.7 Traffic Flow Compositions

Traffic compositions can vary across the network but often the difference in vehicle type proportions is small and hence a single composition may be used for several input links. However links loading significantly different compositions should have specific vehicle compositions, e.g. links that load high proportions of taxis, HGVs or two-wheelers.

5.2.8 Signal Timings

Guidance on how to collect and use signal timing data is provided in B2.4.9. Requirements for VISSIM are largely the same as those required for deterministic models, except where it is necessary to model dynamic control logic such as Vehicle Actuation (VA) or SVD bus priority (see section A5.5). Where these forms of dynamic control have a significant influence on the behaviour of models it is advisable to gather information on all junction detection (e.g. traffic detectors, pedestrian push-buttons) and control logic.

TD has developed a software interface between VISSIM and an offline version of TfL's UTC system. This interface allows TD engineers to simulate the real behaviour of the UTC system and associated applications including SCOOT, SASS and SVD Bus Priority.

5.2.9 Saturation Flows

In most cases, a VISSIM model will be developed to complement an existing validated TRANSYT or LinSig model. Saturation flows from those accompanying models should be used for calibration of the VISSIM model. Guidance on saturation flow measurement is provided in B2.4.7.

Although saturation flow is not a direct input to VISSIM, it is not acceptable to rely on the default saturation flow that results from standard driver behaviour parameters. Typically the VISSIM default saturation flows produce models which appear to run too freely. For models with closely spaced signal-controlled junctions it is important to get the rate of discharge (saturation flow) correct across the major stoplines. TD NP Operational Modelling can provide a spreadsheet to compile VISSIM output information and aid collation of saturation flow data.

Where a validated TRANSYT or LinSig model is not available, it will be necessary to measure saturation flows for the purposes of calibrating the VISSIM model. Some examples are given below of situations where it is critical to measure saturation flows for a VISSIM model:

- Approach has extensive queues, i.e. a bottleneck;
- Approach is an entry into the VISSIM network;
- There are proposed changes to the layout; and
- There are proposed changes to the method of control or intergreens.

This is not an exhaustive list and it remains necessary for the modeller to exercise good judgement when assessing situations where it is critical to measure saturation flow within VISSIM.

5.2.10 Journey Times

It is necessary to have journey time data to validate a VISSIM base model. Journey times should be collected at the same time as the other traffic surveys. However for larger networks it may be necessary to conduct the journey time surveys over several days.

5.2.11 Cycles and Powered Two-Wheelers

For traffic engineering purposes, it is necessary to balance the difficulty of modelling two-wheelers in VISSIM with the potential benefits. Some of the difficulties encountered in modelling two-wheelers in VISSIM are:

- Measurement and calibration of saturation flow;
- The lack of a cyclist behaviour parameter in VISSIM;
- The lack of a consistent PCU value that is independent of flow;
- Sensitivity of capacity to network characteristics (lane width in particular); and
- Increased computation time.

At present the inclusion of two-wheelers in VISSIM should only be used to model their effect on other motorised road users. There is no reliable facility to study the impact of motorised traffic on cycles and powered two-wheelers.

5.3 Model Building Process

This section describes VISSIM model building in three parts:

- Network;
- Traffic data; and
- Control infrastructure.

5.3.1 Network

5.3.1.1 Simulation Parameters

These should be agreed and set at the start of model development. Changing these parameters after calibration will invalidate model results.

The VISSIM Simulation Parameters dialogue for an example model is shown in Figure 15.

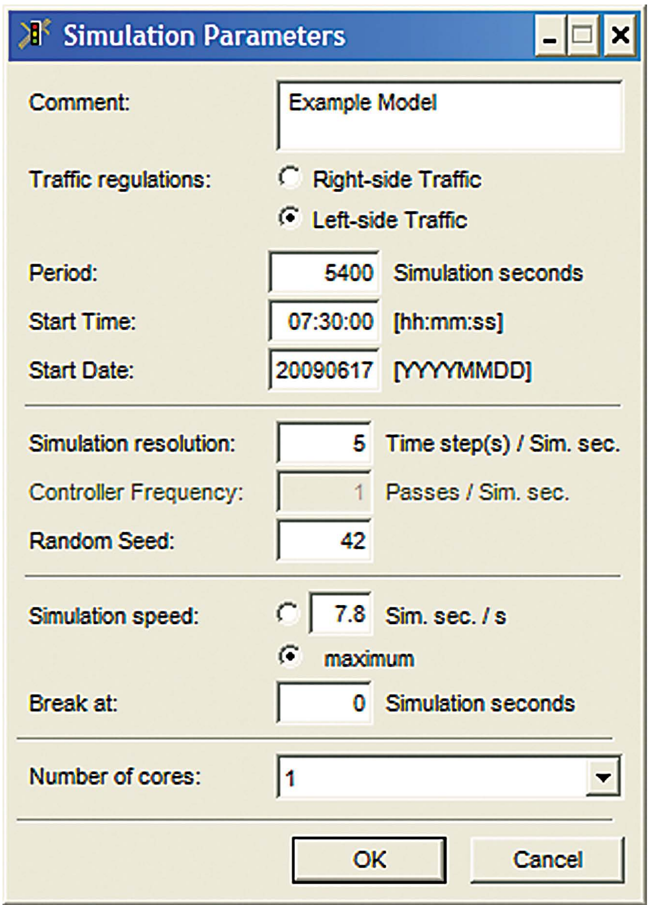

Figure 15: VISSIM simulation parameters for an example model.

5.3.1.2 Time Period

The time period should be adjusted to cover the period of interest with the addition of a warm-up period to pre-load the network with traffic and generate queues prior to the study period. The warm-up period should be at least as long as a typical journey through the network but in many cases a 15 minute warm-up is sufficient.

The use of a cool-down period of a similar duration is recommended. This cool-down period, which follows the study period will allow vehicles trapped in the network at the end of the study period to reach their destination, and therefore be reflected in the simulation evaluation data. Without a cool-down period, results may be biased to show faster journey times.

5.3.1.3 Simulation Resolution

Simulation resolution should be set to the default value of 5 steps per simulation second (i.e. 0.2 seconds per step). The simulation resolution must be chosen before calibration. The simulation resolution cannot be changed later without the need for model re-validation as driver behaviour, and therefore model results, will be changed.

This parameter should not be used to increase the speed of the simulation. Whilst reducing this value does result in faster simulation run times there is an impact on model accuracy. Instead simulation run times can be reduced in VISSIM by removing the animation of vehicles, or by reducing the animation refresh interval.

5.3.1.4 Units

The following settings are recommended:

- Distance: Set to m and km;
- Speed: Set to mph; and
- Acceleration: Set to m/s^2.

5.3.1.5 Links and Connectors

The VISSIM network structure is built using links and connectors. As a general rule, the number of links and connectors should be minimised and connectors should be kept short. Link and connector overlapping should be avoided as this creates unrealistic capacity which will need to be corrected with priority rules and control infrastructure elements.

All turning manoeuvres should occur across connectors, including all movements through the interior of junctions, as connectors allow the modeller to enforce lane discipline and queuing behaviour using the ‘lane change’ and ‘emergency stop’ distance parameters.

When modelling lane gain/loss, a single connector should be used, rather than multiple lane-to-lane connectors, and the link extended as necessary to allow merging and diverging at the correct location (as illustrated in Figure 16). Where rigid queuing behaviour is observed on-street, normally due to local knowledge and often observed at right-turns, links can be split to model each lane separately to allow explicit routing along that link. Alternatively short connectors can be placed within the lane (i.e. they connect a link with itself) allowing routing paths to be specified across those connectors. This is a last resort solution which rigidly enforces queuing behaviour.

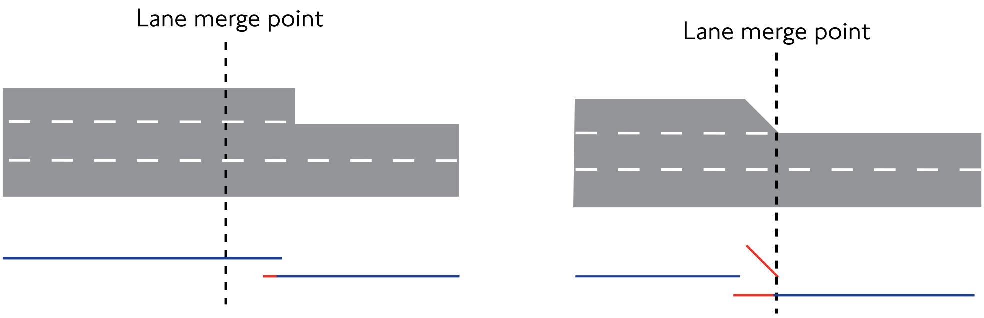

Figure 16: Correct (left) and incorrect (right) connector usage for modelling lane gain or loss.

It is recommended that default link types should be used during base model build. Adding new link types at this early stage complicates the model development process. Further link types can be defined later during the calibration stage as necessary. The number of additional link types used should be kept to a minimum.

Bus lanes can be modelled as part of a multi lane link using lane closures. This is preferable to modelling bus lanes as a separate link which excludes taxis and powered two-wheelers, and doesn't allow buses to overtake stationary buses in an adjacent general traffic lane. This approach also allows the same link/connector structure to be used for time periods where the bus lane is not in operation. If the bus lane is not modelled as a separate link, which is most cases, then it is best to have separate connectors for both traffic and bus lanes. This allows vehicles to be explicitly routed into the correct lanes and thus avoid vehicles entering bus lanes during congested periods.

5.3.1.6 Link Driving Behaviour

Links are assigned a driver behaviour parameter set. For London urban networks the Wiedemann 74 model[56] should be used and the model build started using the default 'Urban (motorised)' behaviour which is assigned to the default 'Urban (motorised)' link type. However, it is recommended that the following parameters be changed in the default 'Urban (motorised)' behaviour:

- Links that allow lateral behaviour should increase the value of 'min. look ahead distance' from 0 to 30m (at 30mph speed limits). This will ensure that vehicles see each other and obey traffic signals when vehicles can queue next to each other in the same lane; and
- Amend 'average standstill distance' to 1.2m for all link types.

It is advised that all other driver behaviour parameters are left at their default values unless supported by site observation and measurement. Should default values need to be changed TD NP believe that changes should be minimal and documented for assessment through VMAP Stage 3.

56 Wiedemann R, *Simulation des Straßenverkehrsflusses*, Schriftenreihe des IfV, 8, Institut für Verkehrswesen, Universität Karlsruhe, 1974 (in German).

5.3.2 Traffic Data

5.3.2.1 Vehicle Models, Types, Categories and Classes

A distribution of vehicle 'Models' are used to define a 'Type' of vehicle. Vehicle models belong to the same vehicle type if they have similar technical characteristics and driving behaviour. The default vehicle models and types provided by VISSIM are adequate for most networks. In addition to those defaults the following are often required for TfL models:

- Taxi: this can be a copy of the default 'Car' type and is often needed as taxi behaviour and routes can be significantly different from other road users;
- Articulated bus: if they operate within the study network;
- Double-Decker bus; and
- LGV/MGV: this type is often made up proportionally of vehicle models that cover a range of vehicle lengths/characteristics, providing on-street behaviour and characteristics do not differ greatly between the two.

Other vehicle types can be created if supported by observation, survey results or where required by the scheme. For example, a scheme may be concerned with speed enforcement measures and so an additional type could be included to model the behaviour of speeding vehicles. When creating vehicle types it is essential that the correct category is assigned to the type. Categories will define certain rules of behaviour. It is also important to check that the correct functions and distributions are assigned to the vehicle type; this is a common error and can seriously affect model calibration.

Finally the vehicle type is assigned to a vehicle 'Class'. Each of the default vehicle types are assigned to a single vehicle class of the same name. Vehicle classes are used to group vehicle types. Many elements of VISSIM traffic control and data collection act on vehicle classes.

5.3.2.2 Functions and Distributions

Functions define the acceleration and deceleration of vehicles in the network, and without site evidence default settings should not be changed. TD NP has conducted surveys of acceleration profiles for some vehicle types, notably articulated buses and HGVs. These profiles can be obtained on request and provided via a base VISSIM template file supplied by TD NP.

TD NP has also developed a range of other speed distributions for cars, motorcycles and buses, for different UK road speed limits and these are also included in the VISSIM template file. These distributions are based on data published by the Department for Transport[57].

57 *Vehicle Speeds in Great Britain 2005*, Transport Statistics Bulletin, SB(06)21, Department for Transport, 2006.

5.3.2.3 Compositions and Demand

It is not always necessary to create a vehicle composition for each input link. Survey data can be checked and a practical decision made about the number of compositions to be used. A single composition should suffice where input links vary in composition by 10% or less.

Many models use several time periods to specify model input traffic flows. This is acceptable, but it is normally not necessary to use more than one time period for each hour of simulated time. The number of time periods used should take the network behaviour into consideration, such as specific times of flow increases and decreases caused by events such as school runs, industrial site shift changes, etc.

Vehicle inputs should also specify ‘Exact Volume’ and not ‘Stochastic Volume’. It is important to be aware that traffic volumes are defined for each time interval in vehicles per hour even if the specified time period is different from one hour.

5.3.2.4 Pedestrian Modelling

VISSIM models developed in version 5.0 or earlier include pedestrians modelled as small, slow moving vehicles, using the same driver behaviour models as for road-based vehicles. Generally pedestrians are included in these models to activate demand-dependant pedestrian stages at signalised junctions or to replicate traffic delay occurring at un-controlled or zebra crossings.

In the case of un-controlled or zebra crossings the number of pedestrians using the crossing and controlling priority rules (conflict zones) require fine-tuning, supported by site observation in order to achieve the correct result. As with other network bottlenecks, sample counts of traffic passing the crossing will assist model calibration.

VISSIM models developed in version 5.10 or later are able to use a specific model for pedestrian behaviour. This approach, called the ‘social forces model’[58], should be used in lieu of the ‘small, slow moving vehicles’ approach used for modelling pedestrians in version 5.0 or earlier.

5.3.2.5 Reduced Speed Areas and Desired Speed Decisions

Reduced Speed Areas (RSAs) are required wherever on-street road geometry causes drivers to decelerate (e.g. bends, corners, humps or poor visibility). For turning manoeuvres it is advised that a set of speed distributions are created, each one applying to a certain range of turn radii, with smaller radii using slower speed distributions. This aids calibration as changing a specific speed distribution will affect all turning movements of a particular radius.

TD NP recommends that RSAs are used at all stoplines to calibrate junction approach saturation flows. If the stopline has the correct saturation flow without a reduced speed area, one should be used with the same speed distribution as the vehicle inputs.

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58 Helbing D & Molnar P, *Social force model for pedestrian dynamics*, Phys. Rev. E, 51, 1995, pp 4282–4286.

This will indicate to the MAE during VMAP that the saturation flow has been checked and calibrated.

TD NP does not recommend use of RSAs for the creation of artificial queues. Queues form for many reasons, for example exit-blocking, parking, merging behaviour, and these should form in the model as on-street.

Desired Speed Decisions (DSDs) are normally used where vehicles move between one mandatory speed limit and another, for instance where entering or leaving a motorway. They are best used in gyratory networks, with DSDs placed across all entries and exits. This will ensure circulatory speeds are appropriate and all vehicles return to normal speeds on exiting. RSAs should be used sparingly within gyratory links as it is difficult to ensure that all vehicles cross the full length of the RSA.

5.3.2.6 Routing Decisions

TD NP advises against manual assignment of flows on multiple routes for a single O/D movement (whether on different routes or on the same route but via a different link-connector sequence).

The use of origin-destination routes is preferred over partial routes, although it is common practice to use partial routes in the absence of O/D data. Where this is done, the modeller should pay close attention to any unrealistic weaving that may occur between the end of one partial route and the start of another. Modellers should also ensure that routing decision start points are placed sufficiently upstream of any connectors to allow vehicles to get into the appropriate lanes without causing unrealistic congestion or blocking.

All vehicle inputs require at least one routing decision. In the absence of this, VISSIM does not produce warnings, but routes traffic across the first connector encountered.

Routing decisions can be specified by vehicle type, but if survey data indicates a close to even proportion of vehicles following a single route then a single routing decision for All Vehicles is acceptable.

Routing decisions must be audited, to ensure the correct link-connector sequence has been defined from start to finish. It is not acceptable to rely on the default path defined by VISSIM.

5.3.3 Control Infrastructure

5.3.3.1 Controller Logic

VAP is the preferred method for implementing signal control logic and timings in VISSIM, even for fixed time signal plans (see B2.4.9). Methods of control rarely change by time of day and so a single VAP procedure can be used to model each peak period using different ‘program numbers’ to determine the stage change timings. A single VAP routine for all peak periods can also be used when minor changes to the method of control take place by time of day, e.g. indicative right-turn stages. VAP is also ideal for accurately modelling demand-dependency.

When coding signal plans using the fixed time control logic within VISSIM, an adjustment should be made to account for the fact that VISSIM treats the red-amber periods as green time.

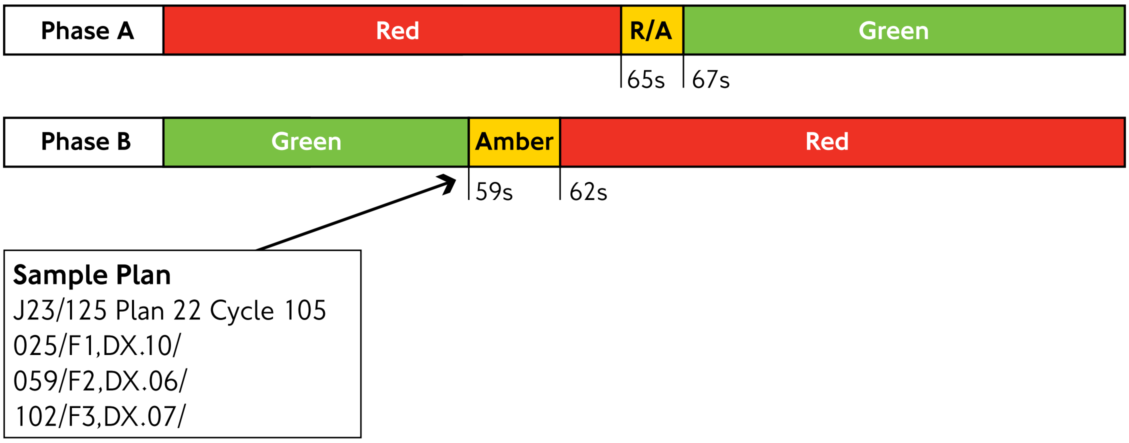

Figure 17: Adjustment of timings in VISSIM to account for Red/Amber (R/A).

The modeller must set the red-end time in VISSIM to the time of green-start from the timing plan. The example in Figure 17 would result in a red end time for Phase A of 67 seconds rather than 65 seconds. This will make the intergreen appear incorrect in VISSIM but vehicle behaviour will more accurately reflect actual reaction times of drivers as they receive red-amber followed by green.

Skeleton LinSig models should be submitted with all base VISSIM models to allow TD engineers to audit signal control elements in accordance with VMAP Stages 3 and 4 (see section B3.3.1).

5.3.3.2 Demand-Dependent Stages

In VISSIM, VAP can be used to model the appearance of demand-dependent stages. While traffic demand is measured by vehicle surveys, pedestrian movements are often not observed. As a consequence the frequency of demand-dependent stages has to be measured from UTC system logs or estimated from on-street observations. Once this frequency is determined it can be applied to all models.

The VAP logic itself may be written in a number of ways; however there are two recommended approaches to modelling demand-dependency in VAP:

1. Using a VAP programme that calls the demand-dependent stages according to data gathered from UTC; or
2. Placing detectors in the models with:
   - Exact demand as surveyed on-street; or
   - The demand manually calibrated to ensure the demand-dependent stage is enabled at a correct frequency.

The VAP function 'TRACE' can then be used to generate calibration data which specifies the number of stage appearances relative to the number of demand-dependant opportunities.

Many VISSIM models will be required to simulate Vehicle Actuated (VA) junctions. Where this is required the modeller should consult with TD Traffic Infrastructure (TI) and refer to Signal Controller Specification documentation.

5.3.3.3 Placement of Signal Heads

Signal heads should be positioned on links rather than connectors, and at least two metres upstream of the end of the link/start of the connector.

5.3.3.4 Priority Rules and Conflict Areas

Priority rules are required to control movements within signalised junctions, such as opposed right-turners. Priority rules in networks which contain give-way junctions and un-signalised roundabouts have a significant impact on vehicle journey times, queues and congestion. Preparing priority rules is one of the most difficult aspects of calibrating a VISSIM base model as model outputs are extremely sensitive to priority rule settings. It is vital that the developer has sufficient experience to model priority rules correctly in VISSIM, thus replicating on-street behaviour in the VISSIM environment.

For priority rules it is useful to ensure that the following are correct:

- Position of the yielding markers (red markers);
- Priority between different streams of traffic;
- Operation of the priority rules;
- Headways (time and distance);
- Yellow box junctions; and
- Vehicle conflicts.

With respect to conflict areas, the movement priority, visibility, gaps and safety distance factors must be specified accurately and realistically enough to reflect on-street observation.

5.4 Calibration and Validation of Base Models

Base models must demonstrate that they replicate observed conditions to a sufficiently high level of accuracy, as described in B2.5.2 and B2.5.3.

VISSIM has a useful feature which can assist with traffic flow calibration and validation, called the 'node evaluation' file. All critical junctions can be defined as nodes, from which VISSIM can collect multiple pre-defined parameters for every turning movement, vehicle type and time period. Such parameters can include traffic flow by vehicle type, average delay by vehicle type, average queue lengths per link and maximum queue lengths per link.

5.4.1 Base Model Calibration

Calibrated models are submitted during VMAP Stage 2. This is subdivided into the creation of a skeleton model during VMAP Stage 2a, followed by a final calibrated model in VMAP Stage 2b.

A calibrated VMAP Stage 2b VISSIM model should have as a minimum:

- Appropriate and correct traffic flow data from on-street surveys, in accordance with the scope and purpose of the models;
- Correct public transport data collected from reliable sources, and modelled accurately. The level of detail of public transport modelling is dependent on the purpose of the models;
- All the correct, on-street signal control data with representative signal timings for the network during the period under consideration;
- Accurately modelled priority rules that result in correct reflection of existing on-street conditions in the models;
- Reduced speed areas placed at appropriate places in the network, and used as a mechanism to calibrate saturation flows; and
- The correct, appropriate link structure which would replicate traffic behaviour on-street.

Calibration can be a lengthy and time consuming exercise. If not approached correctly the process can lead to a situation where one calibration task results in the required output for one parameter at the expense of another and the developer may get caught in a loop making little progress. To avoid this, a calibration strategy should be developed.

The following is an overview of a standard calibration strategy:

- Decide which model parameters are certain and which are uncertain and may need adjustment;
- Error check to ensure that all input parameters are correct;
- Adjust global and link specific capacity parameters;
- Adjust global and link specific demand and route choice parameters; and
- Fine tune model to better match observed travel times, queue lengths, driving behaviour, etc.

In addition, the animation features of VISSIM can be used during calibration to identify irregularities in driver behaviour that may adversely affect model operation.

5.4.2 Validated Model Requirements

Validated base models are submitted during VMAP Stage 3. TD NP will require the following outputs to be reported to indicate that a model has been calibrated and is validated.

5.4.2.1 Saturation Flows

VISSIM does not require an input value for saturation flow. Instead saturation flow is derived from other input parameters. There are two alternative ways to influence the rate at which vehicles travel over signal-controlled stoplines. These are, by modifying the 'driver behaviour' model or by using 'Reduced Speed Areas' (RSAs).

RSAs should be used where there are local inconsistencies in saturation flow rate. Where saturation flows appear to be modelled incorrectly uniformly across the network, it may be appropriate to adjust the parameters of the global 'driver behaviour' models. Modellers should exercise caution when changing the parameters of the 'driver behaviour' model as this may change behaviour in unexpected locations. A 'driver behaviour' model is associated with a link type and therefore a parameter change will affect all the links for which that model is associated.

As mentioned in B5.3.1.6, for London urban networks the Wiedemann 74 'Driver Behaviour' model should be used. The parameters of Wiedemann 74 that influence saturation flow are the 'average standstill distance', 'additive part of safety distance' and 'multiplicative part of safety distance'. The VISSIM manual provides idealised example scenarios to demonstrate the effect changing these parameters has on saturation flow[59]. However these are specific idealised examples and the parameters given cannot be assumed to give the correct saturation flow for individual cases.

RSAs influence saturation flow by changing the speed range of specific vehicle classes along a defined length of road, usually across the stopline.

Modellers should calibrate stopline saturation flows by systematically changing the RSAs and driver behaviour parameters and comparing the model against observed saturation flows. They should use the combination of parameters that result in time headways in under-saturated conditions 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[60]; or
- By producing output from a VAP routine that records and reports 'headways' across detectors that can be placed on top of stoplines.

Special evaluation files should be filtered to remove measurements that do not correspond to saturated conditions (i.e. very large headways). TD NP can supply a spreadsheet which aids the filtering of vehicle headway data.

Wherever saturation flows have been measured on-street, providing the model is a fair representation of on-street conditions, it should be possible to measure saturation flows from the VISSIM model. An inability to collect saturation flow data across a stopline in VISSIM where it was successfully collected on-street should be an indication that the model is not performing as desired.

All observed and modelled saturation flows should be tabulated and the percentage error between the two values reported. According to MAP v2.2, modelled saturation flows values should be within 10% of observed values, or values used in any corresponding validated and approved TRANSYT or LinSig modelling.

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59 *VISSIM 5.10 Manual*, PTV AG, pp119-121, 2009

60 *VISSIM 5.10 Manual*, PTV AG, p315, 2009

5.4.2.2 Traffic Flows

Modellers should use the GEH parameter (see Appendix III) to demonstrate that traffic flows within the model (i.e. internal mid-links, stoplines and individual turning movements) match traffic counts to an acceptable level of accuracy.

MAP v2.2 recommends that, when comparing modelled flow to observed flow volumes, modellers should aim for GEH values less than five. However, TD NP advocates GEH values of less than three for all important/critical links within the model area. Results should be reported to include data showing all observed and modelled flows together with calculated GEH values. Modelled flows should be averaged over multiple seeds, as described in section B5.5.1.

All entry links into the network are required to show modelled flows within 5% of observed flows. This requirement should be achieved since vehicle flows on external links are direct input values and ensures that all assigned vehicle flows are being successfully loaded into the network during the peak modelled period.

5.4.2.3 Demand-Dependency

All demand-dependant stages within the network should show a frequency of at least 90% of that observed on-street. The average count should be reported and supplied along with any generated VAP TRACE files for each simulation run.

5.4.2.4 Journey Times

Modelled journey times should be averaged over multiple seeds, as described in section B5.5.1, and be within 15% of surveyed on-street journey times according to MAP v2.2. Journey time output should be presented as the cumulative journey time obtained by all vehicles that follow individual journey time segments as well as complete journey times for vehicles that follow the entire journey time surveyed route.

5.4.2.5 Queue Data

Queue survey data, whilst not a validation criterion, is useful when determining bottlenecks within the network. It can be used as a measure of the model's performance and for direct comparison with scheme proposals. Modelled and surveyed queues should be compared and presented in accompanying reports.

It should be noted that VISSIM measures queue lengths according to a set of parameters based on vehicle speeds and headways. Changing these parameters will result in different queue lengths being reported where in fact queues have not actually changed. TD NP advises that the default queue configuration parameters are used.

5.5 Considerations During Calibration and Validation

5.5.1 Use of Seed Values

Traffic conditions vary day-to-day as a result of random driver behaviours such as speed selection, lane changing, driver route choice, bus and parked vehicle dwell times. The stochastic micro-simulation traffic model in VISSIM attempts to replicate this day-to-day random variability by altering individual driver decisions based on random numbers. The set of random numbers is generated from an initial 'seed' value specified at the start of a simulation run. A single set of random numbers, generated by a single seed value therefore represents one potential outcome, or one particular day of traffic operation. The actual value of the seed has no significance; however they must be different from each other to produce a different outcome. Basing results on a single seed value has the potential to randomly bias the overall result.

An accepted method of reducing potential bias is to run several simulations using a range of initial seeds and to present mean average results. For this reason both calibration and validation should be conducted using a minimum of five seed values, as stated in MAP v2.2.

It is important to note that the more saturated a network becomes, the more variable the result. This occurs because small adjustments in model behaviour (e.g. lane changes) have an amplified impact within a congested network. It is usual that more simulation runs be used for saturated models. It is possible to calculate the number of simulations necessary to produce a reliable result if the required confidence level is known for a traffic model, but as a guide ten simulation runs are normally sufficient but more may be necessary.

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

5.5.2 Error Files

VISSIM and VAP error files (*.err files) are created when errors exist within the simulation. These files should be thoroughly audited as they may contain indication of errors such as:

- Minimum green and/or minimum stage lengths violations;
- Unusual stage change sequences;
- Vehicles being removed from the network;
- Vehicles reaching the end of links while still searching for routes; and
- Vehicles not being loaded onto the network.

Ideally, no error files should be produced at the end of the simulation runs. However, small error files with non-critical error messages are acceptable within VMAP.

5.5.3 Use of Multithreading during Validation

VISSIM output data cannot be reproduced when using multiple processor cores. In order to generate reproducible results during validation it is therefore necessary to set the number of cores to one in the Simulation Parameters dialogue, as shown in Figure 15.

The use of multiple processor cores may help VISSIM to run faster. The use of multithreading is therefore acceptable during model development but only one core should be used for producing validation data and thus reportable results for model auditing.

5.6 Dynamic Assignment

Dynamic Assignment (DA) is a method of routing trips through a network that includes alternative route choices.

In many cases, VISSIM models developed for London do not include any real alternative routes and therefore using DA is unnecessary. Where alternative routes do exist, modellers should carefully consider what benefits DA will provide, and then to balance this against the added complexity introduced during base model calibration and option/scheme testing. Modelling option testing using DA will require an iterative process which should significantly increase the amount of required simulation time. In cases where dynamic modelling is justified, a combined static-dynamic assignment is preferred.

When using DA, the link connector structure should avoid using multiple connectors between single lanes as this introduces non-existent alternative routes which place an additional burden on the assignment process as well as creating unrealistic and inconsistent queuing behaviour. While it may be necessary to use multiple connectors to enforce particular queuing behaviour upstream of a turning movement this should be employed in addition to route closures for vehicles not making those particular turning movements.

5.6.1 Convergence

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

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

These convergence criteria have been based on DMRB acceptability guidelines for highway assignment models and aim to confirm a stable and converged assignment[61]. Three methodologies which may help a modeller to achieve convergence using DA in VISSIM are outlined in Appendix IV.

61 *Design Manual for Roads and Bridges*, Volume 12, Section 2, Part 1, Chapter 4, p4/29, Department for Transport, 1996.

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

5.7 Proposed Models

All proposed VISSIM models are expected to have corresponding approved LinSig or TRANSYT models, which should hold the same network data.

Input traffic flows and traffic routes should be the same as in the base model except where major network changes are proposed. Where this is the case the proposed reporting should contain a methodology which details assumptions and all other relevant data used when re-assigning traffic flows from the base.

Proposed VISSIM models should also contain optimised signal data derived from a corresponding traffic model. VISSIM is suited to modelling spatial phenomena so it is accepted practice to iterate between VISSIM and the traffic model to achieve a proposed solution, for example during the fine tuning stage of model optimisation identified in B2.6.2. Signal timings may be fine tuned within VISSIM to account for over-saturated conditions following the process outlined in B2.6. Once a solution has been established, final signal timings should be implemented. For audit purposes it is important that signal timings within VISSIM match those delivered with all accompanying modelling. Finalised proposed models should be submitted during VMAP Stage 5.

6 Highway Traffic Assignment Modelling

6.1 Introduction

This section provides advice for the development of Highway Traffic Assignment (HTA) models within London. It emphasises the development and calibration of the highway network, and assumes that a robust set of user demands are available. Whilst the calculation of user demand is only briefly referenced, the importance of obtaining reliable and validated demand data cannot be overstated.

Modellers are advised to speak with TfL Policy Analysis at the outset of any project, for specialist advice on the development of HTA models for major scheme testing in London. TfL Policy Analysis is the custodian of the London Transportation Studies (LTS), RailPlan and London Sub-Regional highway assignment models. Guidance written by the Department for Transport (DfT), available on WebTag[62], and the Highways Agency in the Design Manual for Roads and Bridges (DMRB)[63], should also be considered.

62 **http://www.dft.gov.uk/webtag/**

63 **http://www.standardsforhighways.co.uk/dmrb/**

6.1.1 HTA Modelling in TfL Streets

The TfL Traffic Directorate (TD) retains a stock of detailed local area traffic models. These are used by engineers day-to-day for generating optimised traffic control plans and accurately quantifying the potential impact of schemes. Whilst these models are able to provide an accurate picture of local traffic operations they are unable to represent the wider impacts, particularly with respect to traffic re-assignment. HTA models are therefore required to examine these wider impacts.

HTA models are typically used to predict the strategic (long-term) impacts of changes in transport supply or demand, often as part of a broader multi-modal assessment framework. However in London HTA models are sometimes used to predict short-term traffic re-assignment and congestion impacts due to local network changes. TD is increasingly required to understand the operational (medium-term) implications of proposed network changes. A HTA model produced by TD, called ONE (Operational Network Evaluator), developed upon the VISUM software platform has been coded to a high level of detail and provides the ability to predict the magnitude of operational interventions upon the network.

6.2 HTA Modelling Software

This section principally contains guidance for the development of HTA models within London. In doing so it presents good practice for modelling any location where the urban road network is heavily congested. To represent congested conditions realistically it is important that the chosen HTA software meets specific minimum criteria. These important functional requirements include:

- Accurate turn capacity and delay calculations including opposed turns;
- Limited queuing capacity (i.e. blocking back) at links should be taken into account in route choice algorithms;
- Over-saturated turns should meter traffic proceeding to downstream links;
- Assignment algorithms should converge and produce stable assigned flows; and
- Assignment algorithms should be able to find a number of alternative paths of equal cost between most origin-destination pairs.

VISUM and SATURN, detailed in section A9.4, are commercial modelling packages which meet the above criteria and as such have been applied in a London context. They are both recognised by TD as appropriate for congested traffic assignment.

6.3 HTA Data Collection

For the development of HTA models, as for any other traffic or transport models, good quality data is essential. WebTag and DMRB provide comprehensive advice on the collection of data for HTA models and this advice should be followed.

General advice on collecting appropriate data for traffic modelling can be found in B2.3 & B2.4. However, a different approach is often required for HTA modelling data collection when compared with deterministic and micro-simulation modelling. The study area is generally bigger for HTA models where a network can usually consist of several hundred nodes and interconnecting links. For this reason it is usual to estimate a cost benefit ratio between the data required for network development and resource available for collection (i.e. people, equipment, etc). It is usually not possible to survey and process data for all links and nodes within a network. HTA modellers are therefore often required to select representative locations for sample surveying.

HTA models have unique data requirements which can be broadly classified into:

- Observational (site visits, cordon/screenline surveys, speed and car-parking surveys);
- Written (travel diary and household surveys); and
- Oral (roadside and Telephone interviews).

6.4 Network Development

The modelled HTA network is defined by the area within which link flows, journey times or delays will be significantly affected by the implementation of a proposed scheme. For this reason a HTA network must be sufficient to allow traffic associated with such developments to disperse through the road network in a realistic way.

The scale of HTA network can usually be determined by considering the following issues:

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

The HTA network should then be developed following a defined and repeatable methodology. All network design decisions should be documented to allow accurate auditing.

6.4.1 Zones and Connectors

As a guideline, internal zones should be small enough so that no more than 300 trips are generated from each connector. If a zone has a large number of origin/destination trips, increasing the number of connectors will not be sufficient to decrease the number of trips per connector because the assignment will unevenly load the connectors. The preferred approach is to have one or two connectors per zone and make the zones small enough to achieve the required number of trips per connector.

It is important to check that sufficient capacity is available in the network downstream of an origin connector (and upstream of a destination connector) so that no over-saturation artefacts are created. Zones should be connected to the network via secondary nodes, preferably on secondary links which are already in the network.

The concentration of several zone connectors on secondary links may result in unrealistically high volumes on those links. If this results in over-saturation of the secondary link then its capacity must be increased. If it results in over-saturation of any junction within the main-network then the delay calculation for that node should be disabled. This manipulation can introduce an error during the impedance calculation for the secondary link, but the overall effect is less severe than blocking back a large proportion of zone traffic. This would lead to the model underestimating delays in other parts of the network where zone traffic is missing.

6.4.2 Nodes and Links

It is advisable to import the basic topology of the street network (nodes and links) from a commercially available navigation network (e.g. the Ordnance Survey MasterMap Integrated Transport Layer[64]). Navigational networks normally represent the most up-to-date state of the network and include all driveable roads within their network database. It is necessary to reduce this complex dataset down to a manageable set of primary links on which to perform traffic assignment. However, rather than deleting unwanted links, a filtering method should be used to exclude redundant links from the traffic assignment. Assignment should then be carried out on both the defined primary network and important 'rat runs' within the modelled area. Links not contained in this subset should be designated as closed.

Navigational network data sources typically contain attribute information, detailing functional class, speed restriction and number of lanes. These networks often lack the attribute data necessary for transportation planning purposes. This data must be added after importing the basic topology. Uncongested speeds should be assumed to be constant throughout the length of the links and equal to their speed limit or free-flow measured speed via the 'moving observer' method.

Link capacities and delay curves are required for a transport model but this information is often missing from typical navigation networks. Fortunately precise link capacities are not critical because junctions are the primary source of network delay in congested urban areas. Link classification and capacities should follow DMRB guidance and can be derived from navigation networks by using a combination of functional class and number of lanes. Where mid-link capacity is significantly curtailed, for example due to an uncontrolled zebra crossing or on-street parking/loading, it is necessary to accurately measure capacity through on-site observation. These mid-link capacity bottlenecks should be modelled accurately as they dictate downstream junction capacity.

The number of lanes on a link must be set correctly, and verified on-street. In the detailed HTA junction model these represent the number of through lanes for the two nodes connected by the link. Failing to specify the right number of lanes will result in incorrectly coded junction models with the wrong number of turning lanes. This will generate errors in the determination of turn capacities and delays.

64 **http://www.ordnancesurvey.co.uk/osmastermapitn/**

Links in strategic transport planning models are often coded with an effective number of lanes. This is used, for example, where the kerbside lane of a two-lane street is blocked for parking during part of the day. Instead of coding both lanes, the modeller may choose to code only one effective lane. This practice is discouraged for several reasons:

- Kerbside parking regulations may change throughout the day. If the network is to be used in the future for other time periods (e.g. inter-peak), its lane structure must be revised;
- Kerbside parking normally affects mid-block link capacity, which should be coded independently from the overall link capacity;
- In order to accurately represent capacity in urban networks, junctions must be coded accurately. Link/lane structure therefore must correspond with the physical infrastructure in order to derive accurate lane allocations on the approach to junctions; and
- If at a later stage sub-areas of the models are exported to a micro-simulation, for detailed analysis, the attribute 'number of lanes' translates into the physical width of the street in the simulation. Friction effects from parking manoeuvres may then be explicitly part of the simulation and would therefore be accounted for twice.

Where bus lanes exist along a link care must be taken to represent link capacity accurately. We advise that bus lanes are included in the overall number of lanes, but that the link capacity excludes the capacity of the bus lane. However, because taxis can travel in bus lanes, the final capacity of the link for general traffic and taxis must be increased with additional capacity added to the overall link capacity to account for a proportion of taxis travelling in bus lanes. This additional capacity can be road type specific or to a particular link where site observations exist.

6.4.3 Signalised Junctions

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

HTA modelling software packages will simulate junction capacity using different methods. However, it is common that junction attributes will include data that defines junction geometry and the average method of traffic control.

SATURN relies on a propagation of Cyclic Flow Profiles (CFP) for calculation of the actual turn delays within a junction (see Figure 14). The CFP method allows accurate calculation of delay by inherently considering the impact of platoon progression on junction turn interaction. To achieve the correct capacity SATURN regards all turning movements at a junction as 'assignment links' with specific Volume-Delay Functions (VDFs). Unlike conventional assignment link functions, the volume-delay curve within SATURN is not user specified or pre-defined but is calculated by the software using input information on signal settings, turning priorities and saturation flows.

VISUM uses a different approach, by using an Intersection Capacity Analysis (ICA) module which is based on the Highway Capacity Manual[65] (HCM) method for calculating junction turn capacities and delays within isolated junction models. The HCM methodology treats junctions in isolation and thus disregards the effects of signal coordination. VISUM corrects this within ICA by modifying the junction turn delay based on the link attribute 'ICAArrivalType', a parameter which describes the nature of traffic platoons. Complex and/or large junctions (e.g. dual carriageway junctions) in navigational networks are often not represented by a single node, but instead by a group of nodes. One individual node then corresponds to only one part of an actual junction and application of the HCM formulae to each of these sub-nodes would yield erroneous results within VISUM. The solution adopted in VISUM is to group all nodes comprising a given intersection into a single 'main node'. This can be illustrated by Figure 18, which shows a four leg intersection with separate carriageways in the east-west direction. For the purpose of signalling, capacity and delay calculations this has been combined into a single node within VISUM.

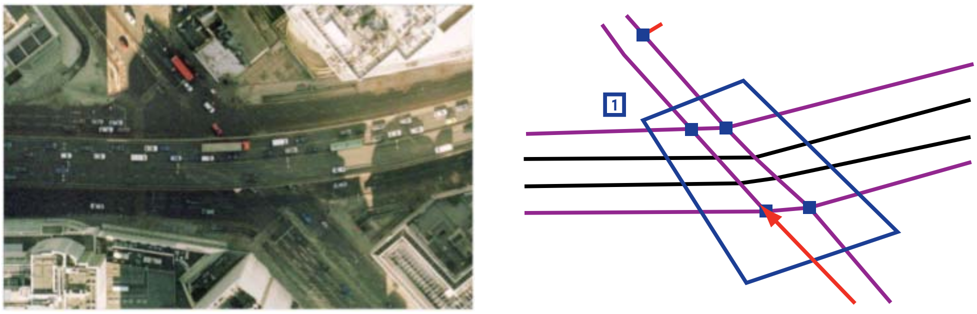

Figure 18: A VISUM main node – as on-street (left) and within the model (right).

When using the ICA method embedded within VISUM it may not seem necessary to specify free-flow turn time (t_0 in VISUM) and capacities for turns. However the bi-level calculation method within VISUM initiates a classical VDF-based equilibrium assignment which requires both free-flow turn time (t_0) and turn capacity. It is for this initial assignment that the attributes need to be specified. Experiments have shown using VISUM that converged solutions are quite stable against changes of the initial t_0 and turn capacity, so the choice of these values is not critical. Recommended values are:

- Initial t_0 = 10s; and
- Initial turn capacity = 1500 PCU/hour x effective number of turn lanes.

The effective number of turn lanes is given by:

- 1.0, if the lane is exclusive; or
- 0.5 or 0.333 if shared with one or two other movements.

65 *Highway Capacity Manual*, Transportation Research Board, Washington, DC, 2000.

The procedure used when converting ICA parameters into turn volume delay functions successively overwrites turn capacities with new estimates from ICA. In order to restore initial values and reproduce results, it is necessary to input initial turn capacities as a VISUM User-Defined Attribute (UDA) instead of the in-built turn attribute. ICA calculations for over-saturated junctions may yield very small capacities. While this should not occur in the converged solution, it may happen during the first iterations and can then lead to numerical problems. A reliable countermeasure is to specify a minimum turn capacity, as a UDA, to use as a lower bound for re-estimated capacities. A minimum capacity of 100 PCU/hour has been found to work in practice. The value can be justified since a number of vehicles can be stored in the junction and clear during the subsequent interstage even when the opposing flow is saturated.

6.4.3.1 Junction Geometry

In HTA models detailed junction modelling should begin by coding accurate junction geometry. The coding of geometric elements should represent information obtained from various sources outlined in B2.3 and B2.4 (e.g. site layout drawings and site observations).

An illustration of junction coding will be provided using VISUM. Detailed junction modelling should begin by defining the orientation of the approach links at a node or main node. The orientation of an approach link is the direction (i.e. north, east, south, or west) from which it approaches the intersection. It serves as a convenient designation of the approach for reporting, but also determines geometric calculations in the node by defining conflicting movements. Link orientations are assigned automatically from link angle, which may not be desirable when modelling main nodes within VISUM. Node approach link orientations must be correctly defined at the beginning of any network development. Link orientations act as a reference for other data in the junction model, meaning subsequent alteration will cause a loss of dependent link data such as lanes, signal group associations, etc.

To correctly model the geometry of a junction it is necessary to specify the number of lanes per approach, allowed turns per lane and the length of effective flared lanes. VISUM will only represent distinct lanes with a constant width. Therefore flared lanes must be coded as separate pocket lanes. The effective length of a pocket lane is the position at which the flared approach allows two vehicles to queue side by side. ICA does not currently consider the finite length of pocket lanes, although future extensions may incorporate this feature to better reflect queuing capacity. Pocket lanes will need to be coded if this feature becomes incorporated within ICA.

Figure 19 illustrates the correct coding of a dual carriageway junction where the east-west direction consists of dual-carriageway links. VISUM is unable to recognise that links belong to a single leg of the same intersection. Furthermore, accidental differences in link angle lead to the north-west leg coming from south of the west leg, similar to the eastern side of the intersection. The correct solution illustrates that it is necessary to manually override the link orientations to designate both of the links on the left as the W leg, and both links on the right as the E leg. Note that the direction of major flow (the thick arrows in Figure 19) is now drawn correctly alongside each of the one-way carriageways.

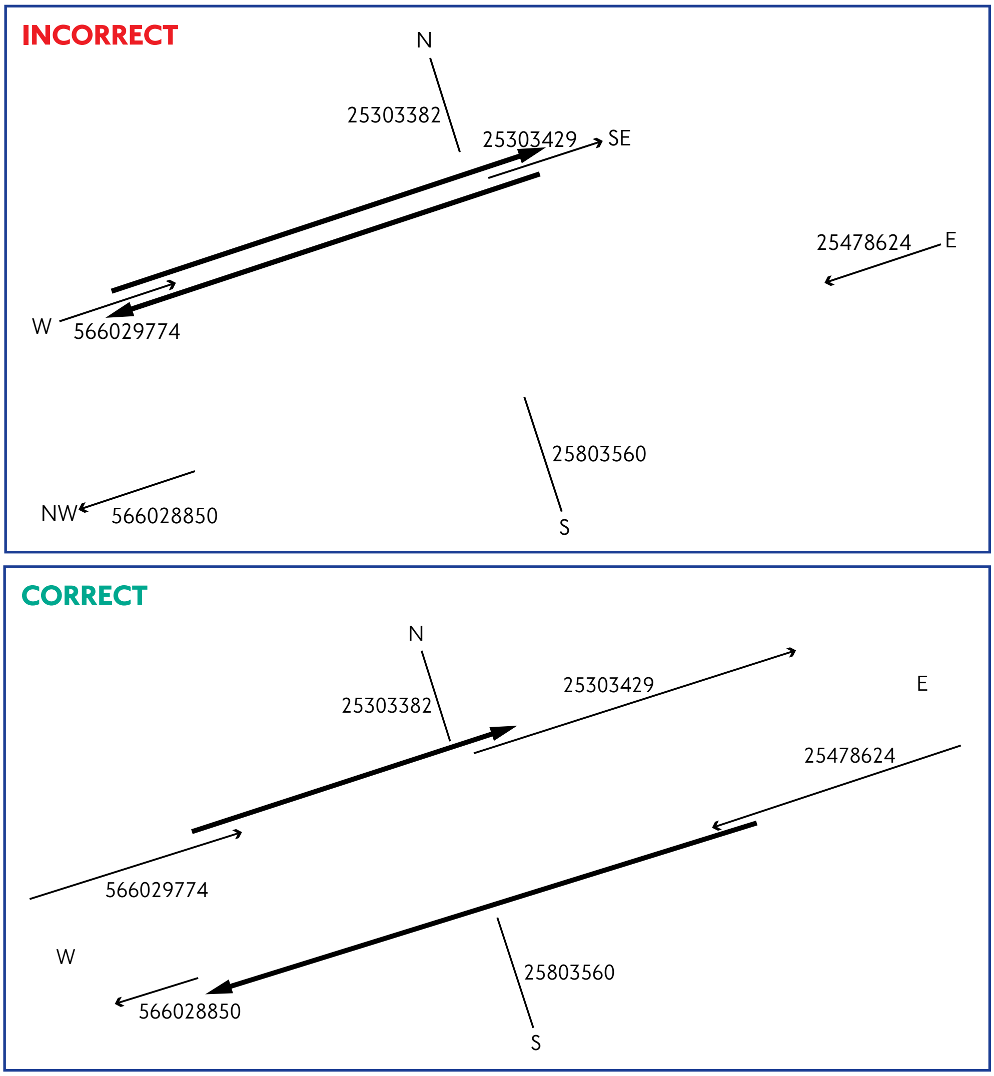

Figure 19: Examples of incorrect and correct network coding using a dual carriageway junction in VISUM.

6.4.3.2 Capacity Considerations

Calculation of effective capacities is an essential component within any congested assignment model. Signal settings and saturation flow are the two main parameters necessary to represent network capacity. The accuracy of these parameters is paramount if a model is to correctly depict available traffic supply.

SATURN and VISUM have specific capacity coding requirements driven by the methodology used to calculate network delay. Both require an average timing plan to be created, therefore it is advised to refer to section B2.4.9, especially if a junction operates with traffic-actuated (i.e. VA) or dynamic (i.e. SCOOT) signal control. Average phase durations and cycle times should be calculated before being coded into the junction control. The presence of demand-dependent stages should be established, with their frequency, along with a determination of which stages receive additional time when an enabled stage is not activated (see section B2.4.9.3).

SATURN uses cyclic flow profiles (CFP) based on turning movements, which consist of four different patterns: IN, ARRIVE, ACCEPT and OUT. The ACCEPT profile is derived independently based on capacity, signal timing and conflicting traffic. The accurate generation of this profile is critical to a model and thus occupies a large proportion of the required coding. The calculation of the saturation flows in SATURN is vulnerable to inconsistency during network coding. This is because modellers must use a level of interpretation when developing a network and thus practitioners may use generic saturation flow values for specific turn types. This may be acceptable for specific networks but the preferred option should be for measured saturation flow values.

VISUM also allows users to override the ideal turn saturation flow. It may be necessary to use this feature when the ICA (HCM) method conflicts with more detailed modelling or site observation. In all other cases use of the saturation flow override is discouraged in VISUM as it effectively disables the sensitivity of the model to changes in junction geometry or signal timing.

There are two important network attributes that have an important influence on ICA results within VISUM:

- Link attribute 'ICAArrivalType' describes the nature of traffic platoons. This should be calculated from the platoon progression on each link, and is used in lieu of signal offset values that are not applied within ICA turn delay calculations; and
- Node attribute 'Sneakers' describes the minimum number of vehicles which will succeed in making an opposed right-turn within each cycle. A single value applies to all movements at the node. For opposed turns with high conflicting flows, the sneakers will be virtually all capacity available for that turn. Care should be taken in setting a realistic value based on the physical storage available within the intersection.

Within VISUM it is also recommended to define a lower threshold in a UDA '*MINCAP*' which maintains a minimum capacity during ICA re-estimation. The lower threshold must be adjusted to be greater than, or equal to, the base volume. The following approach for this adjustment is suggested:

$$MINCAP = \min(\mathrm{MINCAP}_{orig},\ 1.1 * \text{base volume}) \qquad \textit{Eq. (1)}$$

where MINCAP_{orig} refers to the original value (e.g. 100).

6.4.4 Priority Junctions

Priority junctions should be modelled with same level of detail as signalised junctions. Intersection geometry and vehicle gap acceptance is used to calculate capacity at priority junctions.

SATURN requires cycle time duration when coding non-signalised junctions. A default parameter (LCY = 75 seconds) will be used if a value is not entered for a particular intersection. It is advised to enter the value for cycle time of the nearest signalised junction, as failure to do so may impact CFPs between adjacent junctions and potentially poor representation of traffic platooning within the network.

In VISUM, the main input for priority ICA calculations is the major flow, i.e. the direction of priority. Major flow is technically defined as a pair of node legs. Care should be taken when modelling main nodes or nodes with dual-carriageway approaches. As shown in the example within Figure 19, opposing pairs of one way links must be converted to one node leg (by giving them the same orientation) which then allows the major flow to be defined correctly on those node legs.

The ICA calculation of capacity and delays at priority-controlled junctions is primarily based on gap acceptance headways. Critical gap and follow-up gap parameters can be defined by the user or retained as default values provided by HCM. A user-defined override may be required for a roundabout entry as there is no roundabout specific delay model within VISUM. It is advisable that critical gap and follow-up gap values for non-standard priority junctions are estimated within local-scale models such as PICADY and ARCADY (as described in A9.2.2).

6.4.5 Public Transport

Public transport can absorb a proportion of capacity on some network links and turns. The impact of public transport should be carefully considered, particularly on mixed use links with no dedicated public transport lane.

This section explains how the capacity effect of public transport is addressed within VISUM. The number of bus trips during the assignment period is used as a preload for all turns, and for those links without a bus lane.

In SATURN, a bus-only lane is defined to be a full-length lane from the upstream entry to the downstream stopline. This means bus lanes with set-backs cannot be explicitly modelled within SATURN. This full length lane is used exclusively by any form of public transport being coded as a segregated from general traffic.

In VISUM, the assignment procedure can access several link and turn UDAs which are preset during network coding:

Link UDAs

- *BUS_LANES*: a 0-1 integer attribute which indicates the presence of one or more dedicated bus lanes along the link (1 = present); and
- *BUS_LOAD*: the number of buses that pass along the link during the assignment period.

Turn UDAs

- *BUS_LOAD*: the number of buses that pass along the turn during the assignment period.

It is worth noting that *BUS_LOAD* has a significant effect on available capacity making it important to specify consistent values for all links. It is advisable to include bus routes with their timetables in the same network model used for road traffic assignment. It is then possible to use analysis functions to count and assign the number of buses within each assignment period for each link or turn.

6.5 Calibration

Calibration of a HTA model involves altering network parameters (e.g. capacities) and travel demand in an attempt to match modelled data (e.g. traffic flows and journey times) to observed data.

This section will not describe the typical parameters used for this exercise (i.e. turn and link counts, journey times and speeds), as the required methodology is not specific to the calibration of HTA models. It is recommended that attention is paid to the location of base data used for calibration and validation to ensure a consistent level of quality across the model study area. One useful approach is to use traffic counts along a series of north-south and east-west screenlines for validation, whilst using counts within the cells formed by those screenlines for calibration purposes.

This subsection will cover some of the more specific capacity calibration exercises used by TD when HTA modelling using VISUM.

VISUM uses the ICA module for capacity and delay calculation. For the ONE model a number of detailed deterministic models (LinSig/TRANSYT) were used to retrieve capacity delay outputs and overwrite the internal ICA calculation. To do this LinSig/TRANSYT models were coded with identical traffic flow and timing plans as the ONE model. TRANSYT models were also used to indicate the quality of traffic progression between signals. The ICAARRIVALTYPE parameter was adjusted to accommodate the level of progression. The empirical models provided detail about flared approaches. Capacities were then adjusted according to all the information provided.

Delay and DoS from the local scale models were then compared against ICA output. VISUM calibration parameters were then adjusted to align ICA junction performance with the local scale modelling. It is advised that a similar approach be adopted for priority junctions. For junctions of this type the VISUM calibration parameters which require adjustment will be the 'critical gap' and 'follow up time', as these values fundamentally control the time required for an average driver to accept a gap in oncoming flow and merge with traffic.

6.6 Assignment

Route assignment, route choice or traffic assignment relates to the selection of routes (paths) between origins and destinations in transportation networks.

A common assignment procedure within HTA modelling is based on Wardrop's Principle of Equilibrium[66], where travel cost is assumed to depend on the volume of flow in the network. Using this principle, an assumption is made that all drivers have the same perfect knowledge of routes in the network, and that they all seek to minimise the cost of travel without having any preference for the type of road they use (i.e. main or side road). Multiple user class (MUC) assignment can also be used to achieve equilibrium between modelled supply and demand. This is achieved by biasing certain user classes towards longer (rat run) or shorter (sign posted) routes.

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66 Wardrop J G, *Some theoretical aspects of road traffic research*, Proceedings, Institution of Civil Engineers, PART II, Vol.1, 1952, pp325-378.

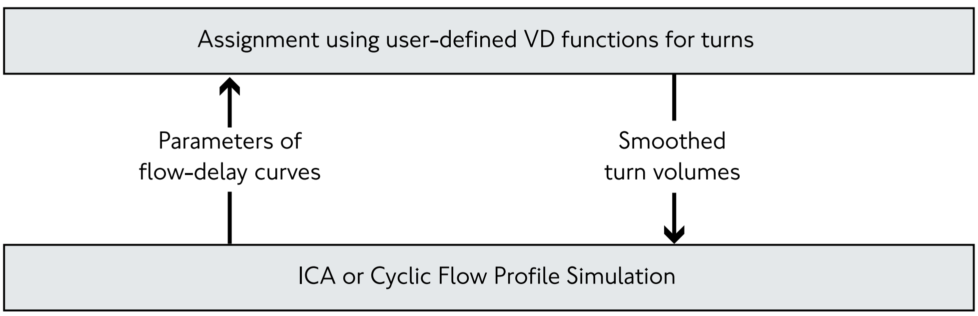
SATURN can undertake MUC assignment using a similar approach to Wardrop equilibrium. Instead of a single 'all or nothing' assignment SATURN completes one assignment for each user class and updates costs after all user classes have been re-assigned. Hence at the end of the algorithm the fraction of trips assigned to each iteration's routes is identical across all classes. SATURN also contains a Stochastic User Equilibrium (SUE) assignment algorithm, but from a practitioner's point of view it is advisable to use Wardrop equilibrium assignment within a congested urban network.

PTV AG advocates the use of the Equilibrium Lohse procedure[67] within VISUM. The Equilibrium Lohse procedure simulates the learning process of road users using the network. Based on an 'all or nothing' assignment, drivers make use of information gained during their previous trip for the new route search. TD believe this is the best methodology for HTA modelling within London using VISUM. This type of assignment was used for the ONE model in combination with Wardrop equilibrium.

6.6.1 Realistic Delay using Equilibrium Assignment in Congested Networks

HTA models are developed to provide a practical approximation of idealised equilibrium in congested urban areas. At the heart of this process is an assignment-simulation loop where HTA modelling software iterates between assignment sub-models until relatively steady flows are obtained. This approach is, in theoretical terms, referred to as a 'diagonalisation method'. An applied example for this method is described below using VISUM, but this approach is applicable to both VISUM and SATURN models.

VISUM uses ICA as a method of deriving turn capacities and delays from junction geometry and control data. This HCM-related approach can also be successfully applied as a post-processor of assignment results. However, convergence cannot be guaranteed and prolonged run times may result if it is used directly during an equilibrium assignment. The use of non-separable impedance functions can also generate convergence problems, i.e. where the impedance of a turn is not only a function of the flow of that turn but also dependent on other turning volumes at the junction. This problem will commonly occur within congested networks where volumes oscillate between subsequent iterations of the assignment.



VD = Volume Delay

Figure 20: A bi-level approach to traffic assignment with operational-level turn delays.

67 Schnabel W & Lohse D, *Grundlagen der Straßenverkehrstechnik und der Verkehrsplanung*, Volume 2, Verlag für Bauwesen, Berlin, 1997.

VISUM and SATURN allow operational-level turn delays and generally use the same approach to overcome the problem as illustrated in Figure 20. After initialisation an iterative loop is generated, which alternates between an assignment using turn VDFs and the calculation of turn delays and capacities using ICA. Executions of the bi-level loop will be called loop iterations, to distinguish them from the equilibrium iterations inside the assignment. Traffic is first assigned to the network within each loop using a small fixed number of equilibrium iterations (typically 5 or 10). The assignment uses turn VDFs which are of the following general form[68]:

$$t_{cur}\,(sat) = \begin{cases} t_o + \beta \bullet sat^k & sat < sat_{crit} \\ to + \beta \bullet sat^k{}_{crit} + d\,(sat - sat_{crit}) & sat > sat_{crit} \end{cases} \qquad \text{Eq. (2)}$$

where sat = volume / capacity ratio

6.6.1.1 Blocking Back

An unconstrained equilibrium assignment in a congested urban network can result in links and turns with a volume capacity ratio greater than one which remain attractive despite inflated delays. This is not a traffic modelling error, as the theory of equilibrium assignment is independent of time. A problem occurs for the modeller when an assignment result is interpreted to represent volumes within a given time period (e.g. the peak hour), because those over-saturated network elements will act as bottlenecks. These over-saturated network elements will in reality produce queues that block back upstream of the pinch-point and meter downstream traffic volumes.

HTA models developed for London's urban road network have to be capable of accurately representing blocking back and its impact on the congested network.

6.6.2 Convergence

High levels of convergence should be achieved in HTA modelling. This is important because if link flows and their corresponding flow-delay curves are not reasonably consistent then there is little confidence in modelled output, such as link flows, costs, etc. Convergence also provides confidence that any differences in traffic flow between converged base and proposed networks can be ascribed to the effects of the scheme being tested rather than random 'noise' which may arise on the base network if flows were compared from one run of assignment to the next.

In VISUM, the bi-level assignment method will be assumed to have converged sufficiently if all of the following criteria have been met:

- The last batch of equilibrium assignment iterations has reached a gap of 0.001;
- 95% of assigned turn flows between two successive loop iterations have converged within 1%;
- 95% of assigned turn flows from the last loop iteration are within 1% of the smoothed flows used for junction capacity analysis; and
- 90% of turn delays from calibrated turn volume delay functions are within 5% of turn delays calculated from the junction capacity analysis module.

68 *Traffic Assignment Manual*, Bureau of Public Roads, Urban Planning Division, U.S. Department of Commerce, Washington, DC, 1964.

These criteria are assessed after VISUM ICA evaluation. If criteria are not met, new parameters for the turn volume delay functions (and in the case of blocking back, new link capacities) will be estimated from the ICA results and the assignment loop will be re-executed.

Concerns regarding convergence are discussed in detail by the DMRB, but TD NP believes the following general guidance should be applied:

> *"Convergence in practice needs to be measured in terms of two desirable properties of the flows and costs calculated by the programme:*
>
> - *Stability of the model outcomes between consecutive iterations; and*
> - *Proximity to the assignment objective, (e.g. Wardrop equilibrium)"* [69]

In the context of SATURN, proximity indicators measure the degree to which the assignment sub-model has achieved its stated aim. In the case of equilibrium assignment this means the degree to which Wardrop equilibrium has been achieved. DMRB recommends 'Delta' (a relative measure of excess travel cost) as the proximity measure for Wardrop equilibrium assignment, and states that it must be less than 1%. Proximity indicators should also include a measure for the simulation sub-model and changes in output Cyclic Flow Profiles. Stability indicators measure the change between concurrent model iterations and are of particular relevance within the assignment-simulation loop. DMRB outlines two types of stability indicator:

- Global indicators, that provide network-wide comparisons of total costs, distances, times and average speeds; and
- Disaggregate indicators, which provide absolute change in individual link parameters such as flow, cost, time, etc.

The most important convergence measure for user equilibrium assignment is the percentage change of traffic flow on the individual links. DMRB states that at least 90% of links should have a flow change of less than 5% and this should be maintained for the final four iterations.

6.7 Model Validation

Network validation data must be independent from data used during calibration. This data independence ensures that validation statistics are a true measure of validation. It is not appropriate to supplement the data used for calibration with validation data in order to improve the quality of model validation.

The validity of a HTA model should be assessed by comparing the model volumes and travel times against field observations. It is felt that cordon/screenline counts are a more realistic target than individual turn/link counts.

69 *Design Manual for Roads and Bridges*, Volume 12, Section 2, Part I, Appendix H, May 1996.

Target validation criteria for these data are:

- 95% of model cordon/screenline flows within a GEH of five compared to observed flows;
- 95% of all modelled route journey times to be within 15% of observed mean times; and
- 75% of model turn flows within a GEH of five compared to observed turn flows.

Extended validation criteria using turn flows may be applied where subarea models for detailed design work are planned to be exported from HTA modelling:

- 95% of model turn flows within a GEH of five compared to observed turn flows; and
- 95% of model turn flows within 100 (PCU/hour) difference compared to observed turn flows.

Accuracy of observed counts must be within ±50 PCU/hour or within a GEH of two (see Appendix III). Journey times should be within ±10% before validation checks are conducted. However, it is important not to seek to achieve one validation criteria whilst ignoring other equally critical aspects of validation.

6.7.1 Assignment (Route Choice) Validation

It is recommended that modellers validate assigned traffic routes in order to ensure that route choice is adequately represented in the model. Through this process it is possible to identify problems with various aspects of the model such as issues with zoning and network connectivity.

Modellers conducting route choice validation should have an extensive knowledge of both the network and prevalent network conditions for each modelled time period. They should have the ability to ‘sense check’ assigned route choice, for example, by using flow bundle analysis in VISUM or the tree analysis function in SATURN. Route choice validation results should be produced separately for each modelled time period and each vehicle class.

CLOSING SUMMARY

These Traffic Modelling Guidelines, produced by the Traffic Directorate within TfL Streets, provide overarching guidance on the appropriate standards of traffic modelling required when proposing a traffic signal scheme on London's urban network.

Modelling experts within TfL and across the industry have contributed to this document. Part A provides a high level overview of traffic modelling for a non-technical audience, whilst Part B presents specific advice and standards for practitioners. The document can be read as a whole entity, but can also be used as a reference for particular traffic modelling issues.

The content of these guidelines was correct at the time of publishing, based on versions of software that were in everyday use in TfL TD. Since traffic modelling software vendors are continually developing new versions of their software, the intention is to treat this document as an evolving entity. It will continue to be updated in the future to provide best practice advice on new products, concepts and techniques as they are developed and tested in our working environment.

All advice provided in the Traffic Modelling Guidelines is non-binding but is directly related to the way TfL operates London's traffic management systems. This document builds upon the success of the two previous versions, which have been used as guidance during the development of numerous traffic models both in the UK and overseas.

The latest version of this document is available to download from: **http://tfl.gov.uk/streetspublications**

We encourage feedback on the advice given in this document. Please address all comments, specifying that they are related to the Traffic Modelling Guidelines *Version 3.0,* to:

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GLOSSARY

AIMSUN	Advanced Interactive Microscopic Simulator for Urban and non-urban Networks, modelling software developed by TSS
ANPR	Automatic Number Plate Recognition
AQMA	Air Quality Management Area
ARCADY	Assessment of Roundabout Capacity And DelaY, modelling software developed by TRL
ASL	Advanced Stop Line (for cyclists)
BP	Bus Priority
BR&P	Better Routes and Places Directorate, formerly the London Road Safety Unit
CE	Checking Engineer, key role identified in MAP
CFP	Cyclic Flow Profile
CLF	Cableless Linking Facility
COBA	COst Benefit Analysis, described in the DMRB
CTM	Cell Transmission Model, new traffic model introduced in TRANSYT v13 in addition to PDM
CYOP	CYcle time OPtimisation, a TRANSYT feature used to select an appropriate cycle time for a modelled network
DE	Design Engineer, key role identified in MAP
DfT	The Department for Transport
DMRB	Design Manual for Roads and Bridges
DoS	Degree of Saturation
DSD	Desired Speed Decision (used in VISSIM modelling)
EQUISAT	A TRANSYT feature that provides an initial set of signal timings prior to optimisation, based on equal saturation of critical conflicting links
FlowRound	Software for the analysis of spiral traffic lane movements at signalised and unsignalised roundabouts, developed by JCT
FPT	Forward Planning Team, formerly Network Assurance Team
GIS	Geographic Information System
GLA	Greater London Authority

HCM	Highway Capacity Manual
HGV	Heavy Goods Vehicle
HTA	Highway Traffic Assignment
ICA	Intersection Capacity Analysis (used in VISUM modelling)
ITS	Institute for Transport Studies, University of Leeds
JCT	JCT Consultancy Ltd, developer of FlowRound, LinSat, LinSig and TranEd
LCAP	London Congestion Analysis Project
Legion	Pedestrian modelling software, developed by Legion Ltd
LGV	Light Goods Vehicle
LinSat	Freely available software developed by JCT, allowing the estimation of effective flare usage based on flow data
LinSig	Modelling software developed by JCT
LSTCC	London Streets Traffic Control Centre (within TD)
LTA	Local Traffic Authority
LTS	London Transportation Studies, strategic model
MAE	Model Auditing Engineer, key role identified in MAP
MAP	Model Auditing Process
MGV	Medium Goods Vehicle
MME	Mean Modulus of Error
MMQ	Mean Maximum Queue
MOVA	Microprocessor Optimised Vehicle Activation
MUC	Multiple User Class (assignment)
NAE	Network Assurance Engineer, key role identified in MAP
NAQS	National Air Quality Strategy
NMD	Network Management Duty (see TMA)
NMG	TfL Surface Network Management Group
NP	Network Performance (within TD), formerly Urban Traffic Control (UTC)
O/D	Origin-Destination (matrix)
ONE	Operational Network Evaluator
OS	Ordnance Survey (Mapping)

OSCADY PRO	Optimised Signal Capacity And Delay: Phase-based Rapid Optimisation, modelling software developed by TRL
P	Promoter, key role identified in MAP
PI	Performance Index, a monetary value used in TRANSYT to assess the cost of stops and delays in a network
PICADY	Priority Intersection Capacity And DelaY, modelling software developed by TRL
PCU	Passenger Car Unit
PDM	Platoon Dispersion Model, the traditional traffic model used in TRANSYT
PRC	Practical Reserve Capacity
.PRT	Output file produced by TRANSYT detailing model results
PTV	Planung Transport Verkehr (PTV) AG, developer of VISSIM and VISUM
QueProb	TRANSYT feature allowing the estimation of effective flare usage based on flow data
RD	TfL Streets Road Directorate
RR67	Research Report 67, publication by TRL describing a methodology for the prediction of saturation flows
RSA	Reduced Speed Area (used in VISSIM modelling)
SAE	Signals Auditing Engineer, key role identified in MAP
SAFENET	Software for Accident Frequency Estimation for NETworks, accident modelling software developed by TRL
SASS	System Activated Strategy Selection
SATURN	Simulation and Assignment of Traffic to Urban Road Networks, modelling software suite developed by ITS
SCOOT	Split, Cycle and Offset Optimisation Technique, developed by TRL
SLD	Site Layout Drawing
SQA-0064	TfL TD Document, Technical Specification SQA-0064, containing Design Standards for Signal Schemes in London (formerly 'TTS 6')
SRN	Strategic Road Network
SUE	Stochastic User Equilibrium (assignment)
SVD	Selective Vehicle Detection
TD	TfL Streets Traffic Directorate, formerly Directorate of Traffic Operations (DTO)

TI	Traffic Infrastructure (within TD)
TfL	Transport for London
TLRN	Transport for London Road Network
TMA	Traffic Management Act 2004
TMAP	TRANSYT Model Auditing Process (see MAP)
TranEd	Software developed by JCT to provide an improved graphical user interface for TRANSYT versions 12 and earlier
TRANSYT	TRAffic Network StudY Tool, modelling software developed by TRL
TRL	Transport Research Laboratory (TRL Ltd), developer of ARCADY, OSCADY PRO, PICADY, SAFENET, SCOOT and TRANSYT
TSS	Transport Simulation Systems, developer of AIMSUN
TSSR	Traffic Signal Supplementary Report
UDA	User-Defined Attribute (used in VISUM modelling)
UGT	Underutilised Green Time
UTC	Urban Traffic Control
VA	Vehicle Actuation
VAP	Vehicle Actuated Programming (used in VISSIM modelling)
VDF	Volume-Delay Function (used in strategic/HTA modelling)
VISSIM	Verkehr In Städten – SIMulation (meaning: Traffic In Towns – SIMulation), modelling software developed by PTV
VISUM	Verkehr In Städten – UMlegung (meaning: Traffic In Towns – Assignment), modelling software developed by PTV
VMAP	VISSIM Model Auditing Process (see MAP)
WebTag	DfT Transport Analysis Guidance

APPENDICES

Appendix I: Underutilised Green Time (UGT) Calculation

UGT is the time difference between the actual measured green time during which full demand occurs (Gd), and the theoretical time that it would take for the platoon to cross the stopline under normal conditions (Gn).

$$UGT = G_d - G_n - L_t \qquad \text{Eq. (3)}$$

Where:

G_d = measured green time under full demand

G_n = (3600/measured saturation flow) x number of PCUs in full demand period

L_t = start and end lost time

The UGT formula for calculating DoS uses effective green time. This is equal to actual green plus leaving amber (three seconds) minus the start and end lost time (L_t). However there are occasions where L_t requires modification to account for link-specific behaviour:

- If full demand exists at the start of green then Lt = one second;
- If full demand exists at the end of amber (leaving amber) then Lt = one second;
- If full demand exists at the beginning of green and exists at the end of amber then Lt = two seconds; and
- If full demand starts and/or finishes at any other time then Lt = zero seconds.

When full demand exists at the beginning of green and exists at the end of amber UGT calculations assume that start and end lost time (L_t) total two seconds, i.e. it assumes that traffic flow takes two seconds to accelerate to saturated flow and two seconds to decelerate. If the model developer believes that start or lost time is different for a surveyed link then this should be incorporated at their discretion. Any modification to default values must be outlined in an accompanying modelling report and analysed to ensure accuracy.

$$G_n = \left(\frac{3600}{S_{FF}}\right) \text{x } q_d \qquad \text{without flare} \qquad \text{Eq. (4)}$$

$$G_n = \left(\frac{3600}{S_{FF}}\right) \text{x } (q_d - F) \qquad \text{with flare} \qquad \text{Eq. (5)}$$

Where:

q_d = Total Flow during full demand (PCU)

F = Effective Flare Utilisation (PCU)

S_{FF} = Saturation Flow (PCU/hr)

DoS Formula by means of UGT

$$DoS = \frac{q\ x \left(\frac{3600}{T_C}\right)}{S_{FF}\ \text{x}\ \frac{G_t - UGT + 1}{T_C}}\ \text{x}\ 100 \qquad \text{without flare} \qquad Eq.\ (6)$$

$$DoS = \frac{q\ x \left(\frac{3600}{T_C}\right)}{\left(S_{FF}\ \text{x}\ \frac{G_t - UGT + 1}{T_C}\right) + \left(\frac{F\ \text{x}\ 3600}{T_C}\right)}\ \text{x}\ 100 \qquad \text{with flare} \qquad Eq.\ (7)$$

Where:

q = Total Sample Flow (PCU)

G_t = Green Time (seconds)

UGT = Underutilised Green Time (seconds)

T_C = Cycle Time (seconds)

F = Effective Flare Utilisation (PCU)

S_{FF} = Saturation Flow (PCU/hr)

Appendix II: Proposed Model Optimisation Process

The process employed for optimisation of a proposed model is dependent on the scope of the model, which indicates the modelling output required, and can be characterised in terms of the following three optimisation stages:

- Phase One – Initial Optimisation
- Phase Two – Fine Tuning & Impact Assessment
- Phase Three – Design of On-Street Controller Timings

The optimisation steps performed during each of three optimisation phases are shown in more detail in Figures A, B & C. These diagrams relate to the overarching discussion presented within the main document in section B2.6 and Figure 7.

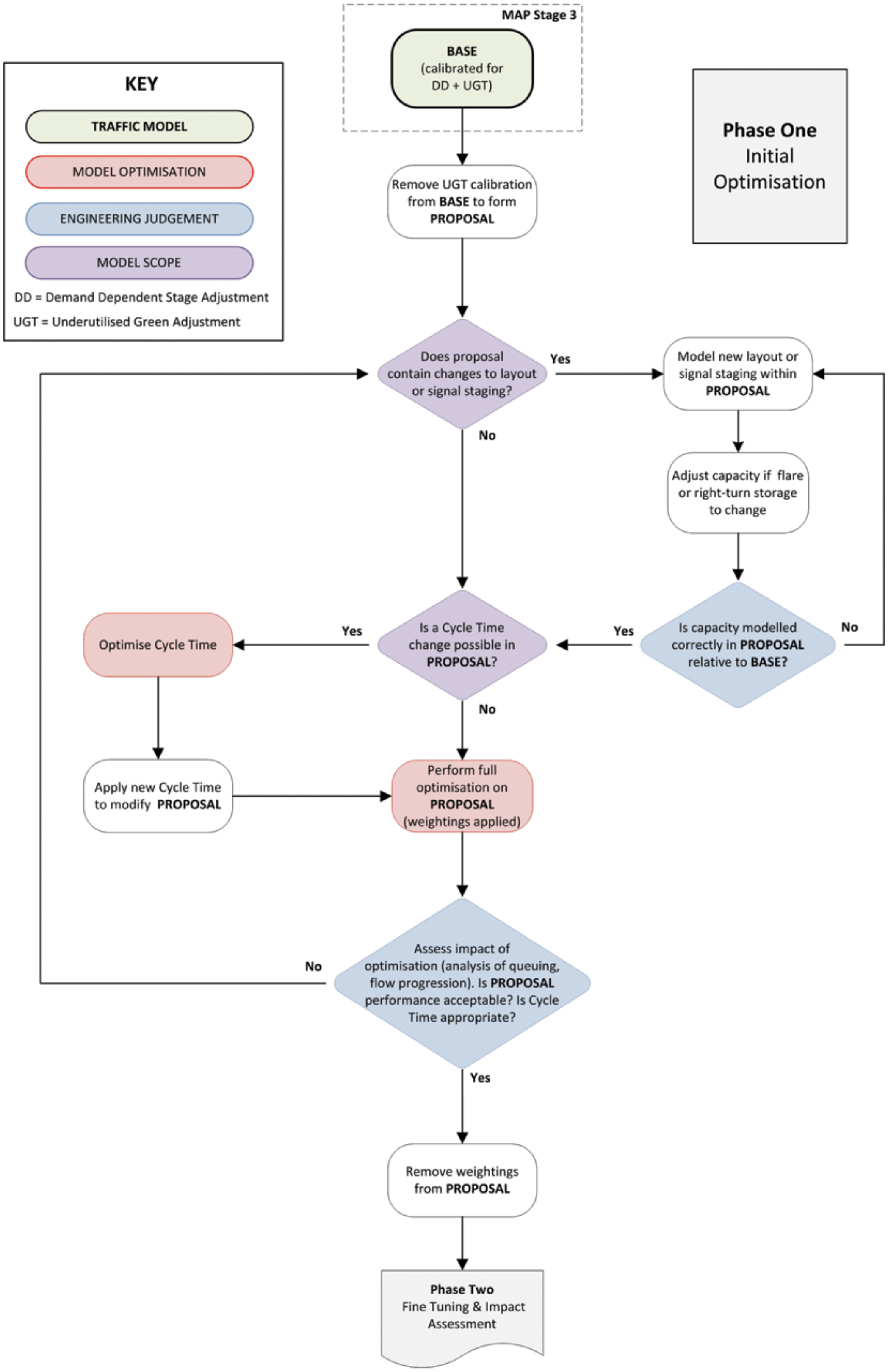

Figure A: Initial Proposal Optimisation.

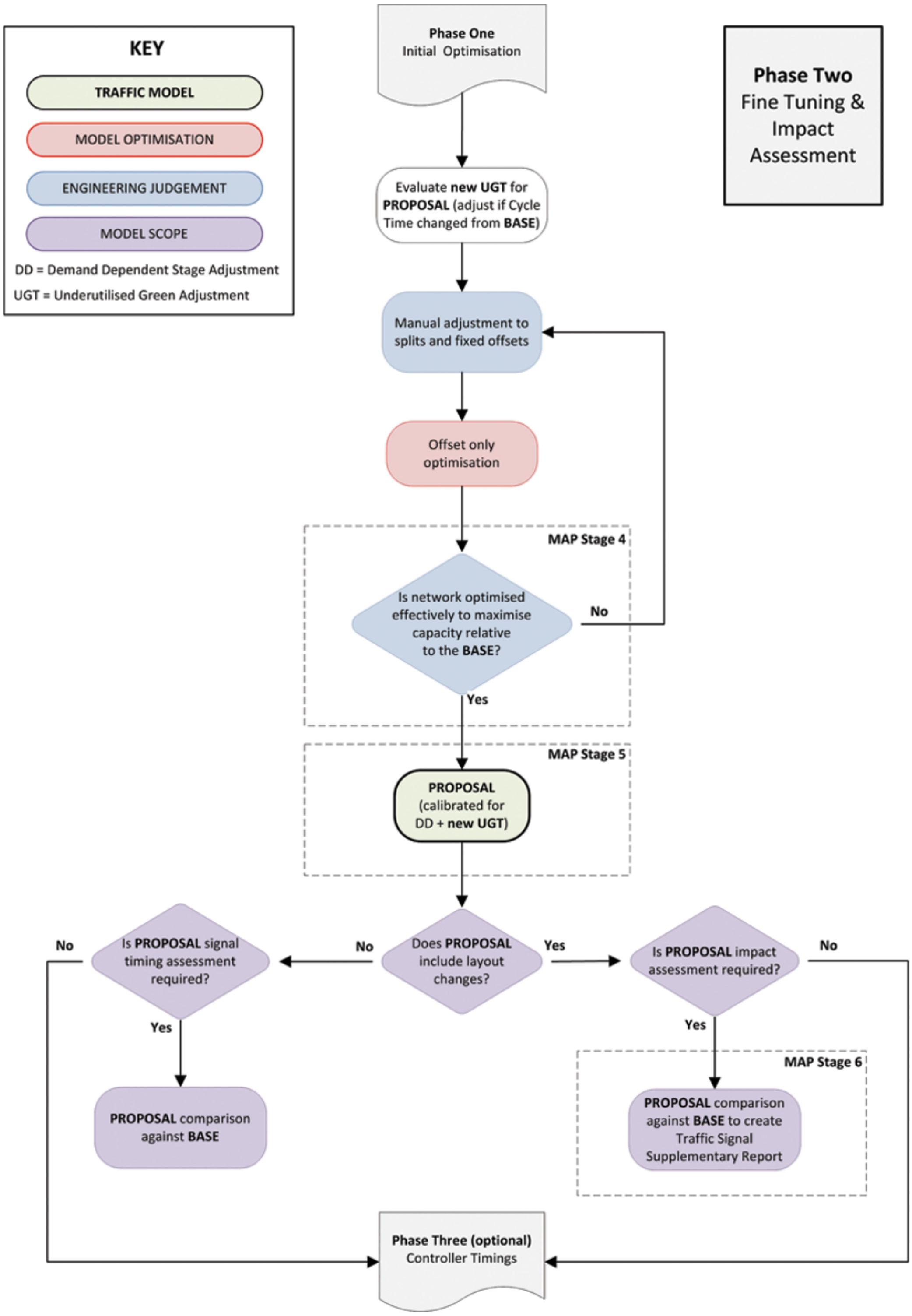

Figure B: Fine Tuning & Proposal Impact Assessment.

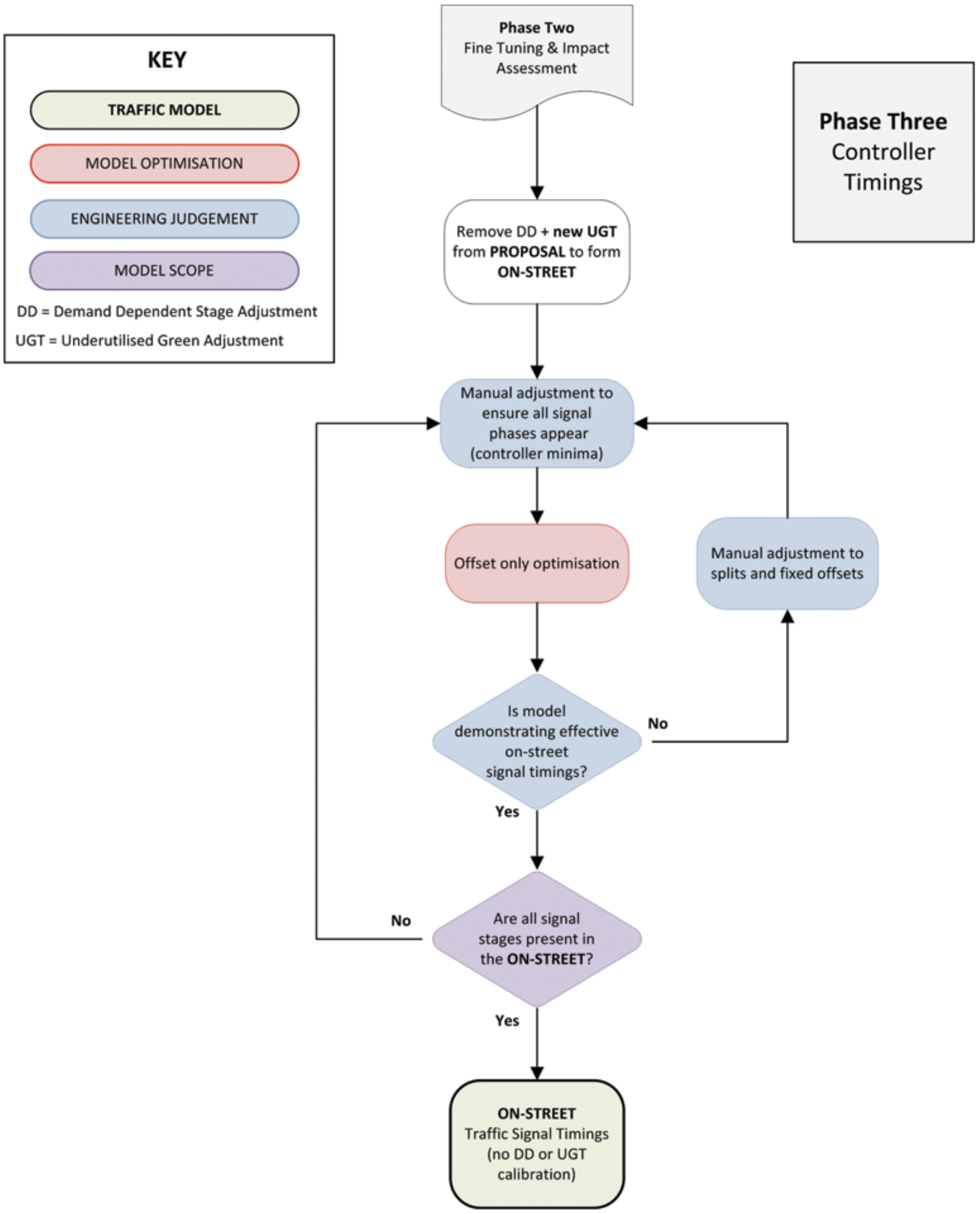

Figure C: Derivation of On-Street Controller Timings.

Appendix III: Flow comparison (The GEH Statistic)

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 statistic is calculated as follows:

$$GEH = \sqrt{\frac{(M - C)^2}{(M + C)/2}} \qquad \textit{Eq. (8)}$$

Where:

M = Modelled flow
C = Counted (Observed) flow

Smaller GEH values indicate a better 'fit' between observed and modelled flows.

Below is a sample set of values to demonstrate the use of the GEH statistic compared with a simple percentage difference:

Table A: Comparative analysis contrasting GEH and percentage values.

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

Appendix IV: VISSIM Dynamic Assignment Convergence Methods

Three steps are outlined below which may help achieve convergence when using Dynamic Assignment (DA) in VISSIM:

- ## DA Method One

If congestion is expected in the network then assign travel demand matrices in batch mode. This process can be initiated at the command prompt using 'VISSIM.exe filename.inp -s9 -v10' or by using the multirun facility. The simulation should start with only 20% of the total origin destination (O/D) demand before running the process. The batch mode will then increase demand (e.g. 30%, 40%, etc) over each successive simulation until reaching 100%. If the network is not congested then the initial step of incrementally loading the O/D matrices can be omitted.

Using the path and cost files from the previous process, traffic should be assigned for 30 to 50 iterations in batch mode whilst continually updating the cost and path data. The cost and path files are overwritten by default at the start of each iteration so need to be renamed and saved in a separate folder after each iteration. The convergence evaluation file (*.CVA), which should be produced at the end of each iteration, should also be saved with each runs cost and path file.

When all iterations are complete the trend of path and edge traffic flow and travel time convergence from the *.WGA and *.CVA files should be studied. It is then necessary to decide whether convergence has been achieved, and if so at what iteration and whether it was 'stable' (i.e. maintained for four subsequent iterations).

- ## DA Method Two

If convergence criteria cannot be achieved using the first method the following technique can improve convergence stability.

For this technique O/D matrices are assigned partially on fixed routes and partly dynamically. The fixed routes can be thought of as the proportion of travel demand that is unaware of the full set of possible routes and rat runs in the network and thereby uses the main signed routes. The part that dynamically assigns can be regarded as the amount of travel demand that fully understands the network and its performance and can therefore exploit any possible route that is available.

TD does not have formal guidance on how to divide the O/D matrix/matrices into the two elements beyond the need to use sound engineering judgement. The fixed routes for the first part of the travel demand may be chosen either through local knowledge of the network or through dynamically assigning those matrix/matrices with an artificially high value for Kirchhoff's exponent. This approach should concentrate this part of the O/D matrix/matrices to a few fast routes which the modeller can then convert to static routes once they are assured over route choice and number of available paths. The travel demand that is dynamic should be assigned over a number of iterations to show stable convergence of assignment.

- **DA Method Three**

The third method utilises external highway assignment software to guarantee convergence. This may be necessary should neither of the first two approaches lead to a stable assignment. Assignment of travel demand is undertaken in VISUM where the path and cost files can be directly exported to VISSIM for further detailed simulation and analysis.

The latest version of this document is available to download from: http://tfl.gov.uk/streetspublications