Transport Modelling Guidelines

Volume 5: Intersection Modelling

June 2020

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1. Introduction

Intersections provide a significant role in the management of control systems within a transport network. Intersections create and inhibit traffic and transport movements while managing a series of conflicting movements over the same space. The value of intersections sits as a cost effective measure to move people across a landscape, without grade separating the distinct movements. Intersections can be broadly categorised into two formats:

- Regulatory mechanism (signal controls)
- Behavioural opportunities (line controls)

The means to develop intersection models provides for opportunities to explore user experiences and the value of infrastructure investment over time.

1.1 Preamble

These guidelines are the fifth volume in the Department of Transport's, Transport Modelling Guidelines. Other volumes as follows;

- Volume 1: General Guidelines;
- Volume 2: Strategic Modelling;
- Volume 3: Mesoscopic Modelling; and
- Volume 4: Simulation Modelling.

It is intended that the document will be periodically reviewed and updated so that it is current and relevant for department delivery teams, stakeholders and modelling practitioners. The intent is that gaps in the document content will be filled over time to give more direction.

Future versions of this document shall incorporate the latest thinking and advancements in data collection and analysis for intersection modelling. As such, this document should be applied for all intersection modelling pursuits that have begun before January 2023, unless updated by a new release. In declaring this expiry date, it is the responsibility of the Department of Transport to update and/or re-release these guidelines for public issue by December 2022.

1.2 Purpose

The document outlines the data collection, analysis and reporting expectations for intersection modelling conducted within Victoria.

The guidelines are intended to help practitioners to better understand the Department of Transport's expectations and to ensure that these specialist reports can be reviewed and comprehended by all stakeholders. This document also aims to showcase the matters relevant in developing an evidence based decision making process to identify and evaluate proposed infrastructure changes for delivery within Victoria. In this way the Department of Transport anticipates a faster process of model reviews and accompanying discussions about proposed changes to the transport network.

These guidelines cover the topics of:

- Modelling scope;
- Data collection and analysis;
- Model development
- Reporting; and
- Development of the narrative.

The guidelines have not been developed as an introduction to transport modelling or traffic engineering pursuits. Such documents already exist and are not repeated within the Department of Transport modelling guidelines.

1.3 Stakeholder focus

The fifth volume of the Department of Transport's Transport Modelling Guidelines has been written to provide advice and direction for two distinct user groups:

- Those with a technical comprehension that seek advice as to deliver to the Department of Transport's expectations. This group are typically transport modellers.
- Those without a technical awareness but who wish to better examine why some technical elements are deemed to be important in the modelling framework. This group comprises those who are new to delivering within this space.

The content is not simply to direct industry leadership on requirements, but also to provide further direction for those who wish to enter this field of investigation. Some discussion on the variation from selected parameters has been explored to showcase to interested parties as to why these measures are so critical to achieve within a professional delivery.

The document also provides direction in ascertaining expectations on a number of requirements and limitations within particular techniques or components, for which industry may have previously sought direction.

1.4 Department of Transport

The Department of Transport, and its predecessors has a long history as the transport agency within Victoria, with more than 100 years of experience. The Department has a focus on the delivery of journeys across the network for all road users as the long term owner of the transport systems across the network and across the state.

While major transport infrastructure projects may be delivered by different government agencies, it is necessary for the Department of Transport to be involved and/or lead the planning, design and construction of these projects, as the Department becomes the owner of each of these projects over time. This involvement is necessary to ensure the quality of delivery so that the Department can adequately operate and maintain this infrastructure.

The Department of Transport's expectations and requirements need to be upheld for the transfer of ownership over time. For some projects, this may be over a longer-term horizon, but for other projects this transfer may be achieved in a shorter timeframe. Therefore, it is important that the Department of Transport statements for each project (typically operations and scope of area for evaluation) are included within the design and analysis of such projects.

The delivery of projects is not limited to design and construction of specific intersections or treatments. For all network modifications the analysis of such projects needs to sit within the wider context of the user experiences and network performance considered by the Department. This may include exploration of connections between services as well as operation of traffic signals within close proximity or further afield from the site of delivery in order to deliver the potential of the programme.

The Department of Transport considers the impacts of projects on the general public. This perspective may produce expectations for model scope and development that differ from the interests of a private sector client. Under such conditions, the Department may require client and consultant teams to revise their initial direction to manage in the interests for all parties involved.

All or any documents produced as part of modelling investigations may need to be provided to media or public enquiries through the Freedom of Information Act (1982). For this reason, the Department of Transport will require projects to be developed and documented so that they can be read and interpreted by any party with or without a technical background. Documents and reports should hold enough of an evidence base to support and identify the strengths and trade-offs associated with a proposed scheme or development.

An absence of supporting documentation with a clear narrative and analysis may hinder the timeframes envisaged as part of project planning.

1.5 Correspondence

All enquiries or correspondence into these guidelines or any transport modelling guidelines developed and released by the Department of Transport should be directed through the one common access point of:

networkdesignservices@roads.vic.gov.au

This is the one address that is equipped and prepared to manage queries of such technical documents. However, a repository of technical documents developed by the Department of Transport is available online for consideration and can be found at the following location:

https://www.vicroads.vic.gov.au/business-and-industry/technical-publications

1.6 Quality assurance

Quality assurance is an important component for the delivery of a project for all parties involved in a development or delivery. Quality assurance processes include suitable measures to ensure that the aspects of the investigation have been conducted appropriately and important issues have not been overlooked. Guidance on quality assurance responsibilities and activities is provided in Section 12 of these guidelines.

2. Overview

These guidelines provide a comprehensive overview into the expectations for the delivery of intersection modelling conducted for the Department of Transport or as per collaborative efforts where the Department of Transport is a stakeholder.

The guidelines are intended to avoid situations where the intersection modelling received by the Department of Transport has core elements missing that have not been considered by those responsible for the development of the models. These missing elements may pertain to matters of collecting and analysing quality data for robust modelling investigations. The implications of utilising low quality data can have a continued impact throughout the model development (e.g. inappropriately selected modelled time periods may result in insufficient intersection capacity being provided to meet traffic demand volumes) and may potentially impact on the delivery and recommendations.

2.1 Guideline structure

This structure of the guidelines aims to explore matters of:

- **Transport modelling** - summarises the types of transport models and when these should be used;
- **Scope formation** - identifying the problem or issue and ensuring the correct modelling tools are used;
- **Data collection** – the types of data that may be required and appropriate sources;
- **Calibration** – developing Base models that are based on evidence and reflective of current conditions;
- **Validation** – ensuring that Base models are sound for subsequent analyses;
- **Option investigation** - developing solutions to mitigate the current or expected conditions;
- **Reporting and presentation** - articulating a narrative to explain the work effort and the formation of the findings; and
- **Quality assurance** - ensuring comprehensive quality assurance and review processes are carried out.

2.2 Developing a narrative

The guidelines outline an expectation (rather than suggestion) of delivery that builds a narrative within an intersection modelling report. This approach is to not only assist the Department of Transport teams with internal matters but also showcase the evidence based decisions that have been developed on any project where stakeholders and community interact. It is imperative that the reporting outlines the work in clear English with reduced jargon. This not only identifies the modelling processes undertaken but also the findings from explored options to all stakeholders without the need for a technical translation.

The Department of Transport will use these guidelines to ensure that standards are delivered before the model is accepted.

Key matters within model development and analysis involve;

- Collecting the appropriate datasets efficiently for analysis (the evidence);
- Building the narrative of the existing and future suggested intersection performance;
- Analytical investigations that are well documented and embed the context so that the end-user can comprehend the investigation and complexity of the matter at hand; and
- Explain the risk and considerations for projects and organisations with the intent to deliver a proposed solution.

3. Transport modelling

3.1 Introduction

Transport modelling allows teams to explore and ask questions about traffic and transport considerations across the transport network to consider matters of planning and operations over the short, medium and longer term horizons. These explorations provided for a number of investigations, can cover broad topics of strategy formation, infrastructure requirements, journey planning and network operations over time.

In all cases the pursuit of modelling tasks are to explore a current (or future) issue of concern and explore measures for resolution to an improved position. The methods used in these investigations will vary by modelling horizon to explore the questions at hand. However, the core of this modelling work remains to develop solutions to assist in design and delivery to ensure that journeys can continue efficiently through the transport network. Some of these explorations are locally driven. At the broader extents are planning and investment needs across the metropolitan and state levels (as well as beyond).

In all situations, irrespective of the scale of the exploration, are the following underlying principles that:

- Investigations are required to be evidence based. This allows stakeholders to comprehend the matters of complexity that relate to the transport network today, before exploring the matters of tomorrow; and
- Scenarios allow for the exploration of complexities to be explored and a number of metrics to be quantified and showcase the value of the investment. The scenarios allow for strengths and weaknesses of each suggested solution to be outlined (including movement of journeys, benefit cost appraisal, complementing network requirements and more).

Modelling should develop a strong narrative of the change impacts (and recommendations) that can be supported by the evidence and data.

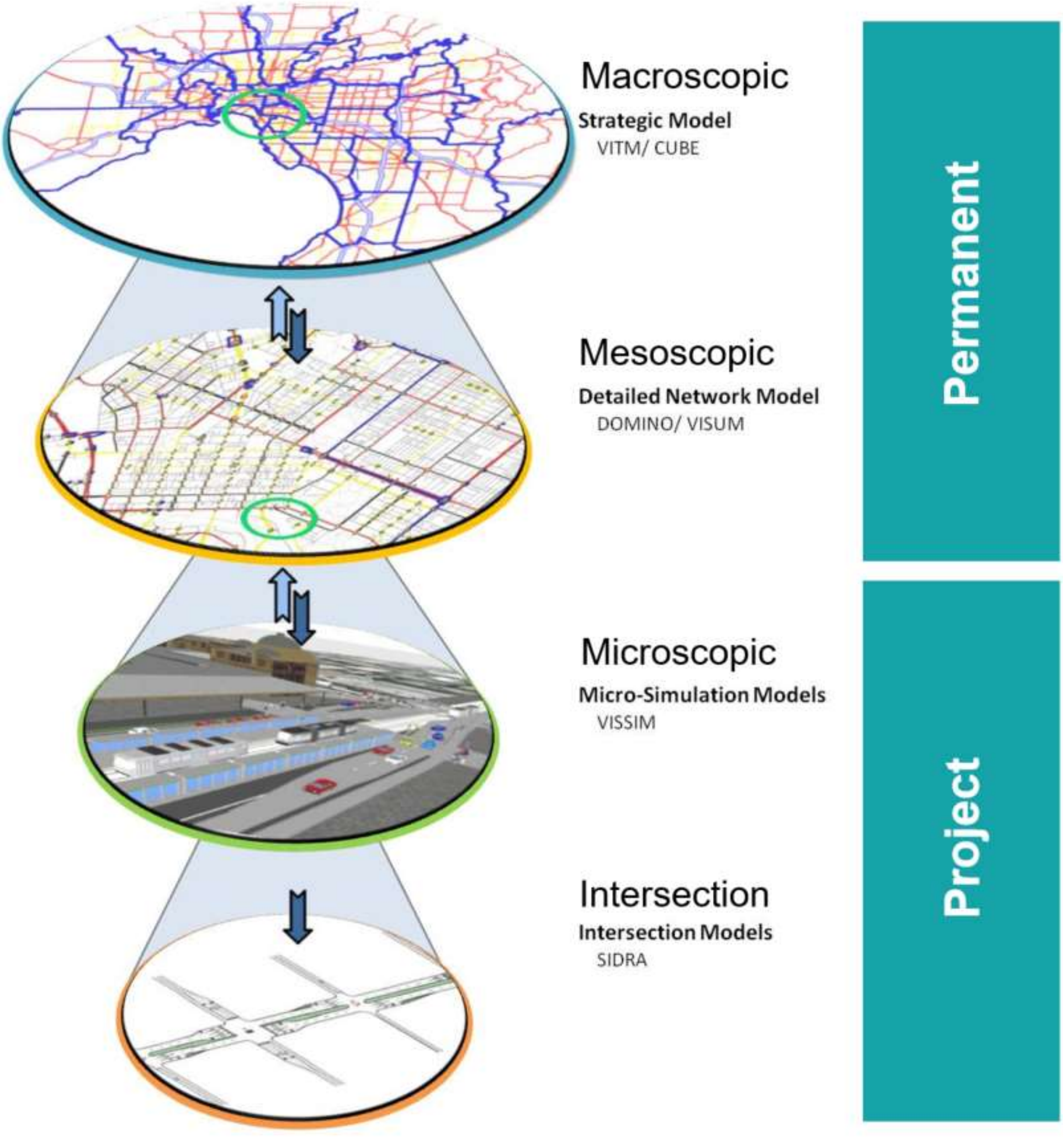
The evidence based platform allows for the complexities of multiple and cumulative network considerations to be evaluated in a comparative process. It allows teams to ask questions and begin to explore answers about proposed changes, including consideration for elements of complexity and choices undertaken from a user perspective. The transport modelling tasks undertaken for the Department of Transport provide for a more educated and robust stance by the organisation for the movement of journeys, the value of investment and additional considerations of drivers' experiences. Ongoing delivery in quality modelling and associated reporting provides for a better comprehension in the value for such a pursuit, which in turn justifies the purchase of further modelling services.

3.2 Model types

Transport modelling operates at various levels of detail and scale. It is important for all delivery managers and modellers to note that many projects involve more than one level of modelling and analysis, due to the varied challenges involved within an investigation (e.g. planning, design, operations, construction etc.). An outline of the transport modelling hierarchy is provided in **Figure 1**. Note that this is not a comprehensive structure. Within each layer of modelling in this hierarchy is the trade-off between factors used to comprehend the delivery of journeys through a network.

At each stage of the modelling pursuit the data requirements used to feed the development are different. Austroads, Guidelines for Selecting Techniques for the Modelling of Network Operations (January 2010) and Austroads, Guide to Traffic Management Part 3: Traffic Studies and Analysis (November 2017) Section 2 provide further commentary on intersection model types. However, note that such structures may not be comprehensive and could be limited to the scope and mandate of these guidelines.

Figure 1: Transport modelling hierarchy used at the Department of Transport



The determination of a modelling methodology may be informed by a number of key factors including (but not limited to) matters of:

- Stage of the project development (strategy formation, business case development, options exploration, concept design, detailed design, operational matters);
- Complexity and significance of the pursuit;
- Geographic scope required for consideration;
- Timeframes for delivery; and
- Accuracy of the result required.

In most conditions the focus of the project deliverable is directed by the project objectives that may typically explore topics of design, patronage, journeys, network resilience, driver safety, network enhancement or other multipronged pursuits. Objectives will vary by projects. However, the modelling requirements to develop a transport model and ensure quality delivery to stakeholders does not change by the intent at hand. Under all circumstances the Department of Transport will inherit the developed solution for the life of the road and needs to ensure that appropriate considerations have been implemented throughout the course of such pursuits.

3.3 Modelling software

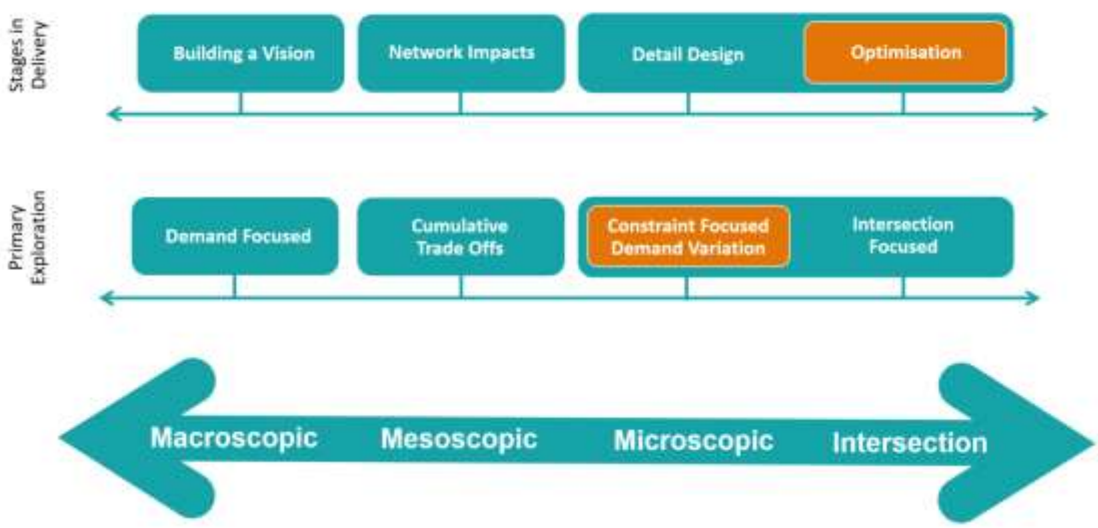
Software used for transport modelling investigations for the Department of Transport should consider the following three key elements before network development.

- The software algorithms used for the calculation and interaction of parameters in the model are published and accessible through literature such as research and conference papers. While the end user may not specifically comprehend how the algorithms operate, it is important that an independent party can review and comprehend how these algorithms achieve the modelled outcomes.
- The solutions applied require an independent team dedicated to customer support that is not simply a duplication of role of the developer.
- The software should be commercially available so that pursuits can undergo an independent review with or without the modelling team that developed the model. This review may be conducted in the shorter term or provide opportunities for third parties to build on this model at a later stage.

3.4 Selecting modelling types

Modelling methods are often dictated by project objectives followed with the technical intricacies of the modelling investigation. **Figure 2** outlines various types of models and the typical stage in delivery and primary exploration. Table **1** includes further criteria that can assist in directing the modelling methods required to meet the objectives of the investigation. However, note that often multiple levels of modelling may be required to build an appropriate narrative on various perspectives into the performance of road networks.

Figure 2: Modelling scales with focus for delivery and exploration



In some scenarios, high-level criteria may indicate both intersection and micro-simulation models as being appropriate. While this may indicate the option of using either for a modelling pursuit, in many instances the base conditions or future options being investigated may necessitate the use of one or the other (refer Section 4.1).

Table 1: Example criteria for selecting model types

Model Criteria	Options	Modelling			
		Macroscopic	Mesoscopic	Microscopic	Intersection
Study Characteristics					
Scope Size	Regional	Yes	Permitting	Rarely	No
	Corridor	Yes	Yes	Permitting	Permitting
	Subarea	No	Yes	Yes	Permitting
	Isolated	No	No	Yes	Yes
Network Size[1]	Large (>1,000 Zones)	Yes	Permitting	Rarely	No
	Medium (Between 100 & 1,000 Zones)	Yes	Yes	Permitting	No
	Small (≤100 Zones)	Yes	Yes	Yes	Yes[2]
Time Periods	Peak Period	Yes	Yes	Yes	No
	Structured Peak Hour	Permitting	Yes	Yes	Yes
Input Data Characteristics					
Granularity	< 15 Minutes	Rarely	Yes	Yes	Yes
	15 Minutes - 1 hour	Permitting	Yes	Permitting	Permitting
Reliability	Data Source	Medium	Medium	High	High
Accuracy	15 Minutes	No	Yes	Yes	Yes
	> 1 Hour	Yes	Yes	Yes	No
Desired Functionalities					
Strategic Direction		Yes	No	No	No
Demand Forecasting		Yes	No	No	No
Route Choice Determination		Yes	Yes	Yes	No
Intersection Analysis		No	Yes	Yes	Yes
SCATS Data		No	Yes	Yes	Yes
Site Specific Capacity		No	Yes	Yes	Yes
Visualisation Animation		No	Yes	Yes	No
Weaving / Merge-Diverge		No	No	Yes	No
Queuing		No	Yes	Yes	Yes
Flow (by link)		Yes	Yes	Yes	Yes
Flow (by lane)		No	Yes	Yes	Yes
Signals Inclusion		No	Yes	Yes	Yes
Signals (Public Transport Priority)		No	No	Yes	Yes
Queue detection		No	No	Yes	No
Rail Level Crossings		No	No	Yes	No
Motorway Interchanges (with managed ramps)		No	No	Yes	No

[1] Zone size and structure changes varies
[2] Multi-intersection models should not include more than ten intersections

4. Intersection modelling

4.1 Introduction

The term of intersection modelling covers a range of model applications, for a varied range of traffic and transport investigations. Intersection models are traffic evaluation tools that utilise analytical techniques on aggregate traffic movements. The models can be used to calculate intersection capacity and saturation, level of service and performance analysis, geometric delay, queuing and signalised intersection and network timing calculations.

Intersection models can be used to compare demand scenarios and treatments of individual intersections and small networks of intersections involving;

- Signalised intersections (fixed-time/pre-timed and actuated);
- Roundabouts (unsignalised);
- Roundabouts with metering signals;
- Fully signalised roundabouts;
- A variety of priority (sign) controlled intersections;
- Motorway interchanges without managed ramps (including single-point urban interchanges, traditional diamond and diverging diamond interchanges); and
- Unsignalised and signalised midblock crossings for pedestrians.

Intersection modelling of the above is covered by the following areas;

- Isolated intersection modelling - modelling of a single intersection; and
- Multi-intersection modelling (where intersections are modelled as a network where the upstream and downstream performance of intersections can impact one another).

As indicated by Section 3.4, there are instances where both micro-simulation and intersection models may be appropriate. However, there are a subset of conditions where intersection models perform poorly, and micro-simulation modelling should be used. These conditions are summarised in Table **2**.

Table 2: Application Limitations

Attribute	Application
Network Size	Where a multi-intersection model of more than ten intersections is required due to the scope of the exploration or area of influence
Variation in Conditions	Where the peak demand volumes and constraints vary considerably over the peak hour, such as: • Upstream/downstream of rail level crossings (irregular arrivals and/or downstream congestion); and • Upstream of managed motorway ramps (irregular downstream congestion). • Peak flow factor is below 70% and possibly even below 80%.
Complex Vehicle Behaviour	Where an intersection model is inappropriate due to complex vehicle behaviour and demand volumes, such as: • On roads with shared traffic and light rail (tram) lanes and kerbside stops (varied operating conditions); and • Where weaving is a known constraint on performance (arterials and motorways).

Whether intersection modelling is appropriate for a specific investigation may not become apparent until after the collection of data, in particular, signal data (which may indicate variation in conditions). Furthermore, measurement or observation of peak queues may result in the need to extend the size of the model, which may necessitate the use of micro-simulation modelling. It is important that practitioners do not commit (and clients do not prescribe) to intersection modelling without an appreciation of these issues. Where there is potential that micro-simulation modelling may be necessary, a staged approach to the modelling is recommended. This would consist of an initial package of work consisting of data collection and analysis, prior to defining the model type and area of influence.

Unlike strategic and mesoscopic models, intersection models are typically not maintained over the longer term as these are often developed for a specific investigation. However, such solutions can be developed and updated through network and land use changes over time.

4.2 Isolated intersections

Single intersection models can be used at isolated intersections or where the effects of signal co-ordination are not required to be modelled explicitly and the area of influence does not extend to/from an adjacent intersection. Single signalised intersection models can provide optimised signal timings under varying demand scenarios and road infrastructure scenarios.

Undertaking option evaluation in a single intersection environment can have significant time and cost saving advantages. However, if the intersection is influenced by another intersection, due to arrival patterns, or is impacted by downstream queuing, then multi-intersection network modelling or micro-simulation modelling should be undertaken. The focus would be to ensure network effects and dynamic variability are adequately considered.

The following conditions are generally appropriate uses of isolated intersection models:

- Priority controlled (e.g. give way and stop rule based) intersections in a generally free-flowing environment with regular vehicle arrival patterns;
- Signalised simple intersections in a generally free-flowing environment with regular vehicle arrival patterns;
- Roundabouts in a generally free-flowing environment with regular vehicle arrival patterns (including metered roundabouts); and
- Signalised pedestrian crossings in a generally free-flowing environment with regular vehicle arrival patterns.

Isolated intersection models are not appropriate:

- Where the queues of vehicles at a closely spaced intersection impacts on the operational performance of an upstream or downstream intersection; and
- In environments where the impacts of signal co-ordination are significant or where arrival flows are influenced by upstream or downstream conditions and are therefore not random.

Generally, in environments where there are irregular arrival patterns or irregular downstream queuing (e.g. level crossings, train arrivals etc.), intersection models (including multi-intersection models) are not appropriate. Simulation models should be used. Where intersections are impacted by adjacent upstream or downstream intersections, but the arrival and departure movements and capacity are constant, then multi-intersection models may be appropriate.

4.3 Multi-intersection

Multi-intersection models are typically used for the analysis and optimisation of a corridor, small network or a complex intersection using analytical software.

Complex intersections are intersections that would generally be considered as a single intersection, but for modelling purposes are modelled as a small network. Examples include priority intersections at a wide median (two-stage crossings) and extended sites where multiple intersections operate under a single signal controller.

Multi-intersection models can be used where micro-simulation modelling is not required (refer Section 4.1), but more than one intersection is required to be incorporated into a model.

Multi-intersection models are generally appropriate for the exploration of the following network types:

- Complex signalised intersections (multiple intersections under a single traffic controller);
- Complex unsignalised intersections, such as T-intersections with a wide median (two-stage crossing); and
- Small networks and corridors (less than ten intersections), where adjacent intersections impact one another, but where journey experiences are regular.

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

An important component of modelling a multitude of signalised controllers is to include all sites within the related subsystem. The sites in a subsystem are a discrete group of signalised intersections in SCATS that are always co-ordinated together, sharing a common cycle length, with an inter-related signal phase split and offset. This can be a critical factor to ensure the analysis is appropriate.

The core task in multi-intersection modelling is to define the extent of the modelled area. While the scope of a project involving modelling may be used for a preliminary definition of the multi-intersection network, it is essential that this network is expanded to include all adjacent intersections where:

- Queues of vehicles at an adjacent closely spaced intersection impact on the operational performance of a central and critical location in the network; and
- The impacts of signal co-ordination from an adjacent intersection on locations within the modelled network are significant.

Techniques for identifying the sites that should be included within multi-intersection models are detailed in Section 5.2. Modelling of more than ten intersections in a multi-intersection model is not considered appropriate and under these situations, micro-simulation modelling should be undertaken.

5. Scope formation

5.1 Project definition

It is important at the commencement of any modelling project to define the project and clearly set out the objectives, including:

- Identifying the problem or issue to be resolved through modelling;
- Determining the key project outcomes to be achieved;
- Establishing the need for traffic modelling; and
- Defining the key performance metrics for evaluating outcomes.

During the project definition phase, it should be made clear where the traffic modelling work sits within the context of the overall investigation.

5.2 Design requirements and the need for modelling

The pursuits requiring intersection modelling are generally focussed around the delivery and exploration of infrastructure at an intersection level and the optimisation of traffic signals. Common applications and investigations include the means to evaluate the traffic performance of:

- Changing the form of intersection control (e.g. changing from priority control to roundabout control or traffic signals);
- Existing intersections that will be subject to additional travel demand volumes (e.g. as a result of a new land use development);
- Changes to existing infrastructure to address an existing or future (predicted) traffic performance issue;
- Modifications to existing infrastructure to address a safety issue;
- Proposed public transport (or cyclist and/or pedestrian) priority measures (including reduced timeframes for general traffic movements); and
- Signal phasing and/or timing changes to optimise the performance of existing infrastructure.

Changes that are proposed to turn treatments at isolated regional intersections may not generally require modelling but shall still require analysis. These sites are typically in low volume regional settings where minimum design requirements such as acceleration and deceleration lane needs are greater than suggested from a modelling analysis. However, if modelling is undertaken, the results may understate the minimum requirements that need to be delivered upon. This may specifically pertain to design elements for deceleration and acceleration lanes. Results from an intersection modelling task may be a function of the demand movements, rather than deliver a design based on the safety requirements. The Austroads guidelines and the supplements in the Traffic Engineering Manual still remain valid within this context and should be adhered to as a minimum design.

5.2.1 Deceleration lanes at intersections

An outline of minimum requirement for decelerations lanes are provided in **Table 3**. These tables are derived from the Austroads Guide to Road Design (Part 4A) and adapted as an easier interpretation to transport modellers. The design speed of the approach road and the design speed of the exit curve should be considered in the requirements for deceleration lanes and for intersection delivery. The table outlines considerations for unsignalised intersections that are provided typically in regional locations – including access and egress from highways (not motorways).

As an example, the data in the table identifies that for a road design of 80km/hr then the deceleration lane (including taper) would need to be at least of 100m in length to the back of queue storage. This would only apply for arrangements where a stopped arrangement (traffic signals, stop line control etc) is on the turn movement. Note that separate to this arrangement is the length of queued traffic (to be measured to the 95th percentile) so that the decelerating vehicle can join the queue rather than to physically join the vehicle in the back of queue. This distance provided is diagrammatically presented within **Figure 3** (item a) to illustrate the road section marked as “D” which is the sum of the taper plus the section of the parallel lane before back of queue lengths from the intersection.

The storage distance (S) needs to be calculated from the intersection modelling and should represent the 95th percentile back of queue length. The total length of the turn lane is arrived by adding the deceleration length and the storage length together.

By comparison the 80km/hr design speed on a priority controlled solution (give way or free flow) on a turn with 40km/hr speeds would require a minimum deceleration lane length of 75m between the taper and the commencement of the turn. This is the element presented in **Figure 3** (item b) also with the distance measure “D” and expects a nominal turn volume (zero or close to this) on this movement into the intersection. The taper and the parallel lane are the two elements that comprise the formation of this distance.

Modelling investigations should therefore be aware of design conditions of the approach, design speed of the turn and the perceived stopping arrangement on the turn in order to identify the minimum deceleration requirements.

Table 3: Deceleration distances required for cars on a level grade

<table>
<tr><th rowspan="2">Design Speed of Approach Road (km/hr)</th><th colspan="9">Length of Deceleration – including diverge taper (m)</th></tr>
<tr><th>Stopped Condition (m)</th><th colspan="8">Design Speed of Exit Curve (km/hr)</th></tr>
<tr><td></td><td>0</td><td>20</td><td>30</td><td>40</td><td>50</td><td>60</td><td>70</td><td>80</td><td>90</td></tr>
<tr><td>50</td><td>40</td><td colspan="3">33</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>60</td><td>55</td><td>50</td><td>40</td><td colspan="2">40</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>70</td><td>75</td><td>70</td><td>60</td><td>50</td><td colspan="2">47</td><td>-</td><td>-</td><td>-</td></tr>
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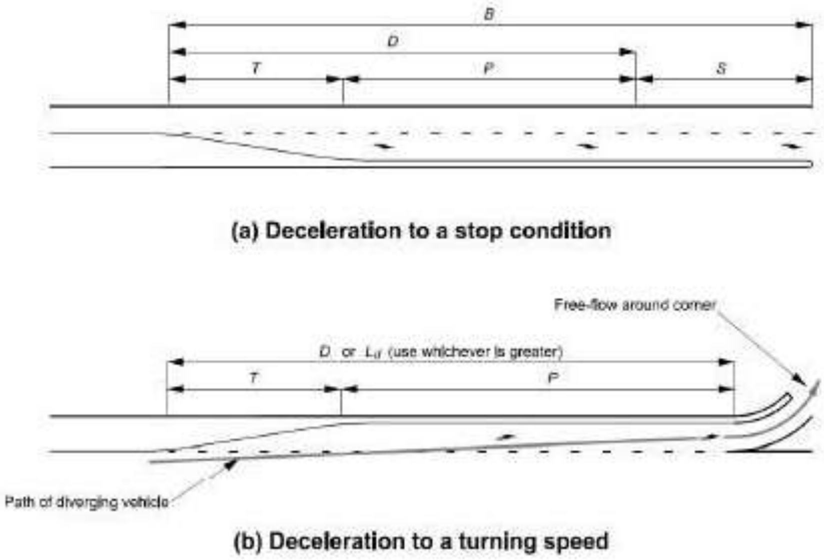
<tr><td>100</td><td>155</td><td>150</td><td>140</td><td>130</td><td>115</td><td>100</td><td>80</td><td colspan="2">67</td></tr>
<tr><td>110</td><td>185</td><td>180</td><td>175</td><td>160</td><td>150</td><td>130</td><td>110</td><td>90</td><td>74</td></tr>
</table>

Values pertain to minimum deceleration requirements for both left turn and right turn movements. Note that the cells in green within **Table 3** pertain to a minimum requirement under the design speeds and should be applied comprehensively within that designated range. Also be aware that the values held within **Table 3** are derived from a level grade and should be extended to account for a setting with gradient.

It is expected that modelling is required for all urban areas both in metropolitan and regional landscapes.

For more information on this matter please refer to the Australian Guide to Road Design – Part 4A (including consideration for truck related modelling and turn requirements within the intersection).

Figure 3: Components of a deceleration turning lane



B = total length of auxiliary lane

D = deceleration length (m)

L_d = diverge length (m)

S = storage length (m)

T = physical lane taper length (m)

P = length of parallel lane for deceleration (m).

Source: Austroads Guide to Road Design (Part 4A)

5.3 Model type

In the circumstance that the project requires transport modelling, consideration needs to be given to the type of model that will be developed. Section 3.4 of this document gives some guidance of the key considerations for selection of Macroscopic, Mesoscopic, Microscopic or Intersection modelling.

If the guidance directs the user to Intersection modelling, the person scoping the project should refer to Section 4 as to whether an isolated intersection model or multi-intersection model may be necessary. It should be noted that the required extent of multi-intersection models may not be immediately apparent until after data collection has commenced. Project proponents who are unfamiliar with this field of expertise should seek experienced assistance before specifying modelling types and extents.

5.4 Data collection

Obtaining good quality data is essential for model calibration and validation. In the absence of good quality data, the base and future year options models are unlikely to produce an adequate representation of the landscape investigated.

Project proponents developing modelling scopes should ensure that the data detailed in Section 6 is collected unless it is definitively not required for the investigation. Attention should also be paid to the hierarchy of various data sources (Section 6.3). Note that application of low hierarchy data may not be acceptable to the Department of Transport and may subsequently lead to project delays until quality data collection issue is obtained.

The Department of Transport recommends a staged approach to the project may be appropriate whereby some initial data collection is undertaken prior to model specification. As an example, this might involve a review of travel time measures on broader areas of the network prior to defining data collection at selected locations.

5.5 Modelling framework

Modelling practitioners utilise traffic modelling to develop an evidence-based evaluation of traffic operation and therefore build a narrative for the investigation. It is critical therefore that an appropriate modelling framework is established which sets out the specific methodology that will be developed and the scenarios to be explored.

The overall modelling framework will vary between pursuits. However, the Department of Transport expects at a minimum, that a calibrated and validated base model is developed for all modelling projects. It is not acceptable to simply deliver results from a change (project) delivery.

5.5.1 Development of the Base model

The Base model is a calibrated and validated model of an intersection or small network reflecting the current or historical operation. A Base model methodology is essential in determining the appropriateness of the intersection modelling platform. A Base model needs to be established for investigations to ensure that benchmarking of the outcomes from the proposed change can be attributed to the delivery rather than to the software components.

As outlined within the chapter on model calibration (Section 7), the tasks at hand are not simply to benchmark the selected criteria. Rather the development task is to ensure that enough evidence is formed to better comprehend the movements and traffic and the general operating conditions when future year and/or project conditions are implemented. This not only pertains to demand, but also to constraints and limitations within the network.

A base model for the required analysis will need to be developed for each and every pursuit undertaken. It is expected that a base model will be developed for at least an AM peak hour and a PM peak hour (or period as appropriate).

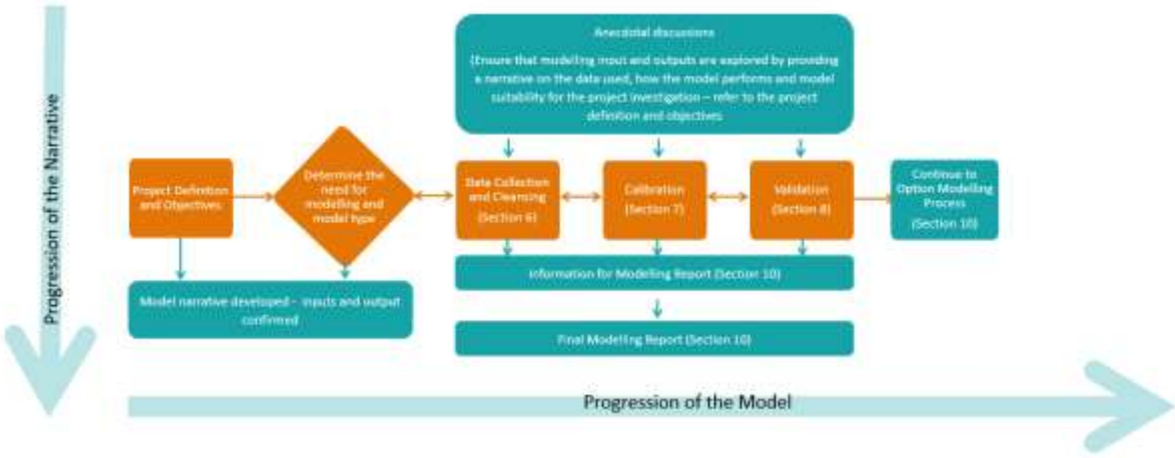
However, additional periods of heightened operational and design matters may require further timeframes to be considered. The requirement of the completion of the two peak periods (AM and PM) aligns to the Department of Transport responsibilities to ensure that appropriate measures are explored and addressed prior to development. A common modelling pursuit is the investigation of new/upgraded intersections to provide access to retail development. In these instances, the peak demand volumes may align with a Saturday peak (generally around midday) and it is essential that these periods of analysis are also explored. Intersection models should not be limited to a peak hour or peak period but adjusted to reflect the issues of the landscape.

Some teams may perceive that new intersections suggest that a base model is not required. This is not correct. Under such conditions a broader area needs to be modelled to identify the scale of results and impacts of the suggested challenge. Models need to be developed to explore conditions of existing sites, which will involve extending the network beyond geographies initially perceived.

It is important that practitioners do not take the task of signal optimisation out of context. When exploring the base year model, a calibrated solution needs to represent the real world operations. Calibration will generally require high quality input data. In the absence of this input data the defaults used by intersection modelling software may provide an optimised model that does not compare to real world conditions such as vehicle queue lengths and vehicle delays.

The process involved in the development of the Base model is shown in Figure 4 which outlines the progression of both the work flow and the narrative at the same time. This alleviates the shortcomings in reporting at the end of the process that jumps to the end result rather than exploring the problem statement and data collection methodology.

Figure 4: Development of the Base model process



5.5.2 Development of the Future and Options models

The option modelling process should only proceed when the Base model is considered appropriate for the intended use (calibrated and validated to the required level of detail). The components of the base model need to be carried through for options evaluation.

The typical approach to the development of options models first considers adjustments to the calibrated and validated Base model to account for future growth in demand and to a design day (generally, the 30th busiest hour of the year). These values are then adopted for respected future year and the associated scenarios which usually include a ‘Do Minimum’ and ‘Do Something’ option.

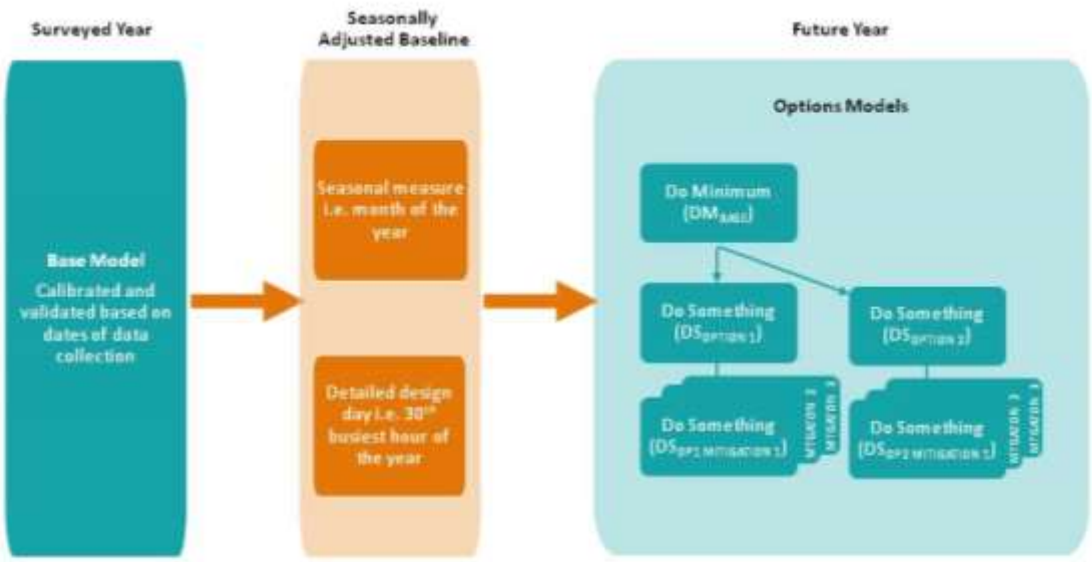
The ‘Do Minimum’ option generally provides a view of the landscape with additional journeys and other ongoing or expected delivery projects, albeit within the suggested revisions from this singular investigation. That is, changes applied beyond the delivery of this analysis. This may be the least cost solution for achieving the other changes to be implemented in the landscape. This option may include

- new land use developments;
- planned new infrastructure projects; or
- prospective signal revisions that occur outside or on the fringe of the network explored.

If the ‘Do Minimum’ option fails to achieve acceptable performance measures, or a change is proposed for reasons other than traffic performance, then the associated changes should be delivered within the ‘Do Something’ scenarios. Dependent on the resulting performance, further modifications may be necessary to address deficiencies in the initial ‘Do Something’ models (i.e. within the options explored). These further modifications are often called ‘mitigations’.

The typical process is outlined in Figure 5 to explore development of a base year model and validation against the data collected. This is subsequently enhanced to provide direction on seasonal adjustments before exploring further horizon considerations (changes in demand and infrastructure).

Figure 5: Development of the Option Modelling Process



It is important that the base year validation be measures against the observed data collected, as well as then producing a seasonally adjusted base year model.

The potential 'Do Something' models should be considered and explored with the relevant stakeholders prior to the data collection process. This may designate a small increment in data collection requirements in order to better value the proposed change to the transport system.

The project investigation, definition and objectives are the guiding information required for this process. Future year modelling and options testing are discussed in Section 9.3 and should be considered when planning this process. Changes need to consider the reference case projects identified (even if not yet committed or funded) in addition to any determined growth rates. The projects listed in the current reference case are those infrastructure builds that are expected to be funded and delivered within the future year landscapes. These projects are not simply aspirational goals.

5.6 Legacy models

Due to the application of intersection models, it is generally accepted that new investigations lead to new models being developed. It is very common that intersection models are treated as disposable.

However, there may be times when a team is required to adopt a previously developed model (or 'legacy model') for an investigation. It is the opinion of the Department of Transport that the professional service commissioned to manage and develop the options also ensures an upgrade of the quality of the Base model to requirements of this Guideline. In this context; if the base model is dated, not calibrated and validated, or poorly developed, then it is the responsibility of the practitioner or project engineer to update these models in accordance with the requirements set out in this Guideline. It is not professionally acceptable to simply dismiss a below standard model as an acceptable baseline.

It should be noted that new versions of modelling software may impact on the results of previously developed models. In this situation, the validation of previously developed models may become void. The Department of Transport does not have a requirement for practitioners to use the latest stable version of modelling software, but requires consistent versions to be applied across Base and Options models within a single investigation. Should a particular version of the software have a known bug that is likely to impact on the results of the modelling, it should be upgraded to the latest stable version. However, the latest version of software is typically encouraged.

Table 4: Scope Formation Modelling review checklist

Review Area	Details	Yes	No	N/A
Modelling software package and version	Modelling software package used for the development of the model and the applicable version specified (review should be conducted using the same version).	☐	☐	☐
Model extents	Model extents sufficient to incorporate all intersections impacted by downstream conditions	☐	☐	☐
	Base Model has been developed	☐	☐	☐
	Models do not include more than ten intersections	☐	☐	☐
	Modelling represents a contiguous landscape	☐	☐	☐

6. Data collection

6.1 Introduction

The development of intersection models and their accuracy to represent the observed conditions is highly dependent on the quality and consistency of input data. To ensure that the quality and consistency is maintained, the source of the data should be outlined. The data used in the investigation should not be assumed to be error free or correct simply because they are provided by a credited or approved source. All data sources have limitations (in both collection and interpretation) but can be used to help establish the narrative.

It is important for practitioners to determine beforehand what datasets are required for calibration and validation of base models, and for development and evaluation of future and options models (refer Section 6.4. Practitioners should then consider what data is available and what needs to be collected based on a hierarchy of data sources (Section 6.4.1).

Models developed for the Department of Transport need to deliver for all modes of on-road transport and hence appropriate datasets (evidence) are required. Some datasets can be obtained retrospectively (e.g. signal operations, SCATS volumes, and travel time data) but other matters including observations directly relate to the survey timeframes.

A data collection and processing strategy needs to be developed that focuses on the following principles:

- Collection period considerations which should cover the typical periods to be modelled. The typical period may not necessarily be a normal day but may require consideration of other factors.
- Special observation on the day of data collection (road accidents, network closures, weather)
- Type of data and modelling purpose, whether it is for model calibration (i.e. direct input of datasets into the model), or for model validation (i.e. independent datasets for model output comparison).
- Level of quality of calibration and validation required and therefore the minimum quality of any data collection activities.
- The potential future year options should also be considered and explored with the relevant stakeholders prior to the data collection process.

Data collection requirements are outlined here. For field survey data collection, typically a Transport/Traffic Survey Specification is developed that outlines the requirement of the collection process. Austroads, Guide to Traffic Management Part 3: Traffic Studies and Analysis (November 2017) section 2 further explores traffic studies and survey considerations.

6.2 Data quality

The quality of data collection is an important consideration as it reduces uncertainty in the data collected and provides a means of developing a more robust transport performance analysis. With any data collection process undertaken, the quality of the data should always be tested and documented in the data collection summary.

If the data quality is considered to be poor, it should always be documented so that a more informed decision-making process is undertaken. This may involve collection of a new sample of data to replace poor datasets obtained previously. This can assist in building the narrative and the approach as part of the calibration and validation process.

Examples that may impact on the quality of survey data include:

- Traffic operation i.e. accident/incident;
- Weather;
- Sporting event (planned/ unplanned);
- SCATS server down; and
- Project budget.

Over the course of the data collection period, a sample of data will be collected. There may be significant variability in the data being measured which may be applicable to vehicle speeds, travel times or traffic volumes. Appropriate statistical procedures should be applied to ensure that outlying results are removed from the dataset(s) prior to establishing inputs for calibration or validation.

6.3 Collection period

6.3.1 Considerations

The data collection period must be designed to cover the typical periods which are being modelled. The typical period may not necessarily be a normal day, but may require consideration of other factors as described in **Table 5**.

Table 5: Data collection period considerations

Criteria	Considerations	Impact and Outcome
Day of week	Consider representative days (avoid weekday/weekend, late night shopping, etc.).	Data is generally collected from Tuesday to Thursday as it considered to be representative of the network demand and is subject reduced impact from weekend related events. However, it may be appropriate to undertake surveys in these periods in addition to the representative days if they are likely to include regular peak periods for analysis (i.e. Saturday in shopping areas). Mondays and Fridays are not encouraged as they are associated with more variation in journey patterns that a typical workday.
	Consider weeks based on seasonality i.e. avoid weeks in the summer months (December, January and February).	Data is generally collected outside the summer months (December, January and February) due to variability in network demand from high volume of holiday activity due to school holidays and public events. The Department of Transport’s preference is to collect data during the months of May and November. However, seasonal sites may require data collection at these times for design and operational planning.
	Consider avoiding school holidays, public holidays, major sporting and special events including adjacent weeks to these sessions.	Data is generally collected on weeks that do not fall on a school holiday, public holiday or special event. Adjacent weeks are generally excluded but will depend on the extent of impact on network demand. Avoid special events that influence the network by more than 10% of additional delay. The AFL Finals Series, Melbourne Cup or a major music event are such examples.

Table 5: Data collection period considerations

Criteria	Considerations	Impact and Outcome
Time of day	Peak periods, inter-peak, off-peak,	Data is generally collected for the peak period, but it may be different across the network as the period may extend into inter-peak or off-peak periods. Typically, demand is collected in the weeks not affected by public holidays or school holidays. The times commonly chosen are 7-9AM and 3-6PM (and 11AM-2PM Saturdays).
	Consider impact from retail centre opening times and school drop off and pick up periods.	Peak fluctuations can occur due to shopping/retail centre and school activity as the chosen time of day should ensure that these impacts are captured otherwise calibration of the network complexity may be difficult to achieve for a specific time interval.
Time increments	Consider the interval at which the various data collection should be provided. Depending on the project investigation, the granularity of the time interval may vary	Data is generally collected in 15 minute intervals to assist with identifying time profiles and any spikes in demand. However, in highly time sensitive operations such as intersections providing access to industrial areas (with specific shift changes) data may need to be collected in more frequent intervals (5 minute).
Adverse or abnormal weather	Consider the impact of adverse or abnormal weather conditions such as heavy storms, lightening, icing surfaces, strong winds, bushfires etc.	Data is generally collected on clear days as adverse or abnormal weather does not provide a typical representation of network demand, is a cause of heightened vehicle incidence, increase caution on the roads and on-road mitigating scheme such as reduced speeds due to extreme winds.
Change in traffic conditions	Consider the traffic conditions that is proposed before or after the data collection.	Data quality may be compromised if a detour is in effect bringing journeys into the area. Alternatively, a traffic control device is installed on the network that impacts the data collected i.e. ramp metering for motorways, accident management, and construction projects.

6.3.2 Special observations

While data collection is ongoing, during the data collection period, consideration should be given to monitoring any abnormal site-specific conditions, for example, interruption to traffic flow due to issues or incidents. It is expected that a site visit is undertaken. This might also be served during the data collection period in order to understand whether there are conditions that may impact on the quality of data being obtained.

A number of considerations that should be included within a report are provided in **Table 6**.

Table 6: Special observations associated with data collection

Criteria	Considerations	Impact and Outcome
Issues or incidents	During field data collection, any issues or incidents need to be captured. The practitioner should ideally visit the site to observe and understand traffic conditions during field data collection periods. E.g. a road crash removes a lane of capacity.	Data quality may be affected depending on the issues or incidents identified during the field data collection. The practitioner's presence on site will assist in the calibration process to simulate as observed rather than just match datasets e.g. illegal movements, emergency services interaction, unfamiliar taxi movements etc.
Anecdotal observations	During field data collection, any site specific characteristics need to be photographed and documented. The modeller should have visited the site prior to development to observe and understand traffic conditions during field data collection periods.	Data quality maybe affected due to site specific characteristics not being documented. Practitioner's presence on site will assist in identifying specific transport behaviour. Typical considerations include: ▪ Queuing that is affecting the demand upstream ▪ Specific under-utilisation of lanes at the approach to intersections ▪ Illegal movements ▪ Treatment deficiencies or driver confusion due to signage or line marking.

6.4 Data sources

6.4.1 Hierarchy of data sources

There are a range of ways that data can be collected or estimated for use in traffic modelling. The level of calibration and validation required for the model will determine the minimum data collection requirements. The Department of Transport generally recommend the following hierarchy of data collection methodologies:

1. **Direct Measurement** of the current conditions at the intersection or network of intersections being modelled through either site observations, counts, or SCATS records.
2. **Measurement through Existing Monitoring** such as applications of SCATS detectors to explore throughput, utilisation, speeds and intersection performance that are subsequent to the installation of the control system.
3. **Comparable Measurement of Sites** in the event direct measurement of the site or sites being modelled are yet to be developed. A site of similar conditions and location might be considered to develop a narrative.
4. **Tables of Values** as provided in this Guideline.
5. **Software Default Values** are generally only appropriate at sites where no other empirical or equivalent observations are available.

In all instances, practitioners should strive to achieve the highest level of data collection possible in order to achieve a properly calibrated and validated models represent real world conditions of the sites in the investigations.

6.4.2 Data types and uses

The range of data collection required for intersection modelling, and its purpose for either model calibration or model validation, is summarised in Table **7**.

Table 7: Type of data collection and modelling purpose

Type of data	Example of Field Survey Data Availability	Example of Historic Data Availability	Data for Model	
			Calibration	Validation
Physical characteristics (Section 6.5)				
Intersection Geometry	Manual measurement Estimate based on aerial photography	Intersection designs and layout plans	Yes	No
Traffic Demand (Section 6.6)				
Traffic Counts	Manual counts i.e. onsite resources, video recording Automatic count systems i.e. tube counts or turn movement counts	SCATS inductive loop counts	Yes	No
Classified Counts	Manual counts i.e. onsite resources, video recording Automatic count systems i.e. tube counts or turn movement counts	-	Yes	No
Pedestrian Counts	Manual counts i.e. onsite resources, video recording	Permanent count sites	Yes	No
Cyclist Counts	Manual counts i.e. onsite resources, video recording Automatic count systems i.e. tube counts	Permanent count sites	Yes	No
Public Transport i.e. schedules, stops and speed	Manual counts i.e. onsite resources, video recording Automatic count systems i.e. tube counts Speed through riding the service Drone footage	Online publications GPS Probes (dependent on public transport type) Ticketing system tracking	Yes	No

Table 7: Type of data collection and modelling purpose

Type of data	Example of Field Survey Data Availability	Example of Historic Data Availability	Data for Model	
			Calibration	Validation
Behaviour (Section 6.7)				
Vehicle Speeds	Radar measurements Automatic count systems i.e. tube counts		Yes	No
Gap Acceptance	Video recording Gap acceptance survey		Yes	No
Lane Utilisation	Manual counts i.e. onsite resources, video recording	SCATS inductive loop counts	Yes	Yes
Parking	Manual counts i.e. onsite resources, video recording		Yes	No
Traffic signals (Section 6.8)				
Signal Operations	Site observations to confirm signal plans	SCATS operation files i.e. SCATS Strategic Monitor Inputs, SCATS Access, LX File Inputs	Yes	No
Signal Times	Generally, not required from surveys as data is collected by the SCATS regional computer	SCATS operation files i.e. SCATS Strategic Monitor Inputs, SCATS Access, LX File Inputs SCATS output files i.e. History File, IDM	No	Yes
Performance (Section 6.9)				
Journey Times	Floating car GPS tracking of public transport Bluetooth/ Wi-Fi	Bluetooth (VicRoads & AddInsight Traffic Intelligence System) GPS Probes	No	Yes (Multi-intersection models only)
Queues	Manual counts i.e. onsite resources, video recording	GPS Probes (speed profiles) Anecdotal evidence	No	Yes
Saturation flow	Manual counts i.e. onsite resources, video recording Loop detector data in saturated conditions Drone footage	SCATS max flow output	Yes	No

6.5 Physical characteristics

6.5.1 Intersection geometry

In order to ensure that the base intersection model is constructed to accurately represent real world conditions, it is necessary to collect information on intersection geometry including, but not limited to, the following characteristics:

- Number of intersection approaches and departures (legs or arms)
- Number of lanes on approaches and departures
- Presence of bicycle lanes
- Lane discipline and control, including shared lanes and designated movements
- Nature and length of short lanes
- Traffic islands including medians
- Widths of all lanes and island features
- Public transport movements and stopping locations
- Pedestrian crossings (locations, lengths)
- On street parking (upstream and downstream)

Physical intersection features can have a significant impact on the modelling outcomes particularly with regard to stop line capacity (where additional lanes significantly increase the total capacity) and queue storage (where overflow queuing from short lanes can impact on adjacent lanes).

The Department of Transport expects that, at a minimum, key geometric features as outlined above are measured from aerial photography e.g. Google Earth. In circumstances where up-to-date aerial photography is not available, direct measurement on-site may be required. The methodology for measuring road and lane widths must have consideration for the safety of field personnel.

In the event aerial photography is not available, and direct measurement is considered unsafe, software default values may be used for lane widths. All other features must be specified based on site conditions.

In reporting and recording data and movements it is important that the intersection is consistently described in an unambiguous manner. For example, a ‘right-turn from the northern approach’ is clear, but a ‘westbound turn’ could come from the northern or southern approaches. For this reason, turns need to reference a compass approach (choice of eight compass standards) such as “Southern Approach, Left turn”.

6.6 Movement Demand

Movement demand is a core input requirement for intersection models. Movement demand typically refers to the number of vehicles, pedestrians or cyclists passing a designated point or section on the road, or undertaking a particular movement (e.g. right turns). However, they can also refer to the number of people, not just vehicles. Movement counts can be collected to ascertain the existing demand for that movement at intersections or mid-block locations (i.e. links between intersections).

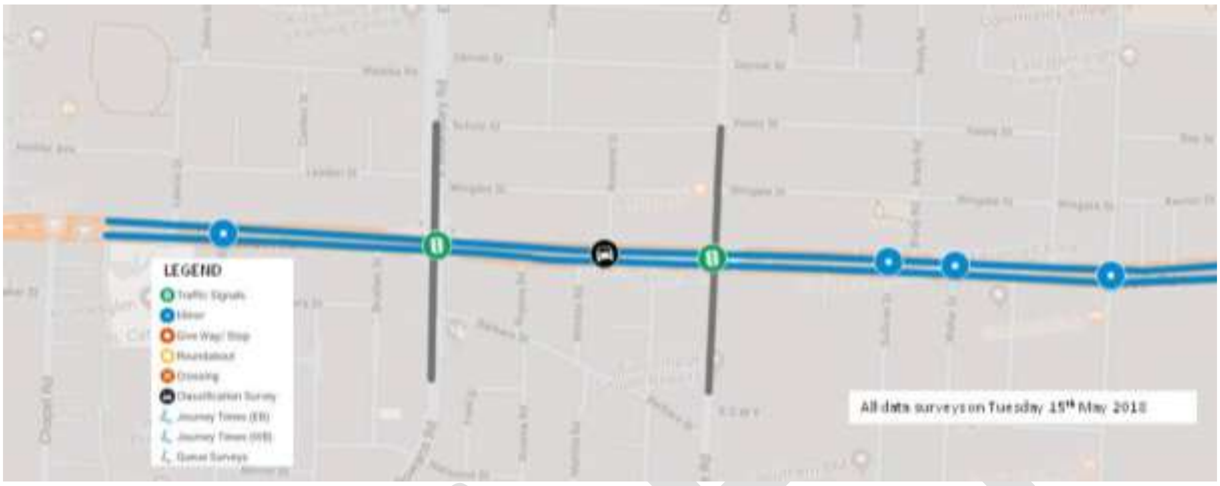
Movement counts are the most commonly applied data type in intersection modelling and are generally used in all areas of the model development. Movement counts should be segregated into appropriate intervals, ideally 15 minutes or less, in order to identify short term peaks and dynamic conditions during the overall peak period.

When collecting count data, counts should be collected for longer than the anticipated peak period (both prior to and after the peak) to ensure that the actual peaks are captured.

It is also important that in congested conditions, traffic count collection obtains the demand for the movement and not simply the throughput achieved. These distinct differences are explained in Section 7.2.3. In order to identify the appropriate components to acquire, teams may need to conduct a site visit prior to arranging data collection. This will assist to determine what data is required for collection before defining surveys for the investigation.

An intersection or network map should be provided to outline the data collection methodologies and locations. This will help to provide context to stakeholders to comprehend the value of the investment made in the investigation. An example of the map to be developed is outlined within **Figure 6** which emphasises data collection along a section of South Road, Moorabbin in May 2018. While this data collection was undertaken through the use of surveys, a process that uses multiple data sources (SCATS, surveys etc) should list this component within the diagram.

Figure 6: Example Data Collection Map



6.6.1 Motor vehicles

There are a number of ways that counts of motor-vehicles can be obtained. A common method is an intersection count survey undertaken by manual observation or video recording.

At signalised intersections, SCATS detector counts are a readily available measurement of traffic demand. These may be supplemented with other surveys where lanes are shared between different movements.

6.6.1.1 Manual and video counts

Manual and video counts are the preferred method of survey of traffic demand at unsignalised locations. This type of survey counts the total number of vehicles of varying types undertaken each movement from each approach at defined intervals.

Generally, the movements occurring in the collection period would be recorded using a fixed video camera. The video would then be processed manually in the office. The advantage of video over traditional manual counts is that the video can be slowed down or sped up to review the operational conditions and demand volumes. Video can also be reviewed at any time, verifying the work conducted. One downside to video is that a single video camera has a limited field of view and may not be able to easily capture the demand across an entire intersection e.g. south facing motorway off-ramps at Toorak Rd interchange. Often more than one video camera is required. The use of additional cameras should also be considered to provide a level of redundancy in case of camera failure.

Drones, or unmanned aerial vehicles (UAVs), are an emerging technology used for recording the movements at intersection. These devices can be equipped with high-resolution cameras to provide an aerial view of an intersection or location for the purpose of traffic data collection. While flight times are often a constraint (batteries last 20-30 minutes) there are methods of achieving long duration surveys through hot-swapping drones or by using a powered tether connected to a generator.

The advantage of drones is that the images provide an overview of movements at intersections. The resulting videos can therefore also be used to explore queue lengths, traffic counts and identify illegal or unconventional movements that would generally be hard to spot on ground mounted videos. The footage also provides more depth in understanding driver behaviour conditions by evaluating how drivers merge, change lanes, keep within lanes and utilise lanes at the approach. This resource can also be used to assist in exploring synchronous matters including signal co-ordination and queuing.

The Department of Transport have a repository of manual count data from detector and survey locations. For further information and project specific request visit the following link: https://www.vicroads.vic.gov.au/traffic-and-road-use/road-network-and-performance/roaduse-and-performance.

6.6.1.2 SCATS Counts

At signalised intersections, SCATS continuously records the number of vehicles passing over vehicle detectors. This historical data provides extensive information around traffic demand in each lane. At these locations, it is Department of Transport preference that SCATS counts are a valid source of count data. However, in many cases this data needs to be supplemented with other surveys due to errors shared lanes. Sources of error include:

- Detector failures (irregular but potential);
- Detector under-counting (common but accountable);
- Detector over-counting (chatter); and
- Detector placement.

Where lanes are shared, turning movement counts will need to be undertaken to determine the vehicles making each movement. This would usually be undertaken using manual or video counts (Section 6.6.1.1). Furthermore, SCATS detectors cannot identify the type of vehicle (car, van, cyclist, or heavy vehicle).

SCATS data is available through the Victorian Government Open Data Portal and can be found at: https://discover.data.vic.gov.au/dataset/traffic-signal-volume-data. An increased volume of SCATS outputs and performance metrics are now provided on a daily basis. SCATS data provides good insights to the regularity of complementing surveys and in the context to determine matters of seasonality. Note that SCATS provides more than just traffic volumes, which helps to develop the narrative of the site (e.g. signal flags).

6.6.1.3 Automatic Traffic Counters

Classified counts are the recording of vehicle types at a designated point or section on the road. These counts are important due to the differing performance characteristics and road space occupied by the various vehicle types (i.e. semi-articulated and rigid vehicles). Specifically:

- Gap acceptance parameters vary between different vehicle types with larger vehicles typically requiring larger gaps in the opposing traffic stream to undertake turning movements.
- Queue lengths are longer with larger vehicles given the increased space occupied.
- Intersection geometry including the size of the intersection, and therefore the amount of time required for various movements, is impacted by heavy vehicles, particularly if simultaneous turns are required.

As a minimum, classified counts should include light and heavy vehicles, but improved model accuracy can be achieved with a greater range of vehicle classifications if required. In such cases, the classification for heavy vehicles could be split into rigid and articulated vehicles, or expanded further to include separate classes for truck and trailer combinations, semi-trailers, B-Doubles, and larger vehicles as necessary. Refer to Austroads Technical Report: Automatic Vehicle Classification by Vehicle Length (August 2006) which details the established vehicle classification system by axle configuration and vehicle length for Australia and New Zealand. This pursuit should be conducted as required.

The term “classified count” may not distinctly consider other modes such as taxis, hire cars, light commercial vehicles, motorcycles or other variants which each may have different access and characteristics in the network. As a result, urban centres typically receive a high proportion of the observed fleet defined as “light vehicles” which encompasses all vehicles of a size comparable to a typical car.

Classified counts can be undertaken manually, by observing on-site or reviewing collected video footage, or via an automatic system such as Automatic Traffic Counts (Tube Counts) which involve placement of pneumatic tubes across the roadway to measure vehicle axle events. A variant of classified counts is a classified intersection turning movement count which are typically undertaken through manual count or a review of video footage whereby a large range of different vehicle types can be identified (Section 6.6.1.1). Further disaggregation of traffic surveys could categorise for motorbikes and bicycles.

Through a combination of tube counts, intersection counts or SCATS data, a profile of vehicle types can be developed for the purpose of modelling.

The Department of Transport expects that any model feature (approach, lane, or movement) that has a distinct vehicular volume comprising at least 10% of the aggregate volume should ensure that these measures are distinctly addressed and specified in the intersection model. This requirement will represent conditions of taxi lanes, HGV movements, bicycle lanes and additional vehicular measures within the metropolitan network.

Considerations for a full classification counts usually occur in areas of high truck presence and turning movements (i.e. where truck volumes are ≥ 10% of total volumes). This may be less significant near suburbia but more significant around industrial land uses, motorways and port locations. Many of the devices used for traffic counts have capability to undertake classification counts. Classification and the length of each vehicle type plays an important role when evaluating storage requirements and queue lengths.

6.6.2 Pedestrians

A site visit is recommended to better understand the local conditions and behaviour of the pedestrian network and to gain an understanding of what factors are influencing the capacity of the network. An understanding of pedestrian demand movements and behaviour is essential with regard to the modelling of signalised intersections and crossings.

For existing signalised intersections and crossings signal history data (Section 6.8.1) should be interrogated to understand the frequency of pedestrian crossing calls as this can have a major impact on signal operations.

At existing locations, where a revision to the intersection control is proposed, pedestrian crossing counts should be undertaken. These would usually be done as part of video surveys of peak periods (Section 6.6.1.1). This is particularly important where pedestrians will be provided with priority over vehicular traffic as it can have a significant impact on capacity e.g. left hand turn movements. The presence of high numbers of pedestrians may also influence the form of intersection control on safety and amenity grounds. The data collection may involve more than just an aggregate number of people at a site but might identify how pedestrians impact the movement of traffic.

Analysis for any site should consider the desire lines of pedestrian movements within the context of the landscape. Data collection may need to consider the demographics of people at the crossing which may comprise a notable consideration of school students, the elderly or wheelchair use. These elements may also have an impact on design specifications including the minimum crossing time requirements. Care may need to be provided on how traffic is held back by the movements at the pedestrian crossing.

6.6.3 Cyclists

The collection method for cyclists may vary depending on the type of facility being considered. Cyclist counts will generally be undertaken as part of manual and video surveys of vehicle demand (Section 6.6.1.1).

Where classified counts of vehicle demand are not being undertaken and it is unclear whether cyclist counts are required, a site visit should be carried out prior to count commissioning. The site visit should consider the extent of interaction of cyclists with other modes in the landscape. If a separate count of cyclists is required, the survey techniques are as per motor vehicles.

The Department of Transport also operates a number of cyclist count stations which volume and speed data is available from. These sites consist of 42 off-road sites and four on-road sites. The data from these count locations is available via the following link:

https://www.data.vic.gov.au/data/dataset/bicycle-volumes-vicroads

6.6.4 Public transport

The impact of public transport is critical in modelling pursuits. In Victoria, public transport typically refers to train (heavy rail), tram (light rail) and bus services. The manner in which the public transport occupies road space, affects signal operation and interacts with off-road infrastructure and other modes of transportation is essential in model development tasks. The style of model will also be impacted by these considerations. A key element related to public transport awareness is the time and frequency allocated to the services during the peak period signal cycles.

6.6.4.1 Routes and schedules

The number of in-service public transport vehicles can be obtained from route and timetable information. Public transport service routes and schedules are available on the Public Transport Victoria (PTV) website - https://www.ptv.vic.gov.au/. An example of this is provided **Figure 7**, which outlines services in the local area, mapped routes with stop locations, and scheduled departure times.

The operation of the public transport service may vary to the routes and schedules developed by PTV due to congestion and signal operations, and temporary factors such as road works and rail occupations. Other services such as school buses or other non-service related vehicles (including dead running movements) need to be considered. The Department of Transport recommend that intersection count data collection (Section 6.6.1.1) include classification of public transport vehicles (primarily buses and trams) and that reliance on routes and schedules only is not sufficient.

Surveys may also need to address matters of the dead-head services and chartered services operating within the period of the investigation.

Figure 7: Public transport routes and timetables (Source: www.ptv.gov.au)

6.6.4.2 Dwell times

Dwell times at stops are an important measure for public transport priority at signals. Surveys of dwell times for different stops and activity may be required using manual or video surveys.

Specific public transport modelling of corridors (where this is the key objective to the pursuit) should not be undertaken using intersection modelling due to the highly variable and dynamic nature of public transport stops. However, at selected locations the public transport dwell times may assist to account for underutilisation of kerbside lanes.

6.7 Behaviour

Driver behaviour can vary due to a number of site specific and local factors. These differences between sites can significantly impact the performance of intersections and should therefore be incorporated into models. In this context, driver behaviour refers to vehicle speeds, gap acceptance, lane utilisation and parking.

6.7.1 Speed

Vehicle cruise speed on both the approach and departure to an intersection is defined as the average uninterrupted travel speed *without* the effect of delay at the intersection.

At isolated sites in regional areas, the posted speed limit may be an appropriate proxy for cruise speed. However, in urban environments, the cruise speed can be significantly lower than the posted speed limit due to environmental factors or the effects of upstream intersection controls.

Cruise speed is an important consideration in intersection modelling. Control delay and therefore Level of Service, is a function of the travel time of vehicles interrupted by the intersection minus the uninterrupted travel time based on the cruise speed. If the cruise speed is overestimated (for example, by applying the speed limit with no consideration for environmental factors), then the intersection delay can be overstated resulting in a worse Level of Service than that experienced by vehicles on-site.

The speed input that is to be used to represent cruise speed is the median observed speed between intersections. This can be collected through means such as Automatic Traffic Counts (Section 6.6.1.1), GPS data sets (Section 6.9.3.2), or point-to-point detection tools.

Speed data values obtained in the off-peak periods (e.g. midnight to 6:00 am) should be used to replace the default software values that represent the intended journey speeds. This is the time of day that typically achieves nominal delay for journeys and produces a dataset of the intended journey speeds with consideration of environmental effects, but in the absence of congestion. This time of day analysis provides a better estimate of unimpeded travel speed. Note that the intended free flow speed is not the signposted speed.

The need for collection of vehicle speed data should be examined at the commencement of the modelling project. In the absence of directly measured vehicle speeds at a site or location, Section 7.3.1 provides approximate measures of cruise speeds against road type and posted speed limit.

6.7.2 Gap acceptance

Gap acceptance is a driver behaviour parameter that substantially influences the capacity of a control point in a priority control situation. Gap acceptance is the situation where road users must wait for acceptable time gaps (and distance) in the traffic stream to which they must give way before they proceed. The gap considered acceptable for the driver to perform the manoeuvre depends on the intersection geometry, the characteristics of the traffic and the type of manoeuvre being performed. In the same situation drivers may be prepared to accept varied gaps. A single person may be willing to accept smaller or larger gaps at different times.

However, in analytical modelling it is assumed that for a given situation there is a single time gap which will anecdotally be accepted by all drivers at all times. This is referred to as the critical gap and it is usually identified as a median value based on observed acceptances and rejections.

The other important value is the follow-up headway. The follow-up headway is which is the minimum additional duration of gap on the traffic stream required to allow one additional vehicle to follow the vehicle preceding it into the same manoeuvre. This involves filling the slot at the line to explore an available gap for access into the intersection.

Typical parameters for critical gap and follow up headways are included in Section 7.3.2. However, there are a range of site-specific situations in which tabulated values may not be appropriate including:

- Abnormal intersection geometry
- High opposing flows cause large delays for minor movements
- High proportions of HGVs
- Tourist areas

The Department of Transport recommends that consideration be given to detailed gap acceptance surveys where site conditions such as the above may influence driver behaviour.

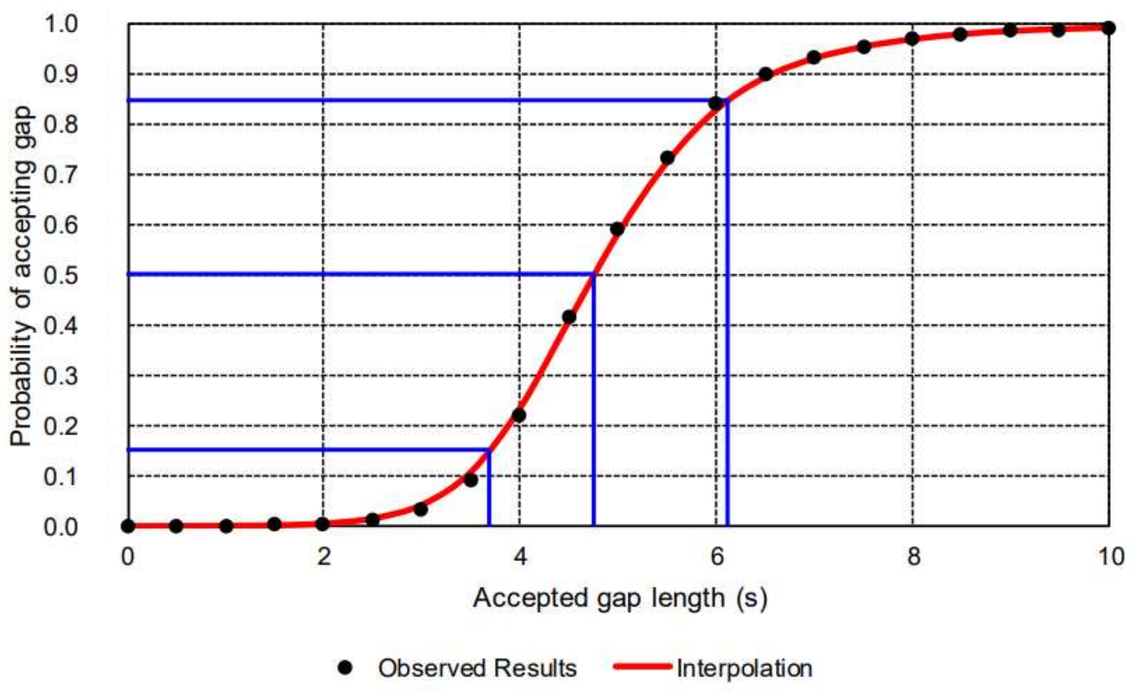
Site specific critical gap and follow-up headway can be obtained through a gap acceptance survey. These can be undertaken manually, but more recently, AI technology has been applied to drone footage to obtain the accepted and rejected gaps of drivers entering a traffic stream.

From the resulting tables of accepted and rejected gaps, the critical gap and follow-up headway can be calculated. There are three methods in common use:

- Greenshields Method;
- Raff Method; and
- Logistical Transformation Method.

The logistical transformation method plots an S-curve of best fit to the cumulative percentage of accepted gap data. From the curve, it is possible to determine the probability that a gap of a certain size will be accepted or the gap that will be accepted by a percentage of drivers. A graphical representation of this method is shown in Figure 8. In the example, the curve of best fit has been solved for 15%, 50% and 85% probabilities, yielding corresponding gap sizes accepted by these percentages of drivers of 3.7, 4.7 and 6.1 seconds respectively. The critical gap is considered the gap which 50% of drivers choose to accept.

Figure 8: Example of logistical transformation method



6.7.3 Lane utilisation

Lane utilisation refers to the proportional number of vehicles undertaking a particular movement at an intersection approach via each lane. Unequal lane utilisation occurs where one or more traffic lanes that provide for a particular turn movement are avoided and that the resulting demand creates an unequal movement across all lanes.

Unequal lane utilisation can impact a variety of metrics including reduced approach capacity, longer queues, reduced opposed turn capacity at signals and other impacts. Potential causes of unequal lane utilisation include:

- Filtered turns from shared through and right lanes;
- Tram or bus stops within a lane;
- High parking turnover adjacent the lane;
- Short lanes on approaches and departures to intersections;
- Turning vehicles in the lane subject to high pedestrian crossing demand;
- Large numbers of heavy vehicles within a lane;
- Downstream merges;
- Parking considerations (upstream/ downstream);
- A large proportion of traffic turning at a downstream location (and moving into that lane in advance of an intersection; and
- The lane being a feeder lane to a trap lane at a downstream location.

Data on lane utilisation can be collected manually, by including a lane component in a traffic count survey, or by obtaining traffic data from SCATS which is primarily a lane count. The need for collection of lane utilisation data should be examined at the commencement of the modelling project by reviewing the potential causes of unequal lane utilisation.

6.7.4 Parking

Parking can have a significant impact on the performance of modelled intersections and the capacity of modelled links. On-road parking can reduce lane capacities and the practical length of turn lanes.

It is expected that the capacity impacts of street parking on intersection approaches and departures are considered in all intersection models. Input parameters should be adjusted as required to account for extent of on-street parking and parking turnover.

Parking surveys generally consist of developing an inventory of parking and then recording occupancy (utilisation) at regular intervals. In some instances where parking is short-term and turnover is frequent, surveys of parking duration may also be required.

The following may be considered when collecting data to explore the narrative of the landscape:

- Parking bay utilisation and turnover in the modelled periods;
- Driver behaviour around parking bays and facilities and the potential impact on through capacity; and
- Parking signs and the impact on dwell times and operation;

6.8 Traffic signals

Signalised intersections have a significant impact upon the capacity of modelled traffic as they manage the time allocated to conflicting traffic movements. The adjustment of traffic signal phases, signal timings, and associated parameters directly control the throughput of each movement and thus dictate matters such as capacity, journey times and user experiences.

It is essential that existing traffic signals utilise the operational parameters, phases and sequencing in operation, cycle and phase times as a means to represent the baseline of conditions prior to implementation of a change.

The traffic signals in Victoria are managed by the Sydney Co-ordinated Adaptive Traffic System (SCATS). SCATS is a real time adaptive traffic control system that adjusts signal timings (cycle times, phase splits and offsets) in response to variation in traffic flow.

Traffic control is performed at both the regional level and local level. Regional level traffic control is undertaken using flow and occupancy data collected from vehicle detectors to adjust signal timings and improve the co-ordination of a corridor.

Local level traffic control is also carried out by traffic signal controllers at each intersection. For local level control, the signal controller manages allocation of green times allowing phases to be extended and terminated early (or skipped) in response to traffic demand. The phase sequencing of the local control must always include a pivot (main) phase that cannot be skipped (permanent demand) or terminated early. The pivot phase is generally the through movement on the major road and is used by SCATS to co-ordinate offset times. Locally SCATS aims to minimise the volume/capacity ratio with the context of the co-ordinated controllers.

All signalised intersections are developed with a Traffic Control System (TCS) number of three or four digits. This is a unique identifier used to identify every signalised intersection and pedestrian operated signals. Listings of TCS numbers can be found in the link below:

https://www.vicroads.vic.gov.au/~/media/files/documents/traffic%20and%20road%20use/scatssitelistingspreadsheet.ashx

Some intersections operate in isolation, but many signal controllers work together through the integration of subsystems. In this way SCATS will aim to operate a small number of controllers to work together to increase the throughput and reduce the localised delays. These locations are typically limited to no more than four of five controllers operating together as a sub-system. The subsystem operates a master controller (often the most complex or constrained location) with adjacent (non-critical) sites providing a supporting role. The offset times between intersections within a subsystem are specified in Offset Plans.

Subsystems are often limited to this geographic extent due to operational considerations including varied pedestrian requirements, number of movements and the consistency of platooning (which dissipates over a larger network size. However, subsystems can be dynamically joined to one another by SCATS with offsets between subsystems being specified in Link Plans.

The SCATS controllers are linked through a regional connection which allows adjacent subsystems to irregularly work together in a more harmonious manner (as required). This is a matter of co-ordination and not necessarily of a cycle time. Some controllers are directed to operate with a set cycle time (such as those within the Hoddle grid), while the road operator has the ability to overwrite the intended delivery through a centralised Traffic Management Centre. A listing of this regional controller systems are provided within **Table 8**. Note that a small number of controllers are operated by local councils and not by the Department of Transport.

6.8.1 Signal operations

Each SCATS region has an LX file which contains the signal setting details of all sites within a SCATS region. The file is obtained from SCATS and contains data necessary for communications, planned signal timings and sequence, inter-green intervals, pedestrian walk and clearance timings. This information is reflective for the surveyed days and builds on the information provided in the operation sheet. The files for co-ordination of signals can also be found within the SCATS Access graphics (**Figure 9**).

Signal operations work to manage the movement of the traffic flows through the landscape. Broadly stated, signalised intersections typically operate in one of two formats, albeit further variation is provided within this space. The two common designations are defined as:

- Control systems by approach
- Control systems defined by turn movement.

Some considerations are provided whereby an approach based control phase is complement by an additional movement. For this reason, a distinct turn movement in an approach based phase would be known as a bonus turn.

As the LX file is in a SCATS command format, it is not able to be accessed by non-SCATS users. However, most of the operational characteristics and parameters of each signalised installation are detailed in Operation Sheets.

The Operations Sheets include the layout in the controller of detector maps and signal groupings, phasing, inter-green and pedestrian times and the controller time settings (albeit not phase times). Most importantly they provide operator notes to outline how and why the intersection operates in the current format. This is a very important element that needs to be explored prior to suggesting changes. Operations Sheets are available through the Victorian Government Open Data Portal and can be found at: https://discover.data.vic.gov.au/dataset/traffic-signal-configuration-data-sheets.

Figure 9: SCATS Access Controller showing selected attributes

Note that a daily file is produced for the LX recordings and this is also provided within the measures held on the open data portal.

Details on any site-specific signal operational matters should be collected prior to commencing traffic modelling of any signalised intersections or pedestrian operated signals. At a minimum the following information should be collected:

- Signal phases available;
- Phase sequencing;
- Pivot phase identification (default phase that cannot be skipped); this is typically denoted in the SCATS system with a Permanent Demand flag.
- Inter-green times;
- Pedestrian walk times and clearance intervals;
- Late starts and early cut-offs (if applicable);
- Pedestrian and/or cyclist priority and safety features;
- Public transport priority (e.g. Tram or Bus phases); and
- Any other site-specific operational information.

It should be noted that traffic signal controllers (sites) are not limited in scale to intersections with only four approaches or even single intersections. While there are restrictions on the physical number of vehicle detectors of a site, the physical extent of the area under control can be extensive. Typically, multiple lanterns within signalised turns of 100m proximity are grouped together into a singular signal controller. **Figure 10** illustrates the operational and physical extent of the Toorak Road/Camberwell Road intersection that also connects with Summerhill Rd. These series of arms operate as one controller rather than as separate operational considerations.

Figure 10: Example of a large site under the operation of a single signal controller

Table 8: SCATS Regional Systems in Victoria.

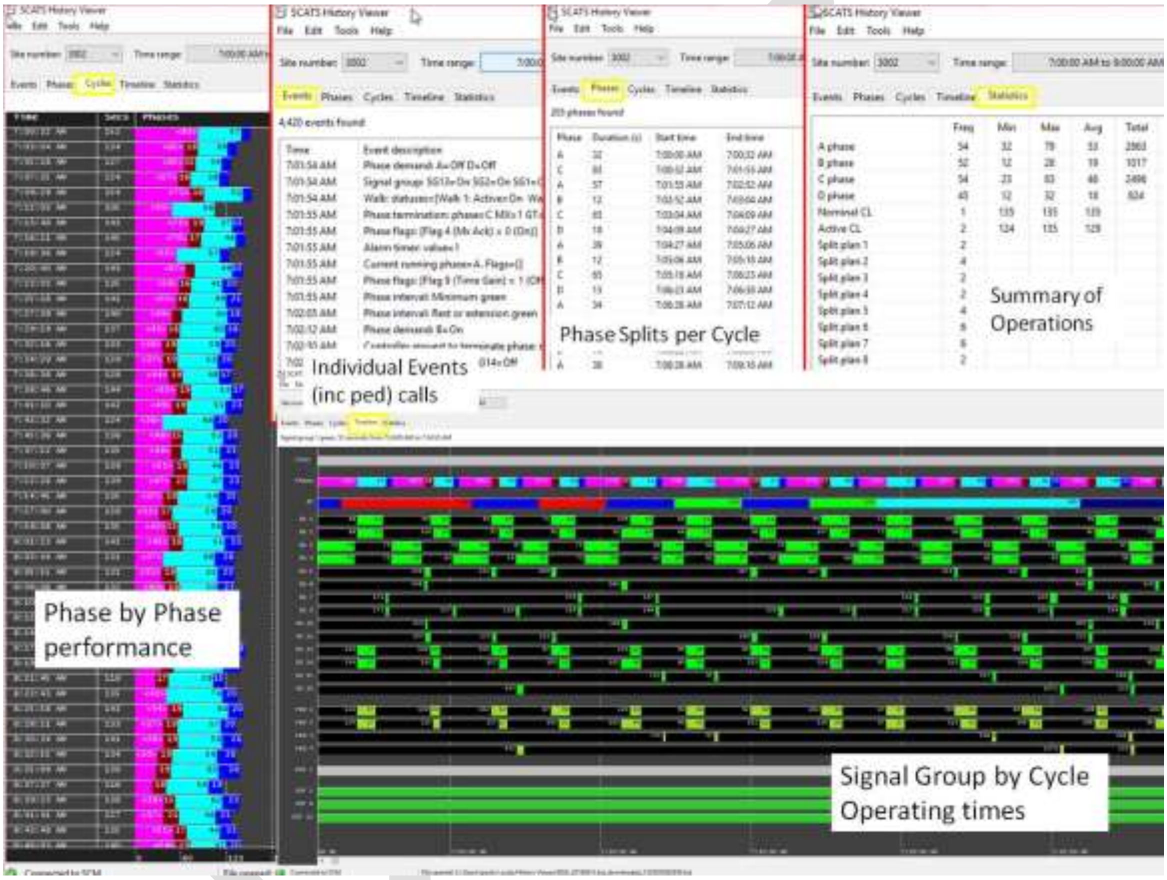
Abbreviation	Reference
BBN	Blackburn
BEN	Bendigo
BRI	Brighton
CA1/2	Carlton
CRN	Croydon
DON	Doncaster
ESS/2	Essendon
FRA/2	Frankston
FT1/2/3	Footscray
GEE	Geelong
GLI	Glen Iris
GRE	Greensborough
KEW	Kew
MC1/2/3	Melbourne Central
MEN	Mentone
MNP	Moonee Ponds
PRS/2	Preston
SK1/2	St Kilda
SPR/2	Springvale
VIC	Regional Victoria
WV1/2	Waverly

6.8.2 Cycle and phase times

The cycle times and phase times in operation are essential for model development. SCATS History files contain all single timing statistics (actual phase times and cycle times) and are recorded continuously. Phase and cycle times used as well as the phase sequencing within the model should be provided within the model development report. This may be an outline of the movements in operation for each phase, as well as a time diagram to illustrate the green splits achieved.

Cycle times are required for model calibration and phase times are useful for determining the phases in operation and durations. The history files also identify the individual calls of pedestrian crossings at the intersections. The SCATS History Viewer is the typical program used by SCATS users to output the signal data (**Figure 11**).

Figure 11: Collage of SCATS history file outputs



The history information can be viewed in five formats: events, phases, cycles, timeline and statistics. For intersection modelling, the most useful format is events (includes pedestrian and special phase calls) and phases (includes the sequence and start and end times of phases called over the reviewed period). The phase information in the phase format should be collected for time periods longer than modelling time periods, extending before and after. This data can also be exported as text files for non-SCATS users. A review should be conducted to ensure that the minimum green times (for pedestrian crossing movements) can be achieved within the scheme.

The Department of Transport is currently investigating the provision of SCATS History text files through the Victorian Open Data Portal (https://data.vic.gov.au/). In the interim, practitioners should request data through:

requestdata@roads.vic.gov.au.

In the past Intersection Diagnostic Monitor (IDM) outputs from SCATS were used in modelling pursuits. IDM files show the phase frequency, minimum phase time, maximum phase time and average phase time for a specified period and pedestrian crossing activations. Although this data format is still available, the files have a number of deficiencies including that the IDM structure needs to be established prior to data collection. By comparison the review from a history file can be extracted retrospectively to explore the operational conditions experienced. Also note that the material provided from the Split Plan outlines what is intended to occur (proportional splits) whereas SCATS History files identify what did occur in the cycle by cycle variation. The Department of Transport does not encourage the use of IDM files as a first means to examine signal operations as history files are a more appropriate analytical solution.

6.9 Performance

6.9.1 Queue lengths

Queues provide a tangible metric of congestion that is comprehensible to stakeholders. This is an item that individual parties remember and benchmark conditions through the hour with the inclusion of anecdotal “back of queue” placements (e.g. queuing back to the post box, the minor road, the next intersection etc.). However, counting or calculating queue lengths is a subjective exercise which is often difficult to define in a fixed manner over the course of a time interval.

Queue length data is the collection of stationary or slow-moving vehicles at an approach to a traffic constraint. Queue length calculation may be difficult since queued vehicles may often still be moving slowly (a rolling queue) and it may not always be clear what criteria should be used to constitute a queue. The data is likely to be collected (quantified) by a number of surveyors it is unlikely that consistent and accurate reporting will be possible across the study area. Alternative collection methodologies include the use of drone surveys. Additionally, software packages may each calculate queue lengths using different criteria and methodologies which add a further level of complexity.

Nevertheless, reporting on queue lengths is important to understand the network impacts and the key measure of benchmarking for intersection models. Queue lengths also assist in identifying the traffic demand and operational issues i.e. closely linked intersections and whether multi-intersection or micro-simulation modelling is required.

There are two main measures of queue length used by various software packages. These are as follows:

- Cycle-average queue – the average queue length resulting from recording the queue length at regular intervals (not coincident with any signal cycle times). This may be a more anecdotal reflection.
- Back of queue – the queue length measured at the commencement of green lanterns (phase commencement) each green phase so that data is reported once a cycle. A time specific measure of queued conditions such as the end of red interval.

The back of queue is the more useful performance measure as it is relevant to design of appropriate queuing space and for phasing to avoid queue spillback in multi-intersection models. It is important to confirm for quality checks that the queue length measure reported by the software and that measured on site are as close to identical as practical.

Surveys should aim to capture photographic evidence of the queuing conditions used for benchmarks and time obtained from the surveys. Queue surveys should be undertaken for the duration of the modelled periods to ascertain reliable estimates of percentile queues. When analysing the results, the impact of changing demand (obtained from traffic counts) should be considered when reporting queues. At locations where the peak demand is over a short period of the modelled hour (e.g. 15 or 30 minutes), it may be appropriate to report queues only over that shorter period.

6.9.2 Saturation flow

The saturation flow rate may be defined as the maximum hourly equivalent volume that can pass through a given traffic movement (or intersection approach) under the prevailing roadway and traffic conditions. This value is usually expressed in the number of vehicles per hour, and considers the traffic composition and geometric constraints of turning movements. It is typically one of the more understated elements of intersection modelling that can have a significant impact on traffic flow and design considerations. Saturation flow is variable and may be different for each lane due to lane utilisation, turn radius and gap acceptance parameters. While this is commonly applied at signalised intersections, a turn and lane specific saturation flow will become more obvious and critical on locations such as roundabouts.

There are a number of ways that saturation flow rate can be determined or estimated. However, if the intersection being modelled is signalised, or there is an existing nearby signalised intersection on the same corridor, saturation flow rates should be obtained from SCATS.

SCATS reports the Maximum Flow parameter for each lane at each intersection for the day in question. This parameter can be used as a high end estimate of saturation flow. To obtain this parameter, SCATS uses detector occupancy and empirical green time splits during each cycle to determine the equivalent hourly throughput of traffic potentially achieved. This measure is recalculated at the end of each cycle over the course of the observed day. It is important to note that saturation flow is constantly changing as detector occupancy is recalculated by the SCATS system. However, the maximum flow figure represents the highest achieved throughput of the day (24 hours) and defines a metric that cannot be exceeded for operation and design.

The SCATS Maximum Flow (MF) figure can be found within the LX files recorded for each region on each day. The figures is determined only for those movements warranted for monitoring, which implies most but not all detectors. For practitioners without access to SCATS, this can be accessed through the Victorian Open Data Portal:

https://discover.data.vic.gov.au/dataset/traffic_signal_strategic_monitor_detector_data

Note that as the figures recorded represent the high end value, which typically would be found outside the peak periods, an estimated reduction from this flow between 5-10% is suggested to present for peak period conditions. This implies that the inputs to intersection models should be lower than this calculation but should never be higher.

Where there is no existing or nearby signalised intersection, advice for estimating maximum flow rate is included in Section 7.2.4. these tables provided by mapping of maximum flow figures are structured by road hierarchy and council location and also by turn movement configuration on the lane. Median values have been tabulated.

6.9.3 Journey times

Travel times are useful for the confirmation of results from multi-intersection models. Journey time refers to the length of time taken for a vehicle travelling along a prescribed route within a defined time of day between two or more key locations. For the effort that drivers endure to achieve their journey, the time spent travelling (and corresponding journey speeds) is one of the more relatable performance measures.

Total journey time is comprised of a number of aspects including:

- Travel between intersections at the *approach cruise speed*
- Deceleration to an intersection control or queue
- Wait time at the stop line or within the queue
- Acceleration to the *departure cruise speed*

When exploring intersection modelling, deceleration, wait time and acceleration are all key components in determining intersection delay. On this basis, journey times can be used as a comparative process by measuring modelled travel time (incorporating modelled delays) to observed travel times.

It should be noted that observed journey time can be highly variable from vehicle to vehicle and depending on a range of dynamic factors present in the transport system. Signal operation is one major contributor to travel time variability. For journey time data collection, a minimum number of runs or sample size (depending on technology used) is required to have a greater degree of confidence in the route travel time.

Practitioners shall adhere to either of the journey time sample requirements provided below:

- Minimum number of runs if using floating car survey: 20 runs per hour per direction for each route

- Minimum sample size from journey time datasets (mobile/probe solutions): 10% of the equivalent daily traffic volume. This value can be decreased to 6% for regional areas (outside the urban growth boundary) where traffic penetration is lower. This sample can be derived from numerous days to meet minimum dataset requirements.

The primary metric within a wide sampling of journey times is the median journey time. The outputs used should focus on the median (50th percentile) and not on the average travel time, as the sample of data can potentially infer a less regular travel time due to variability in the dataset.

6.9.3.1 Floating car surveys

Floating car surveys have been the traditional measure of travel times along routes. In floating car surveys, a driver “floats” with the traffic by attempting to safely pass as many vehicles as pass their vehicle. While this method provides a reasonable estimate of travel times along a route with minimal opportunities for passing (as long as sufficient runs are performed), it can be inaccurate on multi-lane roads due to the inherent difficulties of keeping track of passed and passing vehicles. However, this approach may traditionally produce a sample size that is too small to support for a larger scale investment.

Generally, floating car surveys are conducted with multiple vehicles each departing a set point a few minutes apart. Data is recorded using a GPS tracking device and processed on completion of the survey.

Practitioners should carefully review the resulting data for anomalies as drivers often deviate from routes or stop for a reason unrelated to the survey. The resulting outliners can then have significant impact on the estimated travel times obtained from the survey.

6.9.3.2 GPS Probes

Many drivers knowingly or unknowingly share GPS position data in real time as they travel on the road network. This generates millions of GPS probes on the Victorian road network each year. The GPS probes can be used to investigate journey times. Consideration on the appropriateness of using such technology should be based on the project objectives.

These datasets are available privately through various sources. While penetration of the market is not an issue, data reproduction may be a matter for consideration. Some sources of GPS travel time are publicly available (such as through the Google Maps API) and others are available on a subscription or ‘pay per use’ basis from other suppliers

Whilst penetration into the market is not an issue for most commercial suppliers, the ability to reproduce this data is an important element. That is, a penetration of 10% may miss obtaining experiences of 90% of the fleet, but will showcase the ease of movement and points of congestion across the area of investigation from a more than suitable scale of traffic hits.

6.9.3.3 Bluetooth

Bluetooth technology can be used to survey travel times. Portable or fixed Bluetooth sensors can be placed on the road network and set to record the unique Bluetooth MAC addresses. These addresses are broadcast from mobile phones, in-car entertainment systems and hands free audio systems passing these locations. Travel time between two sensors can then be reported.

While operators of these systems have implemented policies to anonymise data collected using this data collection technique, manufacturers of these devices have more recently implemented MAC address randomisation. This randomisation prevents the use of this technology for travel time data collection. While this change may lead to an ongoing reduction in sampling rate, the sample sizes will inevitably be higher than those obtained using floating car surveys.

The Department of Transport currently operates more than 1500 fixed Bluetooth site locations on the road network. The location of currently operational sites can be found at the following link:

https://vicroadsopendata-vicroadsmaps.opendata.arcgis.com/datasets/48fd4d7e1127453ea5f9bdc757ab00e7_0

6.10 Provision of data

All data collected and used for investigations for the Department of Transport (and other government agencies) needs to be provided to the relevant data manager for inclusion to department data systems.

This should be provided physically on an appropriate drive or disk for longer term storage by the Department of Transport. This should be undertaken without the need for explicit request prior to issue of the final invoice to the Department of Transport or associated agency. Note that due to longevity matters, provision by cloud (download) access does not meet such acceptable criteria. For any clarifications on whom is the correct person to receive the data collected, please direct a query to:

requestdata@roads.vic.gov.au

Table 9: Data Collection review checklist

Review Area	Details	Yes	No	N/A
Data collection	Data is collected for appropriate intervals of analysis	☐	☐	☐
	Data is collected through appropriate techniques	☐	☐	☐
	Operational issues are documented (traffic crashes, weather, events, other disruptions)	☐	☐	☐
	Collection includes multi-modal sets	☐	☐	☐
	Behavioural data is obtained or sourced	☐	☐	☐
	Signal data identifies actual changes rather than intended operations	☐	☐	☐
	Data collected explores demand rather than just throughput	☐	☐	☐
	Back of Queue measures are identified	☐	☐	☐
	Journey time data and speeds and obtained	☐	☐	☐
	Model inputs represent the data collected	☐	☐	☐

7. Calibration

7.1 Introduction

Model calibration is the process by which the practitioner establishes input parameter values in order to reflect the local traffic conditions being modelled. Those conditions are what were observed at a particular time and are supported by collected data.

Ultimately calibration involves producing conditions of driver's experiences to develop a base model. This includes the movements chosen by drivers, and also the friction from other drivers including routes, journey speeds, delays and demand volumes.

The calibration process of intersection models can be broken down into three broad areas of:

- Demand (and capacity) calibration;
- Behaviour calibration; and
- Network calibration.

It is important that the quality of data collected (Section 6) is sufficient to ensure that the model replicates the real world conditions. The results of the calibration process should be thoroughly documented within the development section of the report.

7.2 Demand and capacity

Demand refers to the context of intersection modelling refers to the vehicle, pedestrian, bicycle and passenger volumes performing each movement at the intersection(s) included in the model for the period evaluated.

As part of the calibration process, the carrying capacity of each lane is also configured to replicate local conditions by adjustments to saturation flow parameters. Some solutions explore this examination as a series of discount values from a ceiling threshold.

7.2.1 Movements

For each intersection included in the model, the investigation should determine the movements considered at each intersection:

- Which movements occur; and
- Which are prohibited.

For each movement class (e.g. light vehicles, heavy vehicles, pedestrians, cyclists, public transport) the demand and movements used in the base model should be documented in tables and schematic format for each time period under consideration. The schematic display provides an easy to read mechanism from all stakeholders which should reduce review and approval timeframes. The source of the demand will vary, but could be from SCATS, manual or video counts (refer Section 6.6).

An important part of determining the demand is the specification of the peak periods. These periods can be identified based on review of the collected traffic counts. As noted in Section 6.6, data should be collected or obtained either side of the anticipated peaks to ensure the actual peak periods are captured.

The peak demand volumes should generally be determined for a single peak hour (for each period being investigated). However, due to the variations in conditions over an hour, this time interval may be reduced to 20-30 minutes where there is substantial variation in demand over an hour. Where there is limited variation over an hour period, peak parameters can be specified to take this variation into account (Section 7.2.2).

Typically, the peak period should be identified based on the peaks in total throughput, rather than the peaks in a particular movement. However, other definitions may also be appropriate, for example peak pedestrian movements at pedestrian operated signals. In congested situations it may be more important to consider a peak as the times when user experiences are most disadvantaged (congested) as determined through measures such as lowest speeds (most congestion) or longest queue lengths. In this way the interval with the greatest throughput may not represent the peak hour. More detail on the differences between demand and throughput can be found within Section 7.2.3. A resolution to this matter may involve an exploration of a broader space (away from congested sites) or inclusion of midblock tube counts. Understatement of the problem by misrepresenting the peak period may also understate the benefit achieved with an implementation.

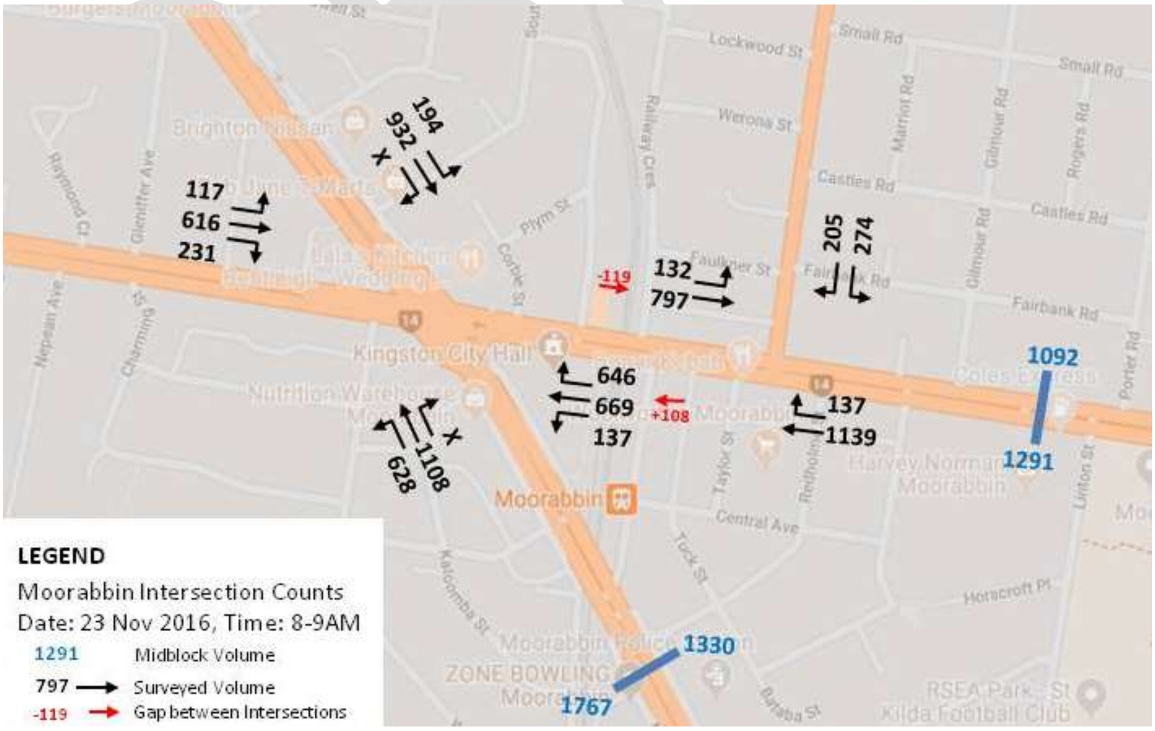
A volume for different user classes should be developed for each grouping defined in the model. This allows for various scenarios to be compared as part of options testing and ensures that the model accurately represents observed conditions (e.g. heavy vehicle storage in turn lanes). It is noted that if counts have been obtained from the SCATS system then heavy vehicles are not explicitly defined. In this scenario, refer to Section 7.2.5.

It is important that the methods used to define the peak period are documented in the report. It is also important that existing demand and surveyed data are not misrepresented. For example, a major construction project could be underway nearby that may impact on the surveyed traffic volumes. Under such conditions the surveyed data may need to be adjusted or “normalised” to better represent conditions that would occur if the major project was not underway. This can be achieved through a review of historical measures such as SCATS volumes. The advantage of this approach is to better determine the achievable benefits from growth once the “temporary” disruption is settled and the traffic conditions return to a similar measure as prior observed.

Practitioners should also be aware that in oversaturated conditions, vehicle counts (throughput) may be a poor estimate of demand. This may require adjustment of the observed counts for each movement (Section 7.2.3).

The peak period demand volumes for each movement should be reported in a graphical format such as the schematic display for an intersection or a corridor outlined in **Figure 12**. This image showcases the surveyed movements as well as the differences between the intersection counts, due to unknown network “sinks” and “sources”. Additional elements within this diagram could also consider elements for midblock count locations or explorations by vehicle type (classifications).

Figure 12: Example Surveyed Turn Volume Network Diagram



7.2.2 Peak flow parameters

Traffic volumes are rarely fixed over the analysis period and typically involve some variation over the peaks periods or hour evaluated. If a peak adjustment factor on the traffic demand is not included, the resulting delays and queue lengths will likely understate operational conditions. This is due to possible shorter-term oversaturation that may not be taken into account. The means to address this issue is particularly important in locations that may have concentrated demand volumes over a short period of time in the peak period; for example, in the vicinity of schools, ports or some train stations.

The peak parameters used in intersection modelling are as follows:

- Total flow period (minutes) (T_f) – The duration of the analysis period (typically 60 minutes);
- Peak flow period (minutes) (T_p) – The duration of the time step (generally in 15 minute increments corresponding with data collection); and
- Peak flow factor (PFF) (percent) – The ratio (as a percent) of the average flow rate (veh/hour) over the highest flow rate interval (scaled) in the peak flow period.

The PFF can be calculated as follows:

$$PFF\ (\%) = \frac{Total\ demand\ in\ T_f}{4 \times Peak\ demand\ in\ T_p} \times 100$$ (where T_f=60 minutes and T_p= 15 minutes)

Table 11 includes examples showing the calculation of the peak flow factor for 24 locations across Victoria. Of this number, nine are urban areas within regional locations while there remaining fifteen are within metropolitan Melbourne. The data identifies that some sites have a peak flow factor above 95% while only one site is below 80%. The highest figures calculated are at 99% suggesting a very flat (consistent) profile across the entire hour.

The peak flow factor estimates produced have been classified into six distinct categories of conditions, as outlined in **Table 10**.

Table 10: Peak Flow Factor Categorisation

Perception/ Use	Display	Peak Flow Factor (%)
Congested		>95%
Busy		>90% - 95%
Operational		>85% - 90%
Expansion		>80% - 85%
Nominal		>70% - 80%
Sporadic		<=70%

The peak flow factor and peak flow period (time interval) are expected to be specified in the report. If there is substantial variation in demand over the peak period (e.g. Peak flow factor <80%), then a shorter period of analysis may need to be considered (e.g. peak 30 minutes rather than peak hour). Alternatively, a micro-simulation model may be more appropriate. If the peak flow factor is less than 70% over the hour, then a revised time interval for analysis is expected. Consideration of these elements should be conducted prior to the collection of surveys, through a review of historic SCATS measures from the location or adjacent sites.

Table 11: Selected Location AM Peak Flow Factor Calculations (SCATS Data)

TCS	Intersection Approaches	Suburb	8:00	8:15	8:30	8:45	Sum	Avg	Max	Min	Range	Range%	Max x 4	PFF%
179	Burwood Hwy/ Brenock Park Dr	Ferntree Gully	868	867	835	835	3405	851	868	835	33	1%	3472	98%
190	Princes Hwy/ Chandler Rd	Noble Park	1079	1130	1035	909	4153	1038	1130	909	221	5%	4520	92%
203	Princes Hwy/ Belgrave-Hallam Rd	Hallam	1212	1212	1213	1172	4809	1202	1213	1172	41	1%	4852	99%
555	Point Nepean Rd/ Lonsdale St	Rosebud	222	247	293	338	1100	275	338	222	116	11%	1352	81%
929	Heatherton Rd/ Corrigan Rd	Springvale	715	769	719	700	2903	726	769	700	69	2%	3076	94%
1200	Vineyard Rd/ MacDougall Rd	Sunbury	359	429	370	456	1614	404	456	359	97	6%	1824	88%
1338	Marathon Blvd/ Aitken Blvd	Craigieburn	275	409	479	523	1686	422	523	275	248	15%	2092	81%
2153	Sydney Rd/ Boundary Rd	Fawkner	765	776	797	711	3049	762	797	711	86	3%	3188	96%
2597	Melton Hwy/ Calder Park Dr	Sydenham	903	918	1075	1019	3915	979	1075	903	172	4%	4300	91%
2722	Taylors Rd/ Sunshine Ave	Keilor Downs	940	1005	1041	1004	3990	998	1041	940	101	3%	4164	96%
2907	Queen St/ Lonsdale St	Melbourne	632	657	695	668	2652	663	695	632	63	2%	2780	95%
3450	Nicholson St/ Elgin St	Carlton	685	710	645	639	2679	670	710	639	71	3%	2840	94%
4808	Swan St/ Church St	Richmond	500	485	503	515	2003	501	515	485	30	1%	2060	97%
4812	Swan St/ Madden Gv	Burnley	811	691	710	653	2865	716	811	653	158	6%	3244	88%
5236	Point Cook Rd/ Dunnings Rd	Seabrook	521	572	624	585	2302	576	624	521	103	4%	2496	92%
5055	Moorabool St/ McKillop St	Geelong	539	625	667	704	2535	634	704	539	165	7%	2816	90%
5065	Princes Highway West/ Pioneer Rd	Waurn Ponds	713	918	1137	1026	3794	949	1137	713	424	11%	4548	83%
5657	Princes Highway East/ Bailey St	Bairnsdale	360	429	483	464	1736	434	483	360	123	7%	1932	90%
5819	Western Hwy/ Doveton Rd	Ballarat	321	447	451	518	1737	434	518	321	197	11%	2072	84%
5903	Gilles St/ Howitt St/ Learmonth Rd	Wendouree	462	553	654	646	2315	579	654	462	192	8%	2616	88%
6082	Goulburn Valley Hwy/ Midland Hwy	Shepparton	389	496	548	587	2020	505	587	389	198	10%	2348	86%
6272	Mitchell St/ Myers St	Bendigo	288	353	429	443	1513	378	443	288	155	10%	1772	85%
6689	Princes Highway East/McNairn Rd	Traralgon	464	471	518	529	1982	496	529	464	65	3%	2116	94%
6812	Princes Highway West/ Banyan St	Warnambool	306	447	492	580	1825	456	580	306	274	15%	2320	79%

7.2.3 Throughput vs demand

Traffic counts generally measure the passing of a vehicle across a point or section. Typically, this can be a stop line at the approach to a set of signals. In uncongested conditions this throughput approximates demand. However, in congested conditions the counts do not include vehicles that intended to travel through the intersection, but were unable to do so. Although the difference may appear to be nominal, the implications on available (spare) capacity may create problems for modelling. This should be explored if there is unmet demand of more than 50 vehicles over the peak hour.

Collection of throughput volumes can only assist in understanding the potential traffic throughput in a congested environment and other techniques and measures are required to further understand the traffic demand of intended movements. A technique is to collect traffic counts outside the queued extents and beyond the area with congestion; e.g. a midblock count rather than a stopline survey. It is important that the queued extent should be captured (representing the unmet demand on the network) adjacent to the study area during periods of congestion. This may be achieved by comparing the upstream turn volumes into the link against those turning out at the intersection in focus. In this condition the midblock count is the demand, but the turning survey is the throughput. Note that a measure of demand could prospectively be achieved from an examination of turning movements at the upstream intersection. However, this typically involves a condition where none of the turns are shared movements and there is nominal opportunities for sources or sinks between controllers. With this approach a diagram showing discharge volume and demand should be presented, with photographic evidence to provide context of the situation.

Where such discrepancies occur between demand and throughput, it is important to benchmark the delivery of both measures within the network being modelled. This should be achieved by a showcase of link turning volumes (into and out from the link) to emphasise the disparity identified.

These sites should also be included as a part of the corridors used for model validation to emphasise the delays and congestion already experienced and observed in this space.

Figure 13 demonstrates the difference between throughput and demand. The upstream signalised intersection flows show a midblock flow that exceeds the number of vehicles that are able to go towards the downstream signalised intersection. The 900 vehicles per hour is the throughput and the 1,200 vehicles per hour is the demand for this signalised intersection approach.

Figure 14 demonstrates the demand and throughput outcomes that result in queuing at a dominant approach to a roundabout, based on site observations. In this instance the performance of the roundabout would be different if the survey were conducted at the stop line as opposed to the back of queue.

Figure 13: Illustration showing the difference between throughput and demand (Example)

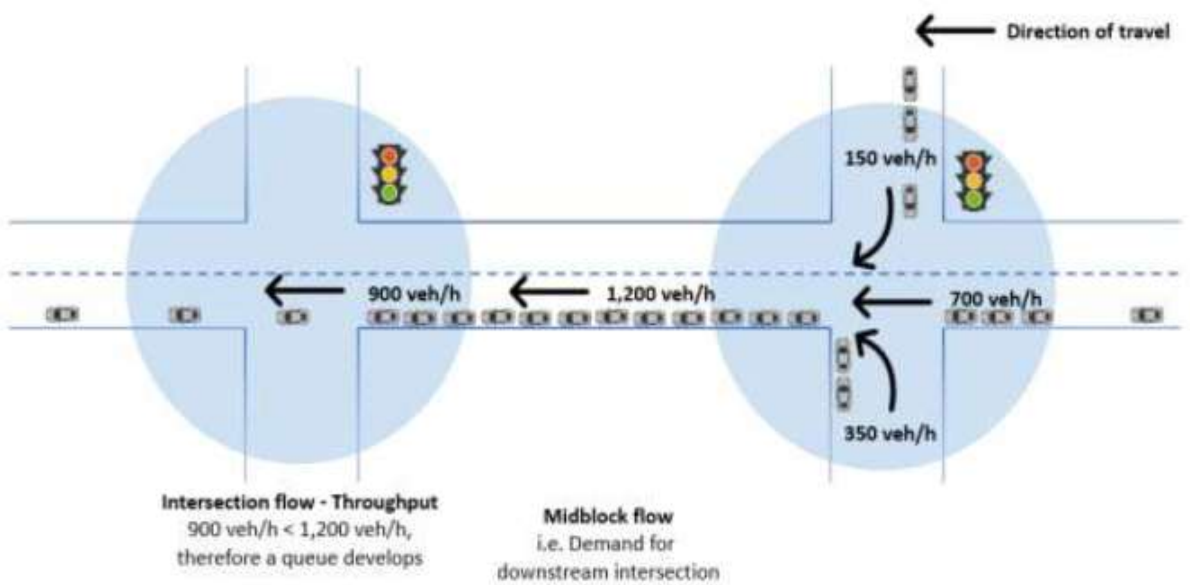


Figure 14: Observed conditions to demonstrate the difference between throughput and demand

7.2.4 Saturation flow

Saturation flow is a key parameter in intersection modelling and the accuracy of lane saturation flows has significant impacts on model outputs. It is an expression of the maximum achievable throughput of a lane and can be influenced by a number of factors, including road geometry, topography, visibility and vehicle classifications.

The accuracy of the calibration is generally limited due to available data and the Department of Transport have a hierarchy of sources for saturation flow rates:

1. **On site surveys** (data collection) – May be required for unsignalised locations where there is an unusual feature or layout that make the application of flow rate parameters from similar sites or local tables unrepresentative.
2. **SCATS -** If an existing signalised intersection, obtain the maximum flow rate parameter from SCATS and adjust to reduce from a maximum figure.
3. **Similar sites** - Obtain the maximum flow rate parameter from SCATS for a nearby signalised intersection on the same corridor or road with a similar function in the road hierarchy.
4. **Local tables -** Utilise the flow rates for the applicable local government area and function in the road hierarchy.
5. **Software defaults** - Utilise the software defaults (generally isolated regional sites only)

Use of software defaults for saturation flows should only occur in circumstances where no other data can be resourced and there is confidence that the values are appropriate. Teams are strongly encouraged to conduct their own site specific investigations. A reminder that the definition of saturation flow should not represent the highest throughput achievable in a singular movement (e.g. two seconds) but reflect a broader interval of throughput over an allocated phase time. Where new infrastructure is to be defined, teams should explore saturation flows from the same hierarchy of roads (and circumstances) and/or localised experiences.

When applying a maximum flow figure from the SCATS system it is important that a scaling factor be applied to reduce this from a high end to a peak hour condition. A reduction of at least 5% from this generated value is expected unless site specific measures can be provided. The scale of reduction may be a function of road hierarchy or proximity from a Major Activity Centre or National Employment and Innovation Cluster.

Where it is not possible to obtain SCATS maximum flow rates for the intersections being modelled (or from similar sites) and where there are no unusual features requiring direct observation of saturation flows, local tables should be applied. These local tables have been prepared from median values for each category, scaled down (reduced by 5%) and rounded values obtained from the SCATS system. The intersections analysed were categorised by road classification and local authority. The results have been separated by lane movements. Table **12** to Table **16** detail local values for a variety of lane configurations from within Melbourne.

Saturation flow may need to be adjusted to account for friction, such as downstream blocking back, lane drops or irregular disruptions in traffic flow (e.g. side road movements or level crossing operations). This refinement may require consideration of more than just a repositioning of green time allocation. Alternatively, this might be represented within the analysis conducted.

Table 12: Empirical maximum flow rates (through lanes)

LGA	Highway	Primary	Secondary	Collector	Local
Banyule	1750	1650	1550	1400	1450
Bayside	1800	1625	1525	-	-
Boroondara	-	1525	1625	1575	-
Brimbank	1700	1600	1575	1525	1425
Cardinia	1675	-	1450	1500	1500
Casey	1600	1575	1575	1425	1350
Darebin	1725	1650	1575	1400	1425
Frankston	1450	1575	1475	1450	1250
Glen Eira	1750	1650	1525	1425	-
Greater Dandenong	1675	1675	1525	1400	1500
Hobsons Bay	1500	1575	1250	1300	-
Hume	1700	1650	1600	1500	1425
Kingston	1775	1650	1675	1425	1250
Knox	1775	1725	1375	1575	1475
Manningham	1525	1700	1600	1450	-
Maribyrnong	1650	1575	1500	1525	-
Maroondah	1825	1725	1575	1675	1375
Melbourne	1525	1500	1450	1375	1275
Melton	1625	1550	1625	1525	1550
Monash	1775	1700	1625	1500	1425
Moonee Valley	1500	1575	1525	1450	1400
Moreland	1750	1600	1525	1450	-
Mornington Peninsula	1650	1400	-	1375	-
Nillumbik	-	1600	1575	-	-
Port Phillip	1675	1600	1500	1250	-
Stonnington	1750	1475	1500	1400	1350
Whitehorse	1775	1750	1600	1650	1675
Whittlesea	-	1675	1625	1475	1500
Wyndham	1725	1550	1575	1475	1425
Yarra	1600	1475	1500	1400	1350
Yarra Ranges	1725	1625	1575	1475	1200

Source: VicRoads LX Files

Table 13: Empirical maximum flow rates (right-turn lanes)

LGA	Highway	Primary	Secondary	Collector	Local
Banyule	1725	1500	1500	1400	1325
Bayside	1600	1500	1650	1425	1150
Boroondara	-	1600	1650	1475	1350
Brimbank	1675	1525	1575	1550	1450
Cardinia	1575	1650	1675	1425	1400
Casey	1550	1500	1525	1375	1325
Darebin	1575	1550	1525	1500	1500
Frankston	1350	1475	1475	1400	1275
Glen Eira	1500	1650	1525	1325	-
Greater Dandenong	1525	1500	1525	1425	1375
Hobsons Bay	1600	1475	1600	1625	1275
Hume	1575	1575	1575	1550	1450
Kingston	1625	1650	1700	1500	1350
Knox	1500	1575	1550	1525	1400
Manningham	1700	1625	1550	1525	1325
Maribyrnong	1575	1500	1450	1500	1250
Maroondah	1625	1600	1575	1650	1425
Melbourne	1600	1550	1425	1375	1275
Melton	1800	1500	1525	1300	1325
Monash	1575	1625	1525	1350	1375
Moonee Valley	1950	1575	1575	1525	1300
Moreland	1725	1525	1575	1275	1325
Mornington Peninsula	1425	1275	1175	1275	1225
Nillumbik	-	1525	1750	1350	-
Port Phillip	1500	1525	1500	1350	1600
Stonnington	1625	1475	1500	1350	1400
Whitehorse	1675	1650	1600	1600	1325
Whittlesea	-	1625	1525	1500	1400
Wyndham	-	1500	1525	1500	1400
Yarra	1650	1650	1375	1375	1275
Yarra Ranges	1500	1500	1700	1350	1500

Source: VicRoads LX Files

Table 14: Empirical maximum flow rates (shared through and right lanes)

LGA	Highway	Primary	Secondary	Collector	Local
Banyule	-	1650	1575	-	-
Bayside	-	1400	1350	1450	1175
Boroondara	-	1475	1500	1450	-
Brimbank	-	-	1450	1325	1425
Cardinia	-	1425	-	1325	1325
Casey	-	1525	1450	1525	1400
Darebin	-	1650	1525	-	-
Frankston	1050	1375	1375	1225	1175
Glen Eira	-	1350	1375	1425	1325
Greater Dandenong	1175	1025	1500	1325	1350
Hobsons Bay	-	1350	1475	-	1400
Hume	-	-	1425	1350	1275
Kingston	1975	1775	1550	1575	1400
Knox	-	-	1525	-	1525
Manningham	-	1600	1525	1450	1325
Maribyrnong	1575	-	1375	-	-
Maroondah	-	-	1675	1625	1650
Melbourne	1600	1625	1400	1300	1075
Melton	-	-	1500	1475	1350
Monash	2150	-	1400	1450	1600
Moonee Valley	-	-	1625	1525	1275
Moreland	-	1575	1675	-	1475
Mornington Peninsula	-	1425	1375	1475	1275
Nillumbik	-	1550	1675	-	1525
Port Phillip	-	1700	1525	1425	1200
Stonnington	-	1350	1425	-	-
Whitehorse	1650	1500	1625	1375	1350
Whittlesea	-	1825	1375	-	1500
Wyndham	-	1625	1425	-	1400
Yarra	-	1325	1475	1700	-
Yarra Ranges	-	-	-	1500	-

Source: VicRoads LX Files

Table 15: Empirical maximum flow rates (left only lanes)

LGA	Highway	Primary	Secondary	Collector	Local
Banyule	1475	1400	1550	1325	1300
Bayside	-	-	1350	1350	-
Boroondara	-	1450	1325	1225	-
Brimbank	1275	1425	1375	1300	1350
Cardinia	-	1200	-	-	1450
Casey	1400	1400	1650	-	1300
Darebin	-	1425	1525	1450	1100
Frankston	-	1425	1275	1225	1250
Glen Eira	-	1325	1400	1500	1125
Greater Dandenong	1425	1575	1525	1250	1250
Hobsons Bay	-	1350	1325	1250	1350
Hume	-	1175	1450	1425	1325
Kingston	1375	1425	1425	1225	1300
Knox	2025	1425	1550	1300	1400
Manningham	1800	1550	-	1250	1350
Maribyrnong	1575	1300	1100	1325	1375
Maroondah	1500	1550	1500	1250	1275
Melbourne	1375	1400	1325	1225	1175
Melton	-	-	-	-	1200
Monash	1400	1800	1675	1400	1325
Moonee Valley	-	1375	1450	1325	1250
Moreland	-	1325	1325	1275	1600
Mornington Peninsula	-	1250	1175	1250	1100
Nillumbik	-	1625	1650	1175	1325
Port Phillip	-	1325	1350	1275	-
Stonnington	-	1100	1425	1425	1225
Whitehorse	-	1525	1450	1350	1275
Whittlesea	-	1500	1425	1375	1150
Wyndham	-	1375	1425	1725	1200
Yarra	1475	1375	1425	1200	-
Yarra Ranges	1550	1025	1375	1250	-

Source: VicRoads LX Files

Table 16: Empirical maximum flow rates (shared through and left lanes)

LGA	Highway	Primary	Secondary	Collector	Local
Banyule	1800	1575	1525	1475	1425
Bayside	-	1600	1475	1350	1700
Boroondara	-	1475	1375	1350	1400
Brimbank	1675	1525	1600	1500	1575
Cardinia	-	-	-	1500	1450
Casey	1325	1450	1800	1375	1250
Darebin	1650	1475	1525	1575	1425
Frankston	1300	1350	1425	1450	1250
Glen Eira	1475	1350	1425	1425	1125
Greater Dandenong	1475	1475	1400	1375	1300
Hobsons Bay	-	1425	-	1175	1325
Hume	1575	1625	1450	1425	1300
Kingston	1775	1500	1675	1300	1425
Knox	-	1550	1725	1575	1350
Manningham	1700	1650	1575	1400	1350
Maribyrnong	1700	1525	1350	1400	1375
Maroondah	1850	1700	1500	1525	1475
Melbourne	1575	1400	1325	1350	1225
Melton	2200	1750	1775	1575	1300
Monash	1825	1575	1525	1375	1325
Moonee Valley	1575	1525	1600	1475	1425
Moreland	1575	1450	1425	1525	1250
Mornington Peninsula	-	1150	1400	1600	1100
Nillumbik	-	1475	-	1425	1325
Port Phillip	1675	1500	1425	1350	1575
Stonnington	1700	1450	1425	1450	1325
Whitehorse	1500	1575	1675	1500	1450
Whittlesea	-	1650	1575	1525	1575
Wyndham	-	1525	1775	1550	1250
Yarra	1525	1400	1475	1275	1175
Yarra Ranges	1625	1550	1525	1275	1425

Source: VicRoads LX Files

7.2.5 Heavy vehicles

The applied numbers or percentages of Heavy Goods Vehicles (HGVs) within the traffic stream can have a noticeable impact on intersection performance. As vehicle demand obtained in data collection may have been collated from SCATS, heavy vehicle demand volumes may need to be separately estimated.

Where manual or video surveys have not been used to obtain intersection throughputs, the following hierarchy of solutions is recommended to determine the number of commercial vehicles undertaking each movement:

1. **Supplementary manual/video turning movement counts** - To determine the volumes of heavy vehicles undertaking each movement;
2. **Nearby classified vehicle counts** – The proportion of heavy vehicles undertaking each movement can be estimated from nearby classified vehicle counts on the same corridor or road with a similar function in the road hierarchy. Consideration should be given to the historical relevance of count. Data from more than five years ago should be discouraged for application.
3. **Classified vehicle counts (similar sites)** – Estimate the proportion of heavy vehicles from similar sites within the applicable local government area and function in the road hierarchy.

It is important to know that the mix of vehicles may vary significantly depending on the location and time of the day. The proportion of heavy vehicles also depends on the nearby land uses, the road hierarchy and the routes used by such vehicles to reach their destinations.

The proportion of heavy vehicles fluctuates throughout the day and is generally lower in the peak periods. For this reason, estimates of the proportion of HGVs should be for the period being investigated rather than for a 24 hour average. That is, the data needs to have relevance.

7.2.6 Pedestrians

The number of pedestrians is a particularly important measure in the calibration process of signalised intersections, or other locations where pedestrians have priority. Pedestrian demand should be included in the following situations:

- At all signalised intersections where pedestrian facilities are provided;
- At all signalised crossing or pedestrian (zebra) crossing locations;
- Across minor roads at uncontrolled intersections in pedestrian activity areas; and
- Shard Use Paths and/or shared zones

Consideration should be provided by time of day intervals, especially at locations that are near to educational centres (schools, universities). Data collection may also need to explore the platooned behaviour in order to calibrate the late start for left and right hand turns.

7.2.7 Cyclists

The inclusion of cyclist volumes will be a function of the investigation and will depend on a number of factors including if there is a dedicated lane or path. In general terms, practitioners should consider includes bicycles as a separate vehicle class in situations where cyclists comprise 5% of total traffic or where cyclists or cycle paths are an important element of the delivery. It is important to allocate this class to the lanes (including dedicated lanes) actually being used by cyclists.

7.2.8 Public transport

The public transport vehicles operating on the road network (trams and buses) can introduce considerable complexities to the modelling process. Tram services should always be included in models as a separate vehicle class. In some instances buses can become a part of the heavy vehicle traffic stream (Section 7.2.5). Bus services should be modelled as a separate movement class where there are designated lanes for their use. Bus characteristics are discussed in Section 7.3.5.

It should be reiterated that intersection modelling is not an appropriate means to model trams in shared traffic lanes. Micro-simulation modelling methods are the right measure to develop such complexities in the landscape.

7.3 Behaviour

Driver behaviour is a key component of intersection models that are used to reflect the movements and decisions made while on the road network. Driver behaviour will require some level of adjustment as part of the calibration process to progress the model towards a representation of the base conditions observed on site. The modelling software will not produce this without direction from the professional teams conducting the investigation and require a refinement of input values so that the effort has value. Typically, these changes will be applied at the intersection, rather than a network level.

The behavioural parameters that are used to calibrate the network or intersection need to be evidence based from similar sites (on the same corridor or road) that have similar functions in the road hierarchy. In the absence of this data, appropriate values for the applicable local government area can be used.

A table or graphic detailing the behaviour parameters used in the calibration process should be included in the report. An explanation should also be provided justifying the variation of these parameters, where applicable. This graphic might present a map of saturation flows or also cycle times utilised within the modelling.

Parameters that are commonly explored within the refinement of intersection modelling include the following key elements:

- Saturation Flow
- Intended Journey Speeds
- Accepted Critical Gaps
- Lane Utilisation
- Parking Controls
- Public Transport operations

Other considerations that should be provided for through empirical observations and data collection involves the following considerations:

- Signal Enforcement (red light running)
- Intersection Blocking (adjustment of saturation flow)
- Wide or Long loads on turning movements
- Illegal Movements that are identified as a regular occurrence
- Misrepresentation of the lane (e.g. driving over painted lines)

Such items that occur on site should be picked up as a part of the behavioural considerations. These elements should be addressed to reflect the current operational matters prior to exploring the impacts of a delivery or network change.

7.3.1 Speed

In intersection modelling cruise speed is an important parameter. In geographically larger networks this can have a significant impact on estimated travel times.

Posted speed limits have a major influence on vehicle speeds on the network. However, many other factors influence the speed that people drive, such as the road environment and surrounding land use. Therefore, a simple application of default settings or signposted speeds may not be appropriate for the representation of actual speeds within the modelled network. This is particularly evident in circumstances where the signposted speed is not achieved when congested in absent (e.g. due to a geometric bend).

The most important speed related input for intersection models is the cruise speed, which is the median free flowing speed between intersections. This can be calibrated to available speed data collected through means such as automatic tube counts, GPS data sets or using tables for similar local sites.

To obtain free-flowing speeds, data obtained in the off-peak periods (e.g. midnight to 6AM) should be used. This is the time of day that typically achieves nominal delay for journeys and produces datasets of the intended journey speeds (without congestion). A suitable metric might be the greatest median or average speed over any hour in the off-peak period.

Where data is not available for the modelled location, data should be sought for nearby sites along the same corridor. If this data is not available for comparable sites, average empirical speeds in Appendix A should be applied. These tables outline combinations of posted speed limit, position in the road hierarchy and Local Government Authority.

For council areas not listed in Appendix A, **Table 17** provides indicative average values. It should be noted that average cruise speeds have not been provided for 40km/h posted speed limits on arterial roads. This is because the majority of these lower limits do not apply in off-peak times when speed zones are in effect.

Table 17: Average free flow speeds (km/h)

	Posted Speed Limit (km/hr)							
Road Hierarchy	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**
Highways	-	40	52	56	66	82	92	104
Primary arterials	-	42	50	59	67	79	84	-
Secondary arterials	-	39	48	55	62	60	75	-
Collectors	32	40	47	-	-	-	-	-
Local roads	26	33	39	-	-	-	-	-

Source: HereMaps data held within Domino Model

7.3.2 Gap acceptance

Gap acceptance is the situation where road users must wait for acceptable time and distance gaps in the traffic stream to which they must give way before proceeding into the intersection. As discussed in Section 6.7.2 gap acceptance parameters (critical gap and follow up headway) should be collected where there is:

- Abnormal intersection geometry
- High opposing flows cause large delays for minor movements
- High proportions of HGVs
- Tourist areas

The Department of Transport have recently undertaken research into gap acceptance parameters within metropolitan Melbourne for partially controlled signalised intersections and at roundabouts. These observed parameters are summarised in Table **18** for cars only and further explored by vehicle type and controller design in **Table 19**.

Table 18: Critical gap summary for traffic signals and roundabouts (cars only)

Situation	Gap for Probability of Acceptance equal to:		
	15%	50% (Critical Gap)	85%
Traffic Signals			
Left turn slip lane	4.7 s	6.1 s	7.6 s
Filter right turn	4.9 s	6.5 s	9.9 s
Two-lane Roundabout			
Left Turn	4.0 s	5.2 s	7.1 s
Two opposing lanes	3.7 s	4.7 s	5.9 s
Three-lane Roundabout			
Left Turn	3.5 s	4.7 s	6.6 s
Two opposing lanes	3.7 s	4.3 s	5.3 s
Three opposing lanes	3.3 s	4.2 s	5.3 s

Source: VicRoads Surveys

The data in **Table 18** indicates a variation in accepted (empirical) gaps at surveyed locations, including variation between the type of control mechanism on site. Note that the surveys identify a longer critical gap for the left turning traffic than for the movement entering the roundabouts for other defined movements (through or right turns). This applies to both two lane and three lane circulating controllers. Critical gaps at unsignalised movements within a signalised controller (left and right turns) are noted to be longer than the equivalent surveyed gaps for the roundabout locations. Note that this data collected represents a survey at a signalised location that does not run a dedicated movement for the right turn traffic.

Table 19: Critical Gap Measurements by Turning Vehicle Type

Vehicle Type	Slip Lane Left Turn	Filter Right Turn	Roundabout Left Turn	Roundabout 2 Lanes Opposing	Roundabout 3 Lanes Opposing
Car	6.1 s	6.5 s	4.8 s	4.7 s	4.2 s
Taxi	-	-	3.9 s	4.6 s	5.0 s
White Van	-	-	4.4 s	4.6 s	3.8 s
Bus	-	-	-	4.9 s	3.9 s
Medium Vehicle	6.5 s	-	5.8 s	5.0 s	4.6 s
Heavy Vehicle	-	-	6.9 s	5.6 s	4.8 s
B-Double	-	-	7.4 s	6.3 s	-
Average	*6.1 s*	*6.5 s*	*5.0 s*	*4.9 s*	*4.2 s*

Source: VicRoads Surveys

The equivalent movements have been explored in more detail within **Table 19** by vehicle class. The surveys identify different scales of experiences from the classes surveyed, including larger gaps for left turns by medium and heavy vehicles. Taxis appear to have a smaller acceptable gap for left turns than cars do, but longer gaps than cars for other movements within a three lane roundabout.

Some software packages have the capability to adjust input values such as gap acceptance parameters based on geometry of the intersection. If an investigation uses site specific gap acceptance values that have been collected, then the adjustment parameters should be managed to ensure that the end solution does not further refine this gap acceptance behaviour.

Further information on gap acceptance parameters can be found in Austroads guidelines and the Highway Capacity Manual.

7.3.3 Lane utilisation

As detailed in Section 6.7.3, lane utilisation is an important factor influencing traffic capacity and performance where multiple lanes are able to be used for a particular movement. Unequal lane utilisation occurs where one or more traffic lanes for a particular movement are avoided by a proportion of drivers. Section 6.7.3 outlines potential causes of unequal lane utilisation.

Analytical models generally use a downstream short lane model to estimate lane utilisation of upstream short lanes. However, noting the potential causes of under/over lane utilisation, calculated lane utilisations can misrepresent the conditions of the landscape. When calibrating intersections where particular movements can be performed from multiple lanes, attention should be paid to the traffic demand volumes in each lane to understand (and calibrate for) instances of lane underutilisation.

Parameters for adjusting lane (under/over) utilisation are often expressed as a percentage less than 100%. Lane underutilisation can be calculated by dividing the volume of traffic using the underutilised lane by the average lane volume across all lanes.

7.3.4 Parking

There are two elements of parking that should be considered in the calibration process:

1) the extent of car parking and
2) the impact of parking turnover on lane saturation flow rates.

The extent of car parking will impact on the short lane length specified in the model. This is generally taken as the upstream and downstream distances from the intersection to the point where parking is permitted. It should be noted that this may differ between time periods being evaluated, dependent on the times used with parking restrictions. Where a clearway is in operation, it is important to note that a continuous lane may need to be recoded as a short lane in other time intervals.

The calibration of the base model may need to consider the parking occupancy upstream and downstream of the location. In situations where parking occupancy is zero, drivers may treat the short lane as a continuous lane than would be indicated by the parking restrictions alone. Failure to take account of this behaviour will likely lead to difficulty in the calibration process. Incorporation of this behaviour requires consideration of both the short lane length being used as well as the lane utilisation factors.

Another element when configuring on-street parking is the impact that parking manoeuvres have on lane saturation. In instances where lane saturation flows have been measured for the entire period, this interference will already be accounted for and should not require further adjustments. Where tables or default values of saturation flow have been used, these measures will need to be revised to take this interference into account. To deliver this change, the analytical modelling software may use a measure of parking manoeuvres per hour to calculate reduction factors on the saturation flow for the adjacent traffic lane. These parking manoeuvres generally follow the Highway Capacity Manual guidance.

Where measured saturation flows are used, adjustments for parking should not be applied.

7.3.5 Public transport

Bus stopping behaviour is generally included in analytical models as a saturation flow reduction factor. This is used to consider buses stopping and blocking traffic in near side and far side bus stops. Where lane saturation flows have been measured, these will already take into account the impact of bus stopping. However, in instances where tables or default values of saturation flows are being utilised, a saturation flow rate reduction should be applied.

Analytical models typically apply this reduction factor based on the approach suggested in the Highway Capacity Manual. This applies a reduction based on the number of buses at stops within 80 metres of an intersection. It is important to determine the number of buses that use the stop.

Tram stops in shared traffic (kerbside stops) should not be modelled using intersection modelling techniques. Micro-simulation modelling solutions should be used to explore the complexity of the landscape.

7.4 Physical characteristics

Calibration of a model requires a review of the physical characteristics and geometry of an intersection. It is important to accurately represent how the intersection is designed and operates. Practitioners should comprehend that the modelling of intersections will involve more than just the replication of the line markings. As discussed in Section 6.5.1, it is important that site visits are conducted at the intersection during the peak times to observe how drivers interact in the landscape.

7.4.1 Intersection geometry

When developing intersection models, it is important to initially enter geometric dimensions of each approach such as number of lanes, lane widths and short lane lengths. However, these may need to be refined based on driver behaviour observed. Where drivers have access to additional pavement space, they may utilise this space in unintended ways. The model calibration should use dimensions based on the actual behavioural use rather than just limited by the line marking. Where practitioners vary dimensions in this way, it should be included in the narrative of the report and considered in the option development.

Instances where practitioners should consider modelling intersections differently from how the controller is marked includes:

- Where a wide kerbside lane is used as two separate lanes (poor lane discipline);
- Where right turn queues extend over chevrons and beyond marked turn lanes into a painted traffic island; and
- Where parking demand is low and drivers use the kerbside (parking) lane as an additional traffic lane (Section 7.3.4).

Practitioners should pay particular attention to the width of traffic lanes at intersections. These wide lanes may operate as two lanes. As an approach with a single wide kerbside lane will perform significantly worse than one with two narrow lanes (one a short lane), calibration is essential.

When calibrating such a modification into an intersection model, observations from more than one period or experience is preferred. Driver behaviour may not always be consistent in such scenarios or time intervals conducted for analysis.

7.4.2 Movement priorities

Intersection modelling software can allow users to specify those movements that generate trajectories with a conflicting movement over a location without a signalised control mechanism. The signed lines give a measure of consistent precedence with a scale of yielding movements.

While the software will apply priorities by default, practitioners should always review these inputs to ensure that these values match the operation of the intersection. This is particularly important at locations with unconventional controls or geometry.

For signalised intersections, this process should be made to determine priorities achieved within the signal phasing of the controller. However, teams should also ensure that a suitable swept path analysis (including simultaneous opposing turn movements) is conducted before finalising the signal phasing. If this task is closed before enough analysis is produced, the design may restrict the ability to deliver a fully (or partially) controlled right at the intersection. This in turn may make the intersection analysis redundant.

7.5 Signalised intersections

The attributes of signalised intersections have a significant effect on the operations and design of traffic movements and the user experiences. Components such as the intended and operational cycle length, the signal plans (again designed and also operated) and positioning of detectors will assist to achieve a solution that is demand responsive and also managed with the context of the adjacent local network. Factors such as pedestrian requirements and public transport priorities will all contribute to the delivery of the experience at a signalised intersection and may even contribute to matters of driver route choice (to minimise delays and journey efforts). For these reasons the specifics of both signalised intersection design and operation will contribute to the requirements and performances of the landscape investigated.

Signalised intersections are developed as a means to control the movement of journeys within a part of the network that typically has multiple conflicting movements with a significant volume of users. This may be a for a current horizon, or prospectively developed for a future year timeframe whereby traffic demand requires greater regulatory control beyond the restrictions of a line control.

It is important to note that the cycle length and phase plans applied will contribute to determine the amount of traffic that can push through an approach to an intersection. With a constant set of demand volumes, a longer phase time may alleviate queue lengths on one approach, but potentially this may be at the expense of the queues of the perpendicular approach. Adjustments to the cycle lengths may have perceptions to mitigate such matters, but over a peak hour or period this essentially reduces the green time for each movement. By comparison shorter cycle lengths may produce more phases and more amber and red time for lanterns (lost time), which again may limit the effectiveness of aspects of the signalised controller. For this reason, it is important to note that the operation of signalised intersections is a balancing act between management of road safety, user experiences and network performances.

A reduction in green time per hour may not always produce a longer queue, but may entice drivers to explore other routes within the network, subject to constraints and opportunities available. As such there may be times when a more complex route choice model that covers both the signalised controller and the distribution of journeys (in an origin-destination format) may be a more appropriate method to explore the conditions of the landscape.

The accurate calibration of signalised intersection and signalised crossings requires the review of parameters to achieve a model that represents the landscape. Modelled signal operations need to reflect the complexity delivered by the controller and not simply limited to the design considerations.

7.5.1 Operational characteristics

When calibrating base models of signalised intersections, users will need to specify phase sequences, cycle times and other parameters to replicate the fixed time conditions or approximate the adaptive behaviour of the landscape. The following parameters should be considered as part of the process:

- Phases used and sequencing;
- Phase frequency (phase actuation);
- Phase green time average, minimum and maximum (used in validation);
- Vehicle settings such as minimum green times, late starts and early cut offs;
- Pedestrian crossing activation frequency (and impact on traffic flow);
- Pedestrian walk and clearance times
- Special purpose phases such as priority public transport phases; and
- Co-ordination with adjacent signalised intersections.

It should be noted that the delivery of a base model should involve the optimisation of phase timings and cycle times in line with the empirical metrics. It is not appropriate to simply deliver a base model using current phase splits and then determine a change or project condition using a completely different method of definition. That is the base model calibration should explore those parameters so that the operational and design elements can be benchmarked for with a future year or changed landscape condition.

A number of sources of information on the operation of traffic signals are discussed in Section 6.8.

7.5.2 Phasing

Signalised intersections typically adopt one of the following formats to explore phase transitions:

- Fixed time signals;
- Scheduled fixed time profiled signals; and
- Adaptive signals.

Fixed time controllers generally only occur at selected inner urban locations (e.g. some locations within Melbourne's Hoddle Grid) where pedestrian movement is an equally weighed control objective. However, the majority of intersections operating under SCATS are adaptive signals operating in a co-ordinated environment. Under such conditions traffic control is performed by both regional level control (cycle time and offsets) and local control (phase sequences and timings). The challenge is to approximate the adaptive (and potentially co-ordinated) behaviour in the peak period with a fixed time operation (sometimes including less frequently called phases).

The first step in the signal calibration process is to examine the operation sheets to identify the signal phases available and the pivot phase (if applicable). A traffic signal phase is a set of non-conflicting movements, that combines signal groups together into a controller solution.

A site in a SCATS controlled system can have a maximum of seven phases. These phases are labelled alphabetically from A to G. If a phase allows alternative movements (known as a sub-phase), these are distinguished by a numeric suffix e.g. E1, E2 etc. The A phase is typically the phase commonly allocated to the through movements on the main road. The pivot phase is the main phase that cannot be skipped or terminated early. This phase is used by the regional controller to determine offset times between traffic signals to co-ordinate movements within the signal subsystem.

Note that phasing diagrams typically do not illustrate a left turn movement when accompanying a through movement. However, they are displayed when explicitly operated. Typically phasing operates with leading right turns, to better ensure that right turn bays do not inhibit the flow of the adjacent through lane movements.

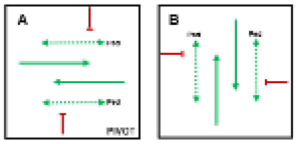
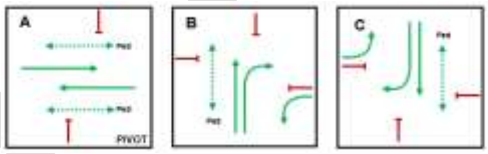
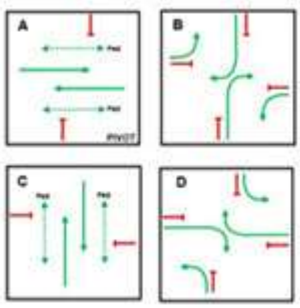
The two more common forms of signal control phase structures used to develop for a four approach intersection are defined as the following:

- Split phasing (approach based phase)
- Diamond phasing (movement based phase)

Note that the design of signal phasing arrangements is a function of the footprint for the controller. The greater the proportion of shared movements from a lane, then typically a reduced set of options for signal phasing are available. This also showcases a strong negative correlation between footprint size and congestion, but of course is subject to context. In this way a smaller intersection with more shared turn movements reduces the flexibility of signal arrangements that can be applied, which generally delivers a more congested and problematic solution. However, this does not in itself suggest that more lanes are needed to clear congestion. Simply that a constrained footprint for design has ongoing implications in operations planning/

More details on these common traffic signal phase sequences are outlined in **Table 20** below for reference. For further details refer to Department of Transport's TEM Volume 1, Part 2.09 and AGTM, Part 9: Traffic operations.

Table 20: Signalised Intersection phase sequence styles

Type and description	Sequence
Two-phase In its most simple case, a sequence of phases would consist of two phases. In this arrangement, pedestrian movements operate in parallel to vehicle movements and right turns are all filter turns. This arrangement may be appropriate at sites with good geometry, low vehicle speeds, low traffic and pedestrian volumes and without a history of severe crashes.	
Split-phasing Split phasing is a very inefficient type of phasing and is generally not used unless diamond phasing is not feasible. Split phasing includes operating the through movement with adjacent controlled right turn, while stopping the opposing through movement. Split phasing is likely to be found at locations where the physical alignment of road approaches are not wide enough to run diamond phasing. Typically, the right turn lane is shared with a through movement given the reduced space on the approach. A key issue with the split phasing is the inflexibility of the phase plan to efficiently deliver journeys with varying demand throughout the course of the day. This may include the time of the day when there is no demand for the right turning movements. The phasing pictorial would also be accompanied by a phase for the right turns from the major road.	
Diamond Phasing Diamond phasing includes a phase where opposite right turns are provided a phase without an opposing through movement. Under this phase arrangement the signal groups are largely allocated by movement rather than by approach. Envisage that the cycle begins on a D phase, despite the A phase as pivot. Right turn bays will require a dedicated lane. Diamond phasing provides more opportunities for adaptive controller solutions for each specific cycle. When there is an absence of demand for right turn movements, these solutions are not required to run. However, when there is uneven demand volumes (e.g. peak periods) then an overlap function can apply as required.	

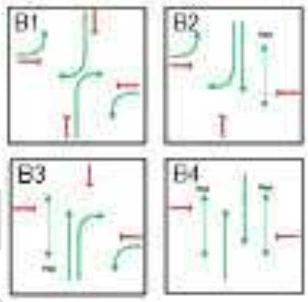
An overlap operates in diamond phasing as a demand responsive solution and will vary for each cycle of operation. Using the above diamond example, the transition from A to B phase can involve any one of the following four options before moving to the C phase:

B1: Both right turns operate

B2: through and right from the north only (no right turn demand from southern approach)

B3: through and right from the south only (no right turn demand from northern approach)

B4: no right turn demand (essentially direct to C phase)



The overlap provides the most efficient operational solution as it is the more adaptive delivery. This notion of an overlap occurs where the signal plans transition from B1 to the C phase through either B2 or B3 when there is a demand for this movement but empty detectors on opposed right turns. This right turn overlap reduces the overall intersection delay. However, the footprint may be wider than other signalised intersections.

At signalised intersections of major crossroads, a diamond phase with overlap is likely to operate for both sets of opposing approaches. This phasing arrangement is referred to as a Double Diamond phasing plan (whereby diamond phases run for both generic north south approaches as well as east west approaches). Single Diamond phase plans exist but are less common and might operate where on a major arterial with limited neck width on the minor roads.

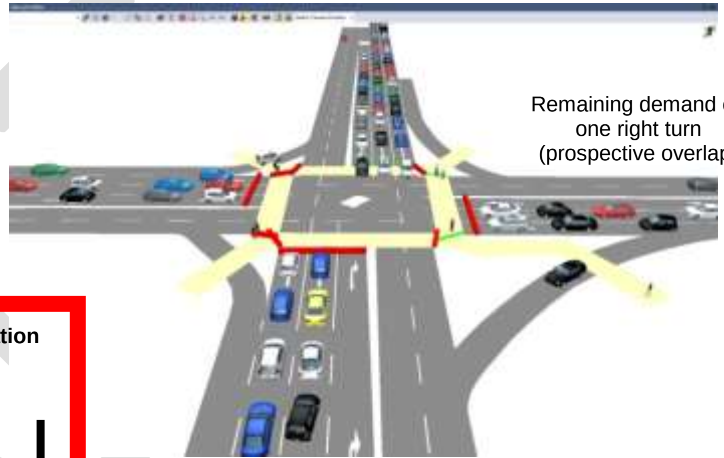
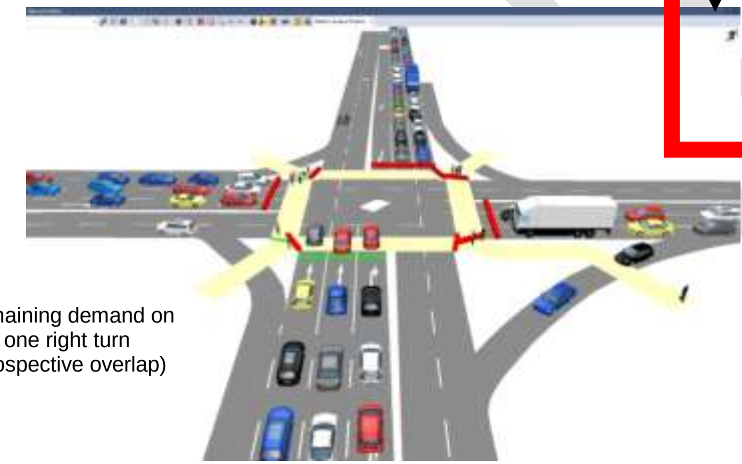
As emphasised within **Table 20** the delivery of Double Diamond phasing provides for more efficient signal operations for both peak and off peak solutions. Modelling and design teams are strongly encouraged to deliver their solution as a Double Diamond arrangement rather than split phasing. This includes acquisition of land to ensure adequate geometric solutions for the development pursuits.

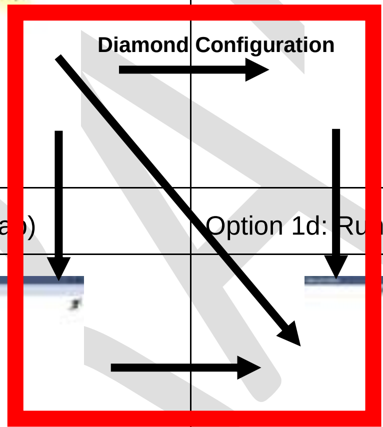
This also provides for more adaptive signal operations that are demand responsive to the conditions of each cycle with opportunities to use the overlap to better reduce delays of the journeys. However, the efficiency of the operation comes at the expense of the footprint of the intersection space required.

The diamond name reference comes from the shape of the prospective movements as the phase transitions to operate the through movements on the two approaches. This shape is outlined within the components that define **Table 21**. Note as well that as all phase operations, the green times are subject to maximum operational times for the phase.

A general principal is to design four approach signalised intersections with a delivery of double diamond phasing. This improvement of efficiency in operations, investment (and user experiences) outweighs the additional land required to develop the intersection. This is an important element when designing new controllers in growth areas as the adjacent land may soon be utilised for other purposes (e.g. site developments). In this way the delivery of signalised intersections should explore and consider the medium to longer term implications as there may be not be an opportunity to revisit the design of critical locations in a future horizon.

Table 21: Demand responsive Diamond Phasing (with Overlaps)

Option 1a: Run Both Right Turns	Option 1b: Run northern through and right turns only (direct or overlap)
	
Option1c: Run southern through and right only (direct or overlap)	**Option 1d: Run through movements (without right turns/ after overlaps)**
	



In addition to exploring the phase sequencing of the sites modelled, the right turn controls should also be examined and incorporated into the design used in the calibrated model. The available formats for right turn control are summarised in **Table 22**.

Typically, but not in all cases, the right turns are leading rather than trailing for a signal plan. This may require the last phase of a cycle to be a right hand turn movement that progresses into a through movement and the commencement of the following cycle.

Table 22: Types of right turn control at traffic signals

	Description and key considerations
Filter right turn	A right turn movement which operates in the same phase as conflicting vehicle (generally through and left turn vehicles from the opposite direction) and/or pedestrian movements. The right turn is therefore required to find safe gaps in that conflicting traffic before being able to turn (the filter). Refer to VicRoads supplement to AGTM Part 9 – Traffic Operations for more direction in a localised context.
Partially controlled right turn	A right turn movement which operates in two phases: • In a phase in which the movement is controlled by a green right turn arrow, and so has priority over conflicting vehicle and/or pedestrian traffic movements; • In a phase in which it can also transition to a filter right turn (refer definition above); and • The termination of the right turn movement is controlled by the normal three-aspect circular displays.
Fully controlled right turn	A fully controlled right turn is a right turn movement which only operates in a phase in which it is controlled by a green right turn arrow, and so has priority over conflicting vehicle and/or pedestrian traffic movements. However, unlike a partially controlled turn, does not allow to filter during any other phase. At the end of its own phase, the right turn is terminated and held on a red arrow display. Signalised Intersections with a double right turn lane are fully controlled movements and will not transition to a partially controlled solution.

Once the available phases, turn controls and phase sequencing has been established, the operation (phase used) and cycle times needs to be specified. The result of this process will be a phase sequence that approximates the adaptive behaviour in the modelled time periods.

The approximation process should include:

- **Plotting** – Preparation of plots of phase by phase duration for each cycle (this should be included in the reporting);
- **Review of cycle time variability** – If cycle time lengths have an observed range of more than 20 seconds between cycles without this being due to pedestrian activation or public transport priority, micro-simulation modelling should be utilised with actuated solutions or SCATSIM;
- **Review of cycle time trends** – If cycle times are trending up or down (or both) during the peak period, the demand volumes and peak parameters (see Section 7.2.2) should be reviewed. Practitioners should consider specifying phases based on a period within the peak with relatively stable cycle times; and
- **Pedestrian actuation and public transport actuation** – The impact of occasional pedestrian actuation and infrequent public transport priority actuation (e.g. bus jumps or traffic leaving a train station after a service arrival) should be considered. The overall frequency that these phases are called for in the model should reflect actual demand volumes, noting that these can significantly impact performance.

At the end of this review, practitioners should have:

- Determined whether intersection modelling is an appropriate tool to model the performance of the intersection;

- Understand how cycle times vary during the peak periods and the potential causes of this variation;
- Identified a fixed cycle time in each modelled period that best approximates the cycle time and the variability during the evaluated period;
- Determined the frequency of pedestrian, bicycle, public transport and special phase activation (if appropriate); and
- Identified approximate phase splits in each period for use in signal validation.

It may be a more important action to realise the ineffectiveness of the work effort and suggest budget for appropriate analysis. Reports should discuss the above and include a figure or table summary of sites with signalised intersections as well as cycle lengths and phase splits. Documentation should outline the style of phase plan as well as accompanying empirical measures from observations (i.e. SCATS history signal data, phase split plans etc.).

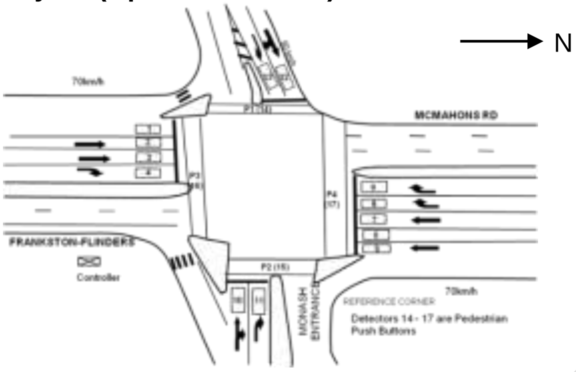
Table **23** outlines a site near to Frankston, while Table **24** examples a signalised intersection in the local council area of Cardinia, in the south-east of Melbourne.

Table 23: Review of signal operations (Example 1)

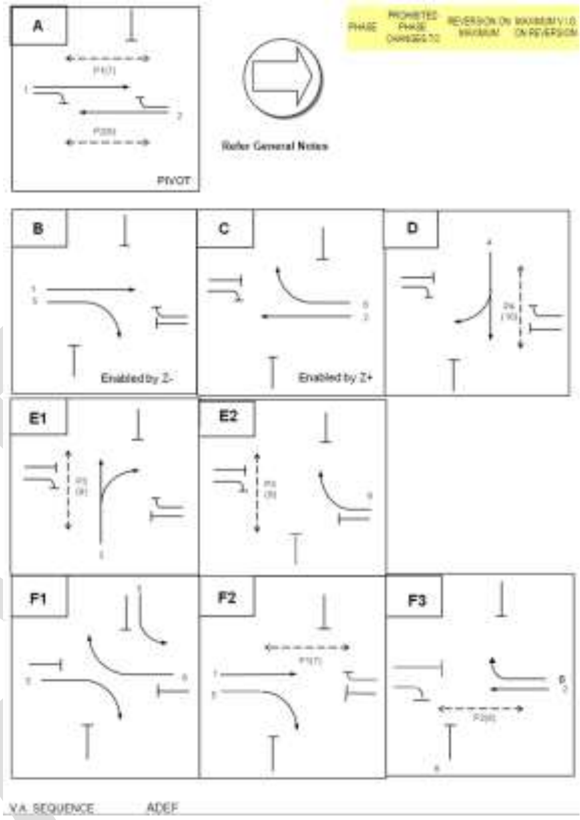
SCATS Site Number: 738

Location: Mooroodu Highway(Frankston-Flinders Road)/Hastings Road/Monash University Campus Entry

Layout (Operations Sheet):



Phasing Diagram (Operations Sheet):



Layout (Aerial Photograph):

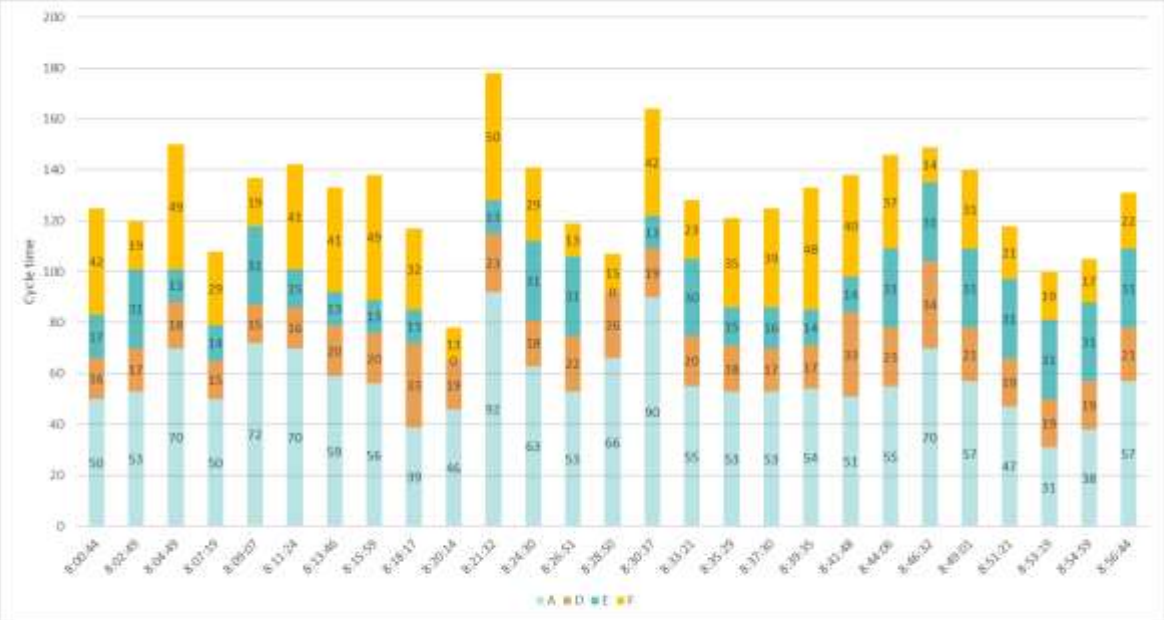
Site Commentary:

The layout and phasing diagrams are orientated 90 degrees from north. Given the adjacent land uses, the demand volumes associated with Hastings Road, will likely be greater than those into and out of the Monash University Campus. The campus may also generate higher levels of pedestrian demand than other locations along the corridor. There is a roundabout within the campus in close proximity to the intersection that may impact on performance.

Signal co-ordination would be important along the corridor, therefore cycle times are likely to be relatively stable. However, a rail level crossing is located approximately 350 m north of the intersection. The rail line is the Stony Point line, which has much lower frequency of services than other Metro services. The impact of the rail level crossing should be examined to confirm that it is appropriate to utilise intersection modelling.

Combined pedestrian walk and clearance times are 23s, 22s, 26s and 29s for P1, P2, P3 and P4 movements respectively. When called these may extend the phase times beyond that required by traffic demand volumes alone.

Phase History:



Experience:

Co-ordinated signals with demand responsive (adaptive) signal times and limited variation across the peak period. Impact of level crossing appears minimal and micro-simulation unnecessary.

Pedestrian movements P4 and P3 operate only in D and E phases respectively and when called result in the longer times occasionally observed for these phases. Care should be taken to accurately represent pedestrian operation in modelling. Increase in pedestrian demand should be included as a sensitivity test.

The roundabout within the Monash Campus should be included in a multi-intersection model.

Timings:

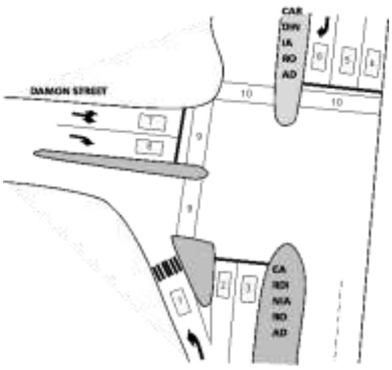
The A, D, E and F phases should be included in the modelled sequence, with phase and cycle times being the average phase times across the entire period (with outliers above 160 seconds cycle time removed). The cycle by cycle analysis indicates that the one hour interval produces a cycle time regularly between 120s and 140s. However, there are several occurrences where the E phase is not called, followed by an extended cycle operation. The specifics of this operational delivery should be explored within the operations sheets to comprehend the triggers for such deliveries.

Table 24: Review of signal operations (Example 2)

SCATS Site Number: 1519

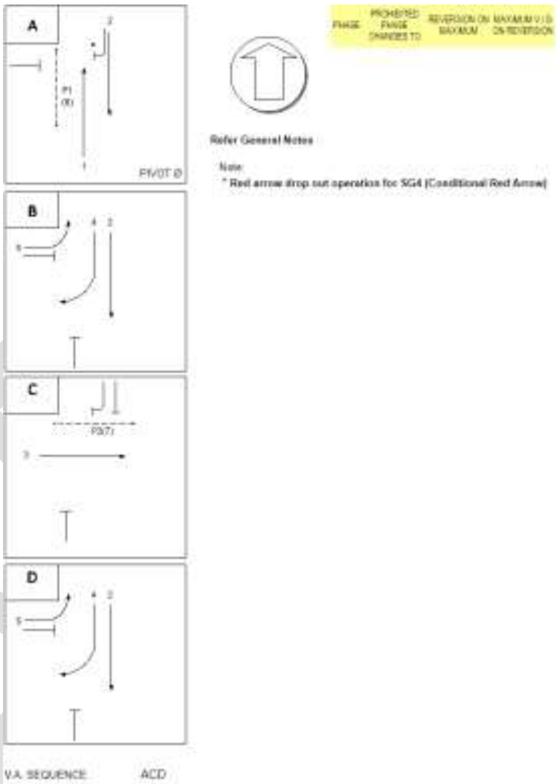
Location: Cardinia Road/Damon Street

Layout (Operations Sheet):



Layout (Aerial Photograph):

Phasing Diagram (Operations Sheet):

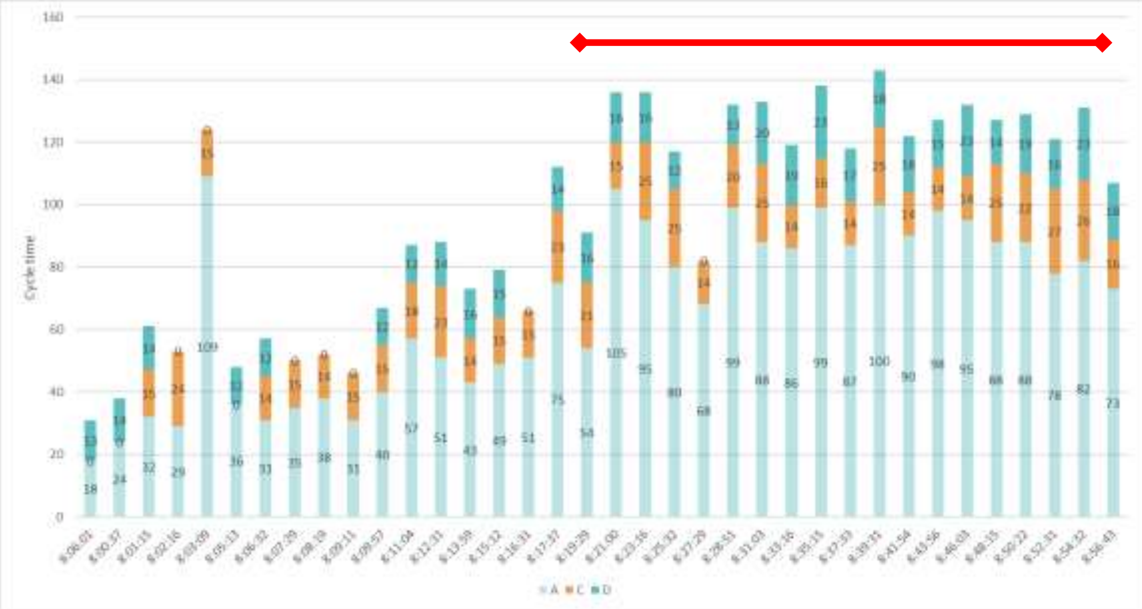


Site Commentary:

The signals provide access between Cardinia Road and a shopping centre and residential area to the west. There are signalised intersections approximately 220m to the north and 322m to the south along Cardinia Road. Co-ordination is likely to have a significant influence on the operation of this site.

Phase C is the only phase that facilitates crossing of Cardinia Road. This takes place on the northern approach of the intersection. The combined walk and clearance times are 22 seconds for this movement and could be an important factor in determining a phase length from the side road into Cardinia Road.

Phase History:



Experience:

The graphic shows that only A, C and D phases operate. The right turn into Damon Street is a leading phase.

The cycle times vary significantly over the analysis period with much lower cycle times in the first half of the analysis period compared to the second half. This appears to be the result of three factors:

- Longer duration of A phase, potentially as a result of higher traffic demand volumes along Cardinia Road or co-ordination with other signal sites;
- More frequent calling of D phase as a result of higher turning demand volumes into Damon Street; and
- Longer duration of C phase, most likely as a result of pedestrian calls.

The above observations indicate that the peak period may not be correctly defined. It is recommended that the phase history for the period 9am to 10am is examined in addition to reviewing the vehicle demand volumes in the later period. Following review of this later period, it may be necessary to adjust the specified period for analysis or even reduce the length of the analysis period (to less than one hour, e.g. 08:20-09:00AM).

It will also be necessary to include upstream and downstream signals on this corridor.

Timings:

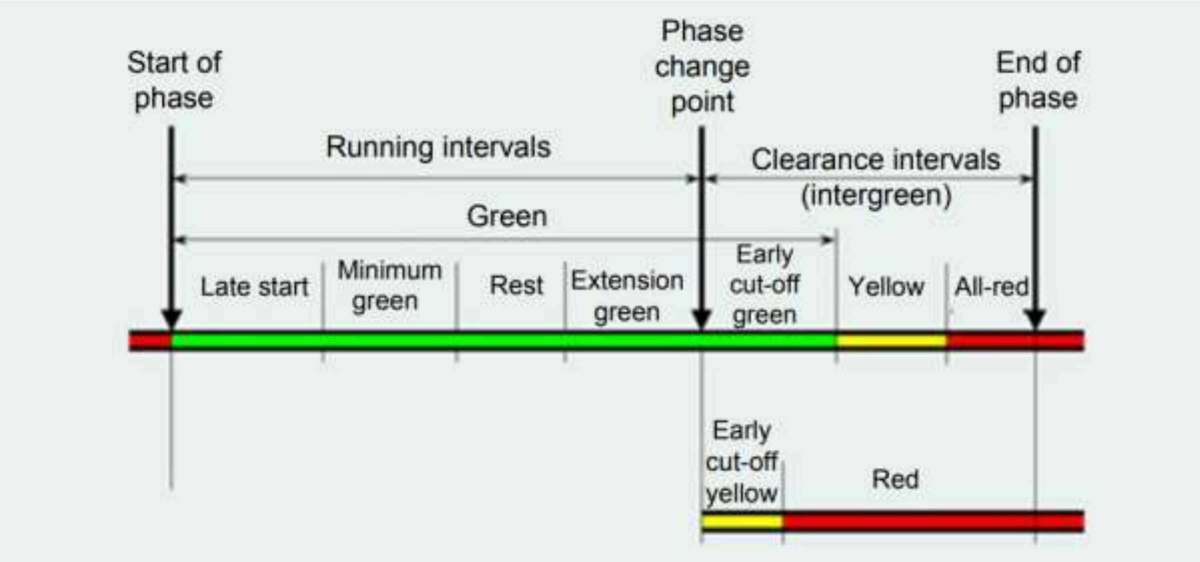
The cycle time used should be based on the operation of the observed cycle times for the period after 8:20am. The cycle time will need to be consistent across the adjacent signalised intersections included in the model.

Phases A, C and D will need to be included in the model. Timings for validation could be based on the average timings observed for the period after 8:20am. Again, signal operations produce a cycle time of between 120-140 seconds.

7.5.1 Vehicle settings

Each traffic signal phase comprises of a number of parts. Each signal phase includes two major components that can be defined as a running part and a clearance part. The clearance time is further divided into other phase intervals. There are also a number of additional signal settings such as late starts and early cut-offs that may need to be incorporated into the traffic signal timings and sequence structure for intersection modelling. These phase intervals are shown diagrammatically in **Figure 15**.

Figure 15: Phase intervals for vehicle traffic



Source: AGTM, Part 9: Traffic operations

A description of these intervals are included in **Table 25**.

Table 25: Summary of traffic controller settings for vehicle movements

	Description
Late start	Allows for the introduction of some signal groups to be delayed for a pre-set time. A common example of the implementation of a late start is delaying the start for vehicles turning across a pedestrian crossing until after the initial part of the pedestrian walk period. Hence pedestrians are protected for the initial part of the walk period. Late starts can also be used for bicycle and bus priority. When late starts are used in this way, cyclists or buses are provided an exclusive green signal in advance of general traffic being given a green signal. In the case of cyclists this provides them for a 'head start' increasing the visibility to traffic travelling in the same direction (and potentially wishing to turn across their path or merge with them down stream).
Minimum green	Ensures that the green signal is displayed to provide enough time for a pedestrian to safely cross the intersection.
Maximum extension green	The maximum extension green (the time after the minimum green) is a setting to avoid unduly long cycle times.
Early cut-off	The early cut-off green period allows the termination of some signal groups earlier than others. For example, at paired intersections, it is commonly used so that the upstream signals can be terminated earlier than the downstream signals in order to

	minimise queuing on internal approaches.
Yellow	Yellow time is the time required to provide sufficient warning of the termination of a phase. It is a function of the operating speed of the movement and the intersection geometry.
All-red	Provides a safe time for vehicles that enter the intersection at the end of the yellow interval before the commencement of the next phase. The all-red time is a function of the movement being undertaken, intersection geometry and the operating speed of that movement.

The determination of appropriate values for the settings discussed in **Table 25** are described in AGTM, Part 9: Traffic operations and TEM Volume 1, Part 2.09.

When calibrating a signalised intersection, practitioners should be aware that many controllers have an early cut off or a late start to particular movements. These are usually incorporated into the signal phasing for operational or safety reasons. It is important that these are accurately represented in the calibration process to develop a model to explore current or proposed design and operational performances.

The details of amber and all red times for signalised controllers and for individual movements can be found within the operations sheets that are developed from signal professionals within the Department of Transport (or as approved by these professionals). I no case should values lower than those as prescribed within the operations sheets be used for the development and calibration of intersection models – either for individual or for multi-intersection models.

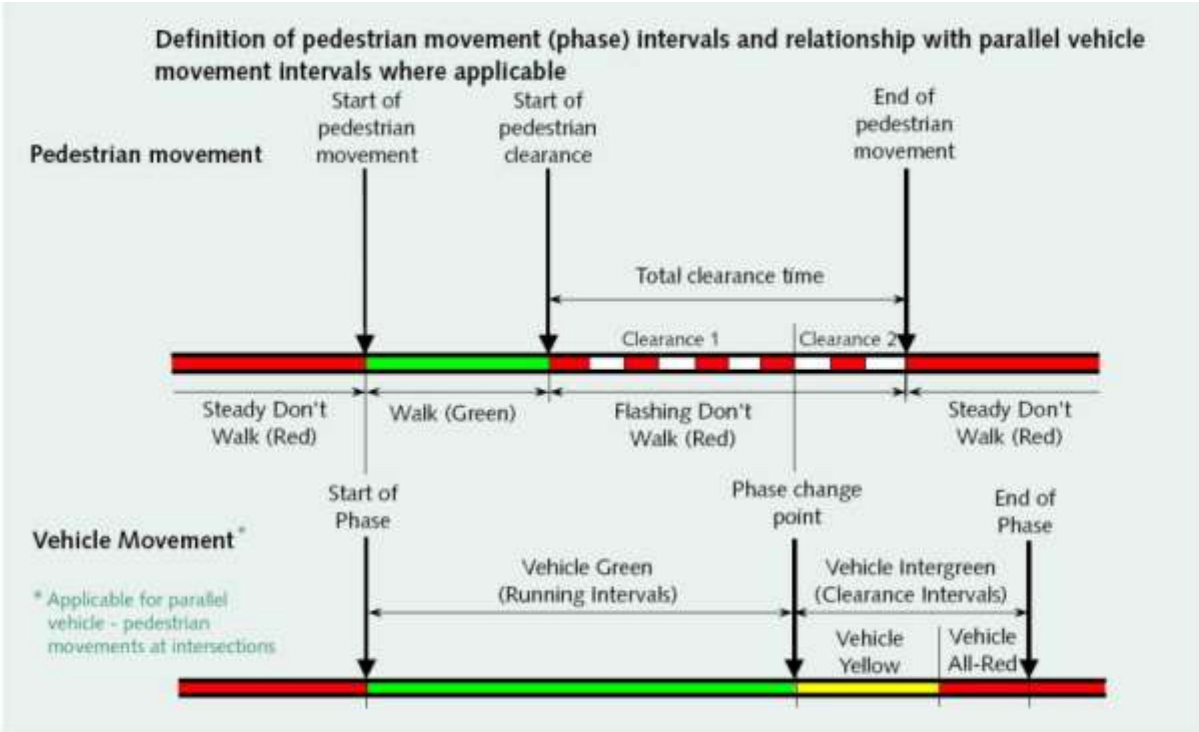
7.5.2 Pedestrian timings

At signalised intersections the pedestrian movements can run concurrently with parallel vehicle movements or run in an exclusive pedestrian phase (e.g. 'Barne's dance' or 'scramble crossings'). At mid-block signalised crossings, vehicle and pedestrian movements run in alternate phases. Generally pedestrian movements (phases) are called by push button operation (activation). The components of the pedestrian intervals in relation to the corresponding vehicle movement intervals are shown in **Figure 16**. However, in selected locations such as the Hoddle grid, pedestrian phases are delivered without the need for activation.

The specific details of pedestrian operated phase lengths can be found within the SCATS controller systems. For those whom wish to better refine their models for a current operational pursuit, it is worth a face to face discussion with signals engineers. This will help to determine the components of the intersection that are guided by the pedestrian requirements. However, the specific components within the operation shall need to be managed by an experienced SCATS operator to showcase the precise traffic allocations.

A general structure for guidance of signal controller settings for pedestrian movements is discussed in AGTM, Part 9: Traffic operations and TEM Volume 1, Part 2.09. A summary of the various settings is included in **Table 26**.

Figure 16: Phase intervals for pedestrian movements



Source: AGTM, Part 9: Traffic operations

Table 26: Summary of traffic controller settings for pedestrian movements

	Description
Walk	The walk interval is a minimum time for the display. This is intended to allow time for pedestrians to begin their crossing and once started continue to cross rather than return to their starting point. In Victoria, the calculation of walk times depends on the carriageway layout. The walk time is intended to enable a pedestrian to reach a point 1m past the median and so be able to complete their crossing in the clearance interval. The times are determined using a walking speed of 1.2 m/s.
Clearance 1	Clearance 1 and Clearance 2 intervals provide time for pedestrians to complete their crossing. When a pedestrian movement is introduced, the phase cannot terminate until the Clearance 1 interval has finished (unless the pedestrian movement overlaps into the next phase. Clearance intervals are calculated using 1.5m/s walk speeds and are calculated based on kerb to kerb crossing distances, unless pedestrians are able to be stored in the median and there is a pedestrian call button provided there.
Clearance 2	Clearance 2 is the second part of the clearance interval and runs concurrently with the phase clearance. Where left and/or right turners are able to filter across the pedestrian movement, Clearance 2 is set to zero (also applies to early cut off intervals).
Don't walk	The steady period of Don't walk is desirably 4 seconds.

7.6 Network calibration

Calibration of network parameters is essential to develop representative models of network operations. There are three main elements to consider in network calibration:

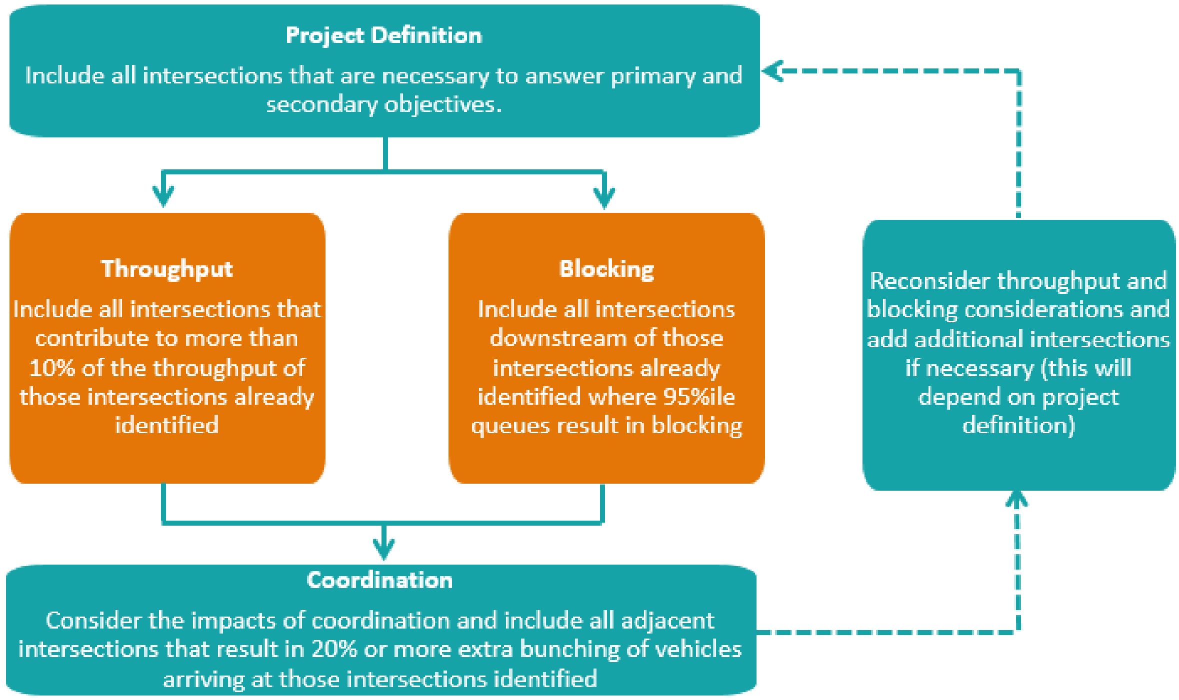
- Network extents;
- Network signal times; and
- Signal co-ordination offset times.

Practitioners should also consider the implications of intersection blocking and feeder lanes (where present).

7.6.1 Network extent

The means to define an extent of the modelled network is one of the most important tasks in intersection modelling. It is important to note that it may be necessary to add additional intersections into a multi-intersection model as the intersection modelling progresses. This may even be required after data collection and analysis has been undertaken. For this reason, it is emphasised to explore the landscape, the operations and the problem before defining a scope for modelling and delivery, as the analysis needs to have a foundation in order to examine the value of the investment. A process for identifying all intersections that need to be modelled is included in **Figure 17**.

Figure 17: Process for defining network extent



The process in **Figure 17** may result in networks that exceed ten intersections. Generally, this would indicate that an alternative modelling approach such as micro-simulation modelling is more appropriate. Networks to be modelled should be limited primarily to corridors, albeit with corresponding adjacent controllers of the same sub-system. Network analysis should not be conducted where traffic assignment involves the manual movement of journeys beyond more than a single corridor.

7.6.2 Signal co-ordination

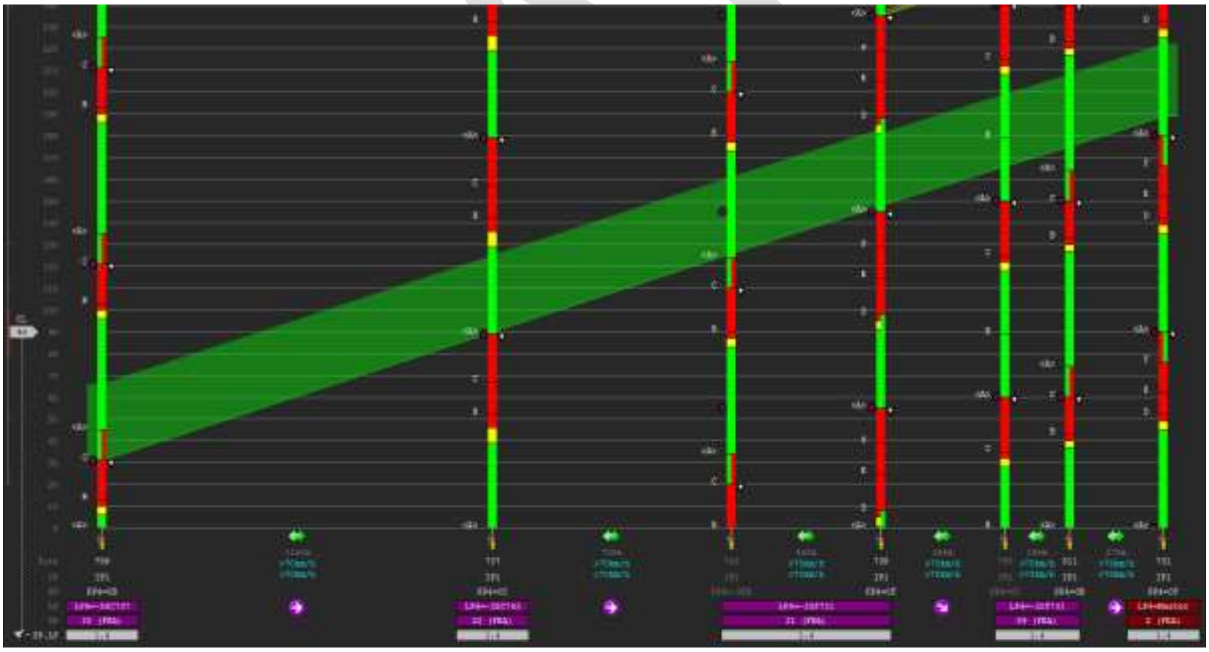
Signal co-ordination is the linking together of consecutive traffic signals along a road to streamline green periods together. Co-ordination aims to minimise overall delay, provide for more reliable journeys and to prevent blockages between closely-spaced intersections where traffic may become congested. This is achieved by increasing the efficiency along the major traffic flow movements in selected and appropriate landscapes.

Generally, to maintain synchronisation, all co-ordinated intersections must operate at similar (often variable) cycle times. In a multi-intersection network modelling, the fixed cycle time must be the same across all intersections. However, in reality sites vary each cycle but are managed through a variable length pivot phase. Some mechanisms aim to explore running double cycles in a corridor, but this is more of an exception given the operational complexities of individual sites (e.g. minimum pedestrian crossing times).

Signal co-ordination can be examined through a time-distance diagram, as shown in **Figure 18**. The green band shows how traffic in one direction progresses through multiple intersections without stopping. Note that signal co-ordination is typically applied in on direction rather than two directions across a corridor.

It is important to understand that in practice, co-ordination does not run optimally as outlined within **Figure 18**. While this diagram provides a well-structured outline of prospective offset times there is significant more variation that occurs within a corridor. Within the landscape there are numerous components that scale down the solution including accounting for extensive perpendicular movements, minimum pedestrian times and storage space in right turn pockets.

Figure 18: Example of signal co-ordination



Source: www.vicroads.vic.gov.au

Co-ordination can be between signals within a subsystem or between subsystems in a region. The relationship between subsystems and regions is complex and built through extensive work in signal reviews conducted by traffic experts. An example to the north of the CBD is shown in the schematic included in Figure **19**.

Figure 19: Schematic example of relationship between subsystem and regions

Key: Region by colour, subsystem by number

The development of the corridor models will approximate the complexity of signal co-ordination. This approximation includes the application of a fixed cycle time to all co-ordinated intersections and static offset times between intersections.

7.6.3 Network cycle times

A review of the phase history of sites within the network to be modelled will reveal the extent of co-ordination between sites, with co-ordinated sites having similar cycle times. If co-ordination is evident in the existing arrangement, then co-ordination should be incorporated into the calibration of the multi-intersection model.

Intersection modelling software requires the specification of a fixed cycle time across all coordinated signalised intersections in the network. This cycle time should be based on the phase history of the critical site in the network (if known) or based on the average cycle times of all co-ordinated sites.

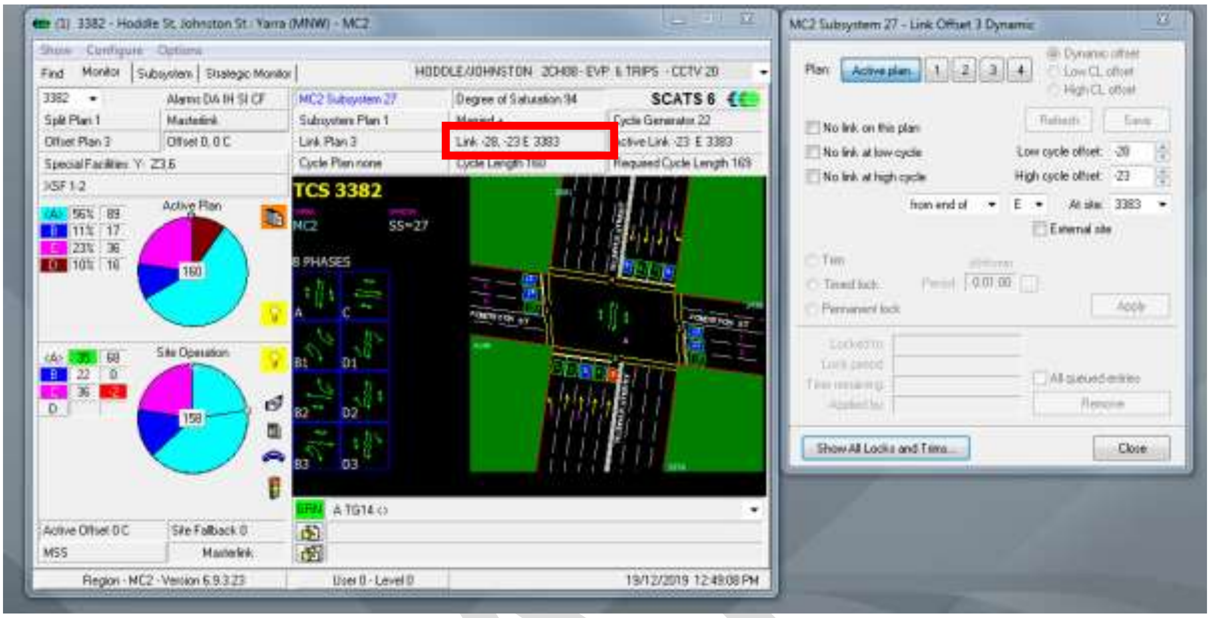
If practitioners require further information on the subsystem and regional configuration, offset (and link) plan details may be found within the SCATS LX file.

7.6.4 Signal offset times

Signal offset times are the interval from the start of the green lanterns at one intersection to the start of the green lanterns at the next intersection. The offsets between intersections can be estimated from the phase history files of co-ordinated intersections. These offsets are the difference in time between when the pivot (main) phase commences at the critical site and the other signalised intersection sites. The offset time should be defined so that there is nominal declaration (delay) as the traffic moves from the signalised controller to the next controller.

The offset times held within **Figure 20** showcases that the controller TCS3382 (Johnston St and Hoddle St, Collingwood) will begin the cycle between 23 and 28 seconds before the end of Phase E in controller TCS3383 (Gipps St and Hoddle St, Collingwood). Although this controller is developed to run a cycle length of 160 seconds, due to the conditions of when this image was obtained the actual cycle in operation was only 158 seconds. However, this may have changed again in the subsequent cycle.

Figure 20: Outline of SCATS Link Plan (co-ordination)



If the critical site within the corridor is not known, then further investigation should be conducted. A good place to begin this process is through a brief discussion with the traffic operations teams in the Department of Transport.

7.6.5 Right-turn storage lanes

A common use for multi-intersection modelling is where there are two closely spaced intersections operating together. Often where this occurs, right-turn storage lanes are provided. These lanes are located at upstream intersections which drivers travel straight through from, but are designated for use by drivers who intend to turn right at a subsequent downstream intersection (Figure **21**).

Figure 21: Example of right turn storage lane

Intersection of St Kilda Road and Toorak Road. Image source: https://mapshare.vic.gov.au/vicplan/

When investigating conditions of an intersection, this functionality needs to be accounted for. If it is not represented than the storage lane is treated as a through lane. The result is that the traffic demand for those turning right at the downstream intersection and those travelling straight through would be evenly spread across the lanes. The calculated queue lengths in the through and turn lanes would therefore not be representative of the conditions experienced.

One approach to address this issue in an intersection modelling environment is to specify a special vehicle class or classes for turning vehicles and to designate the storage lane and right turn lane as for the exclusive use of that subset.

Table 27: Model Calibration review checklist

Review Area	*Details*	*Yes*	*No*	*N/A*
Current operational conditions	Site visit is conducted during the peak period or interval of analysis	☐	☐	☐
	Congestion and extent of queuing observed and commented on, including any unbalanced lane utilisation	☐	☐	☐
	Interaction between modes observed and commented on (e.g. cyclist and pedestrian movements, public transport priority)	☐	☐	☐

	Observations of signal operation made (e.g. variation in signals cycle and phase timing over modelled period)	☐	☐	☐
	Variation in traffic volume and arrival pattern noted, consideration made for appropriateness of intersection modelling techniques	☐	☐	☐
Calibration	Movements accurately represented in base models, including those for all movement classes (e.g. pedestrians)	☐	☐	☐
	Existing demand volumes accurately represented	☐	☐	☐
	Peak periods appropriately identified	☐	☐	☐
	Peak flow periods and peak flow factors identified and included in models.	☐	☐	☐
	Saturation flows appropriately estimated, software defaults not used	☐	☐	☐
	Cruise speeds appropriately identified and entered into models	☐	☐	☐
	Gap acceptance parameters entered, and configured correctly in software	☐	☐	☐
	Intersection geometry accurately reflects current conditions (including lane widths, splitter islands, island diameters, short lane widths and controls)	☐	☐	☐
	Unbalanced lane utilisation is accounted for	☐	☐	☐
	Unusual movement priorities incorporated into models.	☐	☐	☐
Calibration (signals)	Signal phasing reflects operation sheets and observed sequencing	☐	☐	☐
	Minimum phase times accounted for	☐	☐	☐
	Early cut offs and late starts appropriately specified	☐	☐	☐
	Cycle time matches current operation	☐	☐	☐
	Current pedestrian movements represented	☐	☐	☐
	Pedestrian timings (walk and clearance) reflect those in operation.	☐	☐	☐
	Public transport and cyclist priority included in modelling if present.	☐	☐	☐
Model Validation	Back of queue lengths fall within prescribed requirements	☐	☐	☐
	Journey times are within defined thresholds of tolerance	☐	☐	☐
Calibration (multi-intersection)	Network cycle times represent those operating in the SCATS subsystem during the modelled periods	☐	☐	☐
	Signal offsets accurately calibrated	☐	☐	☐
	Feeder lanes across multiple intersections are set up correctly (usually by specifying special movement classes)	☐	☐	☐
	If intersection blocking occurs, model calibration factors are adjusted to produce realistic results	☐	☐	☐

8. Validation

8.1 Introduction

The purpose of model validation is to confirm that the calibrated modelled elements within the Base model can produce performance metrics that closely represents the observed operational conditions. Simply stated, this is a means to ensure that the anecdotal discussions of the intersection or corridor are reflected within the modelled results. A base model cannot be considered to be validated without appropriate reflection of the elements of the site conditions, despite what the benchmarked output may indicate.

To undertake a robust study of potential physical or demand changes to an existing intersection or group of intersections, it is essential that the model is an accurate real world representation of the existing (base) intersection/ network.

This process assists in determining if the achievements of the prospective delivery are a function of the changes proposed or simply an element within the model foundation.

For intersection models, four validation elements are used:

- Utilisation (Degree of Saturation)
- Observed queue lengths
- Journey times
- Signal Operations.

8.2 Utilisation review

The degree of saturation is a measure of volume divided by capacity of a lane, or an approach or intersection. This is a simple measure to explore how well utilised the infrastructure may be. Where an intersection is oversaturated, this indicates that not all the traffic demand can pass through the control mechanism (again noting the difference between demand and throughput). Under such conditions the degree of saturation would be greater than a value of 100%.

Where the throughput (traffic volumes passing through the intersection) has been used to calibrate a model rather than demand (refer Section 7.2.3) a useful validation check is that the utilisation never exceeds a value of one. However, in all cases the demand rather than the throughput should be applied. By comparison, practitioners should also explore to see if the modelled result of the low degree of saturation understates the congestion of the landscape.

A simple check is to see if more traffic enters the upstream approach than departs over the course of the analysis interval. If this is the case, the degree of saturation for the approach, or movement or intersection (as appropriate) should be above 100%. This is a first measure that the Department of Transport will explore and implies the quality of the data collection and model calibration.

8.3 Queue lengths

Queue length comparisons are the primary indicator to suggest that individual intersection models are validated. The queue observation method will provide a comparison with the observed back of queue lengths against that distance reported by the modelling software.

There are two observational measures of queue length depending on the type of intersection being observed.

- For signalised intersections, back of queue measurements need to be taken, that is at the end of the red/ start of green for each cycle the back of queue should be recorded. The survey method is applied for individual lanes.
- For other intersections, back of queue observations should be undertaken at a regular frequency.

Based on the above, median and percentile estimates of back of queue lengths can be made and compared with the software outputs for validation.

One of the most challenging areas associated with queue length validation is the phenomena of 'rolling queues' and the difficulty in determining what is the end of the queue. The model parameters for recording queues should be as defined using measures held within **Table 28** unless there is a justifiable reason why it should be adjusted. Teams conducting investigations need to be aware that queues may be defined with a maximum distance that does not misrepresent the reporting. Reports should not identify that the queue length exceeded the line of site of surveys.

If the reporting of a queue length does not equate to the maximum queue length, then the model needs to be revisited. That is, the extended queue lengths should be recalibrated to better reflect the story of the current and proposed issues within the network.

Table 28: Queue definition parameters

Observed Queue Range (m)	*Acceptable Validation Error (m)*	*Example Observed Queue (m)*	*Demonstration Range (m)*
1-20	10	15	5-25
21-50	15	45	30-60
51-100m	20	95	75-115
101-151m	25	145	120-170
151-200m	30	195	165-225
201-250m	35	245	210-280
251-500m	100	495	395-595
501-1000m	150	990	840-1140
1000m+	200	1240	1040-1440

Another measure of validation of queues pertains to the utilisation of storage lengths. This might simply be a review to determine if the model reflects queued behaviour when the turn bay regularly overflows, or to determine if this is suitably self-contained within the available space. A review between the modelled and observed conditions provides for a worthwhile comparison in defining a benchmark of conditions.

8.4 Signal operations

To enable the Base Model to be used for options testing, traffic signal phase times should be derived from an optimisation process that broadly reflects the existing operational considerations. This will include measures of phase sequence, minimum run times, green time allocation and more measures of the intersection as a controller of conflicting movements. The base model should not be developed with phase times that are not be specified in the calibration process (i.e. user given phase times) as the options testing will then exploring a completely different (and unvalidated) means to deliver a solution.

The observed phase times at signal installations (Section 7.5.2) can be used for benchmarking the validation process. Phase times from a model can be compared against the empirical dataset. These times should be within 20% of observed phase times would be considered an appropriate check on the calibration.

As an example, a signalised controller that runs at 120 second cycle times has a phase that represents 36% of the cycle time (observed). This would equate to 43.2 seconds of each cycle. With a 20% margin of error the deviation allowed is 8.6 seconds of green time. Therefore, an acceptable range for running a base model optimised by parameters would be validated when the phase achieves between 34.5 and 51.8 seconds of green time per cycle.

This comparison is useful in identifying incorrect assumptions and parameters in respect of:

- **Geometry** – e.g. short lane lengths incorrectly defined;
- **Behaviour** – e.g. estimated saturation flows conditions, lane utilisation matters; and
- **Signalised intersections** – e.g. phase sequence not representative of operation (alternative phase calls, phase skipping, minimum greens).

Should optimised phase times vary significantly from the observed phase times, the gap in performance may pertain to separate items that guide the intersection. This oversight might be a means to allow for priority for an adjacent controller. Such an approach may be developed within the signal operations, and have been built for such a deliverable. Under such arrangements, teams might need to review the notes held within the operations sheets as well as the actual phase times produced. It may be that the sequence of phases called may appear to be different in the model than to the functional delivery. Teams should have the ability to review conditions of cruise speeds, saturation flow, peak flow factor, lane utilisation and minimum green times as a first step.

A useful check is to apply user specified phase times in the base model and explore if other calibration parameters (queue lengths, journey times) improve. In these situations, it is important to discuss the potential causes of these differences in the narrative of the report.

The modelling should also be reviewed to ensure that the minimum times specified within the current operations sheets are reflected in the base model prior to delivery to The Department of Transport.

8.5 Journey times

The key validation measure for multi-intersection base model validation and particularly those along corridors is a benchmark of journey times. In most cases a journey time is declared for a specific set of routes in the model, that are collected on site or extracted from historical databases to form the backbone for validation. This was meant to ensure a quality base line before exploring options for consideration.

The validation of journey time should be a process to compare the median journey time of the observed data, as the average observed journey time can be more reactive to the impacts of outlying conditions. The median observed journey time is a more useful and stable value to benchmark the circumstances of regular operations.

The journey time validation process needs to ensure that the collection technique on site is consistent with that adopted in the model. The collection process should ensure that the median journey time on the route can be explored in sections by declaring waypoints. A minimum of two waypoints should be declared so that the investigation can deliver conditions of a corridor in at least three distinct sections. These sections are defined as being the distance between intersection stop lines in an urban area, ensuring that the journey time is recorded when the vehicle leaves the stop line so that the delay for that section is captured. In dispersed areas key location points could be considered in the context of the particular investigation.

The validation criteria should be as follows:

- Modelled journey time to be within 10% of median observed journey time for the full length of the route (Each route can be investigated by section if appropriate).
- Metrics for both modelled and observed times need to be tabulated, to ensure a quantified measure can be undertaken for the journey times along each selected corridor; and

It is an important element that the model validation process limits the risk of errors with the project model. A threshold of error is defined to ensure that the model suitably accounts for the modelled conditions experienced by the drivers. This limit on the error ensures that the benefits from the prospective changes would typically outweigh the benefits from a change model or future horizon.

In this way the validation is used (with an example) to ensure that a 12% journey time benefit is not offset by a 15% margin of error. The smaller gap between observed and modelled results within a modelled setting should better mitigate the project risks and provide for greater potential to deliver the identified benefits.

The routes determined for journey time validation need to meet the following criteria:

- The routes should cover the full extent of the model area. For corridor models, the full length of the corridor needs to be the primary route;
- The routes should not overlap. This will ensure that the validation is not duplicated and misconstrue the error or accuracy of the validation task; and
- The routes should have at least three points for journey time recording.

When analysing the journey time data that will be used for validation, it is imperative that the data is checked against “outliers” for examination or exclusion. Outliers are irregular occurrences in the data sample that may have an adverse effect in reproducing regular operations in the simulation model. If floating car surveys are used, then one way to check for outliers is to explore the GPS tracking file of each floating car run. This may involve a check that the route taken was consistent. However, if data is subject to significant changes on a daily basis, then quality controls need to take place on the day of the survey.

Journey time validation is considered as a primary method for model suitability along corridors and as such requires appropriate exploration and analysis such as journey time reliability. In the analysis of collected data, it may become apparent that some locations within the network are subject to more significant variation in journey times. In these situations, the appropriateness of using a multi-intersection model should be reviewed.

It is important that the reporting of journey times along corridors is provided in a format of minutes (and seconds) rather than simply an aggregate second display (i.e. in mm:ss formats rather than xxs). This will ensure that all stakeholders have a clear determination of the quality of the modelling that is delivered for the investigation. Situations may arise whereby stakeholders will not have enough time to recalculate modelled times (e.g. 267s) when an equivalent metric such as 04:27 minutes can easily be recognised and appreciated.

Table 29: Model Validation review checklist

Review Area	*Details*	*Yes*	*No*	*N/A*
Model Validation	The degree of saturation at the intersections and approaches relate to the narrative of the operating conditions	☐	☐	☐
	Back of queue lengths fall within prescribed requirements	☐	☐	☐
	Phase operations relate to the empirical data and observed settings.	☐	☐	☐
	Journey times are within defined thresholds of tolerance	☐	☐	☐

9. Option investigation

9.1 Introduction

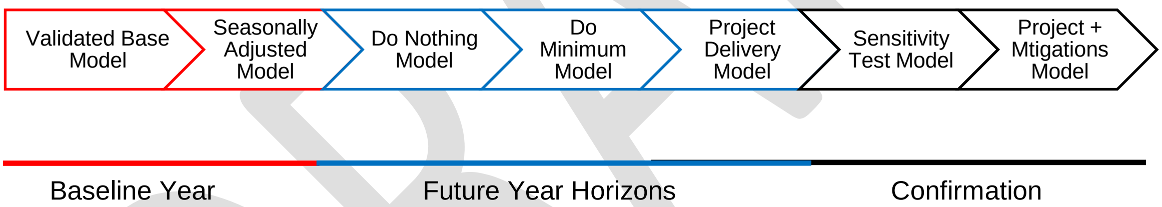
The option investigations that are undertaken will be determined on the purpose of the investigation (Section 5). Typically, these investigations would seek to determine a design or operational requirements for a future demand scenario. Alternatively, the challenge may seek to address a more immediate operational, safety or performance concern.

A typical framework to development of options models considers adjustments to the calibrated and validated base model to account a design day (generally the 30th busiest day of the year). This allows for a constant benchmarking between a base and future design requirement, separate to conditions of the data collection process. As outlined in **Figure 22** a growth factor or future year estimate can then be applied to explore conditions of a projected landscape. Again, note that design requirements are for the 30th busiest hour of the year rather than that of regular conditions.

The future models are then adopted for investigations of (multiple) design and functional options. This may include testing of ‘Do Minimum’ and ‘Do Something’ options models as well as solutions that include design mitigations. The topic of options model investigation is discussed in Section 9.3.3.

It is important to note within this structure that mitigation models should be developed following the analysis of a sensitivity test, rather than the reverse order. That is the sensitivity model should be able to explore the intersection operations which a mildly different set of demand volumes, and then resolved for the attention of the mitigation model.

Figure 22: Investigation Framework



9.2 Conformity

It is important that a number of parameters hold conformity between the Base models and Future or Options models. The measures that need to be consistent across the models are as follows:

- Saturation flow – the saturation flow parameters need to be applied in a consistent manner unless additional scenarios to explore set modifications are introduced into the future year setting.
- Speed – the cruise speeds used in the options investigations need to match those used in the base model. However, if a change is proposed that would impact unconstrained traffic flow speeds, such as a change in the posted speed limit (in which case local default values corresponding to the posted speed limit should be used).
- Gap acceptance – this relationship for site specific behaviour needs to be held consistent in line with the efforts used to explore the model calibration. Unprecedented changes to gap acceptance parameters and the estimated limits of traffic flow may need to be justified through empirical support of similar conditions and volumes (both throughput and conflicting).
- Network size – the area of impact for the project change in multi-intersection options and future year models should be consistent to that of the base model to allow for benchmarking.
- Design horizons – need to account for the 30th busiest hour in the future year rather than simply the forecast demand for a regular day. This may involve exploring the uplift from regular days in current time horizon and the equivalent 30th busiest hour. Application of the

data from a strategic travel demand model may subsequently understate the engineering design requirements to meet existing standards.

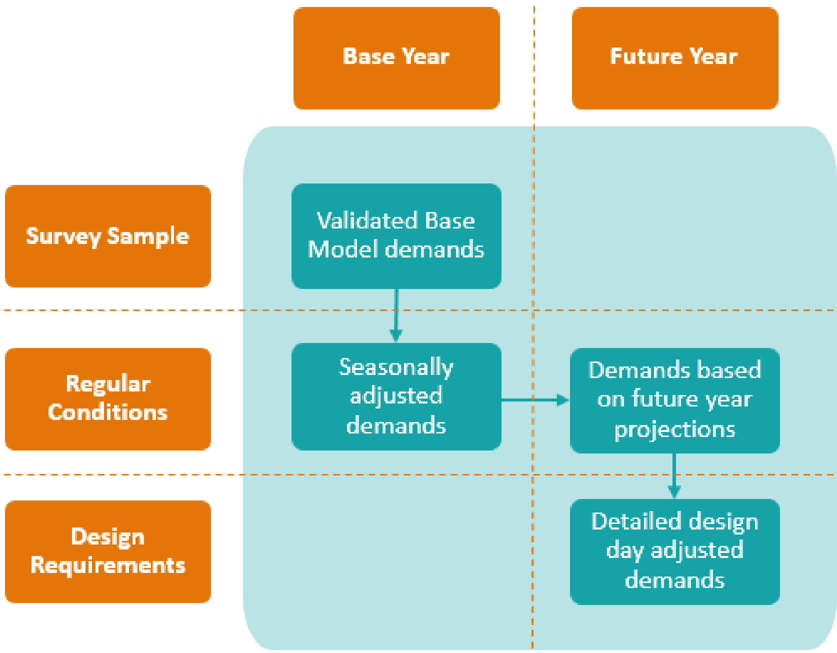
9.3 Demand Estimation

Before testing of Options models can commence, the design demand volumes for a specified future year need to be identified and applied to the base model. This process includes three adjustments:

- **Step 1: Seasonal adjustment** – Adjusting the surveyed base model demand volumes to take into account seasonality;
- **Step 2: Future year projections** – Derivation of demand for future years based on the seasonally adjusted Base model; and
- **Step 3: Detailed design day adjusted** – Future year projections adjusted based on 30th busiest day of the year.

The process is outlined in Figure **23**.

Figure 23: Progression from surveyed demand to design estimates



Existing standards and guidelines outline expectations and requirements for turning movements within intersection designs. However, it is important to consider that a higher volume of heavy goods vehicles might be operating at other times of the day. A review of design requirements should be brought into the analysis to ensure that the delivered solution can perform suitably with a varied traffic composition. This review should entail consideration for both pocket length requirements as well as turning movements provided in a schematic or mapped layout.

9.3.1 Seasonal adjustment

Seasonality or seasonal variation is a consideration that needs to be included when evaluating traffic flow and intersection operations. Data collection to develop the Base Models is often undertaken in response to project timeframes. Generally, this results in data that is not reflective of average demand volumes or operational conditions during the year.

The changes that are attributed to the variation in demand fluctuations as a factor of the survey month is known as seasonality. Seasonality occurs because trip making patterns change throughout the year due to factors including but not limited to the effects of school holidays, public holidays as well as factors of professional annual leave. Seasonality needs to be minimised so that the design considerations of future infrastructure needs are correctly accounted. Although not a part of the base model calibration, this task is required after completion of the base model validation, as the validation uses empirical material collected, while reflection for seasonality is an adjustment.

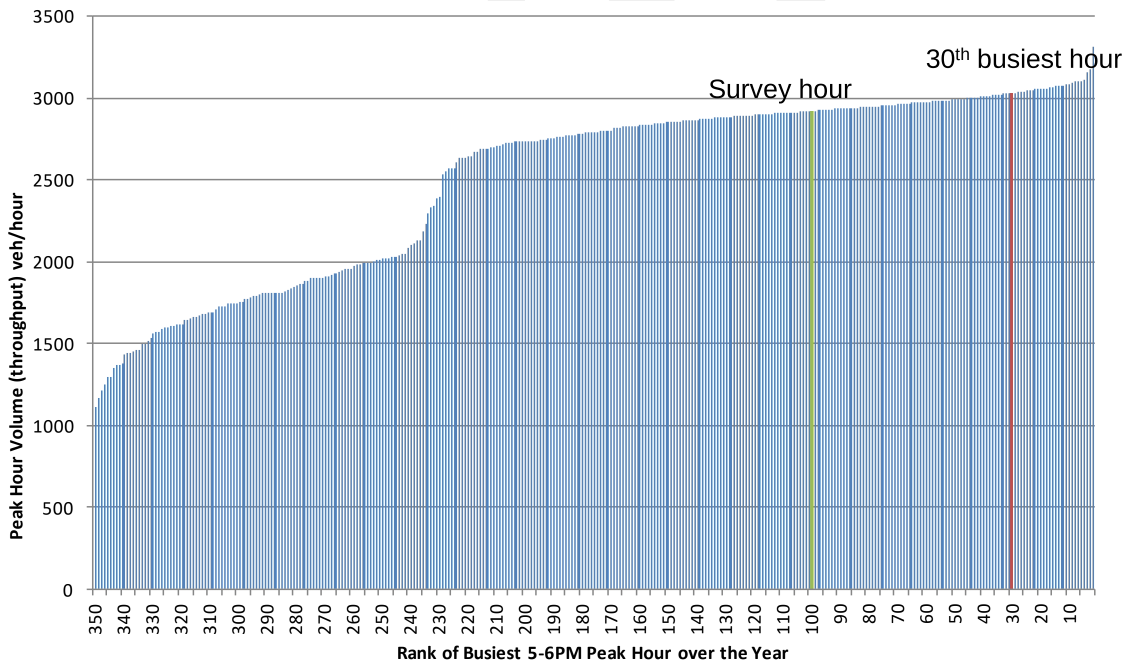
The preferred time period for undertaking data collection are in the months of May or November as these cases best represent the times of year with greater chance of aligning to a day of regular operational conditions. The Department of Transport generally discourages data collection in the summer months. December in particular is a poor month for collecting data for the following reasons:

- The inclusion of two weeks involve little annual leave taken by professionals with higher volumes on the roads and greater congestion around shopping centres; followed by
- Two weeks of significant leave and school holidays, irregular special events, reduced volumes on roads during typical peak hours and highest annual volumes at holiday destinations throughout the state.
- In general, the summer months are a poor representation of seasonality and of trip making patterns across the landscape.

Avoiding data collection during school holidays is also encouraged, particularly in locations where this may be considered to form a noticeable decline in traffic at peak times. However, there may be locations where seasonal volumes need to be considered for design and operational planning, even if of limited investment value across longer periods of the year.

Regardless of when data is collected, it is important to explore a number of standard considerations that may impact the data collection whereby a subsequent adjustment may be required (road construction, road crashes, weather events, etc.).

Figure 24: PM peak hour volume ranking by day of the year to benchmark 30th busiest & surveyed hour



Source: SCATS Data (2016) obtained from OpenData website

The Department of Transport encourage the seasonal adjustment of surveyed demand using locally derived adjustment factors relevant to the modelled intersection(s). This requires a dataset of continuously collected traffic counts over a year-long duration. This mainly limits the adjustment sites to signalised intersections. If signalised intersections are included in the models, or if there is a nearby signalised intersection along the same corridor, data can be extracted to explore local seasonal adjustment factors.

To develop local adjustment factors, the volume for each day or hour of the year will need to be derived from SCATS counts for the adjustment site. Note that this should be held in the context of the pursuit so that analysis of AM peak hours should be held in the analysis of comparative peak hours. However, if the key design requirements are for example for an application with higher user requirements on a weekend (e.g. a shopping centre) then peak hour conditions need to be explored against weekend conditions. Again, note the differences between vehicle demand and throughput. The volume for each day or hour of the year should then be ranked and the daily traffic volume for the 30th busiest hour should then be identified.

The adjustment factor is the gap between the survey or conditions of regularity to achieve the 30th busiest hour. This is as outlined in **Figure 24** whereby a year of data for the hour of 5-6PM has been analysed for site TCS4045 in Glen Iris, Melbourne. This site is the intersection of Toorak Rd and Glen Iris Rd, near to the suburb of Camberwell. The PM peak hour was observed to a have a notably higher throughput in volume in the PM peak hour than for the AM peak hour. The gap between the surveyed PM peak hour and the design requirement of 30th busiest hour was identified to be circa 4% of demand (in an unconstrained landscape). Although this figure might appear to be a nominal percentage, the difference between the survey hour and the design hour can impact on simple vehicle related conditions such as manoeuvrability, density, queuing and delays.

In the absence of suitable adjustment sets from empirical measures that pertain to or near the site, adjustment factors may be used. **Table 33** provides examples of seasonal adjustment factors for the sites included in Figure **25**. Note that these values are examples from a limited sample and only provide guidance on the work expected to be conducted. Practitioners are expected to be able to extract datasets from the open data portal and provide a more thorough representation of peak hours and peak periods of the landscape being investigated.

Further consideration should be conducted when exploring locations with notable seasonal variation. Some locations require design and operational planning beyond typically investment strategies, due to the seasonal nature of traffic within the area. Within Victoria, this might include venues with close proximity to beaches or to ski fields, but may also require further design considerations to manage the network resilience on key arterials during selected events (school holidays/ public holidays/ long weekends) when different journey patterns place varied demands onto the performance of the transport system.

Figure 25: Site locations for seasonal adjustment factors

Table 30: Seasonal adjustment factors (2016) against Annual Average Weekday AM Peak Traffic (AADT equivalent)

Site	Road One	Road Two	Council	Melway Ref.	Seasonal adjustment factors (multiplicative)											
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
117	Maroondah Hwy	Springvale Rd	Whitehorse	048, F08	0.61	0.89	1.06	1.02	1.12	1.06	1.01	1.17	1.02	1.05	1.09	0.90
141	Maroondah Hwy	Manchester Rd	Yarra Ranges	037, G05	0.62	0.88	1.04	1.04	1.16	1.07	0.99	1.09	1.05	1.05	1.06	0.94
170	Burwood Hwy	Stud Rd	Knox	063, J11	0.53	0.95	1.07	1.01	1.13	1.05	1.01	1.21	0.84	1.09	1.16	0.95
196	Princes Highway East	Foster St	Greater Dandenong	090, D08	0.55	0.88	1.06	1.02	1.14	1.03	0.99	1.17	1.05	1.07	1.11	0.91
325	Doncaster Rd	Tram Rd	Manningham	047, D01	0.44	0.92	1.07	1.00	1.16	1.04	1.01	1.22	0.97	1.09	1.16	0.93
422	Springvale Rd	High Street Rd	Monash	071, D01	0.87	1.03	0.97	1.13	1.03	1.06	1.27	1.03	1.13	1.16	0.88	1.00
604	Princes Highway East	Narre Warren-Cranbourne Rd	Casey	110, E06	0.89	1.04	1.00	1.14	1.04	1.01	1.21	1.04	1.09	1.12	0.92	1.00
735	Seaford Rd	Railway Pde	Frankston	099, E05	0.57	0.88	1.00	1.00	1.13	1.08	1.02	1.19	1.11	1.01	1.03	0.97
2194	Pascoe Vale Rd	Somerton Rd	Hume	179, K09	0.54	0.87	1.06	1.03	1.16	1.05	0.97	1.19	1.03	1.06	1.09	0.93
2504	Princes Highway West	Western Hwy	Maribyrnong	042, D03	0.63	0.87	1.03	1.01	1.10	1.03	0.97	1.17	1.08	1.07	1.07	0.95
2638	Melton Hwy	Kings Rd	Brimbank	003, G12	0.56	0.92	1.06	1.02	1.17	1.01	0.98	1.22	1.03	1.05	1.08	0.90
3061	Bell St	Plenty Rd	Darebin	030, G01	0.63	0.86	1.04	1.01	1.10	1.05	1.03	1.14	1.07	1.04	1.08	0.96
3112	Sydney Rd	Brunswick Rd	Moreland	029, G10	0.59	0.87	1.05	1.02	1.13	1.06	1.01	1.19	1.06	1.05	1.08	0.91
3382	Hoddle St	Johnston St	Yarra	044, D04	0.70	0.81	1.03	1.03	1.09	1.05	0.99	1.13	1.06	1.03	1.09	0.98
3501	Millers Rd	Blackshaws Rd	Hobsons Bay	055, B01	0.59	0.86	1.03	1.02	1.13	1.03	1.00	1.17	1.04	1.05	1.11	0.97
3510	Mt Alexander Rd	Puckle St	Moonee Valley	028, J07	0.26	0.87	1.12	1.09	1.19	1.16	1.12	1.19	1.02	1.03	1.01	0.94
3559	North Rd	Koornang Rd	Glen Eira	068, H09	0.50	0.84	1.04	0.97	1.14	1.04	1.01	1.18	1.07	1.08	1.15	0.97
3634	South Rd	Bluff Rd	Bayside	077, B04	0.58	0.81	1.08	1.02	1.18	1.02	1.00	1.22	0.99	1.09	1.12	0.87
4040	Burke Rd	Camberwell Rd	Boroondara	059, J01	0.58	0.85	1.02	0.99	1.09	1.03	1.02	1.24	1.06	1.11	1.11	0.91
4164	Main St	Collins St	Nillumbik	011, K05	0.52	0.90	1.07	1.01	1.17	1.03	1.00	1.20	0.99	1.08	1.11	0.91
4388	Elizabeth St	Victoria St	Melbourne	043, G06	0.64	0.86	1.06	1.05	1.09	1.07	1.06	1.18	1.06	1.01	1.03	0.90
4537	Commercial Rd	Izett St	Stonnington	057, K01	0.59	0.87	1.03	0.99	1.12	1.04	1.05	1.19	1.03	1.06	1.11	0.92
4736	High St	Epping Plaza	Whittlesea	182, A12	0.54	0.87	1.04	1.00	1.14	1.05	1.02	1.20	1.02	1.08	1.10	0.94

Table 31: Seasonal adjustment factors (2016) against Average Weekday AM Peak Traffic (excludes Summer months)

Site	Road One	Road Two	Council	Melway Ref.	Seasonal adjustment factors (multiplicative)								
					Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
117	Maroondah Hwy	Springvale Rd	Whitehorse	048, F08	0.99	0.96	1.05	0.99	0.95	1.09	0.95	0.99	1.02
141	Maroondah Hwy	Manchester Rd	Yarra Ranges	037, G05	0.98	0.98	1.09	1.01	0.93	1.03	0.98	0.99	1.00
170	Burwood Hwy	Stud Rd	Knox	063, J11	1.01	0.95	1.06	0.99	0.95	1.14	0.79	1.02	1.09
196	Princes Highway East	Foster St	Greater Dandenong	090, D08	0.99	0.96	1.06	0.96	0.92	1.09	0.98	1.00	1.04
325	Doncaster Rd	Tram Rd	Manningham	047, D01	0.99	0.93	1.07	0.96	0.94	1.13	0.90	1.01	1.07
422	Springvale Rd	High Street Rd	Monash	071, D01	0.94	0.89	1.04	0.95	0.97	1.16	0.94	1.04	1.06
604	Princes Highway East	Narre Warren-Cranbourne Rd	Casey	110, E06	0.97	0.93	1.06	0.96	0.94	1.13	0.97	1.01	1.04
735	Seaford Rd	Railway Pde	Frankston	099, E05	0.94	0.94	1.07	1.01	0.96	1.12	1.04	0.95	0.96
2194	Pascoe Vale Rd	Somerton Rd	Hume	179, K09	0.99	0.96	1.08	0.98	0.91	1.11	0.96	0.99	1.02
2504	Princes Highway West	Western Hwy	Maribyrnong	042, D03	0.97	0.96	1.04	0.98	0.92	1.11	1.01	1.01	1.01
2638	Melton Hwy	Kings Rd	Brimbank	003, G12	0.99	0.95	1.09	0.95	0.92	1.14	0.96	0.98	1.01
3061	Bell St	Plenty Rd	Darebin	030, G01	0.98	0.95	1.03	0.99	0.97	1.08	1.00	0.98	1.01
3112	Sydney Rd	Brunswick Rd	Moreland	029, G10	0.98	0.95	1.05	0.99	0.95	1.12	0.99	0.98	1.00
3382	Hoddle St	Johnston St	Yarra	044, D04	0.98	0.98	1.03	0.99	0.94	1.07	1.00	0.98	1.03
3501	Millers Rd	Blackshaws Rd	Hobsons Bay	055, B01	0.97	0.95	1.06	0.97	0.94	1.10	0.98	0.99	1.05
3510	Mt Alexander Rd	Puckle St	Moonee Valley	028, J07	1.01	0.98	1.08	1.05	1.02	1.08	0.92	0.93	0.91
3559	North Rd	Koornang Rd	Glen Eira	068, H09	0.97	0.90	1.06	0.97	0.94	1.10	0.99	1.01	1.07
3634	South Rd	Bluff Rd	Bayside	077, B04	1.00	0.94	1.09	0.94	0.93	1.13	0.92	1.01	1.04
4040	Burke Rd	Camberwell Rd	Boroondara	059, J01	0.95	0.92	1.02	0.96	0.95	1.15	0.98	1.03	1.03
4164	Main St	Collins St	Nillumbik	011, K05	1.00	0.94	1.09	0.96	0.94	1.11	0.92	1.01	1.03
4388	Elizabeth St	Victoria St	Melbourne	043, G06	0.99	0.98	1.02	1.00	0.99	1.10	0.99	0.95	0.96
4537	Commercial Rd	Izett St	Stonnington	057, K01	0.96	0.93	1.05	0.97	0.98	1.11	0.96	0.99	1.04
4736	High St	Epping Plaza	Whittlesea	182, A12	0.97	0.93	1.06	0.98	0.95	1.12	0.95	1.01	1.02

9.3.2 Future year predictions

The derivation of demand for a future horizon on any road network is paramount to exploring operational matters and delivering on design and performance criteria. Careful consideration of the approach taken to estimate future demand should be conducted. This is especially important where the site under investigation is located in a growth area or there are changes occurring to land use in the surrounding area.

The tools and information used will depend on:

- The location of the investigation;
- Surrounding land use changes;
- Appropriateness of applying and adjusting strategic modelling outputs, and
- Availability of historical data.

There is no single method for estimating future demand figures. The approach used will likely incorporate a variety of methods and hence it is important that this is clearly documented. The methods used may also differ between movements (e.g. seasonality measures). Where there is considerable uncertainty in the demand estimates, sensitivity testing of demand must be conducted to explore this variability.

The process of demand estimation for design (and economic evaluation) should not be a function of "bumping up" vehicle numbers which often involves a percentage estimate increase on existing volumes. The Department of Transport reserves the right to decline investigations where a percentage growth rate is the key designator to determine demand for future years.

The future scenarios explored for an investigation should be developed around the number of dwellings to be developed from the site. This might result in development of a masterplan with concept designs that are progressed through timeframes for staging and construction. Approval for development should not simply be limited to a single time horizon in the future.

Typically, the Department of Transport will seek the evaluation of intersection or network performance for horizons of at least ten years post construction. However, this may require exploration of a longer timeframe, due to funding arrangements, design considerations and the strategic context of the surrounding area. This future year design target should be rounded up to the next census year e.g. a 2020 base model should be compared against a growth horizon in year 2031. The evaluation of other future horizons may be necessary when exploring developer initiated proposals with staged development that may not be fully realised in the initial timeframe. Note as well that the analysis needs to be based on delivering the infrastructure requirements prior to maturity of the investigation. For this reason, design requirements are a function of elements such as occupancy rates of the housing stock (population) rather than a future year target.

Estimated future demand volumes shall be subject to approval by the Department of Transport and need to pertain to all components of the landscape including population, employment, enrolments, journey accessibility, public transport proximity and policy endeavours in effect. As travel demand modelling utilises strategic solutions, the end result is subject to variation and should not be defined as an absolute measure. Demand estimates may be revised through the investigation.

Future year demand estimates should be explored within the context of the pieces of surrounding network including land uses, infrastructure changes and transport enhancements (public transport services and rolling stock deliveries). These items should be accompanied by network plots to build the narrative of the landscape explored: demand volume plots (maybe by mode as appropriate) as well as speed and volume capacity ratio plots. Note that the values held within these plots should not be considered to be absolute. More particularly the volume capacity ratio plots should not be envisaged as an absolute condition of the future year landscape.

9.3.2.1 Traffic growth

There are a number of approaches to estimating future demand that may be appropriate, depending on data availability, the location and the project scope. Generally, there are two main approaches to calculating growth:

- Strategic and mesoscopic model outputs (Section 9.3.2.2);
- Historic traffic counts (Section 9.3.2.3);
- Manual trip estimation (Section 9.3.2.4);

Care should be taken when using growth factors are considered from historic trends or strategic modelling outputs. Historic trends (past and current volume counts) can assist in determining the increase (or decrease) in various transport modes such as various vehicle types, pedestrians and cyclists. However, this needs to be held within the context of the spare capacity and not developed out of context, particularly where there are network constraints upstream of the intersection (limited capacity) being modelled which might limit growth in demand. Volumes should not simply be read out of context of the network condition.

The Department of Transport has a preference that historic trends should be utilised for modelling intersections within established areas and for suitable capacity constrained models (e.g. network models) that consider route choice. It is preferable that more site-specific specific demand considerations be developed for growth areas. All solutions need to explore the actual carrying capacity of the road to the same extent as demand is considered. Note that strategic estimates of carrying capacity do not provide suitable inputs in these pursuits.

The delivery of a future year estimate should be derived from a likely delivery volume. Teams are encouraged not to use misleading words to explain the forecast, such as “conservative” estimate when a likely or aggressive estimate was expected. If a team wished to deliver on an approach or forecast beyond a likely delivery expectation, this should be explored as a scenario where different factors pertaining to demand or behaviour can be considered. This scenario comparison shall provide context for the alternate approach and considerations. Without a baseline to explore, a conservative estimate by itself will simply slow down any approvals process.

9.3.2.2 Strategic and Mesoscopic model outputs

The Victorian Integrated Transport Model (VITM) as developed by the Department of Transport is a strategic model that can be used to provide direction on demand estimation. The model estimates are derived from land use considerations (population, employment and educational enrolments) amongst other factors. The traffic assignment is then a function on the scale of costs for travelling along various routes to reduce the effort of travel and complete the journey. That is, the demand estimates over time are a function of the network performances rather than a series of independent numbers.

VITM outputs should not be input directly into intersection models. Growth in movements estimated from strategic modelling outputs using interpolation of modelled years can be applied to base model turning movements with caution. However, before this is undertaken, practitioners should understand the following considerations:

- Demand estimates are typically based on standardised trip rates that may or may not be appropriate for the location being investigated
- Traffic volume considerations need to be considered within the context of Travel Zone Access and Egress. Notably, the positioning of centroid connectors can be an important factor on the release of traffic onto the network. This may determine link (and turn) specific volumes, and on the design and operational matters explored. This is particularly an important aspect for use when modelling in intersection movements.
- Demand estimates from the VITM travel demand model are strategic in nature which means that they are validated suitably to determine guidance for policy formation, rather than specifically for design and operational deliveries. All demand estimates should be reviewed within the context of the network specifications.
- Intra-zonal trips need to be considered - These journeys both commence and complete within the same travel zone, for which deterministic models such as the VITM will not assign traffic volumes. Hence the demand figures may be understated for intersection design and operational deliveries; and
- Future year models should be delivered in line with the requirements to meet the design guidelines. Note that these volumes are different (categorically, but feel similar with an initial review) from those values from the strategic travel demand model that utilises the expectation of a regular day of traffic movements (as per the calibrated base model but with different land use values and infrastructure scenarios). Where direction is required, it is expected that the gap

between volumes in the regular set of conditions to the design requirements is in the order of an additional measure of 5% traffic movements.

To minimise the impact of some of these issues, some practitioners favour the application of a demand refinement process such as the PivotPoint model. This process is used to determine a new volume, based on a change (or pivot) on the observed volumes. It should be noted that these demand estimates require enough details of the existing and proposed land uses to calibrate this process and delivery for the volumes generated. This process uses empirical data to then determine how land use changes will impact on trip rates and then road volumes modelled in the network. The functionality is dependent on generation of a synthetic demand matrix, which is compared against the existing demand, as per the VITM demand matrix. However, note that the VITM demand matrices are already a synthetic solution based on a number of limited observations (small sample of household travel surveys, limited traffic volume collection).

Where the purpose of the pursuit is to develop solutions based on a change in demand as a result of land use changes (e.g. a new development), caution should also be undertaken to ensure that demand changes are not being double counted. For this reason, the forecast estimates when using this process need to be substantially reviewed prior to delivery of a design and operational consideration.

Investigations should also consider induced demand and the paradox of traffic assignment with parallel routes in future years. Overdesign of an intersection may deliver an improved intersection performance (Level of Service). However, when out of context from the adjacent or competing locations, an intersection that performs favourable or well can be subject to drawing in additional traffic volumes or generating new trips (induced demand). In this manner the demand estimate may over or understate the demand, subject to the design and delivery of the proposed intersection performance.

One of the key issues with estimating growth from VITM is that strategic models are not capacity constrained and do not take account of the relationship between speed, traffic flow and capacity. One way to derive growth is to utilise a capacity constrained and a validated model, such as a mesoscopic model. DOMINO (Detailed Operational Model for Intersection and Network Optimisation) is a mesoscopic model that is also maintained by the Department of Transport. DOMINO includes capacity constraint and intra-zonal trips (unlike strategic modelling). It is therefore preferable to obtain future demand estimates from solutions such as DOMINO where available rather than manipulate VITM outputs.

Regardless of whether demand volumes are extracted from the VITM or DOMINO platforms, practitioners need to consider access, alternative routes, downstream constraints and pinch points. In all cases the sites analysed need to consider the distance from observed counts (e.g. screenlines or count locations). Values from the travel demand models relating to turns should not be considered to be absolute in any manner.

9.3.2.3 Historical traffic counts

In some locations, or for some movements, strategic transport model information may not be available. Where the surrounding land uses are not substantially changing, it may be appropriate to apply a growth rate on historical traffic counts. Examples where this may be appropriate include rural locations and roads with established development undergoing minimal change in land use.

As historical growth is not always a good indication of future growth, higher limits of sensitivity testing should be applied to test the robustness of the solutions proposed.

9.3.2.4 Manual trip estimation

Manual trip estimation, comprising of trip generation, distribution and assignment to various movements considered in the options investigation may be appropriate. This is particularly relevant to developer-initiated proposals that are not captured by strategic models. In these scenarios, it may be appropriate to alter the future horizon to consider staged development approaches (e.g. land release). Where a developer-initiated proposal will eventually serve a wider catchment than that included in the 10 year post construction horizon, this should be adjusted accordingly. Note that this timeframe may be longer than a ten year window, as a function of the exploration and the funding sources.

9.3.3 Design adjustment

Base model demand volumes with growth adjustments applied provide average peak demand estimates for a future year. These are suitable for use in economic evaluation analyses, but are inappropriate for intersection design. Note that empirical figures such as AADT are not suitable measures to explore design requirements as they are used to examine an average condition (which itself is typically below performance metrics of a regular condition). Measurements such as AADT or ADT can assist to develop the narrative but are not a means to a design.

For intersection design, the peak demand volumes occurring on the 30th busiest hour of the year should be used. The 30th busiest hour is a detailed design adjustment that is considered to provide a balance between the investment in the deliverables and the associated costs. The adjustment will be a single factor that refines the future demand estimates to design demand volumes. This also assist in exploring matters of network resilience.

It is preferable that this adjustment is a site specific value based on a signalised intersection within the network, or one on the same corridor. The factor can be estimated using the same dataset as for seasonality (Section 0) and again plotting the total daily flows and developing a factor based on the difference between the survey hour or condition of regularity and the 30th busiest hour. Note that the 100th busiest day is considered a benchmark as a seasonally adjusted ‘regular’ day.

In the absence of local adjustment factors, the future demand estimate should be increased by a minimum of 5% to provide for design demand estimates.

9.4 Option exploration

The options to be investigated in the exploration process will be compared to the seasonally adjusted model, as derived from the validated base model. This will provide a benchmark for the changed conditions and will need to meet the Department of Transport performance requirements (Section 10).

Options to be explored may have been identified in project scope definition or may need to be developed from an evaluation of the network. These elements are likely to have considered factors other than traffic performance, such as road safety, access and other issues. In other instances, option exploration may be driven by intersection or network performance metrics for current or future year demand estimates. In both instances modelling of the existing network with future demand figures will need to be conducted to explore any performance deficiencies.

Options may be developed as a means to evaluate a proposed intersection layout with future demand volumes. Such arrangements can explore to develop from concept to detailed design, or to explore the presence of bottlenecks forming within the system. Some queries pertain to investigations on the available and future capacity on an approach.

Scenarios that are explored are derivatives of the calibrated and validated base case models with future demand perspectives. These scenarios may include changes to:

- Land use arrangements, and access to the collector and secondary roads;
- Planning of new infrastructure; including revised journeys and route through the city;
- Physical intersection geometry (Section 9.4.1);
- The form of intersection control (Section 9.4.2); and
- Traffic signal controls and operation (Section 0).

There are times when explorations will be conducted to new intersections on an existing network and explore changes to physical geometry or the form of the control. Under such conditions the design should be based on current layouts of spatial (and other) constraints in the design development process. Examples of common constraints may include available road reserve, intersection spacing, proximity to vehicle crossovers and needs of other transport modes. For this reason of exploring changes from the baseline, it is imperative that the future year conditions be derived from the current traffic operations (as appropriate). This implies having a design or project model that is developed based on the same optimisation process as delivered within the base model. To achieve this measure the base model should not simply be a development of phase splits from a historic allocation but the same optimisation structure (phasing, minimum times etc) for the project delivery.

It is important that option testing outlines any assumptions utilised to the range of stakeholders involved in the investigation. Testing of those assumptions is also important, and a sensitivity analysis of demand estimates should be carried out to determine the robustness of solutions.

It is also important to distinguish between models that confirm future design specifications and requirements and those used for economic evaluation. In particular it should be recognised that peak period design demand volumes to confirm future specifications (Section 9.3.3) will likely differ to those used for economic evaluation.

At the end of this process, "Do Nothing", 'Do Minimum' and 'Do Something' Options models will have been produced using future demand estimation.

The operational safety of the users of the intersection is always the primary factor to determine design and operational features. This measure is followed by the efficiency of the site, subject to the movements of journeys and the minimum required times (as applicable). Therefore, traffic modelling should not be used to determine the behavioural conditions but used to evaluate the proposed design and operation. For new intersections, a site investigation shall be conducted to observe local issues such as the horizontal and vertical geometry, sight distances, surrounding area development etc), as well as defining the context of any relevant data sources (e.g. traffic volumes and crash statistics).

9.4.1 Physical changes

The options to be explored within an investigation may not include the development of new intersections or changes in control format. Instead, the options may include modifying existing intersections while retaining the form of control. Changes may include:

- Provision of additional through or turn lanes;
- Modifications to walking and cycling provision (e.g. new crosswalks);
- Provision for public transport access (bus priority lanes, jump starts, raised tram stops)
- Replacement of hazardous conflict locations (e.g. road/rail level crossings)
- Replacing stand-up lanes with slip-lanes; and
- Extending existing turn lane storage.

The physical design should not be led by the modelled transport performance in isolation. It is important that the designs proposed comply with the Department of Transport road design and traffic engineering guidance. The Department of Transport supplements to Austroads Guides and Australian Standards and design notes are available from the following links:

https://www.vicroads.vic.gov.au/business-and-industry/technical-publications/road-design

https://www.vicroads.vic.gov.au/business-and-industry/technical-publications/traffic-engineering

In particular, sufficient turn lane storage for the design vehicle should be based on the requirements in the guidance under conditions where modelling alludes to a reduced or substandard arrangement. Likewise, acceleration and deceleration tapers should be based on design guidance and not on software defaults. In many circumstances the design requirements should be explored before conducting any intersection modelling. The reporting of turn pocket utilisation is an important element to be provided and is a key design item that will be reviewed before approval of design.

It is also important that modellers consider geometric alignment requirements when exploring options. For example, the provision of splitter islands in the modelled design should be considered to ensure that approach and departure lanes are aligned, and that there are locations for signal infrastructure and street lighting.

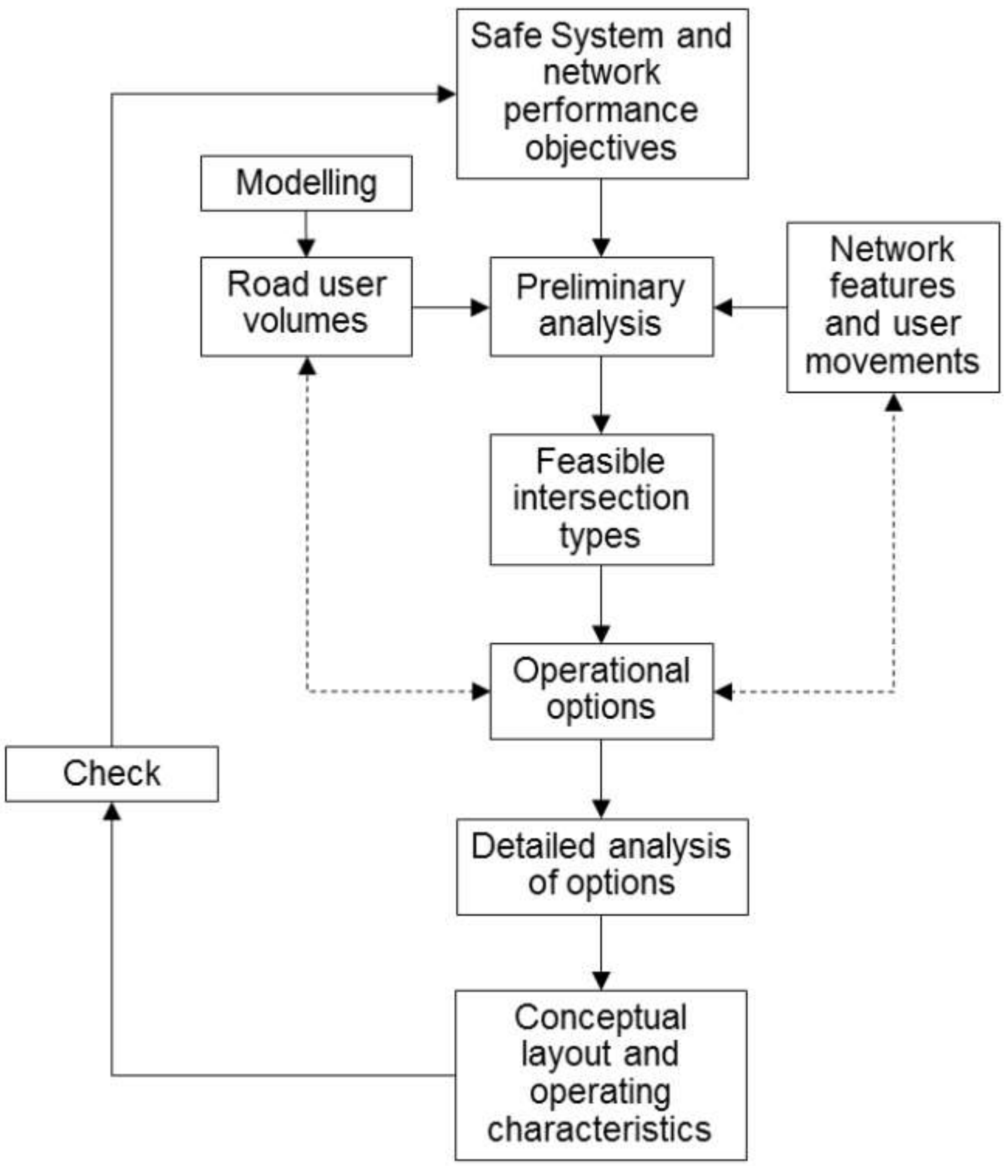
9.4.2 Intersection control

Changes in traffic demand volumes and patterns may necessitate a revision to the form of the intersection control mechanism. This may occur when changes to existing intersections fail to achieve performance requirements, or where changes to existing control are not practical. Additionally, a change in land use may require an entirely new intersection controller to be developed. Common intersection control changes (upgrades) are as follows:

- **Unsignalised intersection to roundabout** – This is likely to occur due to safety or traffic performance. Roundabouts are a particularly useful option to replace unsignalised crossroad intersections which have a very poor safety record.
- **Unsignalised intersection to traffic signals** – This change in control could be due to traffic performance, the desire to provide pedestrian priority or crossings, to improve safety, to manage demand volumes (traffic management) or to improve bicycle access, to assist public transport movements;
- **Roundabouts to traffic signals** – This conversion is often based on traffic performance and may be required where there are unbalanced traffic volumes leading to excessive delay on one or more approaches. Other reasons may be to improve pedestrian and cyclist safety.

Changing the form of intersection control, or the type of form of control for a new intersection should not be based solely on traffic performance outcomes alone. Austroads Guide to Traffic Management Part 6: Intersections, interchanges and crossings includes a process and considerations for selecting appropriate intersection types. **Figure 26** summarises the intersection selection process.

Figure 26: Intersection selection process



Source: AGTM, Part 6: Intersections, Interchanges and Crossings

Note that modelling analysis provides a core component to inform design considerations for a future landscape. However, this work needs to be held in context of the exploration rather than in isolation of the work at hand.

Where it is proposed to change the form of the intersection control, there are multiple traffic management considerations. In addition to the operational performance, safety, geometric controls and user impacts will also need to be evaluated. Key considerations are included in Austroads Guide to Traffic Management Part 6: Intersections, interchanges and crossings and the Department of Transport's Supplement to Austroads Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings.

Often, when changing from unsignalised intersections, the decision will be between introducing roundabout or traffic signals. A comparison of the various factors influencing the choice between traffic signals and roundabouts is included in Table 32. Further guidance on roundabouts and traffic signal design are provided in Section 9.4.5 and Section 6.8 respectively.

Table 32: Site specific factors influencing choice of roundabouts or traffic signals

Site specific factors	Signals	Roundabout
Physical Controls		
• Space available	May be – subject to design	May be – subject to design
• Site topography	May be – subject to design	May be – subject to design
• Access to adjacent properties	May be – subject to design	May be – subject to design
Road Environment		
• Rural area	Unlikely	Likely
• Outer urban or fringe areas	May be	Likely
• Inner urban area	Likely	May be
• High speed approaching traffic	Unlikely – May consider with 80 km/h speed limit & warning signs / flashing lights	Likely - with design features to control approach speed
Road Users		
• Pedestrian needs		
○ Children, the elderly and the disabled.	Likely	Unlikely – unless pedestrian signals provided
○ Significant number of other pedestrians	May be	M - consider pedestrian facilities, low design speed and spare capacity
• Bicyclists needs		
○ Significant number of children or recreational cyclists	Likely	Unlikely – unless off-road facility and pedestrian signals provided
○ Significant number of other cyclists	May be	May be – with low speed design
• Needs of large vehicles	May be	May be
Traffic Management		
• Route or area strategies		
○ Adjacent to linked signals	Likely	Unlikely
○ Isolated locations	May be	Likely
○ Adjacent sites controlled with roundabouts	May be	Likely
○ Control of traffic through a local area	Likely	Unlikely
• Traffic volumes and capacity		
○ Balanced flows	May be	May be
○ Unbalanced flows	May be	May be – possibly with metering signals
○ Significant turning volumes	May be - with adequate turn lane capacity	Likely
○ Minimising off-peak delays	Unlikely	Likely
• Public transport		
○ Trams	Likely	Unlikely
○ Buses	Likely	Likely
○ Adjacent to a railway level crossing	Likely	Unlikely

Table 32 is reproduced from VicRoads' Supplement to Austroads Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings.

9.4.3 Traffic signals

The design of a signalised intersection is a complex task that requires a review of the network operations and desired objectives of the investigation. Intersections are commonly signalised under conditions when the traffic volumes are significant enough to create unmanaged delays or safety concerns in the landscape.

As signalised intersections are a more expensive solution to install and operate (compared to alternate control systems) this style of traffic operation would typically involve a progression of development or traffic volumes to warrant the delivery. However, sometimes there may be conditions where the installation of a signalised intersection is a means for delivery in the longer term. Under such arrangements the installation sits within the context of the changing landscape rather than the current utilisation.

The development of signalised intersections needs to consider a number of primary factors including elements pertaining to the following considerations:

- geometric design
- cycle times
- phase design and sequence
- minimum allowance (safe crossing times)
- driver behaviour (gap considerations and saturation flow); and
- demand volume estimates

Signalised intersections should not be located within 150m from another signalised intersection. Such design elements have the propensity for users to focus on the wrong set of lanterns (see through effect). This may lead to unwarranted movements within the intersection and exacerbate a road safety issue. Under such considerations design of this proximity should explore matters of the road alignment (side roads) to place the controller further apart or consider application of one site to be an unsignalised intersection. Alternatively, incorporation of the two venues into a single signal controller might produce a co-ordinated delivery for journeys within this landscape.

Note that the design of signal phasing arrangements is a function of the footprint for the controller. More lanes with a shared movement, will generate a reduced set of options for signal phasing. Under such conditions a diamond phase option may not be viable, for which split phasing may be the most promising next solution. However, under conditions of high volume demand flows, the limited signal arrangements and competing green time splits may simply generate long queues and delays producing a congestion location. This inflexibility in split phasing and associated traffic congestion is why signal arrangements are preferred as a delivery mechanism. However, this can only be achieved if there is a suitable design for such an arrangement.

Due to the managed movement of journeys within a signalised intersection, a larger area both at the controller and on approach (the neck) may be required to deliver this solution. Subsequent delays on major movements may also increase when compared against an unsignalised solution. However, delays on oversaturated movements would be expected to be considerably reduced.

9.4.3.1 Cycle times

Cycle times provide an important element in managing the traffic demand movements of the intersection as well as managing other components such as queue lengths, relative to the adjacent controllers.

It should be expected that any new intersections developed will be built to brought into the SCATS system operated by the Department of Transport. These solutions may be managed within a network, or even operate in an isolation framework. For those new sites or upgraded sites that are developed within 500m from an existing controller, consideration should be made about incorporating the intersections into a subsystem. There should be a sense of consistency between adjacent locations to streamline the movements of journeys (with consideration for all perpendicular movements)

If the intersections are within 100m of each other, the intersections should be operated under the same traffic signal controller (as one intersection). For intersections between 100 to 150m apart, operation under a single controller may be appropriate (operation as a subsystem would be essential). However, with this distance between controllers there is greater likelihood that drivers may focus on the wrong set of lanterns, potentially creating a safety hazard. For this reason, signalised intersections are encouraged to be located at least 200m (or further) apart from existing venues. This might involve a rethink to the road alignment, or a revisit to the controller format. A small investment in the capital of the program for a better design can alleviate ongoing operational and safety costs once completed.

Most existing cycle times across the metropolitan landscape run an intended length of between 80 seconds to 120 seconds. This is an appropriate length of time for new locations in growth areas developed around the fringes. The volume of controllers with a cycle time beyond this range are quite nominal and are developed on major corridors or selected locations. However, if the intersection will run a cycle length outside of this range (during the peak period), the context for this rationale should be outlined within the reporting. If the solutions adhere to a cycle times longer than 120 seconds, then it is advisable to manage this intended matter with the traffic signals teams in the respective operational region.

At the same time, proposed cycle lengths that are less than 80 seconds (on average) in the busiest periods should also be discussed directly with the signals teams. It may be that they can identify oversights within the work, including pedestrian clearance times, required amber times or calibration matters (saturation flow) that have not been a focus of the delivery.

Sites that are developed through a modelling process need to ensure that the adjacent controllers are considered within the development of the new or refined controllers. These signalised intersections should not be modelled out of context of the adjacent network constraints. This might mean that land use developments (such as that in **Figure 27**) should include analysis of how the adjacent intersections currently operate (the intent as well as the delivery). It may be that the co-ordination matters that will inhibit the expectation for the design and delivery of the development site. In this instance of **Figure 27** the co-ordination is provided and will be maintained for the northern movement amongst the existing controllers (Sites D-B-C). However, the proposed development for the business park pushes journeys out through a new controller at Site A, in which the analysis develops a solution for priority on the eastbound corridor (Sites E-A-B). Under such conditions the operational matters assumed in the modelling (from Site A to B) inhibits the ability to release traffic from the land use, which in turn requires further focus on the intersection design of the new location (Site A).

Figure 27: Example Assumed Corridor Priority (Fictional Application)

However, note that all designs will need to go through further reviews (including civil and electrical components) before they can be classified to be ready for instigation within the network.

9.4.3.2 Phasing arrangements

The signal phasing implemented in operation will be dependent on a number of requirements at the location. These key items include the following considerations:

- The movements of traffic (demand) throughout the intersection
- The movement of pedestrians across the intersection (minimum crossing times required)
- Public transport priority at the location
- The role of the intersection within the subsystem or corridor.
- The geometric footprint available to develop a new or revised location.

As a basic delivery the movement of journeys through an intersection typically would prompt for a diamond arrangement of phases. As discussed in Section 7.5 the diamond phasing allows for flexibility both for conditions of the detectors in each phase of the peak hour (to be demand responsive) but also for off peak periods when tidal movements require different phase delivery. This requires a wider neck on the intersection approach (more capital) but the flexibility will be lost with a split phasing arrangement.

The Department of Transport is unlikely to approve a new signal installation that do not also offer the flexibility to operate diamond turns. Signalised intersections with four approaches should aim to deliver with double diamond phasing sequences. The precise phase times are then a matter for the time interval and horizon applied for the analysis. As the volume and pattern of traffic demand may change throughout the day, week and overtime, it is important that flexible phasing solutions are provided.

An existing issue with split phasing arrangements is that the phase times require utilisation of the controller for both the time required for pedestrians to safely cross, as well as the time occupied by the right turn movements. There is little suggestion that these two time requirements are similar and may emphasise a poor design in oversaturated conditions. Under such arrangements it may be that the diamond phasing solution better manages both the safety and the efficiency targets at the venue.

Recommended signal design objectives are as follows:

- Minimise the amount of lost time by minimising the number of signal phases;
- Operate as many non-conflicting movements during each phase as possible;
- Allow each movement to run in as many phases as possible; and
- Ensure that the phasing provides for all desired pedestrian movements.

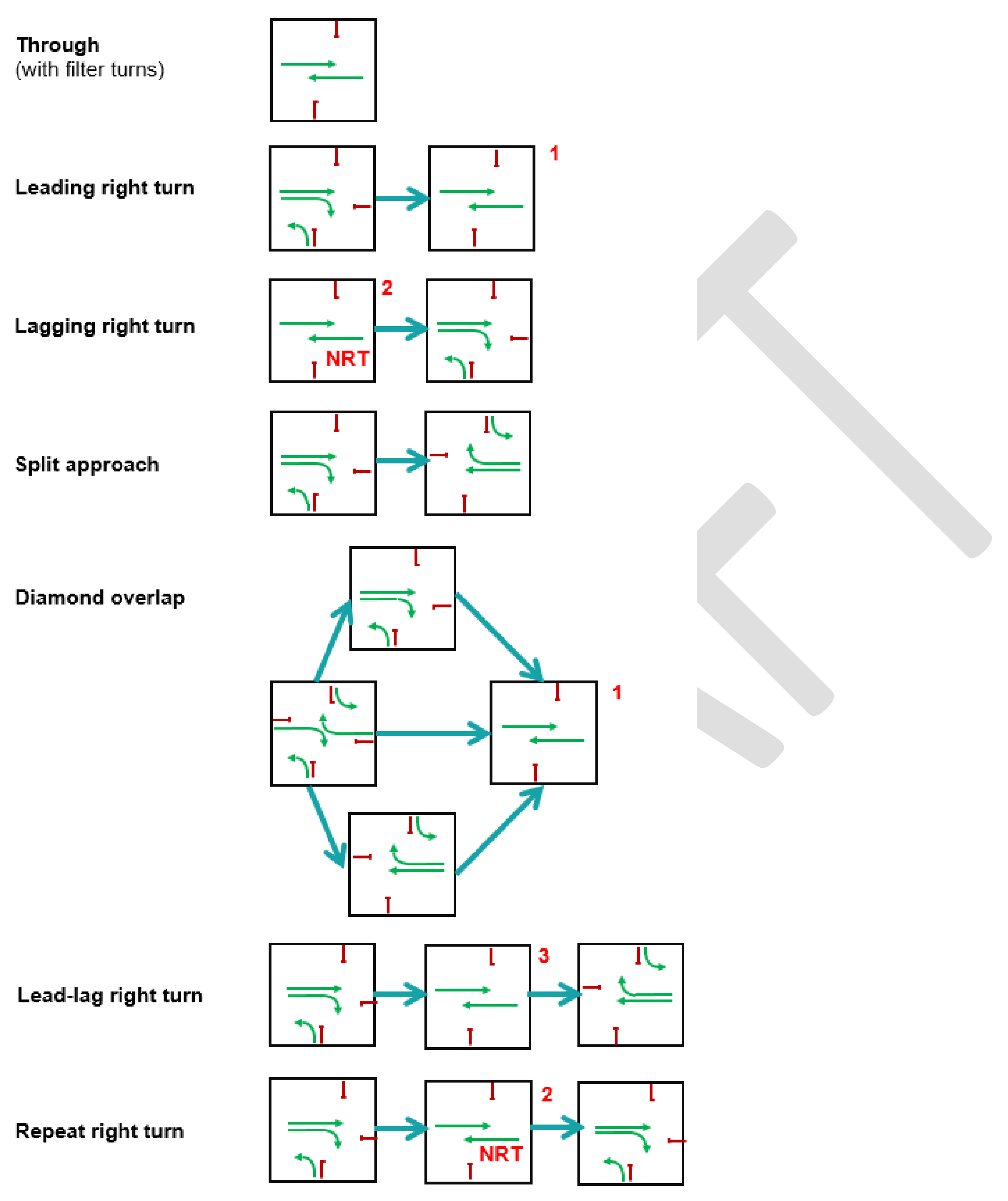
The phase sequences that can be developed into a cycle are presented in **Figure 28**. These alternatives show movements on one road only as a simplification of the schematic design but can equally apply to the perpendicular approaches. While the leading, lagging and repeat right turn phasing options are shown from the western approach, but could equally apply to movements from the eastern approach. The phasing elements listed can then be used to build a phasing structure for a complete signal cycle.

It is strongly encouraged for both inexperienced and experienced transport modellers to review existing operations sheets that are applied by the Department of Transport for current delivery matters. The files outline the current practice of signal design as implemented from experienced professionals working within this framework. These traffic signals configuration data sheets are provided online at the following locations:

https://discover.data.vic.gov.au/dataset/traffic-signal-configuration-data-sheets

Some recent developments within the operational space involve application of some selected right turn movements only in each second phase. This measure reduces the utilisation pressure (oversaturation) on other movements by applying a revised cycle time. Such conditions can be modelled with an extended cycle time (e.g. 240 seconds) rather than a further extended cycle time of up to 160 seconds. However, it is important to note that this application is for a very selective minimum of movements in established locations. This will depend on the storage available for the turn, traffic management objectives for the arterial roads and stakeholder considerations. A consequence of this approach is that average delays per vehicle (on the movement with reduced opportunities) may be increased, albeit for the benefit of the remaining movements at the controller. Note that this approach is a focus on traffic management where alternative considerations have been exhausted and is not considered appropriate for delivery of new land use developments.

Figure 28: Basic elements of signal phasing



1. Both filter right turns may be allowed (and either/or selection of the illustrated phases) subject to a satisfactory safety assessment.
2. Filter right turns from the approach opposite NRT may be allowed subject to a satisfactory safety assessment.
3. The leading turn must be fully controlled, and the lagging turn may be allowed to filter subject to a satisfactory safety assessment.

NRT: No Right Turn (right turn movement must be banned where opposing through movement overlaps).

Source: Austroads Guide to Traffic Management, Part 6

For further advice on traffic signal phasing, refer to Austroads Guide to Traffic Management, Part 9: Traffic Operations.

9.4.3.3 Vehicle settings

Section 7.5.1 provides an overview of the various components to be considered in developing vehicle time settings. For new signal installations, these will need to be determined and incorporated into modelling. A very good guidance to comprehend the required settings is to review the existing operations sheets and timings applied here. Note that these parameters refer to minimum times and conflict considerations, rather than green splits which (in reality) change for each cycle in the interval. For modified intersections, these parameters settings should be reviewed to ensure that they are correct.

The VicRoads supplement to Austroads Guide to Traffic Management, Part 09 includes guidance for calculation of late start, yellow and all red times. Calculation of these parameters should be used rather than metrics applied as software defaults.

9.4.3.4 Pedestrian settings

The discussion within Section 7.5.1 provides a summary of the pedestrian settings for use at signalised intersections. Further specific guidance can be found within the Austroads Guide to Traffic Management, Part 09 on the calculation of walk and clearance times in Victoria. These pedestrian requirements should be determined and applied in place of software defaults.

The range of pedestrian movements at intersections will vary by geography and by the complexity of the landscape. However, as pedestrians are the most vulnerable users within the streetscape, appropriate consideration needs to be applied of the safe movement of persons within the landscape. Delivery in design should also account for varied demographics and capabilities within the development of a signalised controller (with regard to safe crossing times). The provision of safe crossing movements is an aspect that will be reviewed for all new or revised signalised intersections that are submitted to the Department of Transport. Note that these timing requirements may impact on the phase times per hour and per hour, which in turn may also impact on the design requirements and the user experiences.

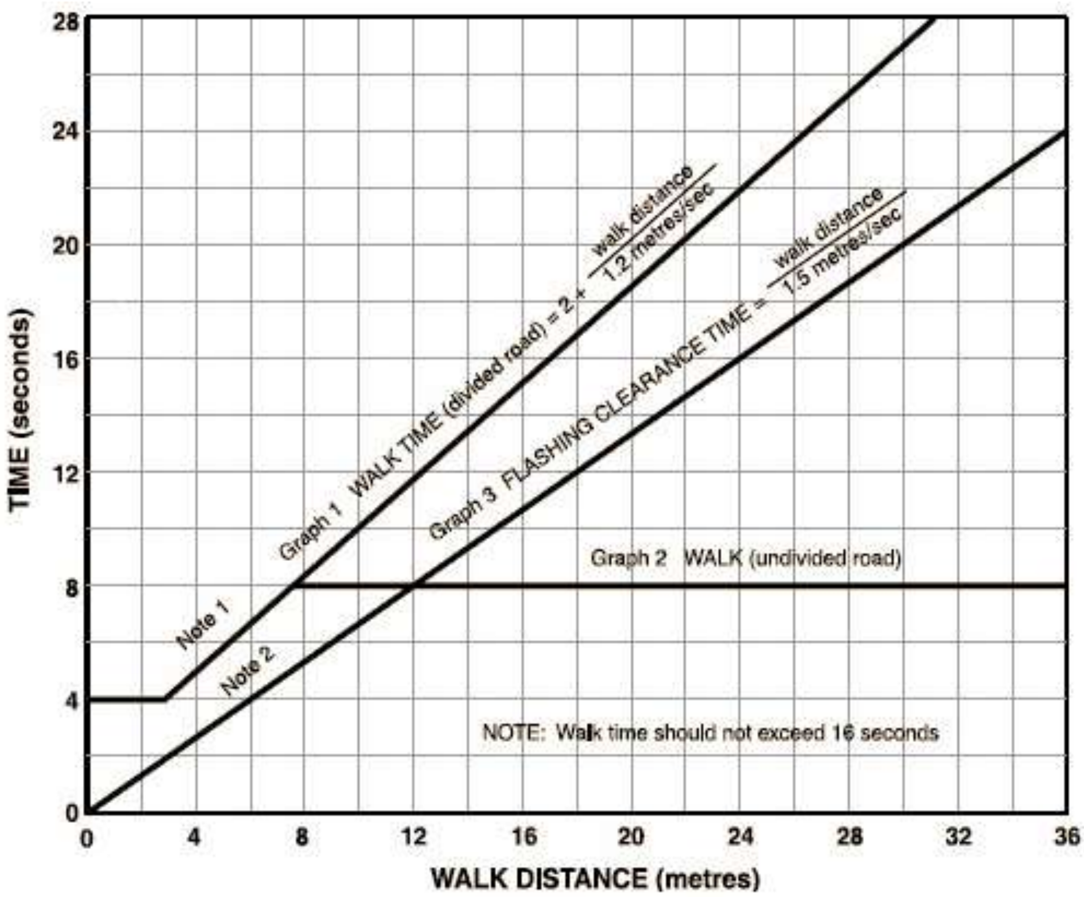
Some locations within urban centres are configured to operate every cycle. This is applied through the Central Business District of Melbourne and in Major Activity Centres throughout the metropolitan areas and the state. The approach is delivered in centres with a regular and significant pedestrian movements. By comparison other venues involve pedestrian movements by button activation. This behaviour should be incorporated into models if present and evident from the SCATS phase history for the site or adjacent sites. Where new or revised sites are expected to have a significant volume of pedestrians, it is expected that regularity of the pedestrian crossing will be required. Some locations such as puffin crossings also define an extended allocation of time for crossings, in order to account for the demographic composition of users.

Pedestrian crossings are expected to be called for each cycle within the peak periods, unless demand is seasonal or infrequent (e.g. subject to a train arriving). However, they may not be required for operations outside the peak periods that occur through the day. Sites closer to public transport stops and land uses with a greater footprint (schools and universities) should be provided with good pedestrian access throughout the day. In all conditions (regular or interrupted experiences) the delays related to pedestrian crossings at an intersection should never exceed 180 seconds.

The components of **Figure 29** provide a direction of the crossing times required for pedestrian movements at both signalised and at unsignalised intersections. Further details are outlined within the VicRoads Traffic Engineering Manual, included an updated series of equations for more an accurate determination of the required crossing times. This application explores for a range of crossing conditions, beyond the limitations of the graphics in **Figure 29**. Nonetheless these are important elements that need to be considered within the design and the operation of the controller. The delivery of a successful intersection is not simply whereby the user experiences from drivers are minimised, but from all users of the location.

Figure 29: Pedestrian Crossing Estimation

Divided Road (Central Median >1.8m)	Divided Road (central Median <1.8m)	Undivided Road
Walk Time: To enable Ped to clear widest road & step 1m onto the other road. (Graph 1).	Walk Time: as for Central Median >1.8m	Walk Time: Calculated from Graph 2 using kerb to kerb distance.
Clearance Time: Provide enough time to clear widest road (Graph 3)	Clearance Time: Provide enough time to clear both roads (Graph 3)	Clearance Time: Graph 3. Provide enough time to clear kerb-to-kerb.



Note 1: Pedestrian Situation Crowded: Add two seconds for each additional row of pedestrians.
Note 2: Supervised Crossing. Additional time may have to be added to allow supervisor to take up position.

9.4.3.5 Right-turn controls

The control of right turn movements is an important aspect of traffic signal design. Not only does the design impact on the user experiences but will also manage the scale of prospective conflicts and the quality of road safety.

The three main techniques for controlling right turn movements are summarised in **Table 33** and consist of the following techniques:

- Filtered Right Turns
- Partially Controlled Right Turns
- Fully Controlled Right turns.

A filtered right turn exists where the right turn movement which operates in the same phase as conflicting vehicle (generally through and left turn vehicles from the opposite direction) and/or pedestrian movements. The right turn is therefore required to find safe gaps in that conflicting traffic before being able to turn.

By comparison, a partially controller right turn is a movement that operates in two states. Initially there is a phase that is controlled by a green right turn arrow and has priority over conflicting vehicle and/or pedestrian traffic movements. This priority will transition into a filtered turn movement so that the opposing through traffic can proceed.

With this type of control, the right turn movement is controlled with either two-aspect (Yellow/ Green) right turn arrow displays or three-aspect (Red/Yellow/Green) right turn arrow displays. Generally, these types of lanterns are also associated with normal three-aspect (Red/ Yellow/ Green) circular displays. The “Red Arrow Drop Out” operation is the preferred form of partially controlled turn to be adopted and should only be used where the right turn movement is from an exclusive right turn lane.

A fully controlled right turn is a right turn movement that only operates in a phase in which it is controlled by a green right turn arrow, and so has priority over conflicting vehicle and/or pedestrian traffic movements. However, unlike a partially controlled turn, it is unable to filter during any other phase. At the end of its own phase, the right turn is terminated and held on a red arrow display (until it operates in the following traffic signal cycle or possibly in a repeat right turn phase).

Table 33: Techniques for control of right turns at traffic signals

	Key considerations
Filter right turn	A filter turn can be considered if there is: • One turning lane; • Three opposing lanes or less; • Low-medium right-turn volumes; • Low-medium opposing through volumes; • Low-medium pedestrian volumes; and/or • A speed limit of 70 km/h or less.
Partially controlled right turn	Filter turns can be considered if there is: • One turning lane; • Three opposing lanes or less; • Low-medium right-turn volumes; • Low-medium opposing through volumes; • Low-medium pedestrian volumes; and/or • Speed limit of 70 km/h or less.
Fully controlled right turn	A fully controlled turn can be considered if there is: • Three opposing lanes or more; • Medium-high right-turn volumes; • Medium-high opposing through volumes; • High pedestrian volumes; • A speed limit of 80 km/h or more; • Two or more right-turn lanes; • Two or more opposing right-turn lanes; • Road safety issues (e.g. poor sight distance); • A relevant crash trend (e.g. a significant amount of recorded casualty crashes that would be solved by this method of control, which have occurred over the latest five-year period); • A tram right-of-way; and/or • Linking/capacity benefits, (e.g. where the phasing implemented includes a lagging right-turn conflict).

Criteria adapted from TEM Volume 1, Part 2.09.

Other alternative right turn treatments based on those included in **Table 33** are occasionally implemented. These include prohibiting the turn for some intervals or throughout the day, or even consideration for operating the turn on every second cycle. Operating a fully controlled turn every second cycle can be considered where:

- The intersection and/or the opposing through movement are/is at or above capacity.
- The right-turn volume is low (e.g. < ~100 vph/lane).
- The volume of a right turn movement can be accommodated in a relatively short phase.
- The queue length can be accommodated within the available turn lane.

Further details of alternative right turn treatments are included in TEM Volume 1, Part 2.09.

The criteria included in **Table 33** shall be used in conjunction with sound engineering experience and judgement to explore intersection or network revisions from a calibrated and validated base year model.

9.4.3.6 Blocking Back Conditions

There are times when a series of signalised intersections may be modelled as a set of adjacent controllers. Modellers applying a change to the landscape should be aware of the potential for signalised controllers to block back from the stop line to the adjacent controller. This can easily be explored by sketching or mapping distances and queue lengths between controllers to determine the logic of the delivery. This may be a review of the 95^{th} percentile back of queue from the stop line.

For those circumstances where blocking back is noted to occur, there are adjustments within the intersection models that need to reflect the limited downstream capacity of the traffic movements. This should be reflected within the analysis conducted and the quality assurance processes internally. To account for the downstream limitations, adjustments should be delivered within the capacity estimates so that there is a reduction of 150% of the deficit between the back of queue and the appropriate storage.

As a hypothetical example, Site A has a queue length of two lanes that is calculated to be a 95^{th} percentile length of 1200m. However, the upstream signalised location of Site B is only 900m away. This would produce a deficit of storage of 300m for two lanes, or 600m of storage. At circa six metres for a vehicle length, this would generate unfulfilled demand of 100 vehicles that could not travel beyond Site B, despite also representing demand for Site A. In this way the capacity on the approach should be reduced for anywhere between 125-150 vehicles per hour. Updated metrics should also be produced for the user experience (level of service), road utilisation and queue lengths of Site B.

There are also times when the extension of queue lengths may carry into the intersection itself. This is referred to as yellow box attention and it design to ensure that traffic does not queue within the intersection where conflicting movements take place. Despite the presence of absence of distinct painted yellow boxes in the middle of the controller, drivers may queue back into the intersection and limit traffic from a side road or access point. While this may seem nominal, the implications for the flow of traffic on the side roads might be a significant constraint to the perpendicular movements, and this may have broader consequences for perpendicular movements on major arterials and freeway ramps. Such experiences are not uncommon during construction staging where limited attention has been directed to the traffic management of the broader network. Again, under such conditions, the intersection, approach and turn movement should account for a reduction in carrying capacity by more than the prospective queue considerations. The cumulative matter of the downstream constraint reduces the opportunities for more of the queued traffic to move through the intersection.

9.4.4 Unsignalised intersections

In situations where there has been a land use change, a new intersection may be proposed to be developed. The first control type commonly to be implemented within a developed landscape is an unsignalised intersection. These unsignalised locations are less expensive to operate and to install than signalised sites but can only accommodate lower volumes. As such the development of an area or region may then require upgrades to controller formats over time. Primary drivers for change are delays (the user experiences), queue lengths and journey times that can be resolved with a modification to the format of the traffic controller.

It is imperative that the exploration of future year horizons consider the design requirements for prospective changes to a controller footprint. This approach may not require design and delivery of the controller in the initial year but will need confirmation of the land allocation to ensure future arrangements (a new controller type) can be delivered.

Failure to account for growth requirements over time may result in the occupancy of adjacent land, which in turn may limit the growth potential of the surrounding network. It is an important aspect to therefore hold the intersection designs within the context of the network development and change. This not only relates to the demand estimation process but should ensure that the development of intersections are explored within the context of the hierarchy of roads across the local or regional network.

A total of seven different design styles of unsignalised intersections are outlined within the Austroads Guide to Traffic Management, Part 6. These are listed in ***Table 34*** as the following configurations:

Table 34: Unsignalised Control Design Treatments

Control Type	***Description***
Basic turn treatments	No separate turn lanes (turns obstruct through movements)
Auxiliary lane turn treatments	Include short lengths of lane to enable through traffic to bypass turning traffic
Channelised turn treatments	Conflicting vehicle paths separated by raised or painted medians/islands
Two-staged crossing	Right turning traffic from the minor road undertakes the turn in two stages across a median divided road.
Seagull treatment	Right turning traffic from the minor road undertakes the turn in a single stage across a median divided road with either a merge or add lane on the departure
Wide Median Treatment	Used on high-speed rural roads at cross-intersection locations to control speed of crossing traffic.
Roundabouts.	Circulatory design for traffic moving through a radial series of gap based access points.

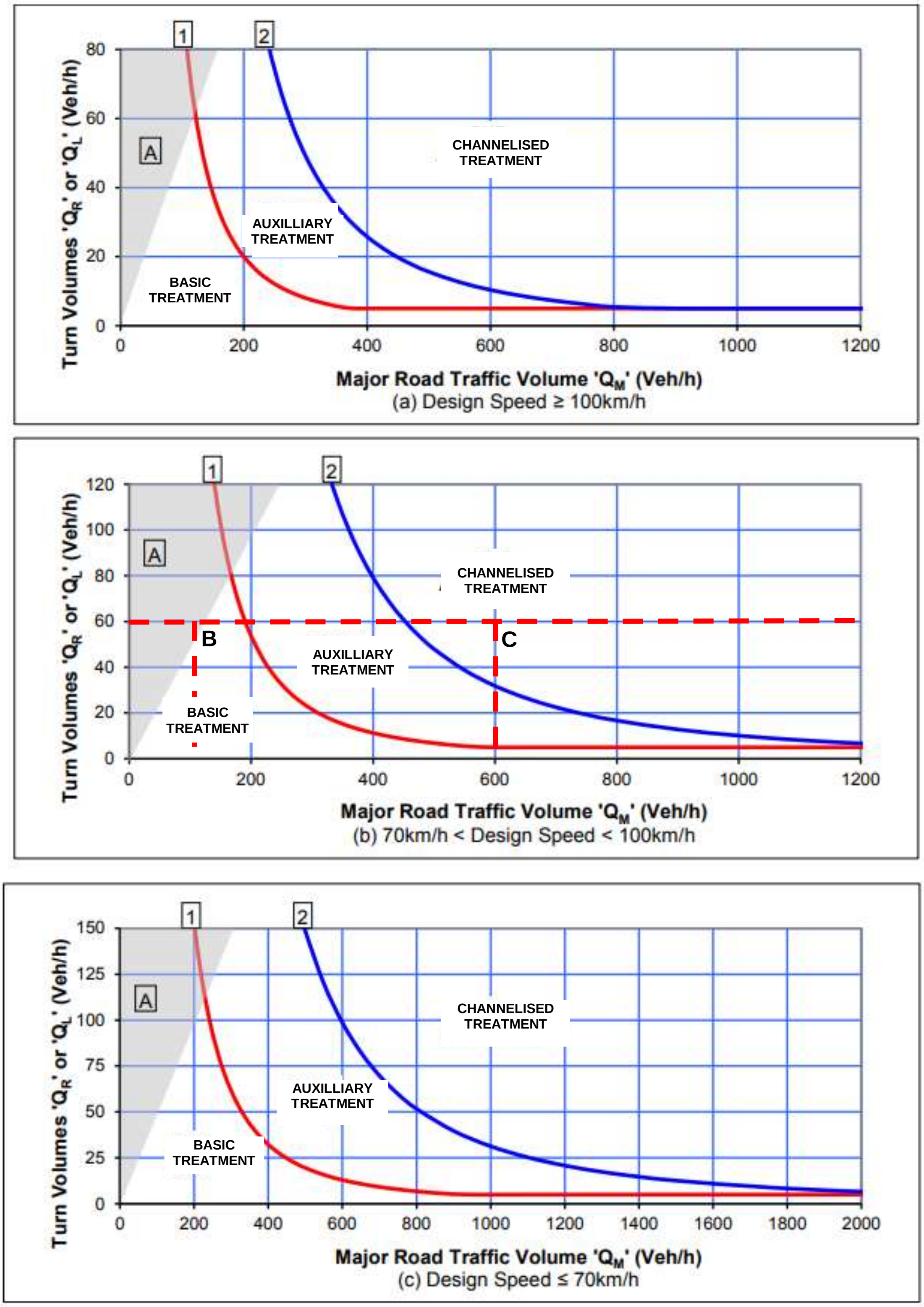
9.4.4.1 Design warrants

If the warrants included in Section 2.3.6 of Austroads Guide to Traffic Management Part 6: Intersections, interchanges and crossings indicate basic treatments are required, then intersection modelling may not be a deliverable. The warrants for basic (BA), auxiliary (AU) and channelised (CH) turn treatments are reproduced in **Figure 30** for three different design speeds and showcase the flow volume of focus against the conflicting volumes. The flow volume for the minor turn appears on the y axis while the conflicting flow on the major road appears on the x axis. Under these conditions a turn volume of 60 vehicles an hour from a road with design volume of 80km/h (Point B) may only require a basic treatment if the opposing low is 100 vehicles. However, if the opposing flow was 600 vehicles (Point C) then a channelised treatment will be required.

If the warrants indicate that basic or shorter length channelised or auxiliary treatments are appropriate lengths, these specifications should overwrite any understated design requirements produced from modelling of a low volume environment.

If it is unclear as to whether transport modelling is required, project proponents are expected to conduct modelling and ensure minimum design requirements are achieved.

Figure 30: Warrants for turn treatments at unsignalised intersections



Note: the minimum right-turn treatment for multilane roads is a CHR(s).

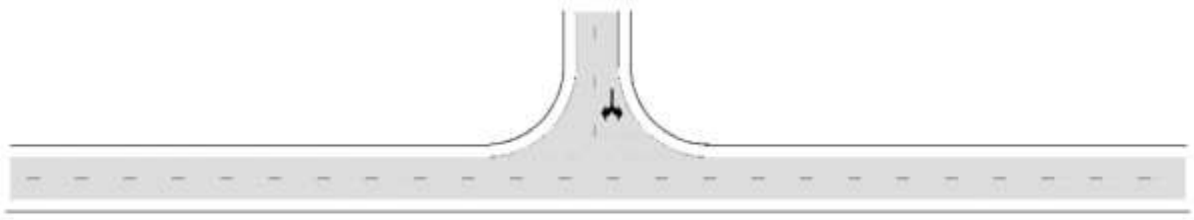
(source: Austroads Guide to Traffic Management, Part 6: Intersections, Interchanges and Crossings)

9.4.4.2 Basic turn treatments

The basic treatment design (**Figure 31**) operates where there are no separate turn lanes at the intersection. Under such conditions, the turns obstruct through movements creating prospective conflicts and are commonly applied at locations where low volumes and low speeds occur. A review of the design volumes for both through and cross movements should be compared against the warrants of **Figure 30** to explore if a modelling task is required.

These designs are compact and low cost, but do not offer protection to turning traffic. As such through traffic will reduce speeds when such traffic leaves the side road. The simple design provides little support for other road user considerations including those of pedestrians, cyclists, motorcyclists and heavy vehicles.

Figure 31: Basic turn treatments



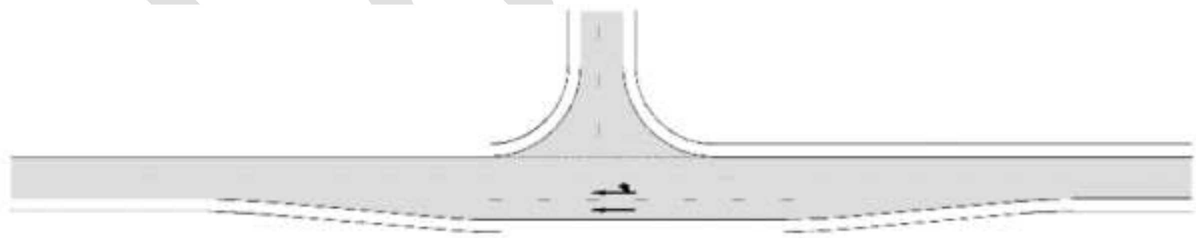
Source: Austroads Guide to Traffic Management, Part 6

9.4.4.3 Auxiliary lane turn treatments

An auxiliary lane treatment occurs where short lengths of lane are produced to enable through traffic to bypass turning traffic. This is displayed within **Figure 32**. The auxiliary lane should be provided under conditions where high-speed, low-volume traffic occurs in regional settings and the manoeuvring volume of turning traffic is sufficient to create a conflict with the following journeys. Thresholds in Figure 30 indicate where auxiliary lane treatments are the minimum requirement above the design of a basic treatment in order to improve safety conditions.

It is important to note that the additional lane is provided to separate for a manoeuvring of a single vehicle. Under such conditions the passing lane allows traffic to bypass a vehicle waiting to turn right. The design is not intended for locations with regular or extensive queuing.

Figure 32: Auxiliary right turn on major rural road



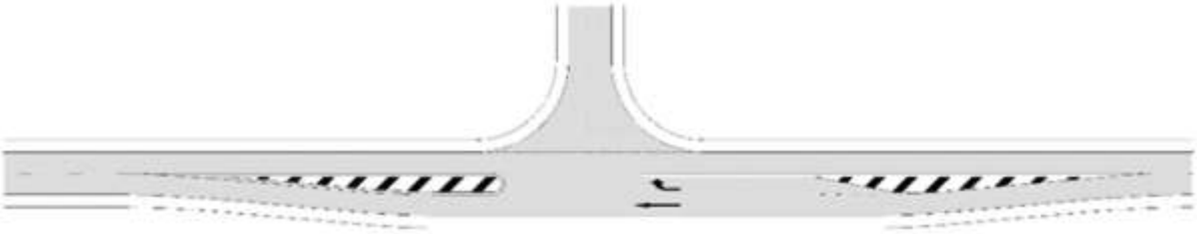
Source: Austroads Guide to Traffic Management, Part 6

9.4.4.4 Channelised turn treatments

The provision of a channelised turn treatment provides a dedicated pocket for turn movements away from the major flow of traffic and where there is regular queuing that does not disrupt the remainder of the journeys at this location. This solution of providing separated lanes by raised or painted medians is required where there is a need to define vehicle paths from the major flow of traffic to the minor road. It is expected that under all circumstances the design of an intersection with intended channelised turn treatments are modelled. This pertains to both the required storage lengths as well as exploring sensitivities of the gap in traffic from the opposing movement.

Channelised turn treatments are useful solutions to cater for unusual manoeuvres or where unwanted movements are to be eliminated. They may also be of value where refuges are required for pedestrians and cyclists or to provide separation between street furniture and vehicle paths.

Figure 33: Channelised right turn



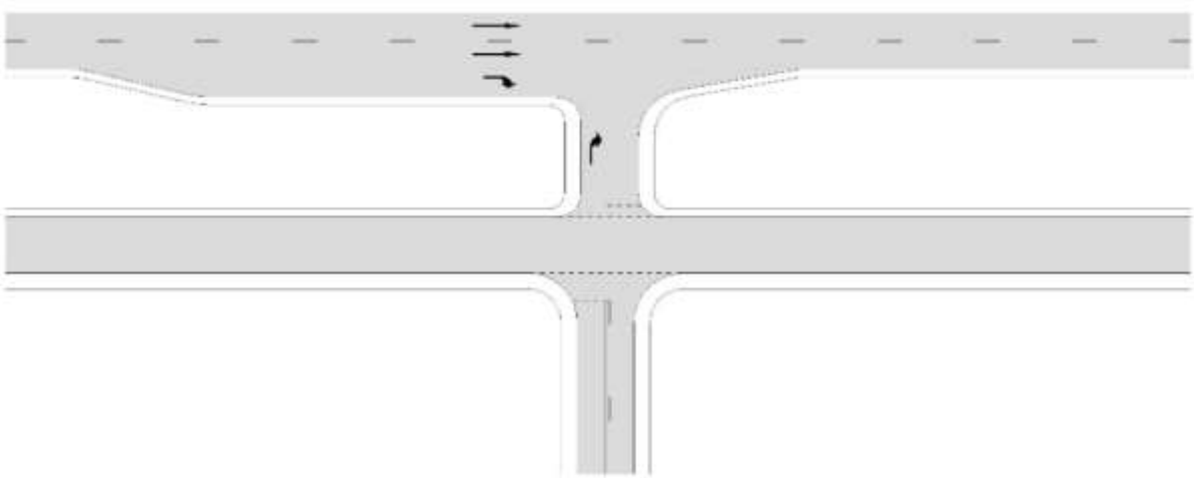
Source: Austroads Guide to Traffic Management, Part 6

9.4.4.5 Two-staged crossing

The delivery of two staged crossings as an intersection design will require a form of modelling to investigate the network complexities as some journeys manoeuvre across two separated carriageways of traffic. This may require operation as a multi-intersection model to ensure that both areas of conflicting movements are accounted for within the design and operation of the location. The two staged approach may be considered as a divided arterial road with minor movements to and from the side road. Note that a two-staged crossing has a number of safety concerns associated with gap acceptance, which might reduce the life of the design. Consequently, investigations exploring this solution should consider the life of the design, the timeframes for a new solution and the disruption caused to replace in interim delivery.

The two stage crossing provides conditions whereby right turning traffic from the minor road undertakes the turn in two stages across a median divided road. This is applied on roadways with wide medians where the volume of right-turning traffic is nominal but the through volumes are significant. Under these conditions the traffic turning right from the major approach has to cross the opposing approach of traffic, while the minor arm needs to account for both major movements. Note that the design may not be appropriate where a substantial number of heavy vehicles turn into the minor road; or where there are more than two through lanes in either directions (reduced turning gaps to/from minor road).

Figure 34: Two-staged crossing



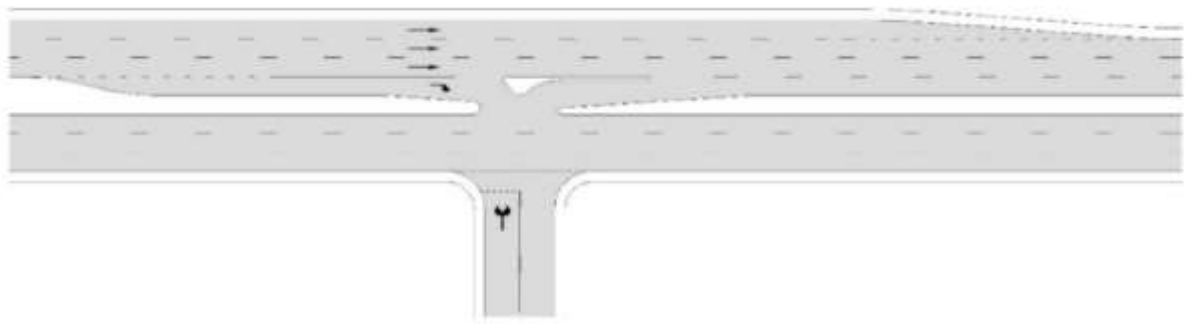
Source: Austroads Guide to Traffic Management, Part 6

9.4.4.6 Seagull

A seagull treatment is a similar design to the two stage crossing but provides for additional support for right turning movements. This may be more appropriate for designs with more than two through lanes, but is not encouraged as a delivery solution due to safety matters and prospective conflicts within the intersection itself. The seagull design represents a T-intersection design with extended merge/ taper or additional lanes on the departure of the major arm. In all cases a seagull design should be modelled to explore delays and queue lengths within the context of the design volumes and suggested gaps for turning traffic. However, modellers will need to consider the arrival patterns of traffic on approach of the through movements to correctly represent the gaps taken by drivers in the conflicting movement.

The design for a seagull treatment has generally not encouraged due to the limited capability to manage higher volumes of traffic and the safety concerns for conflicting movements. This provides a limited life for the delivery of seagull designs, which need to be addressed by exploring the future horizon demand estimates for each location. However, the design may be suitable where there is a significant traffic generator at the stem of the T-intersection. In principle a roundabout can provide the same balance of flows with improved safety performance and longevity in design.

Figure 35: Seagull treatment



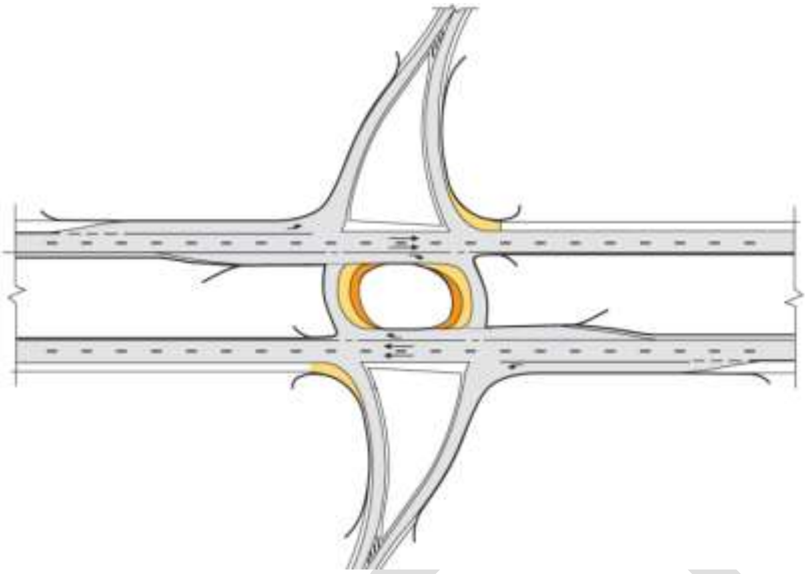
Source: Austroads Guide to Traffic Management, Part 6

9.4.4.7 Wide Median Treatment (WMT)

The delivery of a wide median treatment is s suitable design that can be applied on high-speed rural roads to control speed of crossing traffic into and out from the cross roads. Under such conditions the designs operate as a two fold set of two stage crossings, albeit with four crossing points. The design itself has the appearance of an extended roundabout but with priority for the journeys on the major roads. A wide median treatment requires a form of divided road and is commonly associated with traffic entering or leaving a high speed environment. Wide Median Treatments should not be applied along a corridor when interwoven with larger format roundabouts as this will create confusion amongst drivers.

Delivery and investigation of wide median treatments will always need to be modelled for design acceptance. However, due to the complicated nature of four prospective movements impacting on each other an analytical modelling solution may not be an appropriate methodology to advise on design requirements. Rather, a micro-simulation modelling methodology would be a more appropriate methodology to determine opportunities for gaps and queue storage requirements.

Figure 36: Wide median treatment



Source: Austroads Guide to Traffic Management, Part 6

9.4.5 Roundabouts

At major arterial road intersections with medium and high volumes, either traffic signals or roundabouts are likely to be the most appropriate treatment. Roundabouts work effectively by circulating all approaches concurrently based on the individuals gaps that drivers identify. Roundabouts provide a more cost effective solution than traffic signals in the short to medium term, but just as per other unsignalised intersections have difficulty handling higher volumes of throughput. This is associated with the gap acceptance (behavioural) requirements for drivers entering the controller, on response to the distribution of journeys circulating within the intersection.

Roundabouts are designed and produced with a variety of dimensions, including characteristics of the number of approaches, number of circulating lanes and scale of turn radius (circumference lengths). These components all contribute to the performance of the controller, within the context of the pattern of journeys using the intersection. The geometry design of the roundabout will have an impact on the speeds that traffic circulates. Within urban areas the design of roundabouts on arterial roads may involve two lanes for circulating traffic. However, there are locations with three lanes of circulating journeys. Sites in suburban roads may be limited to a singular lane for circulating traffic, albeit this is based on the demand volumes and pattern of movements.

All roundabouts should have modelling tasks conducted to assist with the design and value of the investment. This pursuit will provide more attention to storage requirements and for pocket lengths to deliver the new or revised solution. The analysis will also provide insights into the potential delays experienced by users as well as the operating metrics of the controller system.

Roundabouts typically have a reduced per vehicle or person delay than signalised controllers achieve. The average vehicle delay at the intersection and the approach is often a nominal value. However, as roundabouts movements are derived using gap acceptance criteria, a subtle change in demand can produce a significant difference in performance result. Notably a reduced number of acceptable gaps can exponentially extend a queue. For this reason, designs of roundabouts are encouraged to explore more wok in model calibration (empirical accepted gaps) and sensitivity of modelled results (increased demand for the controller).

The opportunity to utilise the available gaps created from circulating traffic in a roundabout is not just a function of the geometry design or the volume forecast, but also of the traffic composition from the demand estimation process. An increased critical gap is often required by drivers on approach where the conflict may be with a heavy goods vehicle. Therefore, under new designs or revisions to an existing roundabout special care should be made to account for the traffic composition. Under such an exploration it is not appropriate to simply extract demand from a future horizon. Care needs to be provided to determine the heavy vehicle split at the roundabout. This is a function of both the route and the surrounding land uses that may serve as generators for movements of heavy goods vehicles.

Option exploration for existing roundabouts in urban landscapes may often consider metering within project scope. Use of metering signals part time (in peak periods) are often viewed as an effective way to address excessive queuing and congestion at approaches affected by highly directional flows, albeit at the expense of one movement. Note that it may be that only the dominant movements that require signalisation as the activation will then create the gaps for traffic to access the intersection from other approaches. Subject to the pattern of demand in the landscape, it may be that different approaches are metered at different times of the day. Metering of all approaches at the same time is not encouraged as this can increase both the delays of users and the prospective conflicts within the controller. Note that the dominant movement may not be the approach with the highest demand volume, but that which restricts the formation of gaps for queued traffic.

Modern design considerations for roundabouts on higher speed regional roads will involve a bend on the approach to calm the traffic speeds approaching the for circulating movements. This may reduce the prospective number of crashes that occur within the conflict points of the intersection. Within urban areas provision for cyclist and pedestrian movements is often accounted for within roundabouts on secondary and collector roads.

Roundabouts operate well in localised settings as a means to manage balanced flow conditions. However, they are less effective when investigating corridor performance where co-ordination of flows is an important consideration along a route. Under such conditions a signalised controller might be a more effective means to explore corridor operational pursuits. For this reason, the development of roundabout should be modelled as a multi-intersection solution when signalised intersections are within 100m from the controller.

Designs that explore multi-lane roundabouts in high pedestrian and cyclist activity areas should ensure that solutions examine operations with a signalised controller. This may mitigate the prospective number of conflicts for more vulnerable road users than anticipated from a roundabout design. Investigations should also explore the significant of network planning considerations when developing roundabouts so that access to selected streets are not restricted. Although this may not be a focus of the investigation, it may be that the proposed roundabout design does not provide enough gaps for traffic from the side roads, inhibiting accessibility.

In amongst the geometric considerations to be conducted in developing a roundabout, it is a requirement that the geometric design is to be in accordance with the Department of Transport's existing documentation: Supplement to AGRD Part 4B – Roundabouts

An extensive forecast queue of traffic is likely to encourage consideration for delivery of a signalised controller at the location. This may subsequently increase the capital and operational costs but alleviate the user experiences from an extensive delays to access the intersection. Analysis of roundabouts should not simply be limited to average conditions but provide reporting of individual approaches to the intersection.

Table 35: Option Modelling review checklist

Review Area	***Details***	***Yes***	***No***	***N/A***
Option investigation (conformity)	Saturation flow, cruise speeds, gap acceptance and network extents are consistent across base and options models.	☐	☐	☐
Option investigation (future years)	Strategic model outputs adjusted to create new volume sets rather than being directly included	☐	☐	☐
	If using historical counts, whether historical growth is a reasonable predictor of future growth has been considered.	☐	☐	☐
	Manual trip estimation uses an appropriate future horizon to capture growth (particularly for staged growth).	☐	☐	☐
Option investigation (physical changes)	If auxiliary lanes are the only change being proposed, appropriateness of modelling has been considered	☐	☐	☐
Option investigation (control changes)	Appropriate control options have been determined through a holistic process, not on modelling outputs alone.	☐	☐	☐
	Key traffic management considerations have been reviewed for options under investigation	☐	☐	☐
Option investigation (traffic signals)	Right turn controls are appropriate (filter, partially/fully controlled)	☐	☐	☐
	Flexible phasing is implemented (can run in diamond phasing or split phasing if required)	☐	☐	☐
	Number of phases minimised to reduce lost time	☐	☐	☐
	Early cut offs and late starts included if required	☐	☐	☐
	Yellow and all red times appropriate for vehicle approach speeds and intersection geometry	☐	☐	☐
	Pedestrian timings reflective of how the signals would be configured in practice	☐	☐	☐
	SCATS subsystem cycle time applied, and intersections cycle time is between 80-120s unless otherwise documented and discussed with Department of Transport to develop another viable delivery option	☐	☐	☐
	If an existing isolated signalised intersection is within 500m, option of operating these intersections as a new subsystem has been considered	☐	☐	☐
	Has blocking back been addressed	☐	☐	☐

10. Evaluation

The project investigation will require a number of performance metrics to give direction of the suitability of the prospective design and operation of the landscape. In order to ensure that the narrative that is progressed forward is appropriate, a multitude of performance metrics need to be extracted from the modelling work. This process allows for comparison of a base model, and can showcase the benefit and limitations of the varied scales of investment suggested from the analysis.

The primary indicators of the intersection performances are as follows:

- User experiences (intersection level of service)
- Value of the investment (intersection utilisation)
- Unsatisfied journey conditions (queue lengths)
- Network context (journey times)

In most circumstances it is expected that the reporting of the intersection analysis can provide tabular summaries for the following analytical components:

- The intersection as a controller
- The individual approaches to the controller.
- The individual lanes and movements of the approach

It is important to remember that the options exploration cannot be benchmarked to explore the impacts of the change if the base year measure is not validated and adjusted for seasonality variations. Oversight on base model calibration may lead to misconstrued direction about the scale of investment, which is the reason for ensuring that the modelling challenge can at least present the observed conditions through empirical measurements.

10.1.1 Intersection performance

The evaluation of the user experiences at the intersection provides a framework to comprehend the investment made to manage journeys at a location or within a network. This evaluation can be explored through a number of indicators but is converted into a qualitative manner that can assist all stakeholders to comprehend the delivery solution. This qualitative measure is referred to as a Level of Service and can be derived through a number of performance metrics.

Note that the Level of Service term is a reference to explain a quality measure for a condition or experience. The process to conduct and evaluate the performance metrics of an intersection may use common language but consider different indicators to similar processes such as the “Movement and Place” framework. This structure has a different set of thresholds and targets subject to the hierarchy of the road network. Although the terms used a common, the analysis and reporting should not be confused or misrepresented.

Intersections are commonly evaluated from the user experience of delay, which is the gap between the experienced and the free flow operation. That is a question to explore the period of analysis against a condition with a singular journey within the intersection. The delay calculation is a replacement for the additional effort drivers need to comprehend when at the location of investigation. The reporting of the intersection delay and the corresponding Level of Service is required for all intersection modelling to ensure that an evaluation is conducted. Delivery of delay times can be provided as an integer as decimal points are not required, unless on the fringe of a classification threshold.

The Level of Service used within Victoria for evaluation of intersections is defined from the US Highway Capacity Manual (2015). Previous editions of this document broadly share the same classification system. This definition of performance is also adopted through Austroads, albeit some states apply a different threshold for the same performance measure. Note that the Highway Capacity Manual benchmarks are explored for delivery in an evaluation of an intersection.

The classification explains the performance of an intersection subject to the user opportunities and the infrastructure (capital and operational) provided at the location. A total of six measures are defined in a qualitative manner to explain the condition experienced. In simple terms, a performance of an Intersection at a Level of Service A or B suggests that the intersection over provides for the existing demand (an excess of infrastructure provision) while the Level of Service F implies that demand has exceeded the available capacity of the site.

A Level of Service E condition identifies that there is little growth opportunity and that the intersection is already a congested location. A Level of Service condition of E should identify that changes to the intersection should be explored for a resolution of conditions in the short to medium term. This may imply additional capital (more lanes or extended turn storage lengths) or a revision to the operating conditions (phase sequences, green splits and/or cycle lengths). Within this context note that an operational state of a Level of Service F condition implies that means to mitigate a scheme should have already been explored and implemented where possible.

Design targets for an opening condition may aim towards an experience of a Level of Service C or D, which allows for growth and development over time. Some investment conditions require frameworks for a ten year horizon, while others allow for a longer threshold of maturity. However, future year delivery should allow for an experience that is no worse than a Level of Service E. Again, a Level of Service F means that the demand at the venue is understated to be enough of a problem that the experience is unacceptable.

The performance of intersections for the various options should be presented as a table of outputs presenting average delay and the Level of Service grade. For the purpose of this analysis, roundabouts are considered sign controlled intersections. **Table 36** presents the Levels of Service and corresponding thresholds of performance.

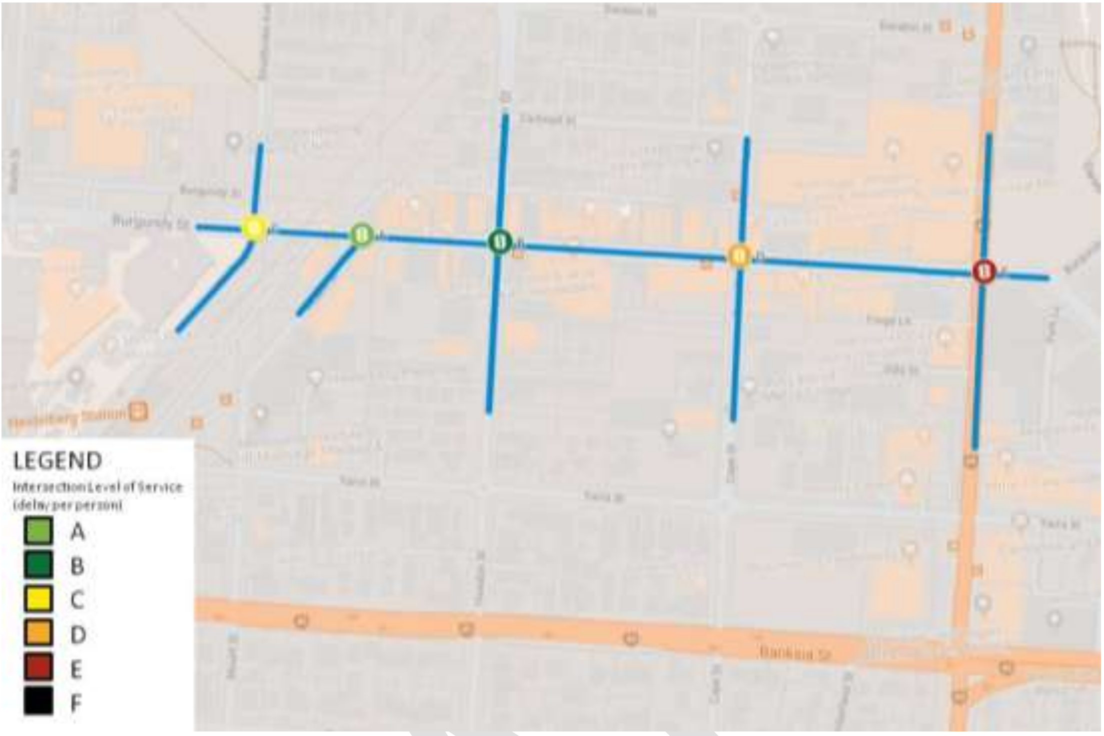
Table 36: Intersection performance measures based on per person delay

Level of Service grade	**Average delay per person (s)**	
	Signalised intersections	**Sign controlled intersections**
A	< 10	< 10
B	10 < 20	10 < 15
C	20 < 35	15 < 25
D	35 < 55	25 < 35
E	55 < 80	35 < 50
F	80 +	50 +

Movement is no longer focused on vehicle delay and should now consider person delay as the appropriate metric. Therefore, delays should be calculated as the average person delay rather than average vehicle delay. Unless otherwise determined through observations particular to the site explored, the public transport services for buses and trams should use an average occupancy of 30 people per service (or maximum capacity if smaller). Private car vehicles should use an average occupancy of 1.20 persons per vehicle for AM peak period models and 1.30 for PM peak period models. Models outside the peak periods should assume an average occupancy of 1.50 persons per vehicle. (business peaks, off peaks, weekend models). These values may differ as the vehicle mix changes through future horizons, and as the introduction of autonomous vehicles becomes more apparent.

Intersections that are modelled in a network condition (a multi-intersection model) should provide a representation within the report of level of service conditions that is easy to be interpreted by stakeholders. The expected form of delivery might be as shown in **Figure 37** whereby the intersection performance is clearly visible within the corridor investigated. Note that the visualisation of the intersections within **Figure 37** does not represent the actual delays experienced by journeys within these locations but is used to convey an outline for this document.

Figure 37: Diagrammatic Level of Service within a multi-intersection model



The network map has been developed through a Google Maps function and presented with label descriptions to outline the suggested performance of the controller. The colour scheme adopted through this process is outlined by the colour systems listed within **Table 37**. Note that this provides a demonstration of colouring for delivery of a user experience. However, the limited colours on option within this format identify that the RGB settings applied are subject to change. A video on the means to create personalised displays within Google maps can be viewed here: https://youtu.be/fLhyr5MGi2g

Table 37: Example Level of Service Reporting Display Formats

Level of Service	***Applied RGB values***	***Display Shade***
A	124 / 179 /66	
B	9 / 113 / 56	
C	255 / 234 / 0	
D	249 / 168 / 37	
E	255 / 0 / 0	
F	0 / 0 / 0	

Delivery of intersection performance as a measure of person delay should not be limited to the controller. Investigations are required to report performance of the intersection in more disaggregate measures to explain the components that produced the indicators. That is, teams should additionally explore delivery of the same style of performance metrics for the following elements:

- Approaches of the intersection/s
- Turns of the intersection/s
- Movements of the intersection/s

An example condition to outline the reporting of level of service for intersections is provided within **Table 38**. This layout showcases both a delay figure for the intersection and the Level of Service classification, which is also presented by a shaded cell colour. Note that the reporting includes the seasonally adjusted model of the base year which is used to determine a benchmark of design against future year considerations. This layout is an example layout of the reporting delivery.

Table 38: Example Intersection Level of Service Reporting Table

Level of Service Result	***Horizon***	***Main Road/ Station Street***	***Main Road/ High Street***	***Main Road/ Centre Street***
Validated Model	Base Model	41 (D)	34 (C)	48 (D)
Seasonally Adjusted Model		51 (D)	50 (D)	57 (E)
Do Nothing Model	Future Horizon 1	83 (F)	78 (E)	82 (F)
Do Minimum Model		79 (E)	73 (E)	78 (E)
Project Model		71 (E)	70 (E)	76 (E)
Project Model with Mitigation		66 (E)	67 (E)	72 (E)
Project Model with Sensitivity		69 (E)	70 (E)	76 (E)

Similar could also be produced for a Level of Service tabulation and display for both approaches to the intersection as well as turn movements at the intersection.

When evaluating a modelled result, it is important to understand that delays do not need to be balanced between movements and that there is value in the operation to give priority to selected movements. For non-prioritised movements, the maximum acceptable delay should be considered. This maximum acceptable delay will vary between locations and movements. Local access movements are likely to have higher maximum acceptable delays than collector streets, which in turn are likely to have higher delays than movements on the arterial road network.

An absolute delay of 120 seconds should not be exceeded for movements out from local streets. Pedestrian wait times to cross an intersection should never exceed 180 seconds. However, in both instances the average condition expected as part of a design and investment should produce a metric less than these values.

10.1.2 Intersection utilisation

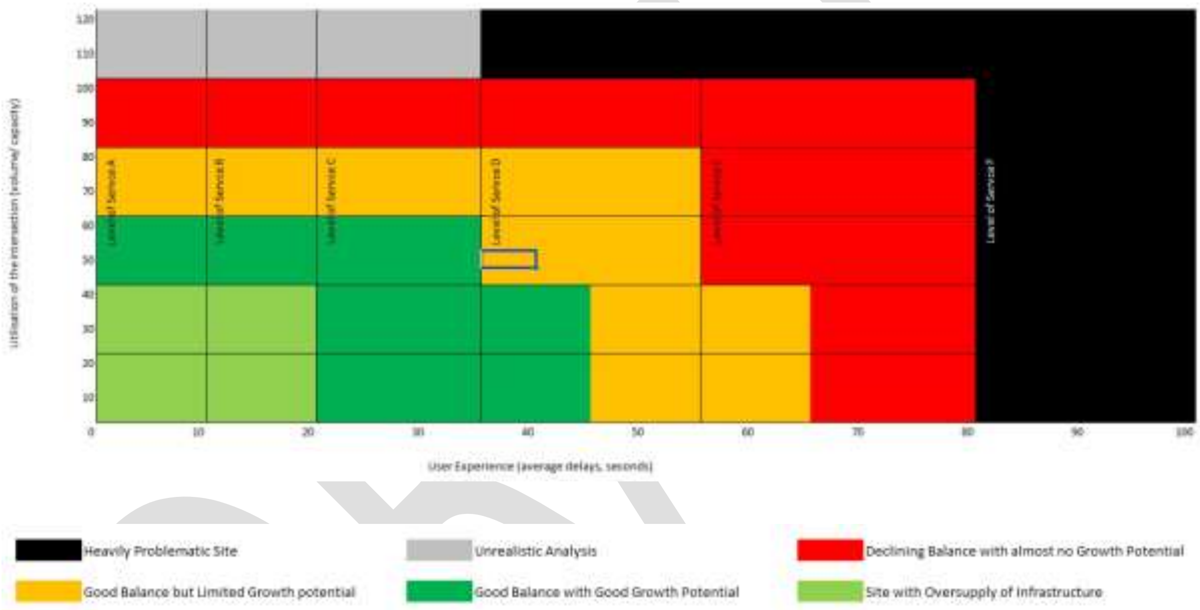
The utilisation of the intersection represents the scale to which the infrastructure is applied, subject to the pattern of demand and the allocated green time. Signalised intersections operate to change green times on a cycle by cycle basis in order to better balance the requirements of the traffic movements. This is the general application of the SCATS system, for isolated intersections and (to a less extent) for co-ordinated signal controllers.

The utilisation of the condition of the intersection is a calculation of the volume divided by the available capacity and is referred to as the degree of saturation. For signalised locations this represents the average of conditions for the operation. However, at unsignalised intersections that figure represents the movement with the highest volume to capacity calculation. Under such conditions the average vehicle delays of a roundabout or sign controlled solution might be low, but can still deliver a very high scale of utilisation (saturation).

The degree of saturation is typically represented as a two decimal figure (e.g. 0.65) or as an equivalent percentage number. Note that values can be achieved above 100% when exploring demand rather than just the throughput of demand. The condition of metropolitan locations along arterial and subarterial roads should consider the movement of the intended movements rather than just the actual throughput. Note that any figure above 80% utilisation does suggest that the intersection has a scale of congestion that requires attention, even if the intersection performance is a Level of Service A or B. This simply states that there is limited spare capacity for growth or change, which may actually be oversights in the traffic analysis (data collection, modelling assumptions, saturation flow) etc. This is a different suggestion than a well designed and comfortable intersection design, but an outline for further consideration within the network performance. This metric further assists with that of the user experience metric to develop a narrative of the intersections explored for the investigation.

This relationship between the utilisation of the intersection and the user experience is conceptually outlined within **Figure 38**. The image presents a situation that suggests that one than a single metric should be used to explain conditions of the intersection or multi-intersection landscape. From a network operations and delivery perspective it should therefore be views that any intersection with a utilisation of 80% or more should not simply be viewed as an uninterrupted delivery, but a prospective site for monitoring (and greater variation) over time.

Figure 38: Concept relationship between User Experience and Intersection Utilisation



The Intersection utilisation targets from the VicRoads supplement to Austroads Guide to Traffic Management, Part 03 are specified in **Table 36** and are outlined for both maximum and desirable settings for the delivery of intersections within the landscape analysed. Note that this analysis is based on suitable calibration (Section 7) and model validation (Section 8) with those attributes brought forward into the analysis of the future horizon. It is expected that the same measure to calculate signal operations is applied, rather than separate methodologies for individual time periods.

Table 39: Intersection utilisation targets

	Intersection Utilisation	
	Signalised intersections	**Sign controlled intersections**
Desirable	0.90	0.80
Maximum	0.95	0.85

While the above are prescribed maximum thresholds, the utilisation of available capacity for future growth should also be considered. In particular, the available spare capacity of intersections within greenfield locations should be explored to account for the scale of surrounding development in subsequent years.

It is expected that base and future horizons will be reported for a degree of saturation for options explored with the investigation. This includes for base model, and future options for Do Nothing, Do Minimum and Do Something solutions. Reporting and presentation of the degree of saturation should be provided for the following intersection components:

- Intersection
- Approaches
- Turn movements
- Land conditions

This material might be provided in separate tables or amalgamated into a single table for different movements. Please ensure that all intersections within the investigation and presented within the reporting of utilisation metrics. Multi-intersection modelling should ensure that there are not gaps within the narrative of the delivery.

10.1.3 Intersection queue lengths

The queue lengths produced from the intersection models should be provided within the reporting conducted for the investigation. Queue length is an important metric to present as a means to understand the operation and complexity of the movement of traffic. The report should provide a tabular and diagrammatic representation of the 95th percentile back of queue lengths. This should be provided as a delivery in metres rather than in vehicle lengths due to the stochastic length of vehicles within the traffic composition using the road network.

The graphical delivery of queue lengths is an important component to showcase to stakeholders, as this measure also assists in discussing the user experiences. Queue lengths can be determined in a mapped format as outlined within **Figure 39**. Although this display represents the queue on the approach, additional metrics should be provided within the reporting so that queue lengths for individual turn movements are reported upon. The back of queue for at least one of these movements should be able to match the length of the queue on the approach.

Figure 39: Example Presentation of Modelled Queue Length (95th percentile back of queue)

An important element within the reporting of queue lengths is ensure that the queue lengths are not longer than the distances between the two controllers. If the queue lengths required are longer than the available space, then the upstream saturation flow should be adjusted to account of the reduced opportunity for the traffic to flow.

The presentation of queue lengths also has the benefit to identify deficiencies in the options explored where demand volumes may not be accommodated suitably within turn lane storage. Under such arrangements the queue length should not exceed 90% of the right turn storage space, upon fear of this overflow from the pocket interrupting the through movement of traffic. Under such conditions where the back of queue exceeds this threshold, the project investigation may need to further model the proposed traffic operations through the use of a micro-simulation solution.

10.1.4 Network performance

The performance of a corridor within a multi-intersection landscape can be explored as a function of the journey times required to traverse the roads. This might be a discounted measure of conditions against the free flow speed (which is not simply defined as the signposted speed).

Analysis of journey speeds along specified corridors should be explored by considering the journey conditions (times and speeds) between each intersection. The corridors (or routes) to be evaluated should include both directions of travel along full length of the road network in the model.

The results of this analysis should be presented in tabulated and graphical form for the base model and options explored. The modelled results should be presented in an “mm:ss” format rather than as an integer of seconds, as this provides for easier interpretation by stakeholders.

Graphical delivery of the journey times along the corridors should be presented in line with the distance plots used for the base models. This process should include key waypoints within the delivery of the journeys so that stakeholders can comprehend the experiences of the end users. This may involve a better outline of those intersections with grater delays than against other locations or options explored. Under conditions that provide notably different operating conditions the journey time graphics can be bought together. However please ensure that the different options or horizons can be clearly differentiated through either different colours or line display formats. A quality assurance process should be conducted so that fresh eyes can identify the different schemes within the same graphic.

10.1.5 Sensitivity testing

The estimation of demand for a future horizon (Section 9.3) is one of the most important aspects of the investigation of options. This process can outline the severity of impact from a notional change in inputs or conditions of the intersection models, in particular as an element that is separate to the estimation of demand volumes. A subtle change in volumes for circulating movements on a roundabout can have a significant impact on gaps for traffic to enter the intersection, which may produce an exorbitant queue length. Similarly, the repositioning of a new collector road to a land use development may have an impact on the turning movements, storage requirements and signal operations for a signalised controller.

Overall it is a challenge to have an assurance about assumptions pertaining to the future year conditions of network operations. As demand volumes are always a prospective estimate from a strategic delivery, the scale of assurance is always worthy of a review. To manage the risk associated with this uncertainty it is necessary to undertake sensitivity testing using the estimated demand volumes.

As a minimum consideration, it is expected that an additional demand element to be used in sensitivity testing are as follows:

- ±5% Established inner-urban areas (Infrastructure design and operations)
- ±10% Greenfield sites, brownfield development and PSP areas (Infrastructure design and operations)
- ±20% Temporary arrangements (Construction staging potentially with traffic dispersion)

The value of this work is

The value of sensitivity analysis within the modelling of intersections provides two key areas of value:

- To determine the scale of risk associated with the demand estimates provided. Sensitivity analysis provides a scale of impact (nominal, mild, significant, critical) should demand estimates vary from the original figures.
- To assist in direction for mitigation solutions. Sensitivity analysis is an important framework for exploring means to extend the life of the intersection design. A few quick wins may produce a favourable delivery that can extend the value of the investment and potentially be used against other trade offs (i.e. may direct value for investment as a development contribution).

The reporting should provide equivalent summary table within the report, with modelled outputs in an appendix. The table and the accompanying appendix should identify the following key considerations:

- Outline of turn volumes applied
- Level of service by intersection, approach and turns
- Utilisation of the intersection, the approach and the turns
- Queue lengths by intersection, approach and turns

Practitioners are advised to contact the Department of Transport if they are uncertain about the appropriate percentage of demand to adjust to model as a sensitivity check.

10.1.6 Economic analysis

The use of transport modelling for economic analysis is not specifically covered by this guide. However, it is important to note that the vehicle demand volumes used in the base, future and options investigations are not generally the same used in economic analysis as per intersection design. In particular the use of traffic demand volumes associated with the 30th busiest day of the year are unlikely to be representative for economic evaluation purposes (but essential for design purposes).

Additionally, models developed for other time periods (interpeak, shoulder peak etc) may also be necessary for economic evaluation. Practitioners would typically be required to develop representative models for off-peak and inter-peak periods. Failure to include intersection performance metrics for these other periods may produce a more favoured solution for options delivery outside of peak periods.

11. Reporting and presentation

11.1 Context and structure

A modelling report brings together all the pieces discussed in this document into one area as a written measure of the work of the investigation conducted. This is the measure that will be used for guidance of the pursuit once the project is closed and the staff have moved to new pursuits or employment (from either side of the investigation). The report is a document that the Department of Transport needs as a confirmation that the investment in infrastructure is explored and accounted for through appropriate processes, data management and analysis. This not only pertains to internal work processes, but also for any Freedom of Information requests that are raised on the topic at hand.

The modelling report should be developed for the entire modelling investigation which includes:

- Development – data collection and 'base model' calibration and validation process(es) and performance benchmarks; and
- Analysis - option testing.

If reporting is provided at separate stages of the investigation, then it is expected that the documentation progresses (and is written/rewritten in context) so that the entire pursuit can be read as a single report. This process identifies that if a report is developed for the base model then the report should be written (or adapted) as an opening chapter into a comprehensive options report.

The modelling report should suitably provide a narrative to tell the three key matters of:

- Story of the problem (narrative);
- The reporting metrics of that issue (benchmarks) and
- The means to address the query (resolution).
- Means to an assurance (sensitivities)

A modelling report should not be required to further be re-interpreted for a delivery manager or for public consideration. This also means limiting the use of technical jargon and ambiguous wording or phrases. Statements should be able to be read in the context in which they were written and intended. Teams might consider the development of an appropriately worded glossary that can sit within the reports delivered.

11.2 Introduction

The introduction should briefly outline the problem identification with subsequent tasks to provide context for secondary considerations within the pursuits. This means that teams should be able to provide an introduction into the modelling space that outlines the strategic background, context and intended deliveries of the pursuit. This approach should showcase to readers how and why there is need to develop a modelling task for the landscape.

It is an important task to outline where the modelling and reporting sits within the context of the investigation, despite appearing obvious to the model development team at the outset. However, modelling projects and reports can often re-appear at a later time, or may be associated with another stage of the infrastructure development (e.g. a complementing project, a transitional development, a project within an approved delivery framework). For this reason, appropriate discussion of the context needs to be provided at this stage of the report formation.

The Department of Transport requires an introduction to the project that outlines the strategic context for the investigation. This forms the building blocks in identifying the project definition and the intersection modelling development considerations. Delivery of this text needs to be more than a simple statement for delivery of business case, but needs to provide the strategic context to confirm the need for transport modelling services and methodology. This may also include changes to the prospective land uses, population, employment and enrolments to the local landscape, or outline the infrastructure plans of the nearby area. The introduction should be held from the perspective of the local community interests and outline the prospective opportunities that may arise from this delivery.

The introduction in the modelling report should outline the following (as a minimum);

1. Project scene which focuses on establishing the setting through description and imagery. This should include the following;
    - Location of the study area;
    - Existing control systems in the network i.e. roundabouts, traffic signals, ramp metering;
    - Land use i.e. industrial, schools, shopping centres, green wedges;
    - Key operations i.e. freight route, cycling corridor, growth area;
    - Key stakeholders i.e. the Department of Transport, Victorian Planning Authority, Yarra Trams etc.;
    - Known safety problems (e.g. crash history); and
    - Congestion locations through available data (i.e. schematic of observed speeds or observations of performance.
2. Project problem definitions and explain with available statistics and imagery (including photographs of observations).
3. Project key performance indicators i.e. project and/or government commitments
4. Strategic context (setting for planning and growth in the area i.e. growth area or established area) and suggested responses that are being considered. Also consider the following;
    - Project scene if there is no change (a "Do-Nothing" or "Do Minimum" approach) by exploring what the VITM strategic model suggests may be forthcoming in the area within a minimum of at least ten years post construction. However some investigations will need to explore infrastructure provision and planning for a longer timeframe than this requirement e.g. roundabouts hold a life for twenty years. Longer timeframes are particularly important for growth areas and along arterial road corridors that service expansion venues.
    - The Department of Transport outlook in the area i.e. expected increase in traffic, journey time, land use shift. This is essential for study locations in growth areas.
5. Preliminary analysis undertaken that identified the impetus to conduct modelling

11.3 Objectives

The development considerations of the modelling that align to the project definition need to be determined before the data collection, calibration and validation are undertaken. The model that is developed for the investigation is often referred to as the "base model".

The project definition in the modelling report needs to explore and explain the following (as a minimum);

- Outline the primary (and any secondary) objectives of the model development;
- Respond to the strategic considerations in the project; and
- Outline the requirements of the modelling pursuit i.e. investigate potential changes in intersection control and/or demand and then investigating operational impacts.

11.4 Project considerations

There are a number of considerations that a project needs to explore and provide direction on within the development of a modelling report. This should assist readers of the report to identify the comprehensiveness of the existing landscape for the investigation and the purpose of such pursuits.

Project specific considerations should be explained within the written format of the report (the narrative to provide the appropriate reader perspective) include the following items:

- Define the scale or study area (map required) showing the location of the modelled intersection(s) in a wider context and at a local level (aerial photographs). This needs to align to the project objectives and show a meaningful approach to the investigation.
- Define the roads by name that connect to the intersections being modelled and nearby roads that may impact on performance (e.g. local street intersections on the approach to the intersection(s) being modelled. The inclusion of roads in multi-intersection models will need to be evaluated on the number of journeys represented i.e. consider a volume threshold of 50 vehicles per hour but consider the impact of minor roads on project objectives (map required).
- Identify future applications as part of the modelling pursuit including:
    - Current and future transport service assumptions for the area
        - Changes in land uses i.e. large scale developments produced within or nearby to the study area;
        - Changes in demand patterns i.e. inter-peak demand formation;
        - Changes in public transport services, schedules, stop locations;
        - Changes in route operations due to changes in road hierarchy; and
        - Changes in project commitments.
    - Identify the impact that these future assumptions may have on the model pursuit and question the appropriateness of the modelling methodology (type/software), including whether a multi-intersection model or micro-simulation solution should be used.
    - Design life of the project needs to be considered and its impact on the surrounding area e.g. infrastructure commitments to upgrade a nearby road in the next 15 years
    - Consider future options testing and how this may impact on data collection requirements and scale of analysis for the investigation i.e. changes in intersection control may change travel patterns.
- Time horizons (future years) need to be specified to appropriately accommodate future demand, including accounting for design requirements as well as regular operational challenges.
- The strategic context of the VITM reference case for ongoing network development and changing demand volumes across the landscape investigated.

11.5 Modelling framework

Modelling practitioners need to develop both the narrative of the project as well as the analytical context of the work conducted. The reporting should outline the narrative in the context of the project objectives before exploring matters of the model inputs and refinements. To complement these tasks, a thorough explanation into data collection, model calibration and validation tasks, should also be outlined within the development report.

It is important that practitioners understand that a goal of the modelling activities is to develop a calibrated and validated base model that represents the current operational plans and deliveries, before progressing to a project design. An optimised base model in itself does not outline for a quality deliverable of the base landscape.

11.6 Data collection

Data collection should be visually presented with details of the collection type, period and source provided in a table format. This approach provides the data collection narrative to the project definition developed for the project investigation.

The preferred method to present the data collection is to provide a map depicting the location of each data source and material obtained. Several image maps may need to be produced to illustrate the whole data collection process and to minimise the conflicts in presenting specific data formats (such as bus routes and travel time collection over the same landscape).

A locality plan should outline how the data collection area fits within the broader network needs to be provided as well. This provides a benchmark for proximity to adjacent intersections that might impact on the investigation conducted. Many readily available mapping tools and online applications are available to meet this requirement including free solutions such as Google Maps.

If the survey was conducted on different dates, it is advised to colour code or develop symbols to showcase the survey date for each site.

11.7 Calibration

The calibration section of the modelling report should present all relevant input data and include a history of the base model development. This section of the report should focus on presenting the model inputs and detailing how the model was developed to ensure a match to the existing conditions.

The calibration section of the report should outline to the reader:

- Details of all SCATS site numbers included in the model, including a discussion detailing any operational relationships with the surrounding network.
- Concise note on site observations, measurements and surveys including both physical attributes and observed driver behaviour.
- A table of the saturation flows used at the intersection and a commentary as to how these were measured/calculated.
- The effective lane lengths used and a discussion where these have been varied from the marked lanes
- A discussion on where a lane configuration has been adopted that differs from that marked.
- The lane utilisation used in the model compared to measured queues or volumes.
- Details of the traffic volumes used, including their source and the seasonal adjustments applied.
- An explanation into the means to determine the peak periods
- Phase and cycle times used as well as the phase sequencing within the model. The report should outline how these measures were determined, including a discussion on signal coding for adaptive solutions. Related matters such as adjustments to take into account pedestrian demand should also be addressed.
- Behavioural observations in relation to gap acceptance, exit-block, parking/loading and public transport.
- Details that outline the model scope (single or multi-intersection model pursuit, and the extent for model inclusion).

11.8 Validation

The validation section of the modelling report should demonstrate how the model compares to existing conditions. Practitioners should detail the validation process, surveys undertaken and any subsequent adjustments to the models.

Any changes to the model inputs or adjustments to parameters in the model software should be documented. The comparison between the validated parameters and observed data should be tabulated and provided within the narrative.

Queue lengths should be reported for all models and travel times should be explored for multi-intersection models. These results should be provided in both tabular and diagrammatic formats.

11.9 Option investigation

The options investigation section of the report must provide a description of the options pursued, covering all aspects of the design and operational considerations. This section needs to also outline the expected scale of impacts from the delivery of the pursuit (including changes in demand volumes). The modifications to the seasonally adjusted model to develop the options model should be based on the changes resulting from the options. This section of the report should include adequate commentary by the modelling practitioner in relation to what components have been changed from the existing landscape in order to deliver the prospective solution.

The options investigation section of the report should include:

- Summary of options;

- Problem definition and option objectives;
- Modelling assumptions and changes to the validated base model;
- Results of the various options being modelled;
- Discussion of alternative schemes considered or investigated; and
- Recommendations and conclusions arising from the options investigation.

It is essential that the practitioner include a clear description of the option being recommended and the criteria used to inform the listed advice.

11.10 Sensitivity and future year testing

The results from the future year horizon and variation to selected parameters (sensitivity testing) should be presented and discussed in the modelling report, with outputs tabulated in line with the options investigation.

The performance of the existing intersection in future years should be examined and discussed, including any changes to cycle and phase times that may be necessitated to accommodate future demand. The implications of these signal operation changes should be discussed in the report. However, it is expected that suggested changes to complex operations or sensitive locations have been raised as a matter for the signal teams whom operate the area prior to delivery of the report.

The robustness of the recommended option should also be discussed, with the impact of additional demand volumes beyond the future year design requirement reported.

11.11 Single intersection model outputs

The reporting of intersections for design and operational matters requires analysis of several metrics as a means to develop a well structured narrative of the prospective changes. These measures aim to determine the impact on the road user and the relative scale of performance at the intersection. The key intersection performance metrics that should be reported for the base model, seasonally adjusted model, project options models and sensitivity testing are as follows:

- User Experiences (Level of Service and delay) by intersection, approach and turn;
- Utilisation (Degree of Saturation) by lane, approach and intersection;
- Unsatisfied Journey Conditions (95^{th} percentile back of queue lengths by lane);
- Storage conditions for turning movements (back of queue for storage lanes)
- Operational deliveries (Cycle times, phase sequence and phase times).

Where the model outputs indicate any performance anomalies, such as lane underutilisation, lane blocking, capacity reduction or other issues, these should be discussed in the modelling report.

Copies of the outputs from the modelling software should be included in the appendices to the report. The performance metrics of these results should also be tabulated in the body of the report to allow for ease of comparison between the current and prospective operating conditions. A diagrammatic or mapped visualisation of the likely conditions should also be presented within the scope of the analysis.

11.12 Multi-intersection model outputs

For each multi-intersection model, outputs for every intersection included in the model should be reported. In addition to the required conditions to be documented for each intersection location, the following network performance metrics are expected for delivery:

- Journey times and average travel speeds along the routes used for validation of the base model (Section 8.5);
- Traffic signal offset times between intersections (for each direction and peak interval explored);
- Signalised intersection operating conditions of cycle times, phase sequences and times; and

In line with the required conditions for single intersection model outputs, the key performance metrics should be compared in a tabular form in the report. Where available visualisations of performance indicators should also be provided. Time-distance diagrams for signal operations along a route should also be provided to showcase the likely cycle times and corresponding offset times between controllers.

11.13 Advisory Comments

As a professional investigation to explore changes to the road and the transport network, it is expected that enough material is provided within the reporting to determine the most suitable delivery framework. This is not simply a matter for clear recommendations by parties and stakeholders involved with immediate access to presentations, but be provided in commentary so that Freedom of Information requests can process this material in the same manner. For this reason, documents need to be written so that they can be read and interpreted by persons from a third party. It is not appropriate to suggest that the reporting will be accompanied by a verbal narrative on site.

Advice provided through a report will need to outline a suggested delivery solution from the options tested within a report. The delivery report cannot provide direction that a solution not explored within the investigation is the preferred scheme for implementation. Statements made to suggest that the appropriate course of action was not explored within the professional service will simply delay the delivery timeframes.

11.14 Delivery of electronic files

Electronic copies of the model data (including all input and output files) should be supplied with the corresponding report. The report should also outline the release version of the software used within the analysis. Candidate or beta releases are strongly discouraged so that professional product releases are used for developing conditions of the landscape.

The structure of the files should be apparent to someone else other than the practitioner who developed them. In particular, care should be applied when naming intersections and multi-intersection combinations in the electronic file. The intersection or network name should reflect the location being modelled, the period, the horizon (current or future year) or sensitivity test, and the option being investigated. The inclusion of street names within appropriate labels are strongly encouraged.

For clarity, all intersection or network models not referenced within the report should be removed from the electronic files. Teams are welcomed to maintain tests or sensitivities undertaken within the delivery files provided that all of the variations (models and changes) are documented in both the files and the report. This selection of changes might be listed in an appendix to the report.

11.15 Images and Diagrams

All maps, figures, charts and tables should be labelled and referenced within the text of the report. It is expected that this visual and tabular content provided is delivered with accompanying text to explain the value of this material included within the report. Materials provided should not just be left to the reader to interpret the results but should receive accompanying text to explain the significance of the content.

Maps and designs that are included within the report should have a north arrow included and clearly visible, so that all stakeholders can identify the context of the material. This can be of significance when stakeholders attend a workshop or session for which the modeller and project team are already very familiar with the images to be presented.

A part of the quality assurance process should involve a manual review of the cross references to tables and charts within a report to ensure that the correct measures are represented. It is not uncommon that reports which are subsequently updated after edits do not involve an update to the cross references. This will produce the need for another issue of the report, or in more particular circumstances, confuse stakeholders and reduce the overall reliance of the statements made within the analysis and reporting.

Table 40: Model Reporting review checklist

Review Area	*Details*	*Yes*	*No*	*N/A*
Reporting	Modelling report includes all discussion of all the items above	☐	☐	☐
	Clear narrative to the investigations	☐	☐	☐
	The modelling report clearly outlines the context, benchmarks and resolution to the investigation	☐	☐	☐
	Data collection methods explained, and data description provided	☐	☐	☐
	Strategic changes in future years discussed	☐	☐	☐
	Clear recommendations are provided	☐	☐	☐
	Appropriate model outputs are included in the report and/or appendices	☐	☐	☐
	Peer review undertaken	☐	☐	☐
	Electronic files are made available and do not include models not discussed in the report	☐	☐	☐
	Electronic files include intuitive names and structures	☐	☐	☐

12. Quality Assurance (QA)

12.1 Introduction

Quality Assurance is often an overlooked area of intersection and network modelling but is a very important element to ensure that projects are not delayed from oversights in the analysis conducted. Practitioners need to warrant that appropriate reviews and checks are conducted in order to ensure the Department of Transport is in a position to approve the findings from the modelling investigations. This should ensure that the debatable content is not provided within the modelling report, nor for the data analysis or collection or model development tasks.

The means to deliver a solution with adequate quality assurance processes in place should result in improved outcomes and minimal rework requirements. Providing a quality delivery should also reduce the risk of a design with an insufficient carrying capacity for traffic reaching a state of detailed design for implementation by projects.

12.2 Roles and responsibilities

At project commencement a detailed review process for intersection models should be established. Roles include:

- Client
- Contractor modeller
- Reviewer (separate to quality assurance)
- Department of Transport review

12.2.1 Client

It is the client's responsibility to allocate sufficient budget and time for the consultant to undertake the modelling activities in accordance with these guidelines. Allocation of insufficient budget or the exclusion of specific tasks necessary to address the tasks included in these guidelines may result in modelling and a modelling report that does not meet the Department of Transport requirements. This may lead to rework, exacerbated delays and ultimately lead to higher costs.

It is also the client's responsibility to ensure that the consultant is adequately briefed about the nature of the proposal or development. This could include constraints on the design (e.g. land availability), anticipated future development and development staging.

The client should also ensure that the consultant undertakes internal quality assurance checks as outlined in these guidelines.

12.2.2 Contractor

The contractor needs to ensure that all models have been developed in accordance with these guidelines. It is not appropriate to deliver from alternate guidelines from other states or nations that are not involved within the Department of Transport's responsibilities.

The modelling report and all models submitted to the Department of Transport for review must also be set up in a logical and consistent manner. This includes appropriately named sites, street names, descriptions including identifying the peak period, time, year, and scenario the model represents. The provision of clear and organised outputs will assist the Department's review process and may enable an efficient evaluation. Models should be developed so that they make sense when measured against more than one criteria.

The contractors involved will also need to ensure all models and the developed report have undergone internal quality assurance checks by a suitably qualified person. This might be a person whom has not been involved in the development of the model but has experience in designing and analysing intersection operations. This may involve more than just an experienced transport professional or a registered engineer. This intent is not to give notional attention as an additional chargeable task, but to ensure that the elements for review are aligned as required within this document. This review should be to produce solutions that reduce the delays in collaborating in steps forward. The Department of Transport expects that a modelling submission holds all delivery components rather than a piecemeal (progress) report. Incomplete reports with a nominal or limited analysis and narrative are unlikely to receive support until the tasks are completed.

Furthermore, a review may not commence until all materials are provided from the developer, supplier or consultant. This may significantly extend review timeframes from initial perceptions by other stakeholders.

Reporting documents should be provided with nominal jargon within the narrative. However, teams might consider the development of a glossary that can sit within the reports delivered. This glossary might be enhanced and applied for all subsequent reports submitted as a standard appendix to their professional services.

The review needs to ensure that input data is consistent and that the model can reproduce the outputs that are documented in the modelling report with valid parameter definition. This requirement should be produced in line with the guidance outlined within this document.

12.2.3 Department of Transport

It is the Department of Transport's responsibility to ensure that a review of modelling work conducted is undertaken in a timely manner. However, the timeframes for consent matters can only pertain to the delivery of a calibrated and validated base model whereby the options considered are documented appropriately.

The Department of Transport cannot be in a position to review an incomplete document where quality assurance controls have not been managed. Feedback to the consultant should be clear and concise.

Table 41: Overall modelling review checklist

Review Area	*Details*	*Yes*	*No*	*N/A*
Modelling software package and version	Modelling software package used for the development of the model and the applicable version specified (review should be conducted using the same version).	☐	☐	☐
Model extent	Model extents sufficient to incorporate all intersections impacted by downstream conditions	☐	☐	☐
	Base Model has been developed	☐	☐	☐
	Models do not include more than ten intersections	☐	☐	☐
	Modelling represents a contiguous landscape	☐	☐	☐
Data collection	Data is collected for appropriate intervals of analysis	☐	☐	☐
	Data is collected through appropriate techniques	☐	☐	☐
	Operational issues are documented (traffic crashes, weather, events, other disruptions)	☐	☐	☐
	Collection includes multi-modal sets	☐	☐	☐
	Behavioural data is obtained or sourced	☐	☐	☐
	Signal data identifies actual changes rather than intended operations	☐	☐	☐
	Data collected explores demand rather than just throughput	☐	☐	☐
	Back of Queue measures are identified	☐	☐	☐
	Journey time data and speeds and obtained	☐	☐	☐
	Model inputs represent the data collected	☐	☐	☐
Current operational conditions	Site visit is conducted during the peak period or interval of analysis	☐	☐	☐
	Congestion and extent of queuing observed and commented on, including any unbalanced lane utilisation	☐	☐	☐
	Interaction between modes observed and commented on (e.g. cyclist and pedestrian movements, public transport priority)	☐	☐	☐
	Observations of signal operation made (e.g. variation in signals cycle and phase timing over modelled period)	☐	☐	☐
	Variation in traffic volume and arrival pattern noted, consideration made for appropriateness of intersection modelling techniques	☐	☐	☐
Calibration	Movements accurately represented in base models, including those for all movement classes (e.g. pedestrians)	☐	☐	☐
	Existing demand volumes accurately represented	☐	☐	☐
	Peak periods appropriately identified	☐	☐	☐
	Peak flow periods and peak flow factors identified and included in models.	☐	☐	☐

	Saturation flows appropriately estimated, software defaults not used	☐	☐	☐
	Cruise speeds appropriately identified and entered into models	☐	☐	☐
	Gap acceptance parameters entered, and configured correctly in software	☐	☐	☐
	Intersection geometry accurately reflects current conditions (including lane widths, splitter islands, island diameters, short lane widths and controls)	☐	☐	☐
	Unbalanced lane utilisation is accounted for	☐	☐	☐
	Unusual movement priorities incorporated into models.	☐	☐	☐
Calibration (signals)	Signal phasing reflects operation sheets and observed sequencing	☐	☐	☐
	Minimum phase times accounted for	☐	☐	☐
	Early cut offs and late starts appropriately specified	☐	☐	☐
	Cycle time matches current operation	☐	☐	☐
	Current pedestrian movements represented	☐	☐	☐
	Pedestrian timings (walk and clearance) reflect those in operation.	☐	☐	☐
	Public transport and cyclist priority included in modelling if present.	☐	☐	☐
Model Validation	The degree of saturation at the intersections and approaches relate to the narrative of the operating conditions	☐	☐	☐
	Back of queue lengths fall within prescribed requirements	☐	☐	☐
	Phase operations relate to the empirical data and observed settings.	☐	☐	☐
	Journey times are within defined thresholds of tolerance	☐	☐	☐
Calibration (multi-intersection)	Network cycle times represent those operating in the SCATS subsystem during the modelled periods	☐	☐	☐
	Signal offsets accurately calibrated	☐	☐	☐
	Feeder lanes across multiple intersections are set up correctly (usually by specifying special movement classes)	☐	☐	☐
	If intersection blocking occurs, model calibration factors are adjusted to produce realistic results	☐	☐	☐
Option investigation (conformity)	Saturation flow, cruise speeds, gap acceptance and network extents are consistent across base and options models.	☐	☐	☐
Option investigation (future years)	Strategic model outputs adjusted to create new volume sets rather than being directly included	☐	☐	☐
	If using historical counts, whether historical growth is a reasonable predictor of future growth has been considered.	☐	☐	☐
	Manual trip estimation uses an appropriate future horizon to capture growth (particularly for staged growth).	☐	☐	☐
Option investigation (physical changes)	If auxiliary lanes are the only change being proposed, appropriateness of modelling has been considered	☐	☐	☐

Option investigation (control changes)	Appropriate control options have been determined through a holistic process, not on modelling outputs alone.	☐	☐	☐
	Key traffic management considerations have been reviewed for options under investigation	☐	☐	☐
Option investigation (traffic signals)	Right turn controls are appropriate (filter, partially/fully controlled)	☐	☐	☐
	Flexible phasing is implemented (can run in diamond phasing or split phasing if required)	☐	☐	☐
	Number of phases minimised to reduce lost time	☐	☐	☐
	Early cut offs and late starts included if required	☐	☐	☐
	Yellow and all red times appropriate for vehicle approach speeds and intersection geometry	☐	☐	☐
	Pedestrian timings reflective of how the signals would be configured in practice	☐	☐	☐
	SCATS subsystem cycle time applied, and intersections cycle time is between 80-120s unless otherwise documented and discussed with Department of Transport to develop another viable delivery option	☐	☐	☐
	If an existing isolated signalised intersection is within 500m, option of operating these intersections as a new subsystem has been considered	☐	☐	☐
	Has blocking back been addressed	☐	☐	☐
Performance	Degree of saturation and level of service for the options being investigated is accurately presented	☐	☐	☐
	Comparison of intersection degree of saturations with required performance requirements	☐	☐	☐
	Level of service evaluated in relation to user experience and potential for growth	☐	☐	☐
Performance (multi-intersection)	Changes in travel times and/or speeds on key routes reported and discussed	☐	☐	☐
Sensitivity testing	Sensitivity testing has been carried out	☐	☐	☐
	Demand adjustments use appropriate percentages of different demand for the location being considered	☐	☐	☐
Economic analysis	If economic analysis is being undertaken, models separate to those used for design have been developed	☐	☐	☐
	The economic evaluation models include models incorporating representative demand sets for peak, inter-peak and off-peak periods	☐	☐	☐
Reporting	Modelling report includes all discussion of all the items above	☐	☐	☐
	Clear narrative to the investigations	☐	☐	☐
	The modelling report clearly outlines the context, benchmarks and resolution to the investigation	☐	☐	☐
	Data collection methods explained, and data description provided	☐	☐	☐
	Strategic changes in future years discussed	☐	☐	☐
	Clear recommendations are provided	☐	☐	☐

	Appropriate model outputs are included in the report and/or appendices	☐	☐	☐
	Peer review undertaken	☐	☐	☐
	Electronic files are made available and do not include models not discussed in the report	☐	☐	☐
	Electronic files include intuitive names and structures	☐	☐	☐

13. Glossary

Term	Description
Demand	The number of vehicles that intended to move past a distinct location (such as a stop line) within a time interval e.g. within an hour. This term is often misrepresented by the actual throughput of a venue. I.e. is the movement of 200 vehicles in an hour a function of those that intended to travel or only those that could achieve this journey.
Do Nothing model	An evaluation of models, typically for future year arrangements, where the demand volumes have changed (due to population or employment changes) but without any infrastructure changes. This scenario provides a comparison for the economic appraisal.
Do Minimum model	An evaluation of models, typically for future year arrangements, where the demands are revised but the infrastructure changes are limited only to existing commitments (but may include longer term components within a reference plan that are yet to be announced e.g. Outer Metropolitan Ring).
Erasable Programmable Read Only Memory (EPROM)	A type of memory chip that retains its data when its power supply is switched off. It houses the unique program that configures the traffic signal controller to a specific operational design of the intersection it's controlling. This includes specifications of which signal groups run in each phase, the sequence of phases, detector functions, detector alarm conditions, conflict points and default time settings.
Intersection Diagnostic Monitor (IDM)	A software feature of SCATS that records (on demand) all of the key operating characteristics of a signalised site for a given time period. Data recorded includes individual and average cycle times, individual and average phase times, number of times a phase runs. Superseded. Encourage teams not to call for this data.
LX File	The data file that feeds into the region computer for each signalised intersection. It contains the data necessary for communications, signal timings, inter-green intervals, pedestrian walk and clearance timings, co-ordination values, flexilink data and variation routines.
Motorway	The term motorway applies to both freeways and tollways, irrespective of the payment to utilise the road network.
Peak Flow Factor	A measure of the demand in the peak hour (or peak period) as a measure against the busiest smaller time interval in that framework (typically a 15 minute period). Values closer to 1.00 represent a consistent demand whereas reduced values such as 0.800 suggest a more varied demand profile.
Peak Hour	A single 60 minute interval. This may be contained within the same hour e.g. 8-9AM or may be over multiple hourly intervals of the e.g. 830-930.
Peak Period	A collection of adjacent peak hours throughput the day to represent the time that the network is busiest to manage demand movements e.g. 7-9AM, 3-

	6PM.
Puffin Crossing	A type of pedestrian crossing facility that allows a variable length crossing period according to the walking speed of users traversing the carriageway.
Sydney Co-ordinated Adaptive Traffic System (SCATS)	An intelligent transportation system developed in Sydney, Australia by former constituents of the NSW Roads and Maritime Services in the 1970. SCATS primarily manages the dynamic (on-line, real-time) timing of signal phases at traffic signals, meaning that it tries to find the best phasing (i.e. cycle times, phase splits and offsets) for the current traffic situation (for individual intersections as well as for the whole network). This is based on the automatic plan selection from a library in response to the data derived from loop detectors or other road traffic sensors.
Shoulder period	The time in a day between a reduced demand volume and a heightened demand volume (or vice versa) for a location. A shoulder period can be applied as the demand builds for a peak period and also as it finishes for a peak period. The significance and length of the shoulder period might be different for either side of the peak period.
Throughput	The intended demand for an hour or equivalent period that could move beyond a set location such as a stop line. This is the volume of traffic that intended to use the infrastructure rather than that which actually did. This term is often misconstrued as traffic demand.
Time Horizon	A distinct future year (e.g. 2031)
Time Interval	A small period of analytical value as a part of the immediate investigation – typically of 5 to 15 minutes length
Urban road	Within these guidelines, the term of the arterial road and the urban road may be used interchangeably. This context then allows for traffic analysis within urban centres (town centres and suburbs) outside the metropolitan area to be applied and explored in the same manner. Application of the term “urban” therefore can be applied for regional cities and towns rather than suggestion of an exclusion from the analysis
Utilisation	A measure of volume (demand) against available capacity. This is known as a volume capacity ratio and is often expressed as a percentage or decimal figure.

14. Abbreviations

Short Form	Longer Form
AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic i.e. not from a sample of a year
AGTM	Austroads Guide to Traffic Management
ATC	Automatic Traffic Count
CT	Cycle time
ECO	Early Cut Off
FY	Future Year
HGV	Heavy Goods Vehicle
HV	Heavy Vehicle
IDM	Intersection Diagnostic Monitor
kph	kilometres per hour
km	kilometres
LV	Light Vehicle
m	Metres (distance)
No.	Number
OD	Origin-Destination
PoS	Pedestrian Operated Signal
QA	Quality Assurance
SCATS	Sydney Co-ordinated Adaptive Traffic System
sec	Seconds
TIA	Traffic Impact Assessment

TMC	Turning Movement Count
veh	Vehicles
VKT	Vehicle Kilometres Travelled
VITM	Victorian Integrated Transport Model
WD	Weekday
WE	Weekend

Appendix A – Empirical cruise speed tables

***Table A1**: Average free flow speeds for highways by posted speed and LGA (km/h)*

	Posted Speed Limit					
LGA	**50**	**60**	**70**	**80**	**90**	**100**
Banyule	-	52	58	65	-	-
Bayside	-	47	52	68	-	-
Boroondara	-	51	55	-	-	-
Brimbank	-	-	53	65	-	98
Cardinia	-	65	65	73	88	97
Casey	41	55	68	67	-	93
Darebin	-	-	55	-	-	-
Frankston	-	54	65	69	88	86
Glen Eira	-	52	56	65	-	-
Greater Dandenong	36	50	52	64	77	84
Hobsons Bay	-	-	53	64	-	-
Hume	-	34	52	69	-	96
Kingston	-	56	54	66	-	98
Knox	-	70	60	63	-	-
Manningham	-	59	56	-	-	-
Maribyrnong	-	51	54	64	-	-
Maroondah	-	56	59	68	-	-
Melbourne	32	42	51	-	-	-
Melton	-	-	61	63	89	97
Monash	-	55	57	65	-	-
Moonee Valley	-	47	-	-	-	-
Moreland	-	54	57	-	-	-
Mornington Peninsula	-	70	62	71	56	-
Nillumbik	-	-	-	48	-	-
Port Phillip	-	47	59	-	-	-
Stonnington	-	54	54	61	-	-
Whitehorse	-	57	60	65	-	-
Whittlesea	-	-	-	-	-	-
Wyndham	-	-	-	53	-	-
Yarra	-	43	48	-	-	-
Yarra Ranges	39	56	57	69	-	68
Average	**40**	**52**	**56**	**66**	**82**	**92**

Source: Here Maps data held within Domino Model

***Table A2**: Average free flow speeds for primary arterials by posted speed and LGA (km/h)*

	Posted Speed Limit					
LGA	**50**	**60**	**70**	**80**	**90**	**100**
Banyule	-	52	61	61	-	-
Bayside	-	53	57	61	-	-
Boroondara	-	44	45		-	-
Brimbank	-	50	57	62	-	-
Cardinia	44	56	67	72	84	89
Casey	43	53	61	64	75	84
Darebin	-	48	54	66	-	-
Frankston	-	46	56	67	-	85
Glen Eira	-	45	57	61	-	-
Greater Dandenong	41	49	53	64	70	86
Hobsons Bay	42	52	55	63	-	-
Hume	21	55	58	68	-	90
Kingston	30	54	58	63	74	91
Knox	-	54	59	65	-	-
Manningham	-	55	60	63	-	-
Maribyrnong	34	46	46	-	-	-
Maroondah	-	51	61	63	-	-
Melbourne	34	40	50	-	-	-
Melton	41	52	62	68	83	95
Monash	-	53	58	64	-	-
Moonee Valley	-	47	58	65	-	-
Moreland	45	47	55	75	-	-
Mornington Peninsula	45	55	63	72	78	82
Nillumbik	46	55	61	72	-	-
Port Phillip	31	46	52	-	-	-
Stonnington	35	42	53	-	-	-
Whitehorse	48	51	57	64	-	-
Whittlesea	-	53	53	70	89	90
Wyndham	43	50	56	67	-	92
Yarra	36	43	50	-	-	-
Yarra Ranges	45	57	64	72	84	79
Average	**42**	**50**	**59**	**67**	**79**	**84**

Source: Here Maps data held within Domino Model

***Table A3**: Average free flow speeds for secondary arterials by posted speed and LGA (km/h)*

	Posted Speed Limit					
LGA	**50**	**60**	**70**	**80**	**90**	**100**
Banyule	36	50	63	57	-	-
Bayside	30	49	39	60	-	-
Boroondara	44	48	47	-	-	70
Brimbank	38	47	55	56	-	83
Cardinia	40	48	54	58	-	86
Casey	45	52	58	60	55	82
Darebin	41	46	55	-	-	-
Frankston	35	51	57	66	60	78
Glen Eira	33	47	56	-	-	-
Greater Dandenong	41	50	47	56	54	75
Hobsons Bay	35	45	43	51	-	49
Hume	38	48	48	64	-	78
Kingston	28	48	57	52	-	89
Knox	34	49	46	43	-	66
Manningham	-	52	55	56	-	77
Maribyrnong	42	46	61	38	-	-
Maroondah	-	50	48	63	-	66
Melbourne	33	43	34	67	-	70
Melton	38	51	56	66	88	83
Monash	-	52	55	40	-	75
Moonee Valley	40	46	68	77	-	70
Moreland	44	45	47	67	-	73
Mornington Peninsula	32	51	62	69	61	73
Nillumbik	40	54	49	73	70	-
Port Phillip	35	43	-	76	-	77
Stonnington	30	44	50	71	-	55
Whitehorse	-	52	41	49	-	78
Whittlesea	33	45	54	44	43	72
Wyndham	37	49	54	58	-	69
Yarra	19	42	37	71	-	68
Yarra Ranges	38	53	60	66	-	-
Average	**39**	**48**	**55**	**62**	**60**	**75**

Source: Here Maps data held within Domino Model

***Table A4**: Average free flow speeds for collector roads by posted speed and LGA (km/h)*

	Posted Speed Limit		
LGA	**40**	**50**	**60**
Banyule	32	39	46
Bayside	31	39	45
Boroondara	31	40	47
Brimbank	32	40	47
Cardinia	33	42	49
Casey	32	40	49
Darebin	30	39	46
Frankston	32	40	48
Glen Eira	30	38	43
Greater Dandenong	31	39	48
Hobsons Bay	31	39	46
Hume	32	41	47
Kingston	31	39	45
Knox	32	40	48
Manningham	32	35	46
Maribyrnong	30	38	44
Maroondah	32	-	49
Melbourne	31	39	47
Melton	32	42	47
Monash	29	39	45
Moonee Valley	31	39	43
Moreland	30	38	46
Mornington Peninsula	32	40	49
Nillumbik	34	42	50
Port Phillip	31	38	40
Stonnington	32	40	41
Whitehorse	32	40	44
Whittlesea	32	43	46
Wyndham	32	41	48
Yarra	31	40	48
Yarra Ranges	33	42	50
Average	**32**	**40**	**47**

Source: Here Maps data held within Domino Model

***Table A5**: Average free flow speeds for local roads by posted speed and LGA (km/h)*

	Posted Speed Limit		
LGA	**40**	**50**	**60**
Banyule	26	-	-
Bayside	-	-	-
Boroondara	-	33	-
Brimbank	26	32	39
Cardinia	26	33	-
Casey	26	33	39
Darebin	-	33	39
Frankston	-	33	39
Glen Eira	-	33	39
Greater Dandenong	-	33	-
Hobsons Bay	-	33	-
Hume	26	32	39
Kingston	26	33	39
Knox	-	33	39
Manningham	-	33	-
Maribyrnong	26	33	39
Maroondah	26	-	39
Melbourne	26	33	38
Melton	26	33	39
Monash	-	33	-
Moonee Valley	-	33	38
Moreland	26	33	39
Mornington Peninsula	26	33	39
Nillumbik	26	33	39
Port Phillip	-	33	39
Stonnington	26	33	-
Whitehorse	-	33	39
Whittlesea	26	33	-
Wyndham	-	33	37
Yarra	26	-	36
Yarra Ranges	26	33	39
Average	**26**	**33**	**39**

Source: Here Maps data held within Domino Model

Appendix B – Observed Survey results

B.1 Introduction

A series of surveys were conducted in May 2019 to explore gap acceptance of varied movements at unsignalised intersections across Melbourne. These explorations used drones (unmanned aerial vehicles) to explore the behaviour of operating conditions of three locations. The approach provides for a measure which captures the entire movement and complexities, and reduces the potential for a change in driver reactions from the experience of being surveyed.

The behavioural elements were obtained by use of computer solutions (artificial intelligence) to explore the movement of vehicles captured through the camera on the drone. This provided insights into the gaps taken or left amongst opposing or conflicting vehicles. This process identified both a stop position and a gate (or decision barrier) between the yielding vehicle and the priority movement.

The data collected was for a two hour AM peak period and a two hour PM peak period for selected venues within the metropolitan Melbourne landscape. This timeframe provided a wealth of vehicle movements producing a total of 21,010 recorded gaps for the AM peak period (7-9AM) and 27,815 recorded gaps in the PM peak period (4-6PM). Surveys dates were managed so that volatility of weather conditions were minimised, specifically for the wind speed.

B.2 Survey Locations

The three surveys sites were chosen due to their specific characteristics for gap acceptance. This does not imply a polarised condition, but provides insights into the direction of these operational manoeuvres within the landscape. Survey locations were identified to represent a condition of different geographies of the Melbourne landscape; one to the western perspective, one to the northern perspective and one to the eastern perspective. Of course more surveys could explore a wider sample of geographic landscapes. The three surveyed sites are as described in **Table B1**:

Table B1: Drone Survey Locations

	Intersection	***Characteristic***	***Drone Position (Corner)***	***Display***
Burwood	Highbury Rd/ Blackburn Rd	Partially Controlled Right hand turn/ left turn slip lanes	North West	**Figure B1**
Laverton	Boundary Rd/ Fitzgerald Rd	High movement of HGVs	North East	**Figure B2**
Thomastown	Dalton Rd/ Settlement Rd	Three lane and high volume roundabout	South East	**Figure B3**

Figure B1: Drone View of Burwood survey location (view from north west)

Figure B2: Drone View of Laverton survey location (view from north east)

Figure B3: Drone View of Thomastown survey location (view from south east)

B.3 Survey Analysis

The surveys explored the turning movements of traffic patterns during the peak periods, in order to comprehend the critical gaps that were achieved by drivers. Together with a notion of the follow up headway, this metric can be used to provide guidance (or insights) on the turn capacity that is observed within metropolitan Melbourne. Although the same of site locations is small, the number of gaps considered is in the order of more than 20,000 considerations per peak hour. This provided for a more substantial dataset into the behaviour of gap acceptance by drivers in the urban landscape.

The analysis behind this methodology used a logistical transformation method to determine the critical gap. Other formats to explore definition of a critical gap are available and are acceptable. This metric is the median value of the gaps taken by drivers for each type of turning movement. The data was original explored by each site location but is accumulated to turn movement within **Figure B4**. A range of accepted gaps are presented as a spectrum as drivers are subject to the own individual choices subject to the road regulations. However, for deterministic solutions, the median value within the sample should suffice for analysis. The median, 15th percentile and 85th percentile figures were provided within **Table 18**.

With allowance for a two second follow up gap, the empirical measurement in **Table B2** identifies that capacity for left turn slip lanes is circa 400 vehicles an hour, with an high end value leaning towards 460 vehicles per hour. By comparison a filtered right hand turn with a two second follow up headway delivers on a calculated capacity measure of between 400-460 vehicles per hour. Both numbers are of course subject to the opposing flow volumes and patterns of platoon behaviour. Turn specifics such as angle and line of sight also come into this context of the Burwood site.

The empirical observations for roundabouts are held in both **Table 18** as well as **Table B3** (for Laverton) and **Table B4** (for Thomastown). The data for left turn movements identifies an average critical gap of 5.0 seconds for two lane roundabouts (Laverton) and 4.7 for three lane roundabouts (Thomastown). With accounting for a two second follow up time, this translates to a turn capacity of 500-540 vehicles an hour for left turns at roundabouts within a Melbourne landscape.

Figure B4: Gap Acceptance Curves (Logistical Transformation Method)

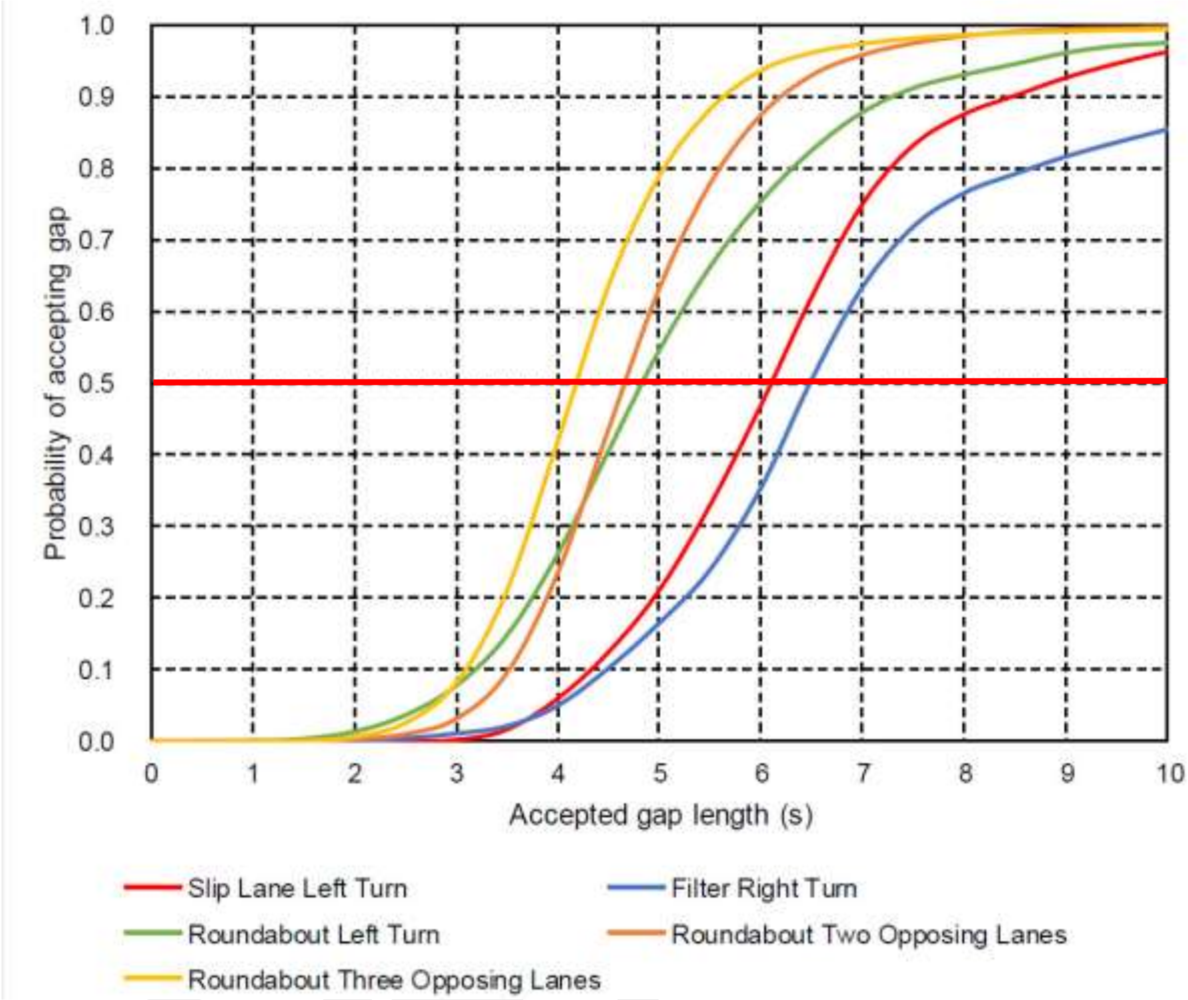


Table B2: Burwood Site Critical Gap Measurements (cars only)

	Left Turn Slip Lane		*Filtered Right Turn*	
Approach	***Sample Size (Gaps Accepted)***	***Critical Gap***	***Sample Size (Gaps Accepted)***	***Critical Gap***
Northbound	0	NA	74	6.0 s
Westbound	34	7.2 s	47	6.4 s
Southbound	5	6.8 s	0	NA
Eastbound	171	6.0 s	9	7.0 s

The data within **Table B3** identifies for the conditions of the through and right turning movements at the Laverton two lane circulating controller. The venue appears to have a well balanced flow of traffic movements with approximately 450-550 vehicles on each approach of lane 1 (outside lane) and 600-650 vehicles in the adjacent lane. Note that this site has a high proportion of heavy vehicles with a figure of 27% of the total volume in the AM peak period and 16% of all traffic in the PM peak period.

Table B3: Laverton Site Critical Gap Measurements (cars only)

	Approach Lane 1 (outside)		*Approach Lane 2 (inside)*	
Approach	*Sample Size (Gaps Accepted)*	*Critical Gap*	*Sample Size (Gaps Accepted)*	*Critical Gap*
Southern	542	5.0 s	641	4.9 s
Eastern	524	4.8 s	615	4.8 s
Northern	451	5.4 s	628	5.2 s
Western	524	5.1 s	667	5.0 s

The data identifies that there is a marginally smaller or similar gap for movements to enter the circulating volume in the inside (faster) lane than there is for the outside (slower) lane. Overall this produces a throughput capacity per lane of 480-520 vehicles per hour. Again, note that this value is not consistent over the hour but subject to the distribution of journeys circulating through the roundabouts that create large enough gaps for traffic to enter the traffic management system. Further analysis could identify that the reduced demand on one approach will impact on the critical gap calculations observed from the adjacent approach. This can be observed whereby the reduced demand on the outside lane of northern approach appears to then impact on the critical gap taken by traffic in the outside lane of the western approach into the intersection.

The Thomastown roundabouts represents a venue with three lanes of circulating traffic and three lanes on each approach to the controller. The demand flow volumes are less consistent on this movement by the approach in **Table B4** than then are in **Table B3**. There is also more variation in the critical gap for individual lanes and movements that downplays suggestion of a pattern in behaviour. That is to suggest that the conditions of the site have more influence in the gaps taken by drivers than the lane hierarchy has an impact. Nonetheless the critical gaps provide an insight that the capacity of turning movements at this location which is in the order of 480-620 vehicles per hour per lane.

Table B4: Thomastown Site Critical Gap Measurements (cars only)

	Approach Lane 1		*Approach Lane 2*		*Approach Lane 3*	
Approach	*Sample Size (Gaps Accepted)*	*Critical Gap*	*Sample Size (Gaps Accepted)*	*Critical Gap*	*Sample Size (Gaps Accepted)*	*Critical Gap*
Southern	648	4.9 s	558	4.9 s	640	4.2 s
Eastern	273	3.8 s	648	4.1 s	484	4.2 s
Northern	181	4.3 s	239	4.2 s	300	4.5 s
Western	365	5.6 s	361	3.9 s	320	3.8 s

Further analysis into these movements is provided within **Table B5**. Note that while **Tables B2** through to **Table B4** were for cars only, analysis by turn movement for all sites provides a different picture of critical gaps accepted by drivers within this Melbourne landscape. For the purpose of this table all survey locations have been compiled together. The data in **Table B5** identifies that there are only cars turning right at the location of the partially controlled turn. However, there are also medium goods vehicles turning left through these slip lanes.

Analysis of the movement within the roundabouts shows a broader range of vehicle types and therefore critical gaps taken by selected vehicle types using distinct trajectories. Note that **Table B5** provides insights of the critical gap accepted by distinct vehicle types moving through the roundabout with the vehicle classification used to define the yielding vehicle. By comparison the data in **Table B6** identifies this classification of critical gaps by vehicles as the priority (or opposing) movement. This is particularly useful to comprehend the movements of the Laverton site (with the high proportion of heavy vehicles). The Thomastown site also has a significant mix of heavy vehicles despite the critical factor being the heavy volume of demand and the limited geometry of the circulating movement.

Table B5: Critical Gap Measurements by Turning Vehicle Type (All Locations)

Vehicle Type	Slip Lane Left Turn	Filter Right Turn	Roundabout Left Turn	Roundabout 2 Lanes Opposing	Roundabout 3 Lanes Opposing
Car	6.1 s	6.5 s	4.8 s	4.7 s	4.2 s
Taxi	*	*	3.9 s	4.6 s	5.0 s
White Van	*	*	4.4 s	4.6 s	3.8 s
Bus	*	*	*	4.9 s	3.9 s
Medium Vehicle	6.5 s	*	5.8 s	5.0 s	4.6 s
Heavy Vehicle	*	*	6.9 s	5.6 s	4.8 s
B-Double or Larger	*	*	7.4 s	6.3 s	NA
Average	***6.1 s***	***6.4 s***	***5.0 s***	***4.9 s***	***4.2 s***
* no sample size, therefore no data available.					

Table B5 identifies a higher accepted gap for medium and heavy goods vehicles and for B-Double services for the left turns at roundabouts as well as for both the movements with two lanes and three lanes of opposing traffic. This may be associated with the slower acceleration from a stopped position associated with this form of vehicle classification. The gap left by heavy vehicles for the left turning movements at roundabouts appears to be further from that of car and taxi than the opposing movement for either design. The dataset does not suggest that there is a different between the gaps utilised by cars, nor by taxis or white vans at the roundabout locations. This is a despite the different nature of the journeys being undertaken (some are commercially oriented).

By comparison to the gaps left by the classification of yielding vehicles are shown in **Table B6**. The analysis of empirical critical gaps left by drivers with varied opposing (priority) movements does not show there to be a significant difference. That is the driver accepts a similar gap whether awaiting a car or a goods vehicle. There are some nominally longer movements when encountering an opposing heavy vehicle, but these metrics may not have a notable change in operating conditions, even on the two lane circulating roundabout. Note that the three lane circulating roundabout has a common accepted gap by drivers irrespective by the vehicle type with priority. This may be due to the complexity of the circulating movements and opportunities for traffic to enter into the roundabout.

Table B6: Gap Analysis by Opposing Vehicle Type

Vehicle Type	Slip Lane Left Turn	Filter Right Turn	Roundabout Left Turn	Roundabout 2 Lanes Opposing	Roundabout 3 Lanes Opposing
Car	6.0 s	6.4 s	4.9 s	4.7 s	4.2 s
Taxi	*	*	4.9 s	4.6 s	4.2 s
White Van	7.0 s	*	5.0 s	4.8 s	4.2 s
Bus	*	*	4.9 s	4.5 s	4.2 s
Medium Vehicle	*	*	5.0 s	4.9 s	4.2 s
Heavy Vehicle	*	*	5.2 s	5.3 s	4.2 s
B-Double or Larger	*	*	5.0 s	4.9 s	4.2 s
Average	***6.1 s***	***6.4 s***	***5.0 s***	***4.9 s***	***4.2 s***

A brief review of the empirical critical gap measures taken from all three sites when compared against the hourly opposing flow is provided within **Table B7**. Although these flows are aggregated by a defined time interval, it is recognised that the gaps and opportunities for individual drives changes throughout this timeframe. The datasets identify a general trend on a subtle decline in accepted critical gaps with a higher volume of opposing traffic. This statement is clear for the reduced gap times observed on the three lane roundabout and present but less evident for both the left turn movements as well as those on the two lane circulating movement. The accepted gap times do not appear to be impacted directly through the overall volume of traffic at the signalised controller (the left turn slip or the partially controlled right turn).

Table B7: Critical Gap Measurements by Effective Opposing Traffic Flow

Hourly Traffic Flow	***Slip Lane Left Turn***	***Filter Right Turn***	***Roundabout Left Turn***	***Roundabout Two Opposing***	***Roundabout Three Opposing***
0-500 vph	*	*	3.8 s	4.5 s	*
500-1000 vph	5.5 s	6.5 s	5.7 s	5.1 s	4.5 s
1000-1500 vph	6.2 s	5.7 s	5.1 s	4.8 s	4.5 s
1500-2000 vph	6.3 s	6.8 s	5.0 s	4.3 s	4.1 s
2000-2500 vph	*	*	4.8 s	*	3.8 s
2500-3000 vph	*	*	4.7 s	*	3.5 s
Average	***6.1 s***	***6.4 s***	***5.0 s***	***4.9 s***	***4.2 s***

Appendix C – Example Report

Widgets Manufacturing New Industrial Site

Intersection Modelling Report

VICTORIA State Government | Department of Transport

Contents

1 Introduction

A planning application is being submitted by Widgets Manufacturing Limited for a proposed industrial development at 1 Swamp Road, Ruralton. The site will generate truck movements in the form of raw material deliveries and manufactured widgets in, addition to passenger vehicles (generally associated with staff).

1.1 Background

Widgets Manufacturing Limited will be the main tenant in an existing industrial subdivision, in a predominantly rural area to the south of Ruralton. The town is expected to grow over time and provide the formation of a retail centre with employment and residential facilities nearby. The industrial site will have vehicle access to Swamp Road, an industrial cul-de-sac that connects to High Street, a State Arterial Road. As detailed in the associated Transport Impact Assessment (TIA) Report, the majority of traffic generated by the proposed development will be between the site and the township of Ruralton via High Street and Main Road (also a State Arterial Road).

The location of the site is shown in **Figure 1**.

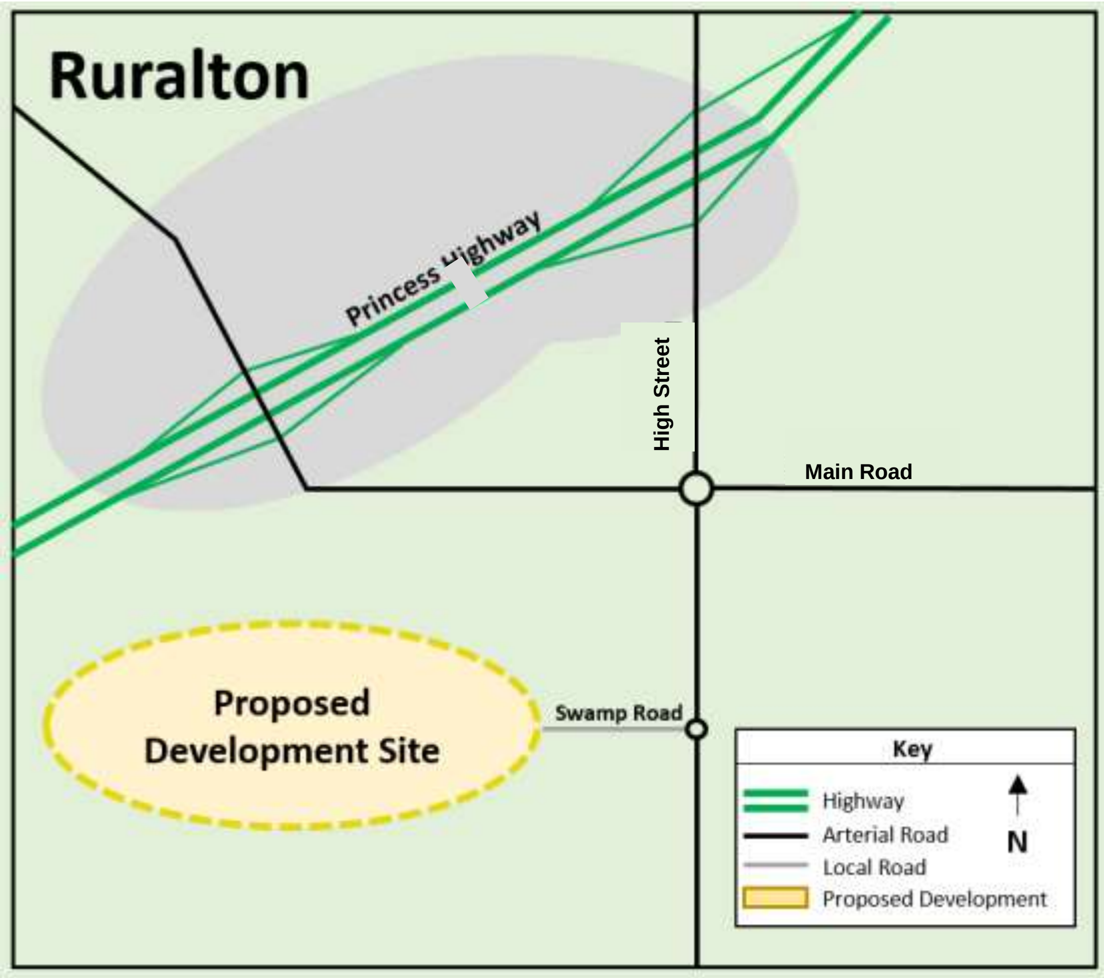


Figure 1: Site location

1.2 Objective

The objective of this modelling pursuit is to evaluate the impact on the performance of the surrounding road network as a consequence of the proposed development, to determine if modifications to the network are required and to evaluate the performance of those modifications.

1.3 Modelling considerations

The majority of traffic generated by the development will travel north from Swamp Road, along High Street to Main Road, before distributing more widely to the Princes Freeway and Ruralton township. Traffic to the development will follow the reverse routes.

The two intersections most impacted by the development are the High Street/ Swamp Road and High Street / Main Road intersections. Both of these intersections are existing single lane roundabouts, and there are no intersections between them (local access to High Street is permitted). Intersection modelling is considered the appropriate modelling tool to assess their performance.

As the two roundabouts are approximately 1.4 km apart and do not currently interact with one another, in terms of arrival patterns or queuing, these intersections can be assessed as isolated intersection models, rather than a multi-intersection model.

This assessment was undertaken using SIDRA Intersection, Version 8.0.5.7916.

1.4 Report structure

This Modelling Report sets out an overview of the model development, calibration and validation process, intersection upgrade assessment and includes the following:

- Data Collection (Section 2)
- Calibration (Section 3)
- Validation (Section 4)
- Future demands (Section 5)
- Performance outputs (Section 6)
- Conclusion (Section 7)

2 Data collection

2.1 Intersection turning movements

Intersection turning movement counts were collected at the two roundabouts on Wednesday 27 November 2019 between 7 am and 9 am and between 4 pm and 6 pm. The traffic count classifications were split between light vehicles (LV) and heavy vehicles (HV).

2.2 Automatic tube count

To understand the vehicle mix, speeds and traffic volume profile of vehicles travelling along High Street, classified vehicle counts were also collected for the seven day period between 25 November 2019 and 1 December 2019. The tube count location was approximately 600m north of Swamp Road.

To supplement the surveys, a site inspection was undertaken on Wednesday 27 November 2019 to coincide with the surveys. Observations of the performance of the intersections, including the extent of queuing, were made during this site visit for the evening peak period.

2.3 Queue length surveys

Queue lengths surveys were undertaken as part of the site visit on 27 November 2019 to coincide with the data collection in the evening peak period. The intention was to record queues on the approaches to the two intersections.

The distance of the back of the queue from the intersection was recorded at one minute intervals. However, it was found that both intersections were operating in free flowing conditions, generally without queues forming.

3 Calibration

3.1 Demand

3.1.1 Movements

The traffic counts collected as part of this study were used for the existing peak hour traffic movements included in the Base model. To determine the peak periods, the total throughput at each of the two intersections in the weekday morning and evening periods was assessed. This was done separately for the two intersections.

The Peak Flow Factors (PFF) for each of the periods (based on 15 minute survey periods) were also calculated. Peak periods and PFF for the two intersections are included in **Table 1**.

Table 1: Peak periods and PFF

	AM	PM
East Road/Swamp Road		
Peak periods	8:00-9:00 AM	4:00-5:00 PM
PFF	0.87	0.90
East Road/South Road		
Peak periods	8:00-9:00 AM	4:00-5:00 PM
PFF	0.91	0.92

The demand inputs used for each movement (including the number of heavy vehicles) in the Base models are shown in **Figure 2** and in **Figure 3**.

3.1.2 Saturation flows

Due to the isolated rural nature of the intersections, the SIDRA intersection software defaults for saturation flow were adopted.

3.1.3 Heavy vehicles

The number of commercial vehicles undertaking each movement during the peak periods were recorded separately as part of the intersection count surveys. The heavy vehicle demand volumes (Austroads Classes 3 to 10) for each movement are specified in Section 3.

3.1.4 Other road users

Both intersections are located in semi-rural/industrial areas away from commercial and residential destinations that would typically generate walking and cycling demand. There are no footpaths on High Street, Main Road or Fourth Street. Pedestrians and cyclists were not observed during the site visit. No bus services operate along High Street or Main Road.

Only motor-vehicle demands were therefore included in the models developed.

Figure 2: Base condition– High Street / Swamp Road peak hour volumes

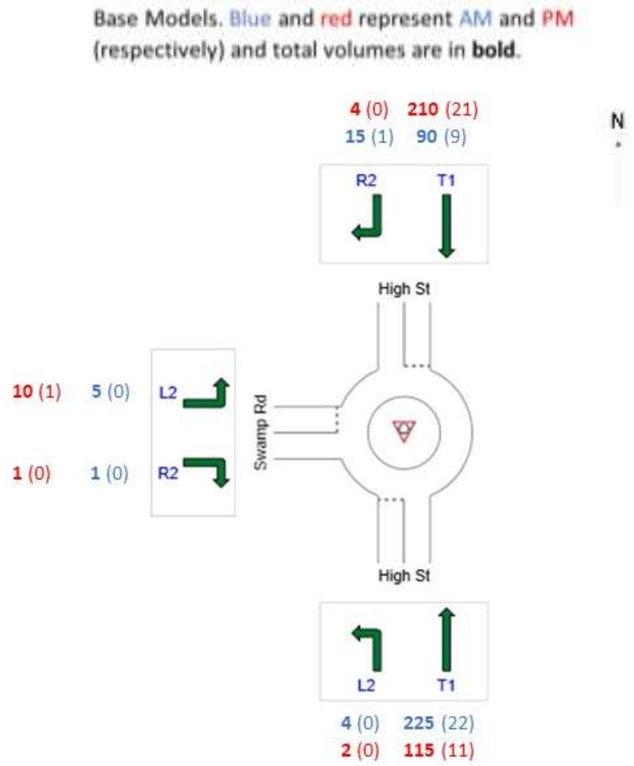
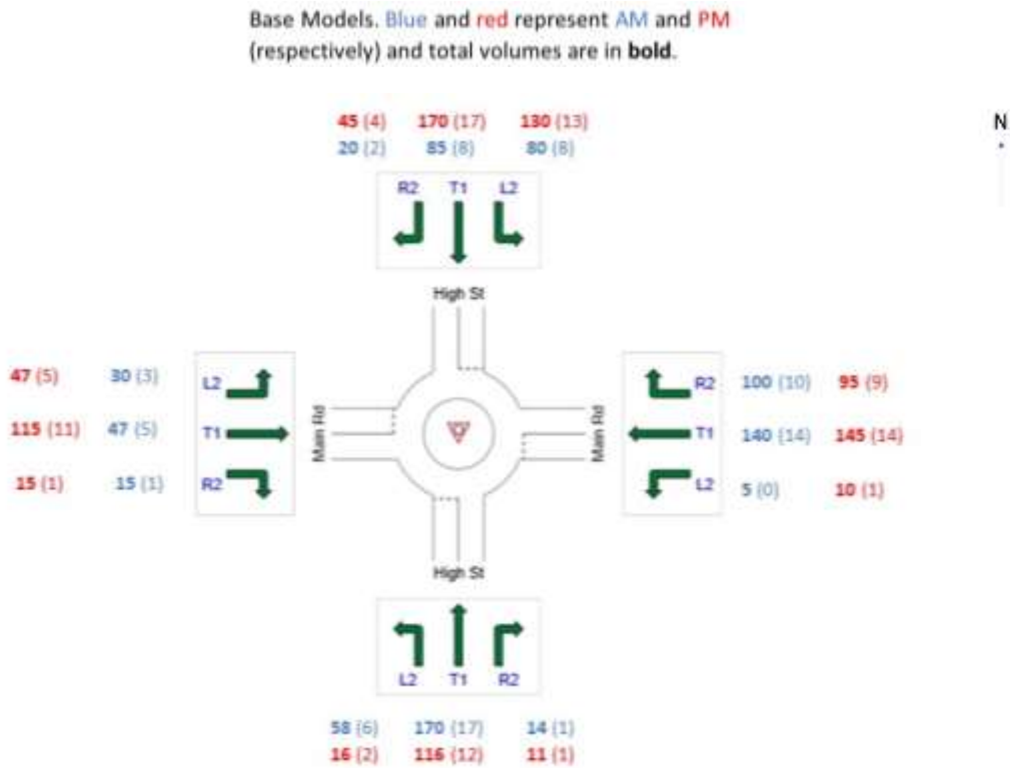


Figure 3: Base model – High Street/ Main Road morning peak volumes



3.2 Behaviour

3.2.1 Speed

Approach speeds for traffic on High Street were obtained from the classified vehicle counts undertaken between Swamp Road and Main Road. Average vehicle speeds were first plotted by time period to determine whether there was variation between the peak and off-peak periods. No noticeable variation in speeds was identified. The average speeds across all periods were therefore used as free-flow speeds. The speed adopted for High Street traffic was 75 km/h.

For South Road, the free flow speed obtained for High Street (75 km/h) was used given the similarities in land use and road environment.

An indicative average speed of 33 km/h was adopted for Swamp Road, based on the speed limit (50km/h) and road classification (local road).

3.2.2 Gap acceptance

Due to the isolated rural nature of the sites and the conventional intersection geometry, the SIDRA intersection software defaults for gap acceptance were adopted. The SIDRA software adjusts the gap acceptance parameters based on the intersection geometry.

3.2.3 Lane utilisation

Both intersections have single approach lanes on all approaches.

3.3 Physical characteristics

The intersection geometry measurements were obtained from aerial photographs. Based on observations of vehicle behaviour, no adjustments to the marked lane geometry were necessary to reflect real-world driver behaviour.

4 Validation

To validate the Base models, a Degree of Saturation (DoS) check was carried out, and estimated queue lengths outputted from the model were compared to those observed. The SIDRA outputs for the Base model are included in Appendix A.

4.1 Degree of Saturation check

The intersection DoS for both periods, at both intersections, were all below 1.0 as would be expected for an existing intersection. The DoS for all periods at both intersections is summarised in **Table 2** below.

Table 2: Base model Intersection DoS

	AM	PM
High Street /Swamp Road	0.15	0.14
High Street / Main Road	0.23	0.28

The comparatively low DoS in the evening peak period are consistent with the observations on site.

4.2 Queue lengths

During the evening peak queue length surveys, traffic was free-flowing on all intersection approaches (no queues). This corresponds with the modelled 95th percentile back of queues outputted from the Base model (refer **Table 3**).

Table 3: 95th percentile base model queue lenths (m)

	AM	PM
High Street /Swamp Road		
South approach (High Street)	7	3
North approach (High Street)	3	7
West approach (Swamp Road)	2	0
High Street / Main Road		
South approach (High Street)	13	7
East approach (Main Road)	10	12
North approach (High Street)	7	17
West approach (Main Road)	5	8

5 Future demands

5.1 Future (without development)

A total of three adjustments to the Base model traffic demands have been made to develop future model traffic demands:

- Seasonal adjustment – adjusting the observed traffic counts to take into account seasonal variation;
- Traffic growth – additional traffic demand as a result of background growth in the future year (10 years post opening of the development); and
- Design hour – adjusting the future prediction from a ‘regular day’ to the ‘30^{th} busiest hour’.

5.1.1 Seasonal adjustment

As there are no nearby traffic signal sites or continuous traffic count sites, seasonality factors have been estimated from tabulated averages for the local government area. The seasonality factor for November traffic surveys in Ruralton Shire is 0.99. This adjustment factor was applied to the observed counts to factor the demand to a regular (100^{th} busiest) day.

Therefore to adjust for a design volumes estimate from a single day of survey As the Future Year volume estimates from the above process provide for volumes on ‘typical’ days, these need to be factored up to the design hour (30^{th} busiest hour).

As there is no appropriate nearby traffic signal site nor continuous traffic count site to estimate adjustment factors for the design hour, an additional 5% increase has been applied to the typical 2031 future year estimates (as per the Transport Modelling Guidelines: Volume 5).

Figure 4: Base condition (Seasonal Adjustment) – High Street / Swamp Road peak hour volumes

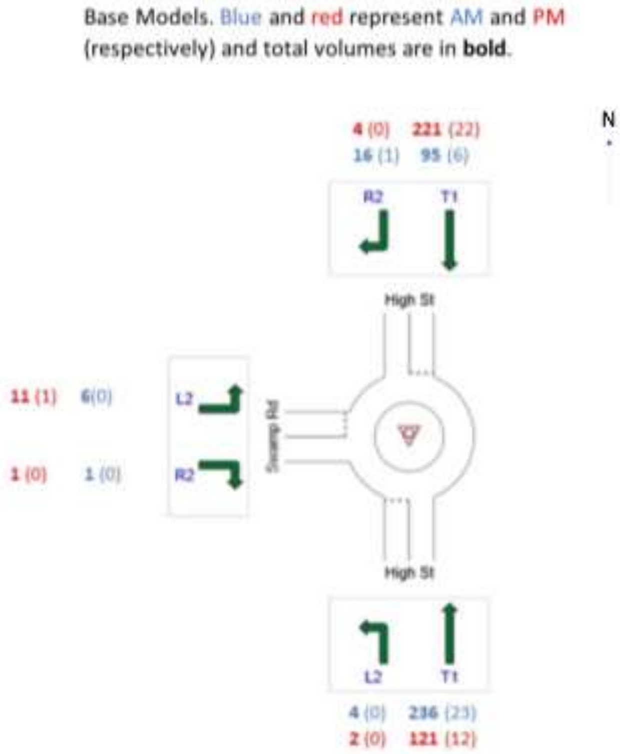
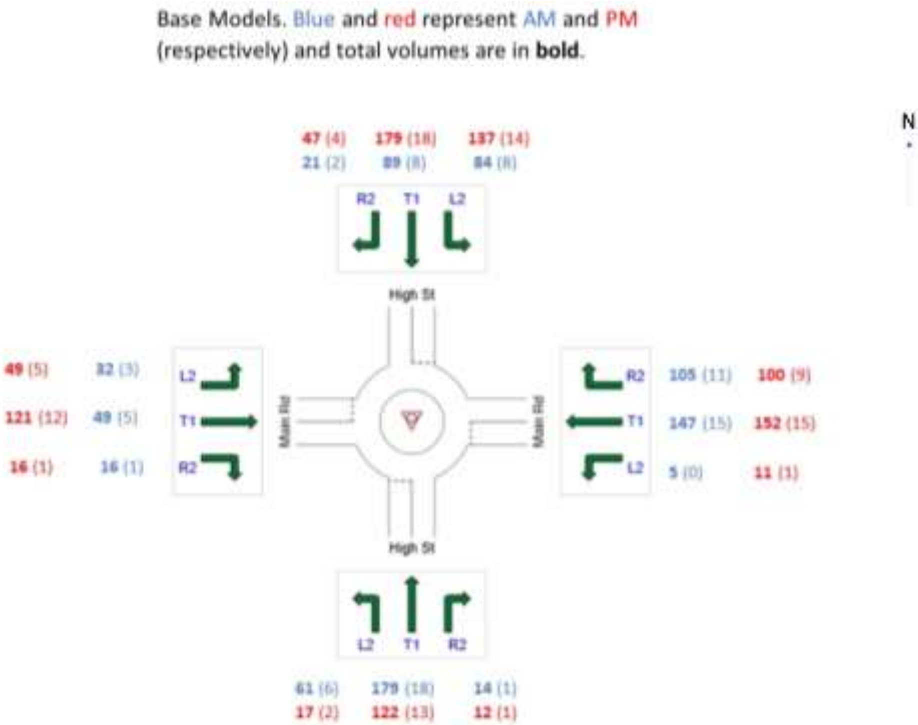


Figure 5: Base condition (Seasonal Adjustment)– High Street/ Main Road morning peak volumes



5.1.2 Traffic growth

To estimate traffic growth, strategic model outputs were used to calculate the change in traffic volume from the Base Year (2019) to the Future Year (2031). The Future Year of 2031 was chosen as it is 10 years post opening of the proposed development. In this time is expected that the town centre will begin to form with additional retail centres and employment developing. This is expected to be serviced from the growing population in new centres developed within Ruralton. A major shopping centre chain is expected to take shape within this timeframe near the corner of Main Road and High Street, providing a notable change in economic exchanges within this locality.

The strategic model includes the arterial road links of High Street and Main Road. The change in traffic volumes along these links in the AM and PM periods (1 hour estimates) was extracted from the strategic model and is shown in Figure 6.

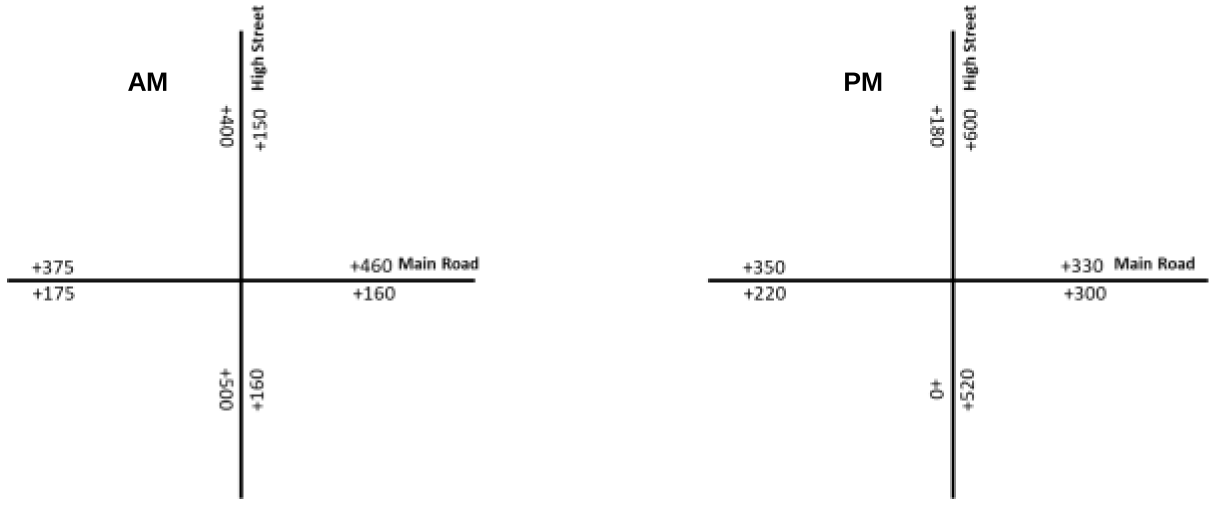
Figure 6 shows that the link change volumes extracted from the strategic model are a major revision to the urban landscape. These represent notable growth per annum across both Main Road and High Street associated with the ongoing development of Ruralton, with a town centre forming shape by 2031 around the intersection of High Street and Main Road.

The link volumes on High Street in the Base Year in the strategic model were also compared to the automatic tube count results. It was found that the Base model volumes were approximately 7% less than the observed volumes. Therefore an adjustment to the trip rates in this area has been conducted as a recalibration of the local behavioural conditions.

The adopted changes in link volumes provide an estimate of the traffic growth on the network for the Future Year. A large part of the change in volumes is associated with the new multi-level shopping district planned at the intersection of High Street and Main Road. While this venue is anticipated generate employment within the retail and service sectors, there will also be an attraction to the venue for non-employment based journeys. In addition to this measure, two additional floors are earmarked for office based commercial employment.

To estimate the change in turning movement volumes, the existing percentages of approach volumes performing each turning movement were applied to the link volumes and adjusted to approximate the entry and exit volumes.

Figure 6: Strategic model extract - 1hr link change volumes (2020-2031)



The overall estimate for the 2031 horizon at the intersection of High Street and Main Road is provided within Figures 7 and Figure 8. The measures used in Figure 7 provides estimated turn volumes for on High Street and Swamp Road, with the anticipated peak hour volumes are provided within Figure 8 for High Street and Main Road.

Figure 7: 2031 peak hour estimate (Seasonally Adjusted) – High Street / Swamp Road peak hour volumes

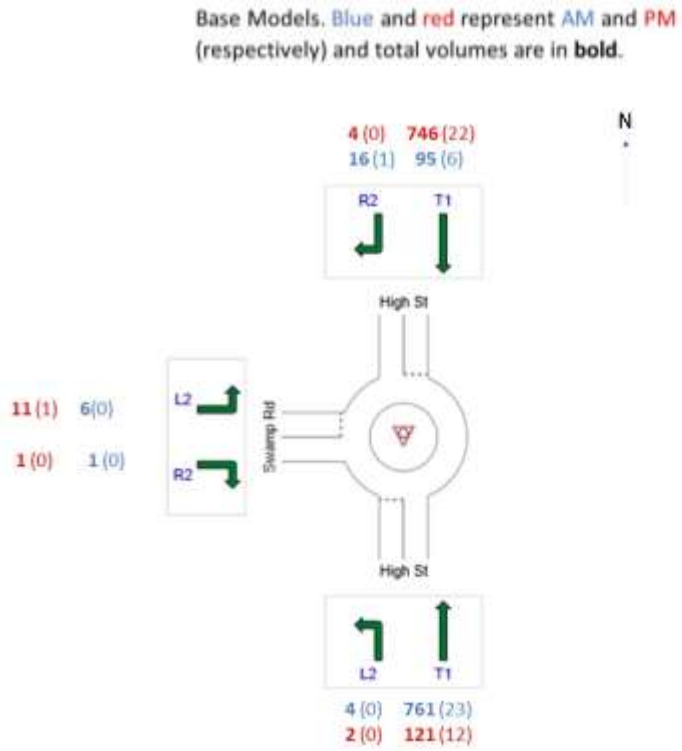
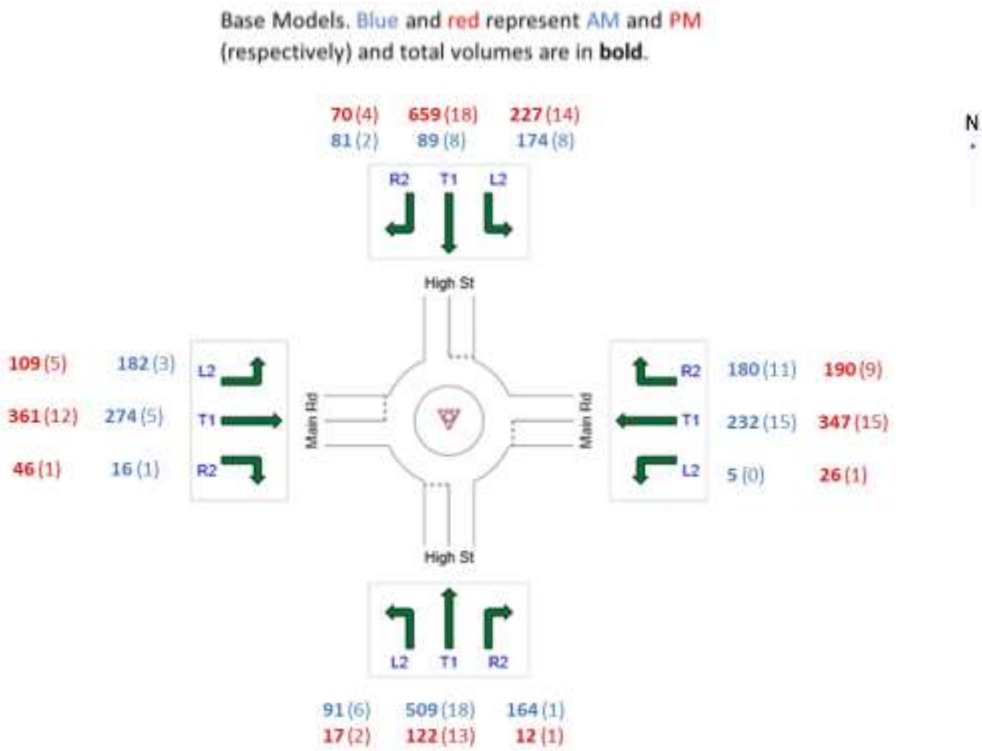


Figure 8: 2031 peak hour estimate (Seasonally Adjusted) – High Street/ Main Road morning peak volumes



The analysis identifies a significant growth in the AM peak hour on High Street at Swamp Road for the northbound and southbound movements. However, traffic volumes on Swamp Road and unchanged. There is also significant growth on Main Road moving through the intersection with High Street.

5.2 Development traffic

The traffic generation of the site is discussed in the Traffic Impact Assessment which outlines trip rates and estimation within the anticipated distribution of journeys. The estimated traffic generated by the proposed development in the peak periods is shown in **Table 4**.

Table 4: Traffic generation (vehicles/hour)

	AM		PM	
	LV	**HV**	**LV**	**HV**
Inbound	180	10	30	10
Outbound	20	10	220	10

The trip distribution assumptions outlined in the impact assessment report are as follows:

- From Swamp Road:
    - 90% north along High Street; and
    - 10% south along High Street.

- From High Street (south):
    - 50% north along High Street (north);
    - 30% west along Main Road; and
    - 20% east along Main Road.

The same trip distribution splits were applied in the opposite direction to represent the counter flow of journeys generated leaving the site within the peak periods. The resulting distributed development traffic volumes are shown in **Figure 9** to **Figure 10**. The cumulative impacts of the seasonally adjusted traffic volumes (design purpose) together with the development traffic estimates are identified within **Figure 11** for High Street/ Swamp Road and in **Figure 12** at High Street/ Main Road.

Analysis of these turn movements identifies a notable growth in AM peak hour traffic demand for the right turn from the northern approach of High Street (at Swamp Road), and reciprocal equivalent for the left turn out from Swamp Rd in the PM peak period. Other movements at this intersection are nominal in change, by comparison. This has an impact on the High Street/ Main Road intersection for all movements to the southbound departure leg. By comparison the southern approach to the intersection received a significant increase in journeys in the PM peak hour. This increase applies to all turns from the approach.

Figure 9: 2031 peak hour estimate (Development Traffic) – High Street / Swamp Road peak hour volumes

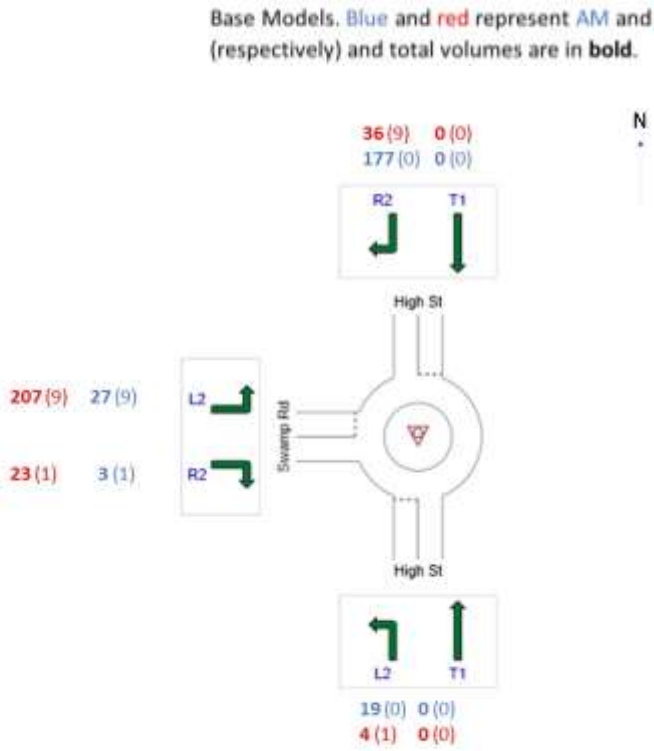


Figure 10: 2031 peak hour estimate (Development Traffic) – High Street/ Main Road morning peak volumes

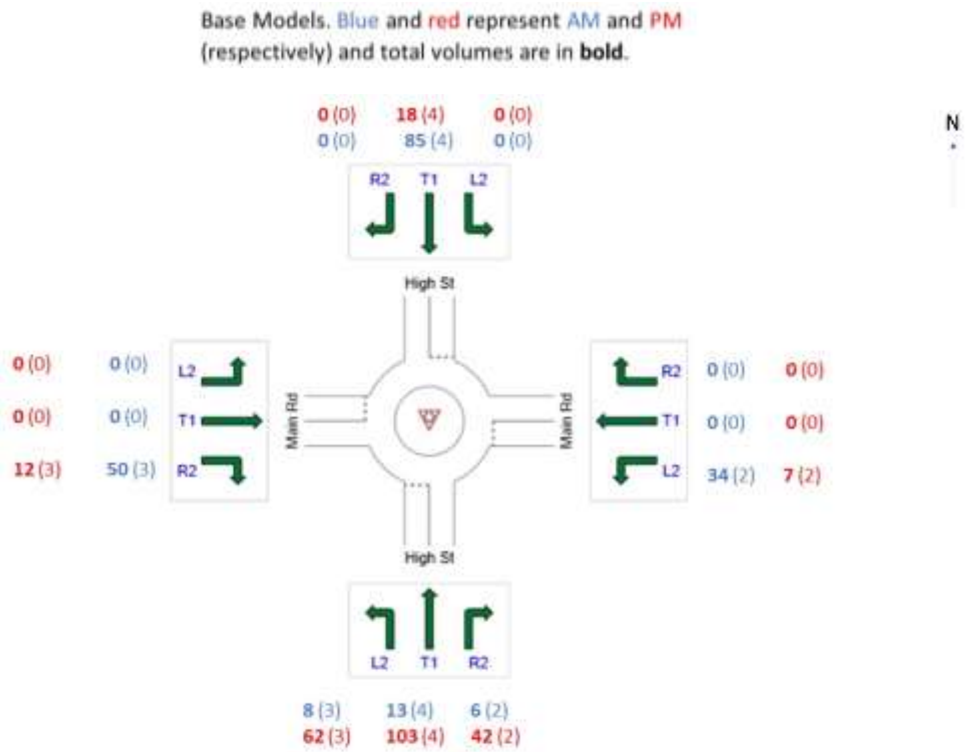


Figure 11: 2031 peak hour estimate (Seasonal Adjustment with Development) – High Street / Swamp Road peak hour volumes

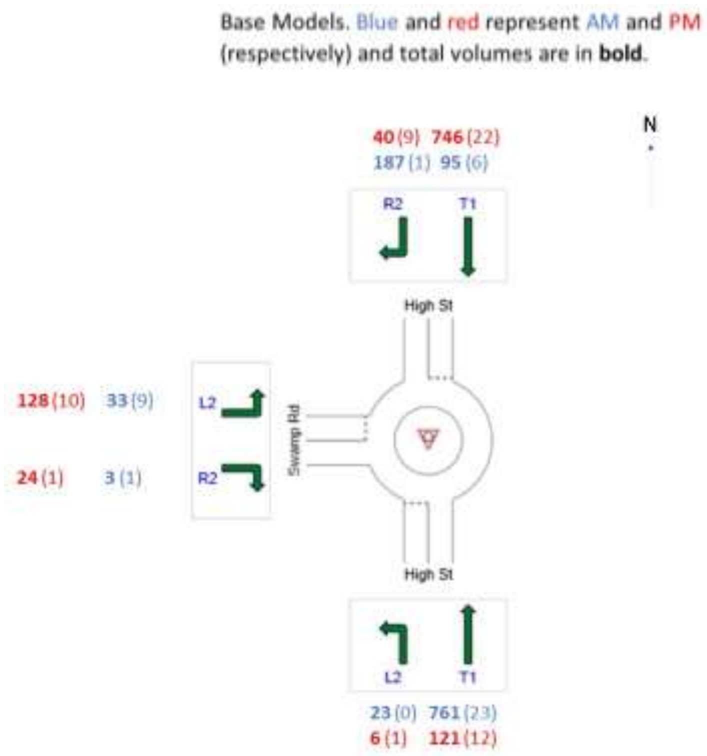
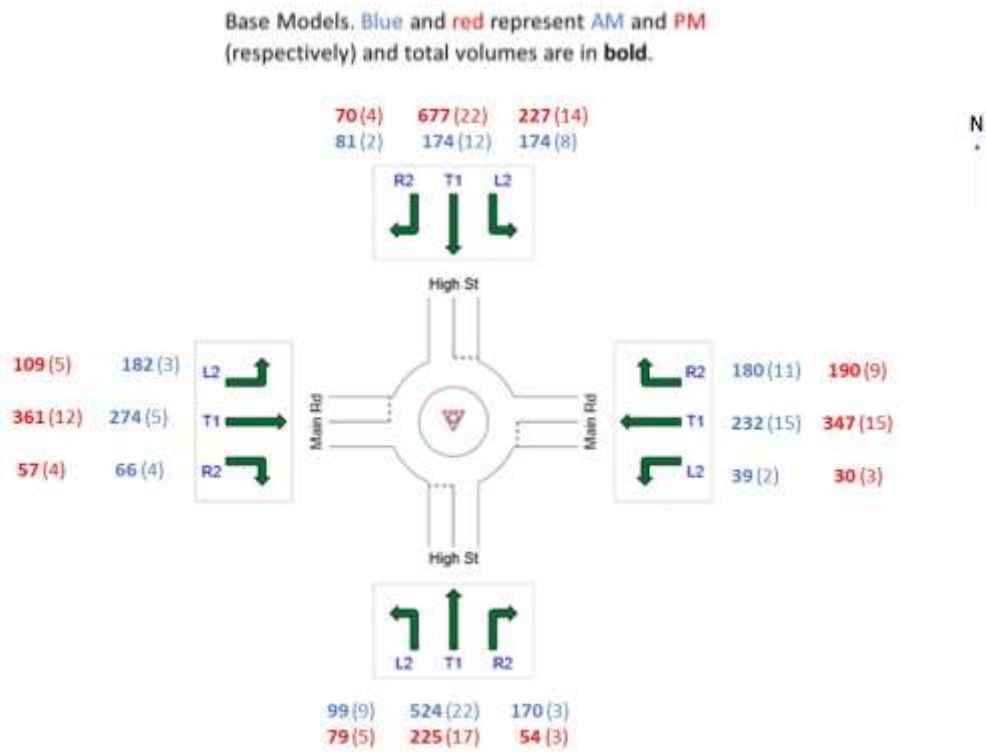


Figure 12: 2031 peak hour estimate (Seasonal Adjustment with Development) – High Street/ Main Road morning peak volumes



5.3 Sensitivity Explorations

A sensitivity test on the design features were also explored as a function of anticipated traffic volumes. The approach provides direction on minor modifications to intersection geometry that may need to be applied on the basis of stochastic variation on the forecast demand of journeys. This process allows for recognition that the comparative processes of demand estimation, trip distribution, model calibration and unsignalized intersection operations are complex deliveries for which a singular answer may not provide enough assurance to the delivery.

In this arrangement, an additional traffic demand of 10% of both the background traffic and figures of the development estimate were applied to the combined future design volumes. This is as per appropriate for a brownfield development location.

The emphasis of conducting this sensitivity is driven by two distinct actions:

- To confirm the design aspects considered within the context of this change and complementing deliveries on the landscape; and
- To explore the suitability of revisions in light of prospective differences on the demand estimation conducted for this pursuit.

This approach allows for exploration into potentially problematic issues to be resolved, from considerations that may develop from a mildly misconstrued demand estimation process.

Other sensitivity tests that might be conducted within this landscape include a revision to the critical gap measures, an adjustment to the Peak Flow Factor or the traffic composition at these locations.

Suggested turn volumes, with an additional element of demand for this sensitivity can be found within **Figure 13** and **Figure 14** to explain movements at both High Street/ Swamp Road and that of High Street/ Main Road.

Figure 13: 2031 peak hour estimate (Seasonal Adjustment with Development) – High Street / Swamp Road peak hour volumes

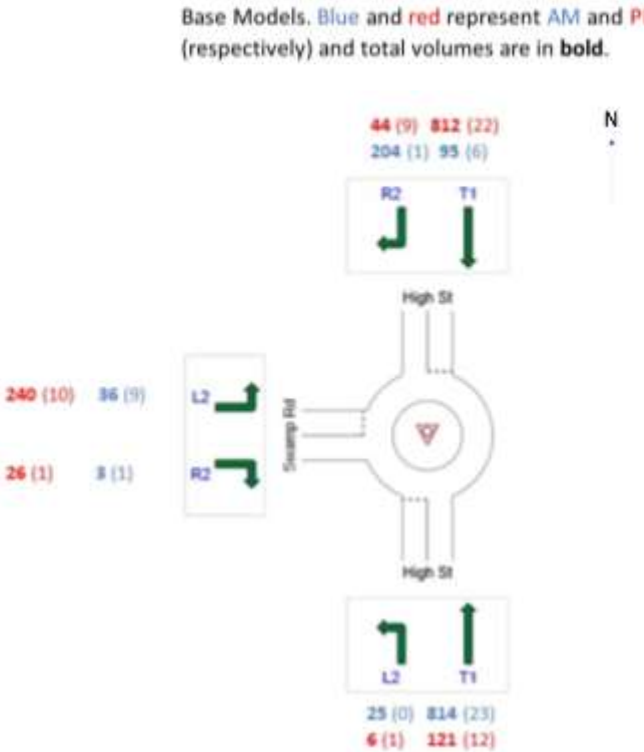
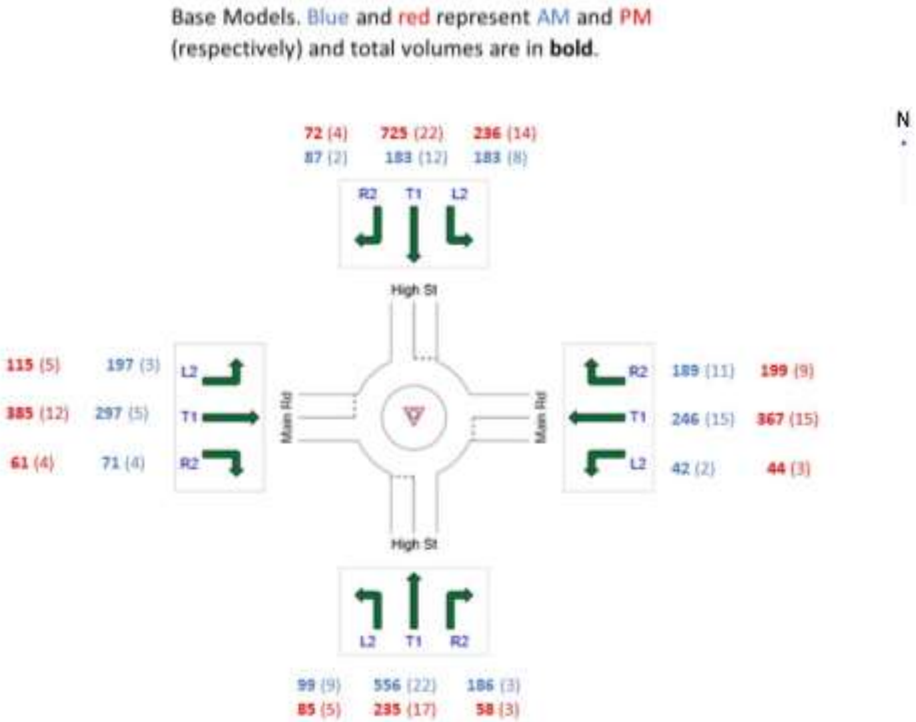


Figure 14: 2031 peak hour estimate (Seasonal Adjustment with Development) – High Street/ Main Road morning peak volumes



6 Performance outputs

The following tables provide the outputs of the future models for the 2031 Future Year, 2031 Future Year with development and 2031 Future Year with development with an additional 10% demand as a sensitivity test. The SIDRA outputs for the future scenarios are included in Appendix B of this report.

Table 5: Degree of Saturation (DoS)

	AM				PM			
	Base	**2031**	**2031 w/Dev**	**2031 w/Dev +10%**	**Base**	**2031**	**2031 w/Dev**	**2031 w/Dev +10%**
High Street / Swamp Road	**15%**	**46%**	**57%**	**62%**	**14%**	**45%**	**48%**	**53%**
South approach (High Street)	15%	46%	57%	62%	8%	8%	8%	8%
North approach (High Street)	7%	7%	17%	18%	14%	45%	48%	53%
West approach (Swamp Road)	1%	1%	7%	9%	1%	1%	18%	18%
High Street / Main Road	**23%**	**103%**	**119%**	**145%**	**28%**	**110%**	**109%**	**122%**
South approach (High Street)	23%	83%	89%	98%	14%	20%	50%	54%
East approach (Main Road)	19%	32%	40%	43%	22%	110%	104%	105%
North approach (High Street)	14%	37%	46%	47%	28%	98%	109%	122%
West approach (Main Road)	9%	103%	119%	145%	16%	45%	57%	62%

Table 6: 95th percentile back of queue lengths (m)

	AM				PM			
	Base	**203 1**	**2031 w/Dev**	**2031 w/Dev +10%**	**Base**	**2031**	**2031 w/Dev**	**2031 w/Dev +10%**
High Street / Swamp Road	**7**	**29**	**39**	**44**	**7**	**20**	**35**	**41**
South approach (High Street)	7	29	39	44	3	3	4	4
North approach (High Street)	3	4	10	11	7	20	35	41
West approach (Swamp Road)	2	1	4	5	0	0	9	10
High Street / Main Road	13	215	356	562	17	302	428	646
South approach (High Street)	13	122	160	245	7	12	36	42
East approach (Main Road)	10	20	26	28	12	302	253	272
North approach (High Street)	7	23	31	31	17	258	428	646
West approach (Main Road)	5	215	356	562	8	29	44	55

Table 7: Average delay (seconds)

	AM				PM			
	Base	2031	2031 w/Dev	2031 w/Dev +10%	Base	2031	2031 w/Dev	2031 w/Dev +10%
High Street / Swamp Road	**6**	**6**	**8**	**8**	**6**	**6**	**6**	**6**
South approach (High Street)	6	6	8	8	6	6	6	6
North approach (High Street)	7	7	9	9	6	6	6	6
West approach (Swamp Road)	3	7	9	10	2	2	2	2
High Street / Main Road	**7**	**31**	**46**	**78**	**7**	**43**	**51**	**72**
South approach (High Street)	7	21	27	43	7	9	12	13
East approach (Main Road)	8	9	10	10	9	97	76	76
North approach (High Street)	6	10	10	10	7	35	72	124
West approach (Main Road)	8	80	137	243	7	8	11	12

Table 8: Level of Service (LoS)

	AM				PM			
	Base	2031	2031 w/Dev	2031 w/Dev +10%	Base	2031	2031 w/Dev	2031 w/Dev +10%
High Street / Swamp Road	**A**	**A**	**A**	**A**	**A**	**A**	**A**	**A**
South approach (High Street)	A	A	A	A	A	A	A	A
North approach (High Street)	A	A	A	A	A	A	A	A
West approach (Swamp Road)	A	A	A	A	A	A	A	A
High Street / Main Road	**A**	**C**	**D**	**F**	A	**D**	**E**	**F**
South approach (High Street)	A	C	C	D	A	A	B	B
East approach (Main Road)	A	A	A	A	A	F	F	F
North approach (High Street)	A	A	A	A	A	D	F	F
West approach (Main Road)	A	F	F	F	A	A	B	B

The tables outlined in Section 6 identify that the intersection of High Street and Swamp Road appears to operate acceptably through to a 2031 horizon. The Degree of Saturation is reasonable and the delays are consistently low with a consistent Level of Service A implying a nominal delay at the location. Queue lengths would be extended up to 40m in this instance. Even with an additional measure of demand, the intersection will continue to performance very reasonably.

However, the intersection of High Street and Main Road tells a different story. This intersection identifies problems on the Western Approach from 2031, which is hindered in the PM peak hour by additional matters on the eastern and then the northern approach (once development is introduced). All three approaches are oversaturated at times through the day with a volume to capacity ratio in excess of 100%. Queue lengths are 350-420 metres in length.

7 Mitigation and Resolution

The tables outlined in Section 6 confirm the need for changes within the intersection of High Street and Main Road in order to successfully deliver journeys through this venue by the horizon of 2031. Overall the modelling results identify a change in undesirable conditions and an excess of delays as follows:

- Western Approach: naturally forming from background traffic during the AM peak period
- Eastern Approach: naturally forming from background traffic during the PM peak period; and
- Northern Approach: forming with the introduction of the development site and additional trips moving to and from this venue.

This analysis identifies for failure and unacceptable operating conditions on three of four approaches over the day by the horizon of 2031. There are several viable mitigation options to explore how to resolve these challenges, which includes the following considerations:

- Demand management techniques
- Infrastructure build (e.g. bypass)
- Infrastructure upgrade (convert roundabout to signals)
- Infrastructure reconfiguration (upgrade roundabout from one circulating lane to two)

Such arrangements of potential problems can utilise the suggested conditions of the sensitivity measure to explore the scale and significance of a suggested revision. In this display the suggested changes have been applied to both projected horizon (with development) and with the additional 10% demand volumes. This assists to determine in the infrastructure changes are appropriate or if other matters arise from the suggested scheme.

As a means to mitigate the congestion of the roundabout at High Street and Main Road, a two lane circulation reconfiguration has been proposed for delivery before 2031. This process would ensure flaring of the intersection and more capacity within the turns. However, the ability to carry more traffic may be offset by the reduction in gaps on the approach for traffic to enter the controller.

The results of the intersection modelling to analyse the suggested changes of road supply and demand of vehicular journeys have been provided within the tables of **Table 9** through to **Table 12**. These measures account for both AM and PM peak hour considerations (and seasonal design considerations) for the 2031 horizon with development, plus that equivalent year with both development and mitigations, as well as a third scenario of development, mitigation and additional demand estimate.

Results documented include the degree of saturation (volume/ capacity ratio), the 95th percentile back of queue length and both average vehicle delay and the corresponding Level of Service.

The modelling analysis identifies that an additional circulating lane for the roundabout will alleviate congestion across all approaches to the intersection. Approaches that are critical in the AM or the PM peak hour will achieve alleviation of the issue by providing more capacity within the venue. The degree of saturation for these congested approaches will fall below 100% with consistently reduced queuing. A further application of the sensitivity with additional demand of journeys identifies that the approaches continue to achieve an operation that is better than a level of service F. In all cases the movements at the intersection performs appropriately.

Table 9: High Street/ Main Road Degree of Saturation (Mitigation Tests)

	AM			PM		
	2031 w/Dev	**2031 w/Dev + Mitigation**	**2031 w/Dev + Mitigation + 10%**	**2031 w/Dev**	**2031 w/Dev + Mitigation**	**2031 w/Dev + Mitigation + 10%**
High Street / Main Road	**119%**	87%	95%	**109%**	79%	89%
South approach (High Street)	89%	87%	95%	50%	49^	55%
East approach (Main Road)	40%	26%	28%	104%	75%	91%
North approach (High Street)	46%	29%	33%	109%	79%	89%
West approach (Main Road)	119%	76%	92%	57%	38%	40%

Table 10: High Street/ Main Road 95th percentile abck of queue length (m) (Mitigation Tests)

	AM			**PM**		
	2031 w/Dev	**2031 w/Dev + Mitigation**	**2031 w/Dev + Mitigation + 10%**	**2031 w/Dev**	**2031 w/Dev + Mitigation**	**2031 w/Dev + Mitigation + 10%**
High Street / Main Road	**356**	**356**	**562**	**428**	**114**	**187**
South approach (High Street)	160	145	213	36	35	43
East approach (Main Road)	26	15	16	253	78	132
North approach (High Street)	31	16	16	428	114	187
West approach (Main Road)	356	78	134	44	22	25

Table 11: High Street/ Main Road Average Vehcile Delay (s) (Mitigation Tests)

	AM			PM		
	2031 w/Dev	**2031 w/Dev + Mitigation**	**2031 w/Dev + Mitigation + 10%**	**2031 w/Dev**	**2031 w/Dev + Mitigation**	**2031 w/Dev + Mitigation + 10%**
High Street / Main Road	**46**	**45**	**76**	**51**	**17**	**25**
South approach (High Street)	27	24	36	12	12	14
East approach (Main Road)	10	9	10	76	25	43
North approach (High Street)	10	9	9	72	16	26
West approach (Main Road)	137	28	49	11	11	13

Table 12: High Street/ Main Road Level of Service (Mitigation Tests)

	AM			PM		
	2031 w/Dev	**2031 w/Dev + Mitigation**	**2031 w/Dev + Mitigation + 10%**	**2031 w/Dev**	**2031 w/Dev + Mitigation**	**2031 w/Dev + Mitigation + 10%**
High Street / Main Road	**D**	**D**	**F**	**E**	**B**	**C**
South approach (High Street)	C	C	D	B	B	B
East approach (Main Road)	A	A	A	F	C	D
North approach (High Street)	A	A	A	F	B	C
West approach (Main Road)	F	C	D	B	B	B

8 Conclusion

Based on the future year modelling, both intersections will continue to operate with good user experience. There is available capacity for additional growth across all scenarios with the inclusion of an additional circulating lane at the roundabout of High Street and Main Road. This demonstrates that the road network will continue to operate acceptably, even when an additional 10% demand is applied across the network.

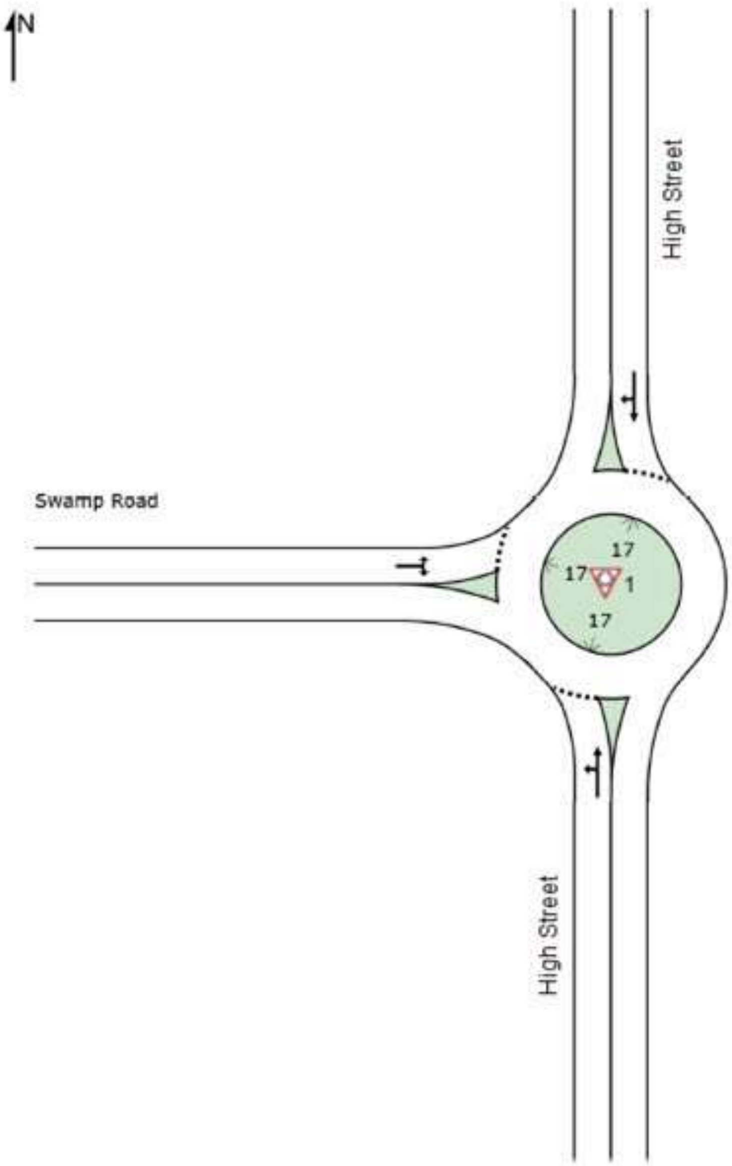
Note that a real report would provide a thorough review of the work conducted and provide a comprehensive conclusion rather than a two sentence summary. This might entail details of alternate options and the performance indicators as a result of varied designs or sensitivities. A conclusion should provide a fresh reader with a comprehensive explanation of the work, not simply a summary statement that omits context.

Appendix A: Base year SIDRA outputs

SITE LAYOUT

Site: 1 High Street/ Swamp Rd

Site Category: (None)
Roundabout



LANE SUMMARY

Site: [High St/Swamp Rd AM Base Year]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	280	8.6	1807	0.154	100	6.1	LOS A	0.9	7.1	Full	500	0.0	0.0
Approach	280	8.6		0.154		6.1	LOS A	0.9	7.1				
North: High St													
Lane 1[d]	119	9.5	1716	0.070	100	6.6	LOS A	0.4	3.4	Full	500	0.0	0.0
Approach	119	9.5		0.070		6.6	LOS A	0.4	3.4				
West: Swamp Rd													
Lane 1[d]	7	0.0	1374	0.005	100	2.5	LOS A	0.0	0.2	Full	500	0.0	0.0
Approach	7	0.0		0.005		2.5	LOS A	0.0	0.2				
Intersection	386	8.4		0.154		6.2	LOS A	0.9	7.1				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

LANE SUMMARY

Site: [High St/Swamp Rd AM Base - Base Year Design Hour]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	273	9.6	1684	0.162	100	6.1	LOS A	1.0	7.5	Full	500	0.0	0.0
Approach	273	9.6		0.162		6.1	LOS A	1.0	7.5				
North: High St													
Lane 1[d]	126	7.1	1736	0.073	100	6.6	LOS A	0.5	3.5	Full	500	0.0	0.0
Approach	126	7.1		0.073		6.6	LOS A	0.5	3.5				
West: Swamp Rd													
Lane 1[d]	8	0.0	1356	0.006	100	2.5	LOS A	0.0	0.2	Full	500	0.0	0.0
Approach	8	0.0		0.006		2.5	LOS A	0.0	0.2				
Intersection	407	8.7		0.162		6.2	LOS A	1.0	7.5				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

LANE SUMMARY

Site: [High St/Swamp Rd PM Base Year]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	133	9.4	1711	0.078	100	6.0	LOS A	0.4	3.3	Full	500	0.0	0.0
Approach	133	9.4		0.078		6.0	LOS A	0.4	3.3				
North: High St													
Lane 1[d]	243	9.8	1714	0.142	100	6.1	LOS A	0.9	7.2	Full	500	0.0	0.0
Approach	243	9.8		0.142		6.1	LOS A	0.9	7.2				
West: Swamp Rd													
Lane 1[d]	13	9.1	1473	0.008	100	1.0	LOS A	0.1	0.4	Full	500	0.0	0.0
Approach	13	9.1		0.008		1.0	LOS A	0.1	0.4				
Intersection	389	9.6		0.142		5.9	LOS A	0.9	7.2				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

LANE SUMMARY

Site: [High St/Swamp Rd PM Base - Base Year Design Hour]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	140	9.4	1711	0.082	100	6.0	LOS A	0.5	3.5	Full	500	0.0	0.0
Approach	140	9.4		0.082		6.0	LOS A	0.5	3.5				
North: High St													
Lane 1[d]	256	9.8	1714	0.149	100	6.1	LOS A	1.0	7.6	Full	500	0.0	0.0
Approach	256	9.8		0.149		6.1	LOS A	1.0	7.6				
West: Swamp Rd													
Lane 1[d]	14	9.2	1461	0.009	100	1.0	LOS A	0.1	0.4	Full	500	0.0	0.0
Approach	14	9.2		0.009		1.0	LOS A	0.1	0.4				
Intersection	409	9.7		0.149		5.9	LOS A	1.0	7.6				

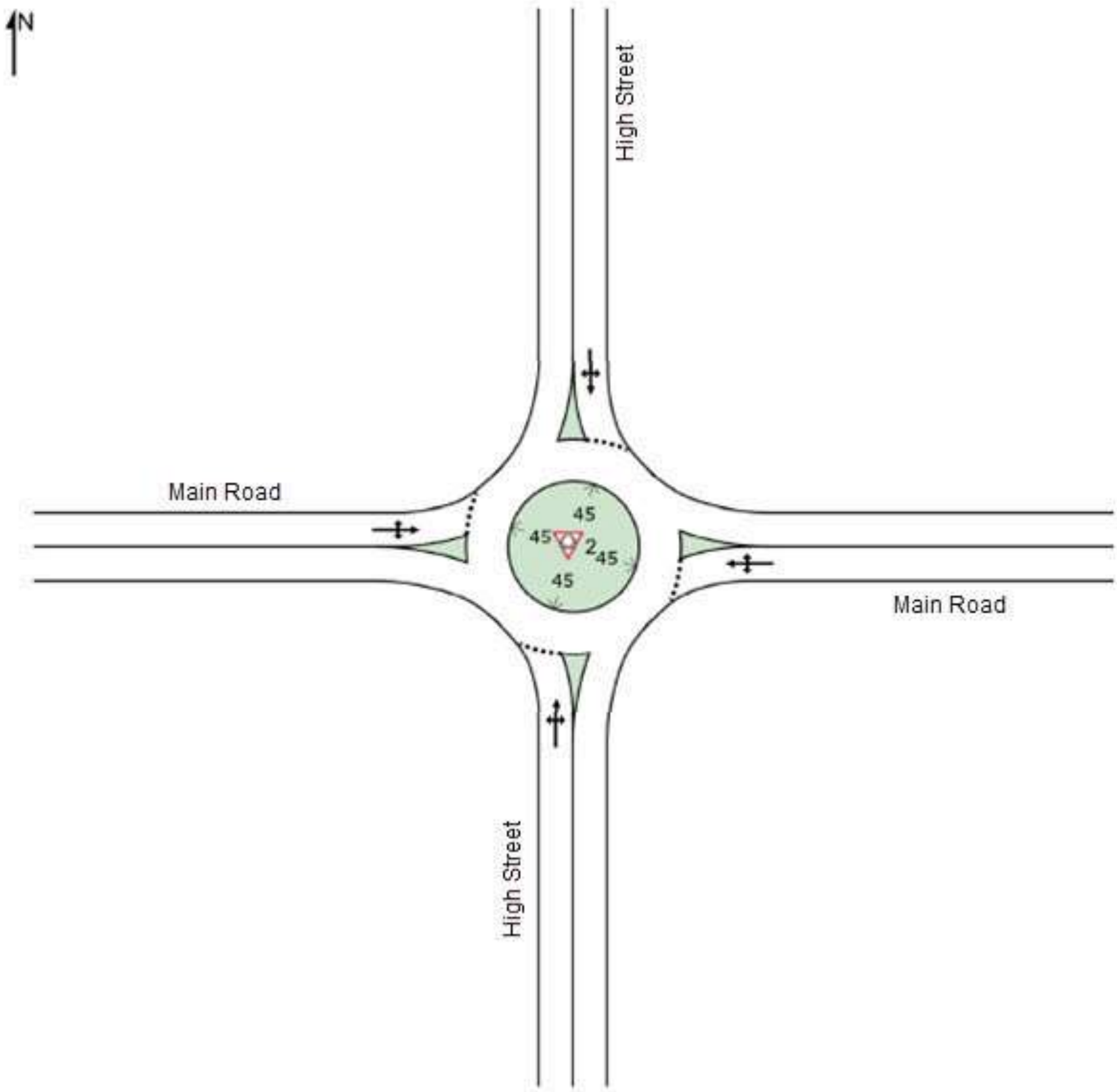
Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

SITE LAYOUT

Site: 2 High Street/ Main Road

Site Category: (None)
Roundabout



LANE SUMMARY

Site: [High St/Main Rd AM Base Year]

New Site
Roundabout

Lane Use and Performance	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	274	10.0	1212	0.226	100	6.8	LOS A	1.6	12.5	Full	500	0.0	0.0
Approach	274	10.0		0.226		6.8	LOS A	1.6	12.5				
East: Main Rd													
Lane 1[d]	278	9.0	1470	0.189	100	8.3	LOS A	1.3	9.8	Full	500	0.0	0.0
Approach	278	9.0		0.189		8.3	LOS A	1.3	9.8				
North: High St													
Lane 1[d]	210	9.7	1540	0.136	100	5.8	LOS A	1.0	7.4	Full	500	0.0	0.0
Approach	210	9.7		0.136		5.8	LOS A	1.0	7.4				
West: Main Rd													
Lane 1[d]	105	9.0	1169	0.089	100	7.6	LOS A	0.6	4.6	Full	500	0.0	0.0
Approach	105	9.0		0.089		7.6	LOS A	0.6	4.6				
Intersection	867	9.8		0.226		7.1	LOS A	1.6	12.5				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

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LANE SUMMARY

Site: [High St/Main Rd AM Base - Base Design Hour]

New Site
Roundabout

Lane Use and Performance	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	289	10.0	1198	0.243	100	7.0	LOS A	1.8	13.6	Full	500	0.0	0.0
Approach	289	10.0		0.243		7.0	LOS A	1.8	13.6				
East: Main Rd													
Lane 1[d]	292	9.0	1409	0.200	100	8.4	LOS A	1.4	10.5	Full	500	0.0	0.0
Approach	292	9.0		0.200		8.4	LOS A	1.4	10.5				
North: High St													
Lane 1[d]	220	9.7	1531	0.144	100	5.8	LOS A	1.0	7.8	Full	500	0.0	0.0
Approach	220	9.7		0.144		5.8	LOS A	1.0	7.8				
West: Main Rd													
Lane 1[d]	110	9.0	1143	0.096	100	7.7	LOS A	0.7	5.0	Full	500	0.0	0.0
Approach	110	9.0		0.096		7.7	LOS A	0.7	5.0				
Intersection	911	9.8		0.243		7.2	LOS A	1.8	13.6				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

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LANE SUMMARY

Site: [High St/Main Rd PM Base Year]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	163	10.5	1163	0.140	100	7.0	LOS A	1.0	7.4	Full	500	0.0	0.0
Approach	163	10.5		0.140		7.0	LOS A	1.0	7.4				
East: Main Rd													
Lane 1[d]	284	9.6	1264	0.225	100	8.9	LOS A	1.6	12.4	Full	500	0.0	0.0
Approach	284	9.6		0.225		8.9	LOS A	1.6	12.4				
North: High St													
Lane 1[d]	392	9.9	1406	0.279	100	6.5	LOS A	2.2	16.9	Full	500	0.0	0.0
Approach	392	9.9		0.279		6.5	LOS A	2.2	16.9				
West: Main Rd													
Lane 1[d]	201	9.6	1277	0.158	100	6.6	LOS A	1.1	8.3	Full	500	0.0	0.0
Approach	201	9.6		0.158		6.6	LOS A	1.1	8.3				
Intersection	1040	9.6		0.279		7.3	LOS A	2.2	16.9				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

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LANE SUMMARY

Site: [High St/Main Rd PM Base - Base Year Design Hour]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	172	10.5	1139	0.151	100	7.1	LOS A	1.1	8.1	Full	500	0.0	0.0
Approach	172	10.5		0.151		7.1	LOS A	1.1	8.1				
East: Main Rd													
Lane 1[d]	298	9.6	1243	0.241	100	9.0	LOS A	1.8	13.5	Full	500	0.0	0.0
Approach	298	9.6		0.241		9.0	LOS A	1.8	13.5				
North: High St													
Lane 1[d]	413	9.9	1390	0.297	100	6.6	LOS A	2.4	18.3	Full	500	0.0	0.0
Approach	413	9.9		0.297		6.6	LOS A	2.4	18.3				
West: Main Rd													
Lane 1[d]	211	9.6	1256	0.168	100	6.7	LOS A	1.2	8.8	Full	500	0.0	0.0
Approach	211	9.6		0.168		6.7	LOS A	1.2	8.8				
Intersection	1094	9.8		0.297		7.4	LOS A	2.4	18.3				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

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Appendix B: Future year SIDRA outputs

LANE SUMMARY

Site: [High St/Swamp Rd AM - Future Year]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	805	3.0	1742	0.462	100	6.0	LOS A	4.1	29.1	Full	500	0.0	0.0
Approach	805	3.0		0.462		6.0	LOS A	4.1	29.1				
North: High St													
Lane 1[d]	117	7.1	1736	0.067	100	6.6	LOS A	0.5	3.6	Full	500	0.0	0.0
Approach	117	7.1		0.067		6.6	LOS A	0.5	3.6				
West: Swamp Rd													
Lane 1[d]	7	0.0	745	0.010	100	7.1	LOS A	0.1	0.5	Full	500	0.0	0.0
Approach	7	0.0		0.010		7.1	LOS A	0.1	0.5				
Intersection	929	3.5		0.462		6.1	LOS A	4.1	29.1				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

LANE SUMMARY

Site: [High St/Swamp Rd AM - Future Year + Development]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	825	2.9	1458	0.566	100	7.5	LOS A	5.4	38.7	Full	500	0.0	0.0
Approach	825	2.9		0.566		7.5	LOS A	5.4	38.7				
North: High St													
Lane 1[d]	297	2.8	1766	0.168	100	8.7	LOS A	1.4	9.8	Full	500	0.0	0.0
Approach	297	2.8		0.168		8.7	LOS A	1.4	9.8				
West: Swamp Rd													
Lane 1[d]	38	27.8	528	0.072	100	8.6	LOS A	0.5	4.4	Full	500	0.0	0.0
Approach	38	27.8		0.072		8.6	LOS A	0.5	4.4				
Intersection	1160	3.7		0.566		7.8	LOS A	5.4	38.7				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

LANE SUMMARY

Site: [High St/Swamp Rd AM - Future Year + Development +10%]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1 d	883	2.8	1434	0.616	100	7.8	LOS A	6.2	44.4	Full	500	0.0	0.0
Approach	883	2.8		0.616		7.8	LOS A	6.2	44.4				
North: High St													
Lane 1 d	315	2.7	1768	0.178	100	8.8	LOS A	1.5	10.6	Full	500	0.0	0.0
Approach	315	2.7		0.178		8.8	LOS A	1.5	10.6				
West: Swamp Rd													
Lane 1 d	41	25.6	478	0.086	100	9.5	LOS A	0.6	5.3	Full	500	0.0	0.0
Approach	41	25.6		0.086		9.5	LOS A	0.6	5.3				
Intersection	1239	3.5		0.616		8.1	LOS A	6.2	44.4				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

LANE SUMMARY

Site: [High St/Swamp Rd PM - Future Year]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1 d	129	9.4	1712	0.076	100	6.0	LOS A	0.4	3.2	Full	500	0.0	0.0
Approach	129	9.4		0.076		6.0	LOS A	0.4	3.2				
North: High St													
Lane 1 d	789	2.9	1772	0.446	100	6.0	LOS A	4.3	30.7	Full	500	0.0	0.0
Approach	789	2.9		0.446		6.0	LOS A	4.3	30.7				
West: Swamp Rd													
Lane 1 d	13	9.2	1478	0.009	100	1.8	LOS A	0.1	0.4	Full	500	0.0	0.0
Approach	13	9.2		0.009		1.8	LOS A	0.1	0.4				
Intersection	932	3.9		0.446		5.9	LOS A	4.3	30.7				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

LANE SUMMARY

Site: [High St/Swamp Rd PM - Future Year + Development]

New Site
Roundabout

Lane Use and Performance	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	134	9.9	1630	0.082	100	6.2	LOS A	0.5	3.8	Full	500	0.0	0.0
Approach	134	9.9		0.082		6.2	LOS A	0.5	3.8				
North: High St													
Lane 1[d]	827	4.0	1715	0.482	100	6.3	LOS A	4.9	35.3	Full	500	0.0	0.0
Approach	827	4.0		0.482		6.3	LOS A	4.9	35.3				
West: Swamp Rd													
Lane 1[d]	265	4.4	1511	0.176	100	1.9	LOS A	1.3	9.3	Full	500	0.0	0.0
Approach	265	4.4		0.176		1.9	LOS A	1.3	9.3				
Intersection	1226	4.7		0.482		5.4	LOS A	4.9	35.3				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

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LANE SUMMARY

Site: [High St/Swamp Rd PM - Future Year + Development +10%]

New Site
Roundabout

Lane Use and Performance	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	134	9.9	1622	0.082	100	6.2	LOS A	0.5	3.8	Full	500	0.0	0.0
Approach	134	9.9		0.082		6.2	LOS A	0.5	3.8				
North: High St													
Lane 1[d]	901	3.6	1714	0.526	100	6.4	LOS A	5.7	40.9	Full	500	0.0	0.0
Approach	901	3.6		0.526		6.4	LOS A	5.7	40.9				
West: Swamp Rd													
Lane 1[d]	279	4.2	1512	0.184	100	1.9	LOS A	1.4	9.8	Full	500	0.0	0.0
Approach	279	4.2		0.184		1.9	LOS A	1.4	9.8				
Intersection	1314	4.4		0.526		5.4	LOS A	5.7	40.9				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

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LANE SUMMARY

Site: [High St/Main Rd PM - Future Year]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	158	10.5	777	0.205	100	9.4	LOS A	1.6	12.4	Full	500	0.0	0.0
Approach	158	10.5		0.205		9.4	LOS A	1.6	12.4				
East: Main Rd													
Lane 1[d]	593	4.5	537	1.103	100	98.9	LOS F	41.5	301.5	Full	500	0.0	0.0
Approach	593	4.5		1.103		98.9	LOS F	41.5	301.5				
North: High St													
Lane 1[d]	1006	3.7	1030	0.977	100	35.3	LOS D	35.6	257.5	Full	500	0.0	0.0
Approach	1006	3.7		0.977		35.3	LOS D	35.6	257.5				
West: Main Rd													
Lane 1[d]	543	3.5	1207	0.450	100	7.5	LOS A	4.1	29.2	Full	500	0.0	0.0
Approach	543	3.5		0.450		7.5	LOS A	4.1	29.2				
Intersection	2301	4.3		1.103		42.8	LOS D	41.5	301.5				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
Roundabout LOS Method: SIDRA Roundabout LOS.
Lane LOS values are based on average delay per lane.
Intersection and Approach LOS values are based on average delay for all lanes.
Roundabout Capacity Model: SIDRA Standard.
SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

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LANE SUMMARY

Site: [High St/Main Rd PM - Future Year + Development]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	377	6.9	761	0.495	100	11.8	LOS B	4.9	36.3	Full	500	0.0	0.0
Approach	377	6.9		0.495		11.8	LOS B	4.9	36.3				
East: Main Rd													
Lane 1[d]	600	4.8	575	1.043	100	75.6	LOS F	34.7	253.1	Full	500	0.0	0.0
Approach	600	4.8		1.043		75.6	LOS F	34.7	253.1				
North: High St													
Lane 1[d]	1025	4.1	937	1.094	100	72.4	LOS F	59.0	427.8	Full	500	0.0	0.0
Approach	1025	4.1		1.094		72.4	LOS F	59.0	427.8				
West: Main Rd													
Lane 1[d]	555	4.0	978	0.567	100	10.7	LOS B	6.1	44.2	Full	500	0.0	0.0
Approach	555	4.0		0.567		10.7	LOS B	6.1	44.2				
Intersection	2557	4.6		1.094		58.8	LOS E	59.0	427.8				

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Intersection and Approach LOS values are based on average delay for all lanes.
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Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
HV (%) values are calculated for All Movement Classes of All Heavy Vehicle Model Designation.

d Dominant lane on roundabout approach

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LANE SUMMARY

Site: [High St/Main Rd PM - Future Year + Development + Intersection Upgrade]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	377	6.9	768	0.491	100	12.2	LOS B	4.7	35.8	Full	500	0.0	0.0
Approach	377	6.9		0.491		12.2	LOS B	4.7	35.8				
East: Main Rd													
Lane 1	215	5.1	507	0.424	57[5]	13.4	LOS B	3.8	28.1	Short	60	0.0	NA
Lane 2[d]	385	4.6	515	0.747	100	31.5	LOS C	10.7	78.2	Full	500	0.0	0.0
Approach	600	4.8		0.747		25.0	LOS C	10.7	78.2				
North: High St													
Lane 1	207	7.0	912	0.227	100	8.5	LOS A	1.8	13.6	Short	60	0.0	NA
Lane 2[d]	778	3.5	985	0.790	100	16.9	LOS B	14.2	102.0	Full	500	0.0	0.0
Approach	985	4.2		0.790		15.1	LOS B	14.2	102.0				
West: Main Rd													
Lane 1	198	4.1	958	0.207	57[5]	8.1	LOS A	1.0	11.7	Short	60	0.0	NA
Lane 2[d]	358	3.9	982	0.365	100	9.3	LOS A	3.0	21.8	Full	500	0.0	0.0
Approach	555	4.0		0.365		8.9	LOS A	3.0	21.8				
Intersection	2517	4.7		0.790		15.7	LOS B	14.2	102.0				

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SIDRA Standard Delay Model is used. Control Delay includes Geometric Delay.
Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
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5 Lane under-utilisation due to downstream effects
d Dominant lane on roundabout approach

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LANE SUMMARY

Site: [High St/Main Rd PM - Future Year + Development + Intersection Upgrade +10%]

New Site
Roundabout

Lane Use and Performance

	Demand Flows Total veh/h	Demand Flows HV %	Cap. veh/h	Deg. Satn v/c	Lane Util. %	Average Delay sec	Level of Service	95% Back of Queue Veh	95% Back of Queue Dist m	Lane Config	Lane Length m	Cap. Adj. %	Prob. Block. %
South: High St													
Lane 1[d]	398	6.6	727	0.548	100	14.4	LOS B	5.8	43.2	Full	500	0.0	0.0
Approach	398	6.6		0.548		14.4	LOS B	5.8	43.2				
East: Main Rd													
Lane 1	229	4.6	445	0.515	57[5]	18.5	LOS B	5.2	38.8	Short	60	0.0	NA
Lane 2[d]	413	4.4	454	0.909	100	56.0	LOS E	18.2	132.1	Full	500	0.0	0.0
Approach	642	4.5		0.909		42.6	LOS D	18.2	132.1				
North: High St													
Lane 1	248	5.8	876	0.284	100	9.0	LOS A	2.4	17.4	Short	60	0.0	NA
Lane 2[d]	839	3.3	943	0.898	100	25.5	LOS C	21.9	157.3	Full	500	0.0	0.0
Approach	1087	3.9		0.898		21.7	LOS C	21.9	157.3				
West: Main Rd													
Lane 1	209	3.9	918	0.228	57[5]	8.3	LOS A	1.8	13.1	Short	60	0.0	NA
Lane 2[d]	382	3.6	950	0.402	100	9.6	LOS A	3.4	24.6	Full	500	0.0	0.0
Approach	591	3.7		0.402		9.2	LOS A	3.4	24.6				
Intersection	2718	4.4		0.909		22.9	LOS C	21.9	157.3				

Site Level of Service (LOS) Method: Delay (SIDRA). Site LOS Method is specified in the Parameter Settings dialog (Site tab).
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Gap-Acceptance Capacity: SIDRA Standard (Akçelik M3D).
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5 Lane under-utilisation due to downstream effects
d Dominant lane on roundabout approach

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