Transport modelling for project managers -

a critique of Austroads Report AP-R621-20A

Prepared by

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Technical Note
Akcelik & Associates

August 2020

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ACKNOWLEDGEMENTS

Akcelik & Associates Pty Ltd acknowledges the contributions by numerous users from many countries around the world through their valuable comments towards the development of SIDRA SOLUTIONS software products.

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Transport modelling for project managers - a critique of Austroads Report AP-R621-20

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Updated: 22 August 2020

Reference:

AKÇELIK, R., BESLEY, M., ESPADA, I. and NASH, D. (2020). *Transport modelling for project managers - a critique of Austroads Report AP-R621-20*. Technical Note. Akcelik & Associates Pty Ltd, Melbourne, Australia.

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Dr Rahmi Akçelik is a leading scientist and software developer with 50 years of practical, research and training experience in the area of road traffic operations, traffic engineering, management and control. He is Director of Akcelik and Associates Pty Ltd (trading as SIDRA SOLUTIONS). He has 350 technical publications in his area of expertise. He is the author of the SIDRA INTERSECTION and SIDRA TRIP software packages. Rahmi served as member of various US Transportation Research Board Committees. He has trained several thousand professionals in over 300 workshops, courses and seminars.

Awards received by Rahmi include the *2014 Roads Australia Award for Technical Excellence* in recognition of the exceptional achievement of an individual in a technical or scientific area relevant to transport, the *2008 ITE ANZ Contribution to the Transportation Profession Award, the 1999 Clunies Ross National Science and Technology Award* for outstanding contribution to the application of science and technology, *and the 1986 ITE US Transportation Energy Conservation Award.*

MARK BESLEY

Mark Besley is a scientist and software specialist who has worked in the traffic management area since 1980s. He has been making a significant contribution to the development of the SIDRA SOLUTIONS software in collaboration with Dr Rahmi Akçelik during the last 30+ years. He has trained several thousand professionals in over 300 workshops, courses and seminars.

Mark has been involved in many aspects of research on traffic operations including traffic network models, incident detection, fuel consumption estimation, traffic data collection and analysis.

IAN ESPADA

Dr Ian Espada joined Akcelik and Associates in November 2019 as a Senior Traffic Modeller / Analyst. Ian has more than 18 years of work experience in the role of researcher, transport/traffic planner, transport survey specialist, transport demand modeler, and transport economist. He had an 11-year career at the Australian Road Research Board where he was the team leader of the Network Operations Team under the Future Transport Systems Working Group.

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DAVID NASH

David Nash is an accredited SIDRA INTERSECTION trainer. He graduated from the University of Melbourne as a Civil Engineer in 1978 and attained a Graduate Diploma in Technology Management in 2003. He has over 35 years of experience in traffic engineering, having worked with the Commonwealth Department of Transport, Country Roads Board, Road Traffic Authority and VicRoads. He worked on the design and operation of traffic signals and the early SCATS installations in Melbourne and Singapore. He has also had overseas work experience in Indonesia, Thailand and Ireland.

David lectured in Transport Engineering at Swinburne University of Technology and has conducted many workshops and webinars. David is Principal of Traffinity, a traffic engineering consultancy based in Melbourne, Australia. He is the secretary of the Institute of Transportation Engineers - Australia and New Zealand Section.

SUMMARY

This technical note presents a critical review of the Austroads Report AP-R621-20 (Building Transport Modelling Management Capability) on the subject of guidance to traffic and transport modelling project managers. The authors recommend that Austroads undertakes a major revision of this report urgently to address the fundamental issues and some technical details raised in this review. Such a revision would rectify the inconsistencies in the model categorisation scheme and its implications for model choice. It would also introduce corrections to a large number of incomplete discussions and errors in technical details pertaining to analytical and simulation modelling for intersections and networks.

This review should be of interest to project managers, modelling guide developers and modellers using analytical and simulation software in the area of transport and traffic modelling. The authors hope that the profession will discuss the issues raised in this review rigorously.

The report under review states its purpose as "*to develop guidance to assist project managers of modelling projects to make informed decisions when commissioning Simulation (Mesoscopic and Microscopic) and Intersection modelling services, as well as managing or communicating the associated processes.* This statement summarises its inconsistent approach to addressing the general *transport and traffic modelling* field as a "*Simulation and Intersection modelling"*. This approach leads to inadequate and biased advice to managers of transport and traffic modelling projects.

Inadequate assessments and many erroneous statements in the report under review underrate traffic modelling in general and the software packages listed in its model categorisation table in particular. Traffic and transport modelling deals with complex systems and therefore uses complex mathematical techniques whether it is analytical or simulation, and whether it is single intersection, small network or large network modelling. It is hoped that the discussions presented in this review clarify most of the misleading statements and conclusions of the report.

Section 2 of this review includes general considerations about model categorisation which is important in relation to decision making by managers of modelling projects. The inconsistencies in the categorisation system given in the report are discussed and a proposed modification of the model category system is presented. The proposed traffic and transport model categorisation system uses the geographic extent of the area to be modelled as the basis of *Model Types* with clear relationships to the *Model Level of Detail* and *Modelling Technique*. Detailed discussions are presented to explain the reasons for the proposed changes. A method is proposed for the assessment of model categories and key model features that apply to individual software packages rather than lumping together different software packages into forced model categories. A short summary of other traffic and transport modelling guides is also presented, pointing to those supporting the system proposed in this review report.

In *Section 3*, more specific technical aspects of the report are discussed in detail. These include capacity estimation as a function of road geometry, traffic flows (demand) and signal timings; modelling of peak demand (analysis) period; treatment of pedestrians and vehicle classes including bicycles, buses and trams / light rail; and 23 points discussing some erroneous, incomplete or misleading aspects of the report under review.

Section 4 presents a summary of the conclusions and recommendations for an urgent revision of the report under review.

The *References* section includes a list of publications that support the critique presented in this report. *Appendices A to D* include some supporting material. *Appendix E* includes a copy of the original model categorisation table given in the report under review as well as a copy of the table showing the changes made in applying the proposed transport and traffic model categorisation system of this review.

1 Introduction

This technical note addresses the subject of guidance to traffic and transport modelling project managers and presents a critique of the Austroads Report AP-R621-20 (Building Transport Modelling Management Capability).

This is not a comprehensive review of the large report but rather a limited one addressing some basic premises as well as various technical aspects of the report that are of concern to the authors of this review. It focuses on fundamental issues of model categorisation given in Section 2, and the intersection and network modelling issues raised in Section 4 and various appendices of the report.

When not clear, this report will be referred to as "the report under review", or " the Austroads report under review", or "the Austroads report" according to the context, and this technical note presenting the critical review of the report will be referred to as the "review report", or "technical note".

The report under review states its target audience as "*project managers with no specific technical experience in modelling*" and its purpose as "*to develop guidance to assist project managers of modelling projects to make informed decisions when commissioning Simulation (Mesoscopic and Microscopic) and Intersection modelling services, as well as managing or communicating the associated processes. The guidance is not intended to equip readers with technical knowledge and detail about models themselves….*".

In describing its scope, it lists "*guidance that are considered important when managing or commissioning modelling work*" including "*Understanding transport models and the process*." and " *Selecting the right modelling platform and software to investigate particular issues*.".

The purpose of the report quoted above indicates its inconsistent approach to addressing the general *transport and traffic modelling* field as a "*Simulation and Intersection modelling"* field since simulation applies to intersection modelling as well as network modelling. This approach leads to inadequate and biased advice to managers of transport and traffic modelling projects.

At the same time, the report includes technical details that are incomplete and includes incorrect statements.

The purpose of this technical note is to propose a revision of the report to urgently address the fundamental issues and some of the technical details raised.

As such, this report should be of interest to the following people whose work includes the area of transport and traffic modelling:

- project managers,
- modelling guide developers, and
- modellers using analytical and simulation software.

It should be noted that, in relation to the SIDRA INTERSECTION software developed and supported by the authors, the report acknowledges that "*SIDRA is the most popular intersection modelling software in Australia and New Zealand.*", and the software has a significant place in the Austroads Traffic Management Guides. However, no consultation had taken place with the authors in the development of the Austroads Report AP-R621-20.

Section 2 of this review report includes general considerations about model categorisation which is important in relation to decision making by managers of modelling projects. The inconsistencies in the categorisation system given in Table 2.1 and Figure 2.3 of the report under review are discussed and a proposed modification of the model category system is presented. The proposed traffic and transport model categorisation system uses the geographic extent of the area to be modelled as the basis of *Model Types* with clear relationships to the *Model Level of Detail* and *Modelling Technique*. Detailed discussions are presented to explain the reasons for the proposed changes. A method is proposed for the assessment of model categories and key model features applying to individual software packages rather than lumping together different software packages into forced model categories. A short summary of other traffic and transport modelling guides is also presented, pointing to those supporting the system proposed in this review report.

In *Section 3*, more specific technical aspects of the report are discussed in detail. These include capacity estimation as a function of road geometry, traffic flows (demand) and signal timings; modelling of peak demand (analysis) period; treatment of pedestrians and vehicle classes including bicycles, buses and trams / light rail; and 23 points discussing some erroneous, incomplete or misleading aspects of the report under review.

Section 4 presents a summary of the conclusions and recommendations for an urgent revision of the report under review.

The *References* section includes a list of publications that support the critique presented in this report.

In *Appendices A to D*, some supporting material is given. *Appendix E* includes a copy of the original Table 2.1 of the report under review as well as a copy of the table showing the changes made in preparing the proposed system in *Table 1* of this review report.

2 Traffic and Transport Model Categories

2.1 What is Wrong with Austroads Model Categorisation?

As stated in the Austroads Report AP-R621-20 (Building Transport Modelling Management Capability), modelling by software has been playing an increasingly important role in the assessment of traffic and transport projects. It is therefore important to identify the most relevant defining characteristics of traffic and transport modelling software for the benefit of managers responsible for commissioning and managing modelling projects. In this section, the basic premises of the modelling categories and hierarchy presented in the Austroads Report (summarised in Table 2.1 and Figure 2.3) are discussed.

In preparing the proposed modifications, the following were the main concerns regarding the contents of Austroads Table 2.1. In *Appendix E, Figure E.1* shows the original Table 2.1 of the Austroads report.

1. The title ***Model Level*** in the header of the first column of the table is categorised as:
    - *Strategic Models*
    - *Simulation Model*
    - *Intersection Models.*

   This does not present a consistent categorisation since the *Strategic Models* and *Intersection Models* categories relate to the ***type of model***, i.e. to *model functionality* and *area of application* whereas the *Simulation Model* category relates to a ***modelling technique*** <u>not a *model level*</u>.
2. Macroscopic model, Mesoscopic model and Microscopic model categories in the second column of the table titled ***Sub-category*** are, in fact, <u>main categories</u> of ***model level*** (model level of detail).
3. Analytical model and Simulation (macrosimulation, microsimulation) model in the third column of the table titled ***Other terminology*** are ***modelling techniques***. Intersection model in this column of the table is a **model type** (*model functionality*, *area of application*) which is inconsistent with being in the same column as categories representing ***model level*** of detail.
4. ***Key model features*** in the fourth column of the table raise a few issues of concern:
    - *Mesoscopic models* are described as "*simplified simulation of individual vehicles*" whereas other simulation models have been described as mesoscopic models, e.g. cell transmission models (Burghout 2004), and "simulation of second-by-second platoon movements" as used in software packages listed in the last row could also be qualified as mesoscopic simulation.
    - The table states the key feature of "Intersection models" as "*Simplistic calculation of intersection performance and operation*". The text of the report indicates that this assertion is a result of erroneous considerations. This is discussed in *Section 3*.
    - Lack of reference to the capability to model alternative intersection control treatments, namely signals, roundabouts and give-way or stop sign control which is important in assessing models (Akçelik 2011a,b, 2012b,c, 2018, Akçelik and Besley 2005)
5. Categorisation of the ***software packages*** in the last column of the table is problematic since they are forced into an inconsistent model category scheme as described in 1 to 3 above. Most software packages listed in the table have capabilities for modelling ***intersections and networks*** using a mixture of ***analytical and simulation modelling techniques*** which involve ***macroscopic, mesoscopic and microscopic levels of detail***. Thus, the table gives a misleading impression about those listed in the last row labelled as "Intersection Models", especially in view of the erroneous assertion of "simplistic calculation".

   The subject of software packages is discussed in some more detail in *Section 2.3*.

   Also refer to *Point 19* in *Section 3.3* for a discussion on mesoscopic models.

2.2 Proposed Modification to Austroads Model Categorisation

2.2.1 Proposed Changes to Austroads Model Categories and Hierarchy

Table 1 presented here is the proposed modified version of Table 2.1 (***Model categories***) of the Austroads report. This addresses the concerns expressed in Section 2.1. *Figure 1* shows the Austroads report Figure 2.3 (***Traffic and transport modelling hierarchy***) with modifications that reflect the proposed system presented in *Table 1*. In *Appendix E, Table E.1* shows the details of the changes made to the Austroads report, and *Figure E.1* shows the original Table 2.1 of the Austroads report.

In line with the proposed changes in *Table 1* and *Figure 1*, it is also recommended that, in Figure 5.1 (Integrated modelling interdependencies) of the Austroads report, the text "Simulation Model" in the middle box is changed to "Network Model" (see *Point 18* in *Section 3.3*).

The proposed model categorisation system presented in *Table 1* as a modified version of Table 2.1 of Austroads Report AP-R621-20 is based on the following **framework for categorising traffic and transport models** that aims to use consistent criteria:

- ***Model Type***: The type of *area* and the *network size* as a rough guide are used to identify the Model Type (model functionality, area of application) as included in the fourth column of the table (Key model features).
  - ***Strategic Transport Models***: Very large networks (city scale, regional scale)
  - ***Large Area Traffic Models***: Medium to large networks (up to 30-100 intersections, maybe more).
  - ***Intersection and Small Area Traffic Models***: Single intersection and small networks (up to 10-20 intersections).

  Strategic models are identified as more relevant to *transport modelling* whereas Intersection, Small Area and Large Area Traffic Models are more relevant to intersection and network modelling for various purposes that require detailed analysis.

  Figure 2 illustrates the concept of area type and network size as a basis of defining Model Types. This is in line with the text "*Typically increasing geographical coverage / network size*" in the upward arrow in Figure 2.3 of the Austroads report (as seen in *Figure 1*).

  In *Figure 1*, the separate "Intersection Model" level of Figure 2.3 of the Austroads report is removed as this is included in the *Intersection and Small Area Traffic Models* level. Note that the text in grey boxes of Figure 2.3 of the Austroads report is much the same with "corridor level" included in the "Intersection Model" box. This change introduced in *Figure 1* is consistent with the discussions in Sections 4.2.3 (*Corridor Models*) and 4.3 (*Selecting Model Extents*) of the Austroads report.

- ***Model Level*** *(of detail)*: It is useful to remember the definitions of the terms (Oxford Dictionary).
  - ***Macroscopic***: Relating to large-scale or general analysis.
  - ***Mesoscopic***: Of or relating to a scale intermediate between microscopic and macroscopic.
  - ***Microscopic***: Concerned with minute detail.

  Figure 2 shows the applicability of these *Model Levels* to *Model Types* described in *Point 1* above.

- ***Modelling Technique***:
  - ***Simulation Model***: This term is used for modelling of traffic moving in a network as *individual vehicles* or as *groups of vehicles* (small packs of vehicles or larger platoons).
  - ***Analytical Model***: This term refers to algorithmic models that combine mathematical model elements (based on a combination of traffic theory and empirical derivations) to determine complex system states. The US Highway Capacity Manual Edition 6 (HCM 6), Chapter 9 (Glossary and Symbols) defines an Analytical Model as "*A model based on traffic flow theory, combined with the use of field measures of driver behaviour, resulting in an analytical formulation of the relationship between field measures and performance measures such as capacity and delay.* "

Table 1 Modelling categories:
proposed modified version of Austroads Report AP-R621-20, Table 2.1

Model Type	Model Level	Modelling Technique	Key model features	Examples of software packages
Strategic Transport Models	**Macroscopic**	Macro-analytical model Hybrid Macro-Meso simulation model	Very Large Networks (city scale, regional scale) Estimation of trips between origins and destinations at specific time periods. Estimation of mode choice and route choice. Estimation of link, route, area and network travel statistics. Constant link capacities assumed. Demand modelling, multimodal analysis, highway assignment	**Macro-analytical** • Aimsun • Cube Voyager • EMME • OmniTRANS • QRS II • STRADA • TRACKS • TransCAD • PTV Visum
Large Area Traffic Models	**Mesoscopic**	Meso-simulation model Meso-analytical model Link-based and lane-based simulation and analytical modelling of road geometry, traffic flows and signal platoons.	Medium to Large Networks (up to 30-100 intersections). Simplified simulation of *individual vehicles* and other methods of the propagation of flow in discrete time intervals along a sequence of links. Models are likely to encompass all intersection control types (Signals, Roundabouts, Give-way and Stop Controlled, Uninterrupted) Constant capacity parameters. Multimodal analysis. Vehicle classes and pedestrians. Static and Dynamic traffic assignment.	**Meso-simulation** • Aimsun • Cube Avenue • Dynameq • OmniTRANS • PTV Visum/Vissim **Analytical (Meso / Micro)** • LinSig • SCATES • SIDRA • SATURN • TRANSYT • TRANSYT-7F • PTV Vistro • SYNCHRO
Intersection and Small Area Traffic Models	**Microscopic**	Micro-simulation model Micro-analytical model Detailed lane-based simulation and analytical modelling of road geometry, traffic flows, drive cycles and signal platoons.	Single Intersection and Small Networks (up to 10-20 intersections). Detailed lane-based simulation of individual vehicles. Models are often restricted to specific intersection control types (Signals, Roundabouts, Give-way and Stop Controlled, Uninterrupted). Capacity parameters estimated or constant. Multimodal analysis. Vehicle classes and pedestrians. Static and Dynamic traffic assignment.	**Micro-simulation** • Aimsun • Commuter • CORSIM • Cube Dynasim • Paramics • SUMO • SYNCHRO (SimTraffic) • PTV Vissim

- Key changes in the table are shown in this colour.
- Arrows show most relevant relationships between the Model Type and Model Level.
- Numbers of intersections describing Network size are rough values to indicate the scale of the model.

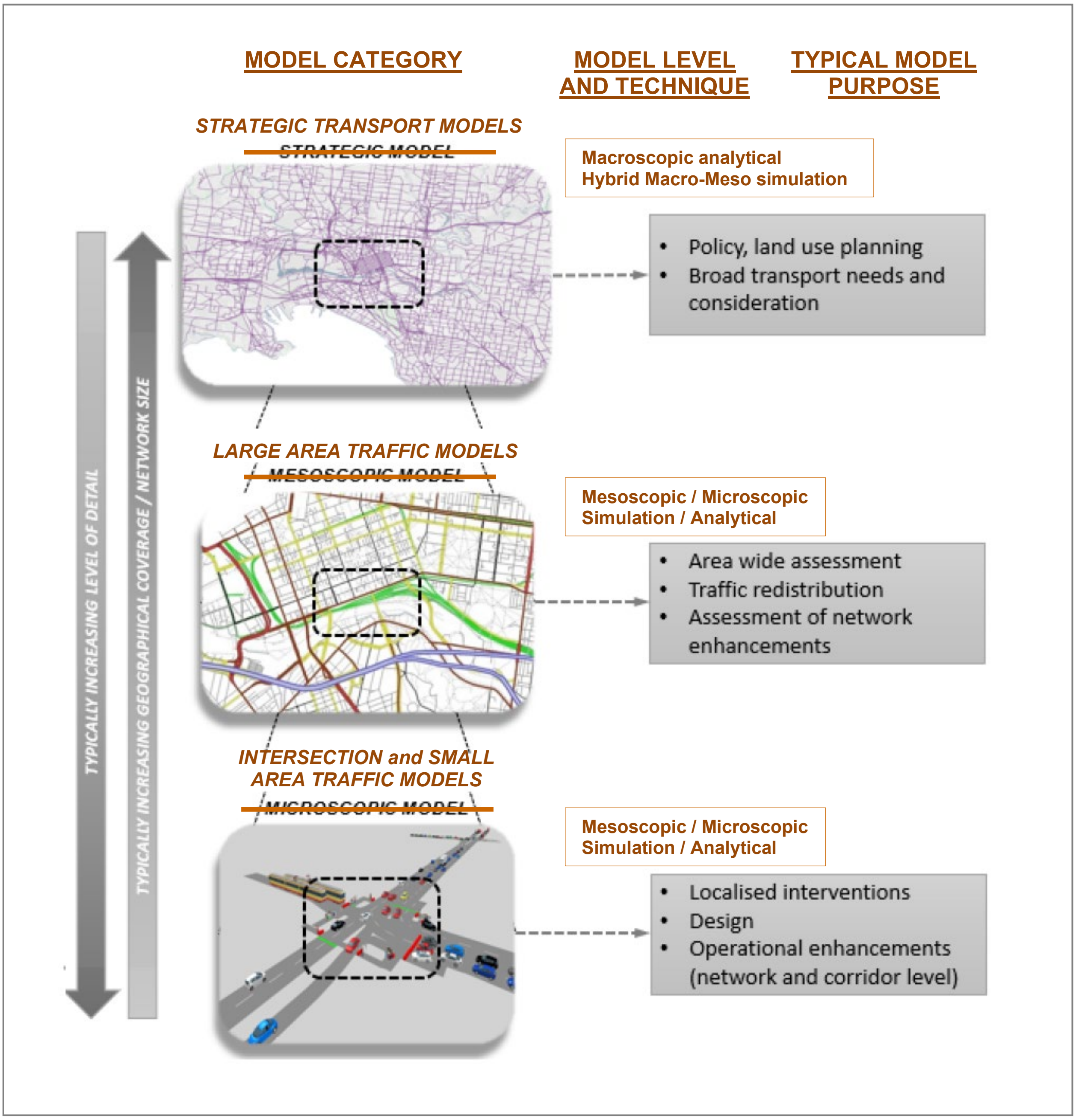


Figure 1 - Traffic and transport modelling hierarchy:
proposed modified version of Austroads AP-R621-20, Figure 2.3

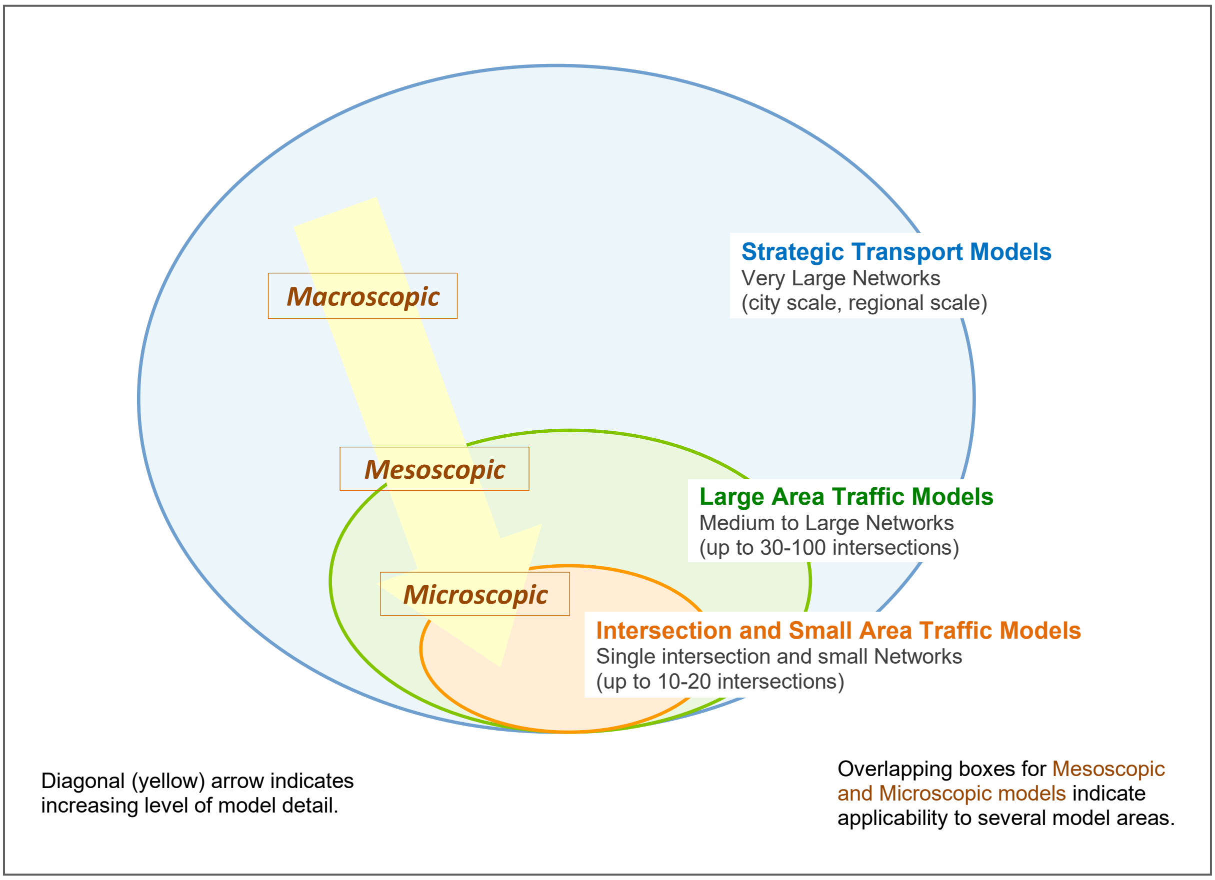


Figure 2 - Model Types according to area type and network size

In Appendix B, Section B.3.2 (Defining the Model Extent), the Austroads report states that "*In reviewing agency guidance, the review considered the advice offered on how to determine the <u>geographic extent of the area to be modelled, and the level of detail required</u> to represent the <u>road and transport network within this area</u>.*".

Unfortunately, the modelling categories and hierarchy presented in Table 2.1 and Figures 2.3 and 5.1 of the Austroads report fail to follow this basic premise whereas it is met by the proposed changes in *Table 1* and *Figure 1* presented here.

2.2.2 Model Level of Detail - Traffic Movements and Road Geometry

Clear definitions of *Model Level* (of detail) and the *Modelling Technique* as described above helps to understand that, in categorising traffic and transport models:

(i) a simulation model can be macroscopic, mesoscopic or microscopic, and

(ii) an analytical model can be macroscopic, mesoscopic or microscopic.

The Macroscopic / Mesoscopic / Microscopic categories of *Model Level* in the Austroads Table 2.1 appear to be based on ***traffic movements*** only (individual vehicles or not, and how traffic demand volumes are treated). An important element to determine *Model Level* is the level of detail in modelling the ***road geometry*** (infrastructure on which traffic movements take place). This view accepts the importance of not only vehicle-to-vehicle (or movement-to-movement) interactions but also vehicle-road geometry interactions. The difference between lane-based, link-based and approach-based models can be understood only by due consideration to this aspect of model level of detail.

Figure 3 from the SIDRA INTERSECTION User Guide describes a more detailed framework for categorising traffic models according to the level of detail considering ***both traffic movements and road geometry***:

- Increasing Model Level in representing ***road geometry*** implies:
  - ***Approach-based Models***: All traffic movements on the approach to an intersection (including its upstream section unaffected by intersection queues) are aggregated into one *link* ignoring vehicles moving and queueing in individual lanes, for example the UK TRL roundabout model implemented in the ARCADY software (Akçelik 2011a).
  - ***Link-based Models***: Traffic movements are aggregated into *multiple links* (lane groups) as dictated by shared lanes. See the definition of Link / Lane Group in *Figure 3*.
  - ***Lane-based models***: Traffic movements and queuing are modelled as they occur in individual lanes, including the capability to model lane changes between intersections (with potential to model weaving). The capacity and performance of all exclusive lanes and shared lanes are modelled individually.

    Figure 4 illustrates the difference between Lane-based model and Link-based models.
- Increasing Model Level in representing ***traffic movements*** implies:
  - A range of models exist from basic ***speed-flow models*** used in strategic transport models to modelling of ***individual vehicle movements***.
  - Simulation of ***platoon movements*** in networks of signalised intersections is usually incorporated into analytical network models.
  - Modelling of detailed ***vehicle paths***, i.e. speed-time traces consisting of acceleration, deceleration, cruise and idling elements (modelled using initial and final speeds, acceleration and deceleration times and distances, and idling times) is useful in modelling fuel consumption, emissions and operating cost as well as intersection geometric delays with high accuracy levels.

    Figure 5 generated by the SIDRA TRIP software package (Akcelik & Associates 2011) illustrates the concept of detailed vehicle path modelling.

Figure 3 shows the spectrum of model level of detail varying from approach-based or link-based ***speed - flow models*** used in strategic transport models (***macroscopic analytical***) to lane-based modelling of ***individual vehicle movements*** in intersection, small area and large area traffic models (***microsimulation***).

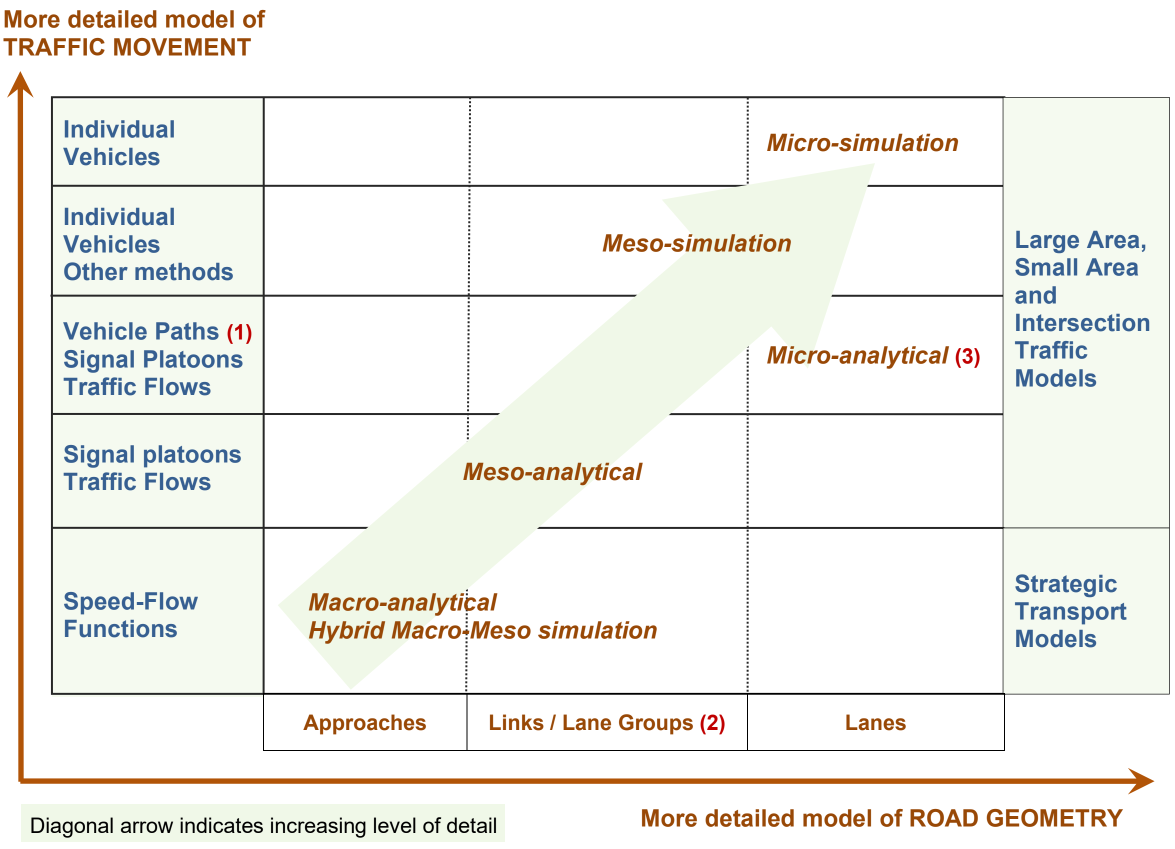
Arrows in *Figures 2 and 3* indicate the increasing level of model detail with ***mesoscopic models*** shown in the middle position of the arrow.

The framework described above and shown in *Figures 2 and 3* makes the assessment of model level of detail clearer and can be used in assessing capabilities of software packages without bias.

As noted in *Figure 3*, SIDRA INTERSECTION is considered to be a ***micro-analytical model*** because it is a ***lane-based*** model like microsimulation models, includes detailed modelling of ***vehicle paths*** (using drive cycles) and midblock lane changes and models lane-based second-by second platoon patterns for signalised intersection networks.

SIDRA INTERSECTION seems to be unique as an analytical intersection and network model in being *lane-based* (Akçelik 2013, 2014b, 2015, 2016a,b) and in modelling *vehicle paths* using the *four-mode elemental model* (cruise - deceleration - idling - acceleration elements). This method of modelling vehicle paths requires detailed acceleration and deceleration models (Akçelik and Biggs 1987, Akçelik and Besley 2001b) and is essential for modelling geometric delay as well as fuel, emissions and operating cost (Akçelik 1983, Bowyer, Akçelik and Biggs 1985, Akçelik and Besley 2003, Akçelik, Smit and Besley 2012, 2014, Taylor and Young 1996) with high levels of accuracy as shown in the SIDRA TRIP simulation results in *Figure 5*.

Refer to more detailed discussion in *Appendix A* including discussion of stochastic vs deterministic model features.



(1) **Drive cycle** (four-mode elemental) method is used to model ***vehicle paths***, i.e. speed-time traces consisting of acceleration, deceleration, cruise and idling elements (modelled using initial and final speeds, acceleration and deceleration times and distances, and idling times).

(2) **Link / Lane Group** is a set of lanes used by a movement or a number of movements with shared lanes including different movement classes in shared lanes.

(3) **SIDRA INTERSECTION** is considered to be a ***micro-analytical model*** due to being a lane-based model like microsimulation models, including detailed modelling of vehicle paths (using drive cycles) and modelling lane-based second-by second platoon patterns for signalised intersection networks.

Figure 3 - A general framework for road traffic models according to the levels of detail of traffic movement and road geometry

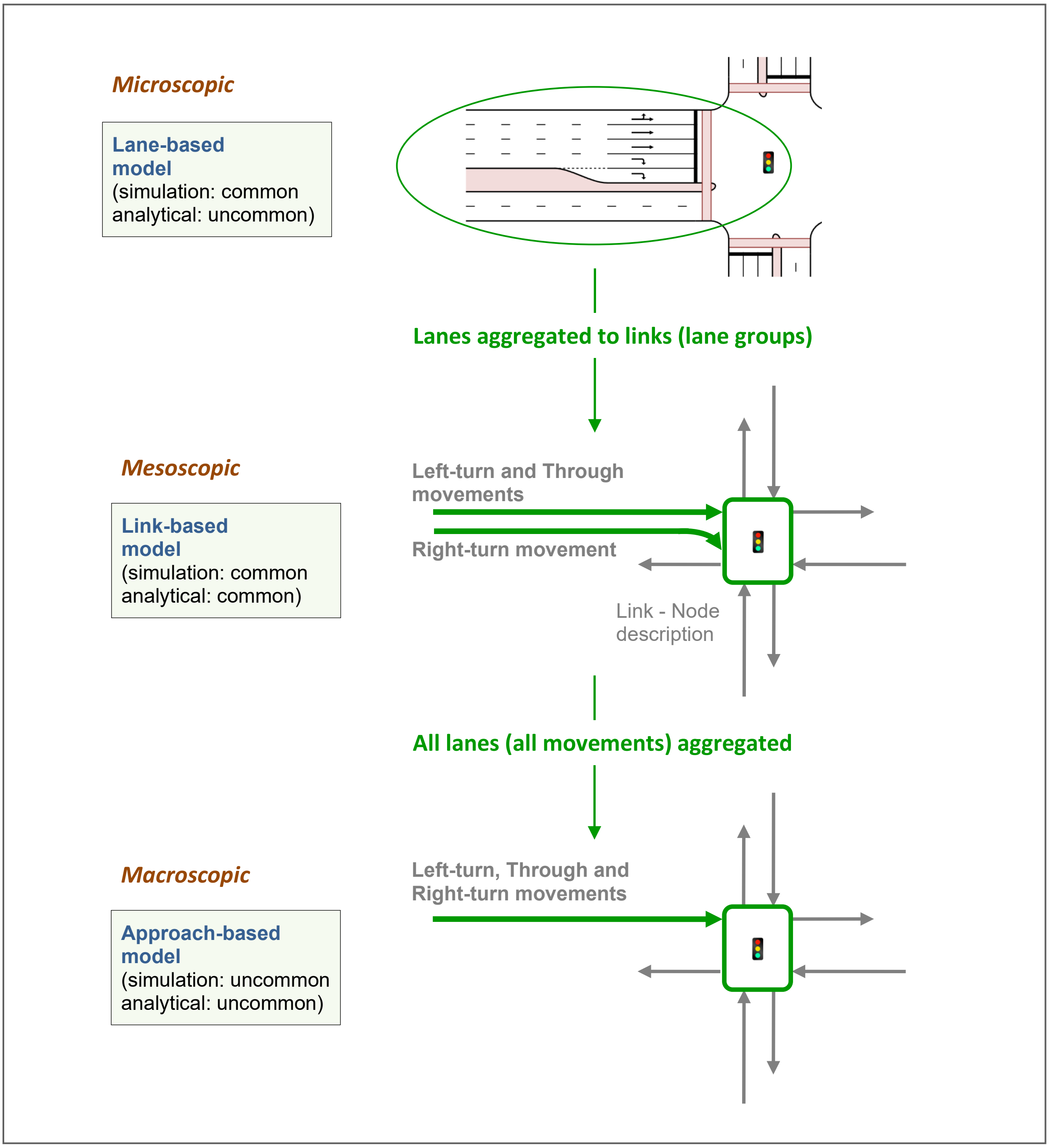
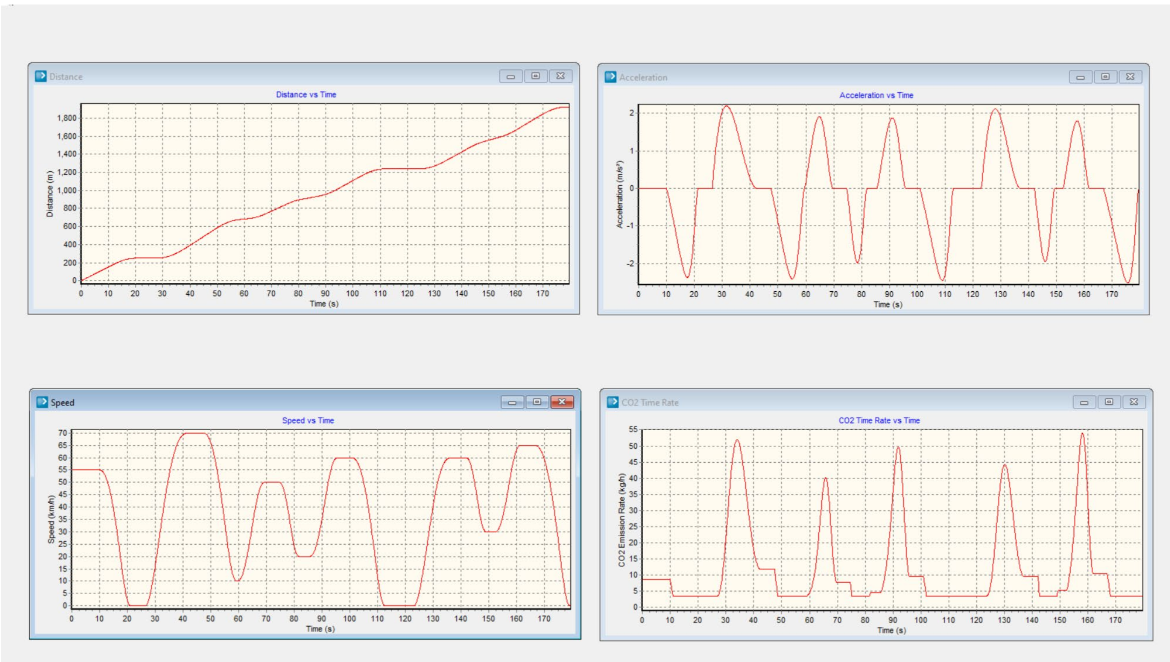


Figure 4 - Lane-based, Link-based and Approach- based models



Event Characteristics / **Acceleration Statistics**

Event Grp	No.	Mode	Speed Initial (km/h)	Speed Final (km/h)	Time User (s)	Time Sim (s)	Distance User (m)	Distance Sim (m)	Grade (%)	Average Acceleration (m/s²)	Highest Acceleration (m/s²)	Highest Jerk (m/s³)	Highest Power (kW)	Highest Force (kN)	Total Energy (kJ)
1	1	Cruise	55.0	55.0	10.0	10.0	-	152.8	0.0	0.0	0.0	0.0	6.4	0.42	63.9
1	2	Deceleration	55.0	0.0	-	11.4	-	97.2	0.0	-1.34	-2.37	1.0	5.9	0.38	2.9
1	3	Idle	0.0	0.0	5.0	5.0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	4	Acceleration	0.0	70.0	-	16.0	-	188.8	0.0	1.22	2.19	0.90	39.5	3.4	347.0
1	5	Cruise	70.0	70.0	5.0	5.0	-	97.2	0.0	0.0	0.0	0.0	10.4	0.53	51.8
1	6	Deceleration	70.0	10.0	-	12.2	-	145.7	0.0	-1.37	-2.41	0.91	9.7	0.50	6.2
1	7	Acceleration	10.0	50.0	-	10.1	-	84.8	0.0	1.1	1.91	-0.62	29.9	3.0	156.4
1	8	Cruise	50.0	50.0	5.0	5.0	-	69.4	0.0	0.0	0.0	0.0	5.4	0.39	26.8
1	9	Deceleration	50.0	20.0	-	7.3	-	71.0	0.0	-1.14	-1.98	0.92	4.4	0.32	1.6
1	10	Cruise	20.0	20.0	-	3.6	20.0	20.0	0.0	0.0	0.0	0.0	1.4	0.26	5.2
1	11	Acceleration	20.0	60.0	-	10.3	-	114.4	0.0	1.08	1.87	-0.61	37.9	3.0	214.2
1	12	Cruise	60.0	60.0	5.0	5.0	-	83.3	0.0	0.0	0.0	0.0	7.6	0.45	37.8
1	13	Deceleration	60.0	0.0	-	12.1	-	114.1	0.0	-1.38	-2.45	1.1	7.0	0.42	4.0
1	14	Idle	0.0	0.0	10.0	10.0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	15	Acceleration	0.0	60.0	-	14.0	-	137.0	0.0	1.19	2.11	0.77	33.3	3.2	245.8
1	16	Cruise	60.0	60.0	5.0	5.0	-	83.3	0.0	0.0	0.0	0.0	7.6	0.45	37.8
1	17	Deceleration	60.0	30.0	-	7.4	-	92.5	0.0	-1.13	-1.96	0.89	6.4	0.38	2.8
1	18	Cruise	30.0	30.0	-	3.0	25.0	25.0	0.0	0.0	0.0	0.0	2.4	0.29	7.2
1	19	Acceleration	30.0	65.0	-	9.4	-	124.0	0.0	1.03	1.8	-0.65	42.0	2.9	228.6
1	20	Cruise	65.0	65.0	5.0	5.0	-	90.3	0.0	0.0	0.0	0.0	8.9	0.49	44.4
1	21	Deceleration	65.0	0.0	-	12.8	-	132.6	0.0	-1.41	-2.52	1.1	8.3	0.46	5.4
Trip (Total or Highest)			70.0	70.0	NA	179.6	NA	1,923.6	0.0	-1.41	-2.52	1.1	42.0	3.4	1,489.6

Figure 5 - Drive Cycles for detailed modelling of vehicle paths - an example from SIDRA TRIP

2.2.3 Other Modelling Guidelines

It is useful to note model categories presented in various other guides.

- The **Main Roads Operational Modelling Guidelines** (MRWA 2018), Section 2.11.2.1 (Model Categories for Validation) specifies three categories:

  "***Model Category 1****: Single intersection or short corridor model (up to four full movement intersections). Models in this category are built and used to assess the performance of intersections or corridors under different design layouts or traffic conditions.*

  Model Category 2*: Small area network or long corridor model with limited route choices. Models in this category are developed to assess the performance of networks or corridors under different traffic management schemes.*

  Model Category 3*: Large area networks including multiple long corridors with various routes between origin and destination zones, and use dynamic traffic assignment. Models in this category are generally used in transport network planning, assessment of traffic management and road schemes.* "

  This system is close to the proposed system given in *Table 1* and *Figure 1.*

- The **Transport Model Development Guidelines** (NZTA 2019), Section 3 discusses seven ***purpose type categories*** that are "*based on the intended purpose for which the model would be applied and geographic coverage – two elements which are generally interrelated. The categories are not specific to any particular modelling software or technique. These categories and definitions should not be considered absolute and some crossover may exist for certain study areas/projects.*"

  These purpose type categories are:

  A: Regional transportation assessments.

  B: Strategic network assessments.

  C: Urban area assessments.

  D: Transport Agency scheme assessment / project evaluation (within area of influence/focus).

  E: Small area with limited route choice/corridor assessment.

  F: Single intersection / short corridor assessment.

  G: Special case high flow / high speed / multi-lane corridor assessment.

  As it is based on ***geographic coverage***, this categorisation is in line with the proposed system given in *Table 1* and *Figure 1* in principle. *NZTA Guidelines Section 3 - Purpose Categories* is reproduced in *Appendix C.*

  The Austroads report, Section B.2.2 discusses the NZTA Transport Model Development Guidelines in some detail.

- The Transport for London **Traffic Modelling Guidelines** (TfL 2010), Section 2.3 (Transport Modelling Hierarchy) presents "*different levels of modelling*" as ***Strategic Model***, ***Cordon Area Model***, ***Micro-simulation Model*** and ***Local Area Model***. It states: "*Transport modelling operates at various levels of detail and scale, covering regions all the way down to single junctions.*" and "*Local area modelling handles traffic moving through a localised network, ranging in size from an individual junction to multiple junctions. This level of modelling focuses in detail on the capacity of individual links and junctions, and the interaction between them. A high level of accuracy is required relative to cordon area modelling*".

  The emphasis of the TfL guidelines on "*levels of detail and scale"* and the system of "Strategic Model, Cordon Area Model and Local Area Model" it uses is in line with the proposed system given in *Table 1* and *Figure 1* although it adds the Micro-simulation Model to this system, for reasons such as "*to model the impact of variability upon network behaviour, and ... representing complex traffic problems, for example the impact of parking or incidents upon the network*".

The Austroads report, Section B.2.2 discusses the Transport for London Traffic Modelling Guidelines in some detail.

- The Roads and Maritime Services NSW **Traffic Modelling Guidelines** (RMS 2013), Section 2 (Levels of Traffic Modelling) presents "*five distinct levels of scale and detail*", namely ***Strategic models, Highway assignment models*** (microanalytical and mesoscopic simulation levels), ***Microsimulation models, Corridor models*** (multi-intersection / small network models) and ***Single Intersection models***. It lists software packages used by the authority. It should be noted that, although SIDRA is listed as the Single Intersection model used by RMS in this 2013 guide, Network modelling capability was first introduced in Version 6 of the software SIDRA software in 2013 and has been developed continually in Versions 7 (2016), 8 (2018) and 9 (2020).

  The system of "Levels of Traffic Modelling" is in line with the proposed system given in *Table 1* and *Figure 1* to some degree as it lists Microsimulation models for network modelling.

- The VicRoads **Transport Modelling Guidelines, Volume 4: Simulation Modelling** (VicRoads 2019), Section 2.3 (Model Types) and the draft **Volume 5: Intersection Modelling** (VicRoads 2020), Section 3.2 presents a "*modelling hierarchy*" similar to the Austroads report: Macroscopic (Strategic Model), Mesoscopic (Detailed Network Model), Microscopic (Micro-simulation Models) and Local Application / Intersection (Intersection Models).

  The critique of the modelling categories and hierarchy presented here applies to these VicRoads guidelines as well.

2.3 Assessing Software Packages

As stated in *Section 2.1*, most software packages listed in Table 2.1 of the Austroads report:

- have capabilities for modelling ***intersections and networks,***
- use a mixture of ***analytical and simulation modelling techniques***, and
- involve ***macroscopic, mesoscopic and microscopic levels of detail***.

Forcing groups of software packages into boxes in an inconsistent model category scheme (as discussed in *Section 2.1*) creates misleading impressions especially for those listed in the last row labelled as ***Intersection Models***, particularly in view of the erroneous assertion of "*Simplistic calculation of intersection performance and operation.*".

The proposed modified scheme shown in *Table 1* (given in *Section 2.2*) changes the alignment of these software package groups (last column) with the categories based on ***Model Type***, ***Model Level*** (of detail) and ***Modelling Technique***. Arrows show the applicability of the software groups to model categories in a flexible way.

Note that the first column of *Table 1* (***Model Type: Strategic Transport Models***, ***Large Area Traffic Models, Intersection and Small Area Traffic Models***) is also separated from the first and third columns (***Model Level*** and ***Modelling Technique***) with arrows showing multiple relationships.

A particular observation is made about inclusion of the SATURN software package in the mesoscopic model group in Table 2.1 of the Austroads report. In the Key Model Features column of the table, this category is described as "*Simplified simulation of individual vehicles by the propagation of flow in discrete time intervals along a sequence of links.*". We believe that the SATURN software uses a mesoscopic level signal platoon simulation model rather than individual vehicle simulation.

SATURN has been moved to the group of ***Analytical (Meso / Micro)*** models in *Table 1*. SYNCHRO is included in this group as well. This group includes SIDRA, Linsig, TRANSYT, TRANSYT-7 since these packages (possibly PTV Vistro and SYNCHRO as well) use similar "simulation of **vehicle platoons** by the propagation of flow in discrete time intervals (second-by-second) along a sequence of **links** including platoon dispersion" except the SIDRA model which uses **lane-based** platoon movements rather than **link-based** movements in other software listed.

"SimTraffic" is added next to SYNCHRO in *Table 1* to clarify that this is the microsimulation model associated with SYNCHRO whereas SYNCHRO itself is an analytical model based on the US Highway Capacity Manual methodology.

Another important concern raised in *Section 2.1* is that the Austroads report discusses technical aspects of signals only and ignores roundabouts and sign control. Capability to model ***alternative control treatments***, namely *signals*, *roundabouts* and *give-way or stop sign (priority) control* as well as modelling *uninterrupted flows* is important for transport and traffic modelling project managers (Akçelik 2011a,b, 2012b,c, 2018, Akçelik and Besley 2005). While the saturation flow is the key parameter for signalised intersections, gap acceptance parameters (critical gap and follow-up headway) are key parameters of similar importance for roundabouts and sign-controlled intersections. The capability for robust modelling of roundabouts and sign-controlled intersections using gap acceptance methodology should be an important factor in the choice of software packages for traffic and transport modelling projects.

Capacity is the key parameter in evaluating performance of traffic and transport systems. The Austroads report gives good emphasis to discussing *demand modelling* but not enough to *capacity modelling*. It is important to understand the significance of capacity in establishing the difference between analytical and simulation models, especially because of some shortcomings of the micro-simulation and meso-simulation models in indirect modelling of capacity (Akçelik and Besley 2001a). This understanding is essential for project managers and modellers alike. This subject is discussed in detail in *Section 3.1*.

An alternative to handling the relationship between model categories and software packages is to remove the listing of software packages from *Table 1* (corresponding to Table 2.1 of the Austroads report). The proposed table without the listing of software packages is shown in *Table 2*.

A separate table such as the one shown in *Table 3* could be prepared for the assessment of applicable model categories and key model features applying to individual software packages. This would help with the selection of software packages for the specific purposes of traffic and transport modelling projects.

In *Table 3*, the *four-mode elemental* model for vehicle path modelling forms *drive cycles* consisting of the *Cruise- Deceleration - Idling - Acceleration* elements where each element is specified by initial and final speeds as well as acceleration and deceleration time and distance values. .

The simpler *three-mode elemental model* uses *Cruise - Stop - Idle* elements. The model uses the "number of stops" where "Stop" represents a simplified stop-start cycle (Akçelik 1983, Bowyer, Akçelik and Biggs 1985, Akçelik and Besley 2003, Akçelik, Smit and Besley 2012, 2014, Taylor and Young 1996).

Consultation with software developers is recommended in developing such a table. Such an assessment table should be updated regularly as the modelling capabilities of the software packages extend continually. In *Table 3*, only the assessment of SIDRA is shown because of the familiarity of the authors with the software. Refer to the SIDRA INTERSECTION User Guide and features documents (Akcelik & Associates (2020a,b).

Table 2 Modelling categories:
proposed modified version of Austroads Report AP-R621-20, Table 2.1 <u>without software packages</u>

Model Type	**Model Level**	**Modelling Technique**	**Key model features**
Strategic Transport Models	**Macroscopic**	Macro-analytical model Hybrid Macro-Meso simulation model	Very Large Networks (city scale, regional scale) Estimation of trips between origins and destinations at specific time periods. Estimation of mode choice and route choice. Estimation of link, route, area and network travel statistics. Constant link capacities assumed. Demand modelling, multimodal analysis, highway assignment
Large Area Traffic Models	**Mesoscopic**	Meso-simulation model Meso-analytical model Link-based and lane-based simulation and analytical modelling of road geometry, traffic flows and signal platoons.	Medium to Large Networks (up to 30-100 intersections). Simplified simulation of *individual vehicles* and other methods of the propagation of flow in discrete time intervals along a sequence of links. Models are likely to encompass all intersection control types (Signals, Roundabouts, Give-way and Stop Controlled, Uninterrupted) Constant capacity parameters. Multimodal analysis. Vehicle classes and pedestrians. Static and Dynamic traffic assignment.
Intersection and Small Area Traffic Models	**Microscopic**	Micro-simulation model Micro-analytical model Detailed lane-based simulation and analytical modelling of road geometry, traffic flows, drive cycles and signal platoons.	Single Intersection and Small Networks (up to 10-20 intersections). Detailed lane-based simulation of individual vehicles. Models are often restricted to specific intersection control types (Signals, Roundabouts, Give-way and Stop Controlled, Uninterrupted). Capacity parameters estimated or constant. Multimodal analysis. Vehicle classes and pedestrians. Static and Dynamic traffic assignment.

- Key changes in the table are shown in this colour.
- Arrows show most relevant relationships between the Model Type and Model Level.
- Numbers of intersections describing Network size are rough values to indicate the scale of the model.

Table 3 Assessment of model categories and key features applying to software packages

Software >>		SIDRA	Software X	Software Y
Model Categories				
Model Type (area and network size)	*Strategic Transport Model*	x		
	Large Area Traffic Model	✓ (1)		
	Intersection and Small Area Traffic Model	✓		
Model Level of Detail	*Macroscopic*	x		
	Mesoscopic	✓		
	Microscopic	✓		
Modelling Technique	*Simulation*	✓ (2)		
	Analytical	✓		
Key Model Features				
Road Geometry	*Lane based*	✓		
	Link / Lane Group based	x		
	Approach based	x		
Vehicle Paths	*Acceleration - deceleration*	✓		
	Fuel, emissions, operating cost	✓		
	Four-mode elemental (3)	✓		
	Three-mode elemental (3)	x		
Pedestrians	*Signalised crossings*	✓		
	Unsignalised crossings	✓		
Traffic Control	*Signals*	✓		
	Roundabouts	✓		
	Give-way or stop sign control	✓		
	Uninterrupted flows	✓		
Capacity Model (Capability to estimate key model parameters)	*Saturation flow (Signals)*	✓		
	Follow-up headway and Critical gap (Roundabouts)	✓		
	Follow-up headway and Critical gap (Sign control)	✓		
Network Model (Link-based and lane-based models)	*Signal platoons*	✓		
	Capacity constraint	✓		
	Queue spillback (exit blockage)	✓		
	Midblock lane changes	✓		
	Midblock inflow and outflow	✓		
	Network signal timing	✓		
Demand Modelling	*Peak Flow Factor*	✓		
	Variable Demand Model	x		
Traffic Demand Estimation	*Traffic assignment*	x		
	OD matrix estimation	x		

(1) Up to 50 intersections.

(2) Includes signal platoon simulation (second-by-second lane-based movement of platoons) as a mesoscopic simulation feature.

(3) Four-mode elemental vs three-mode elemental model: See the text for brief explanation.

3 Comments on Technical Details

In this section, comments on various technical aspects of the Austroads Report AP-R621-20 are presented.

As a general comment in relation to *Model Categories* (*Section 2*), discussions on "Intersection Models" in Section 4 of the Austroads report should be mostly read as a discussion on "Analytical Models" and most of the discussion is applicable to "Network Models".

3.1 Capacity: Model Estimation of Key Parameters

The Austroads report gives a lot of emphasis on demand modelling but not enough on capacity modelling. "*Model calibration for microscopic models*" in Section 3.6.1 of the report only discusses the GEH statistic (a measure used to assess the correlation between observed and modelled turning movements) which is relevant to the network traffic assignment feature rather than "microsimulation model". This manifests the problem of model categories used in the report.

The Austroads report ignores important calibration issues that need to be discussed in relation to microsimulation models. In discussing "*Model validation for simulation models*" in Section 3.6.1, the report mentions various parameters including saturation flow in a dismissive way:

> "*it is becoming increasingly difficult for modellers to achieve some of the calibration and validation targets set out in various guidelines*" and
>
> "*a modeller can do everything possible to achieve the calibration and validation targets. However, in doing so they may have disrupted the integrity of the model itself by adjusting certain parameters or not replicating the operating conditions of the network*".

In Appendix B.8 (Intersection Analysis), Section B.8.2 (Calibration and Validation) of the report, there is much discussion of the saturation flow parameter but the relevance of this to micro-simulation and meso-simulation models is not discussed.

In relation to model calibration, "*Where is capacity in simulation?*" is the question to be asked to establish the difference between analytical and simulation models, especially for understanding micro-simulation and meso-simulation models as discussed below. This understanding is essential for project managers and modellers alike. Refer to Section 2 of Akçelik and Besley (2001a) for detailed discussion.

Capacity is the key parameter in evaluating performance of traffic and transport systems (that is why various jurisdictions have Capacity Guides, e.g. the US Highway Capacity Manual, TRB 2016).

Capacity is the *supply* in traffic and transport operations as a *demand - supply* system. It is the *service rate* that determines the performance of intersection lanes / movements, and travel times / costs in network traffic assignment.

Analytical strategic transport models use constant capacity values which limit the effectiveness of these models significantly.

In *analytical intersection and network traffic models*, the capacity parameter is used in equations to estimate degree of saturation (v/c ratio), delay, queue length, stop rate, and is used in the fundamental speed - flow - density equations. Thus, Capacity is also a key parameter in the Level of Service measure based on delay, density, and so on.

In *analytical models*, the equations used to estimate capacity and performance of intersections and networks, and the methods to estimate the key parameters of *capacity* as a function of *road geometry*, *traffic flows (demand)* as well as *signal timings* (cycle time, green time) for signalised intersections, are based on well-established traffic theory and empirical methods.

In answering the question "*Where is capacity in simulation?*", we need to discuss the key parameters that determine capacity.

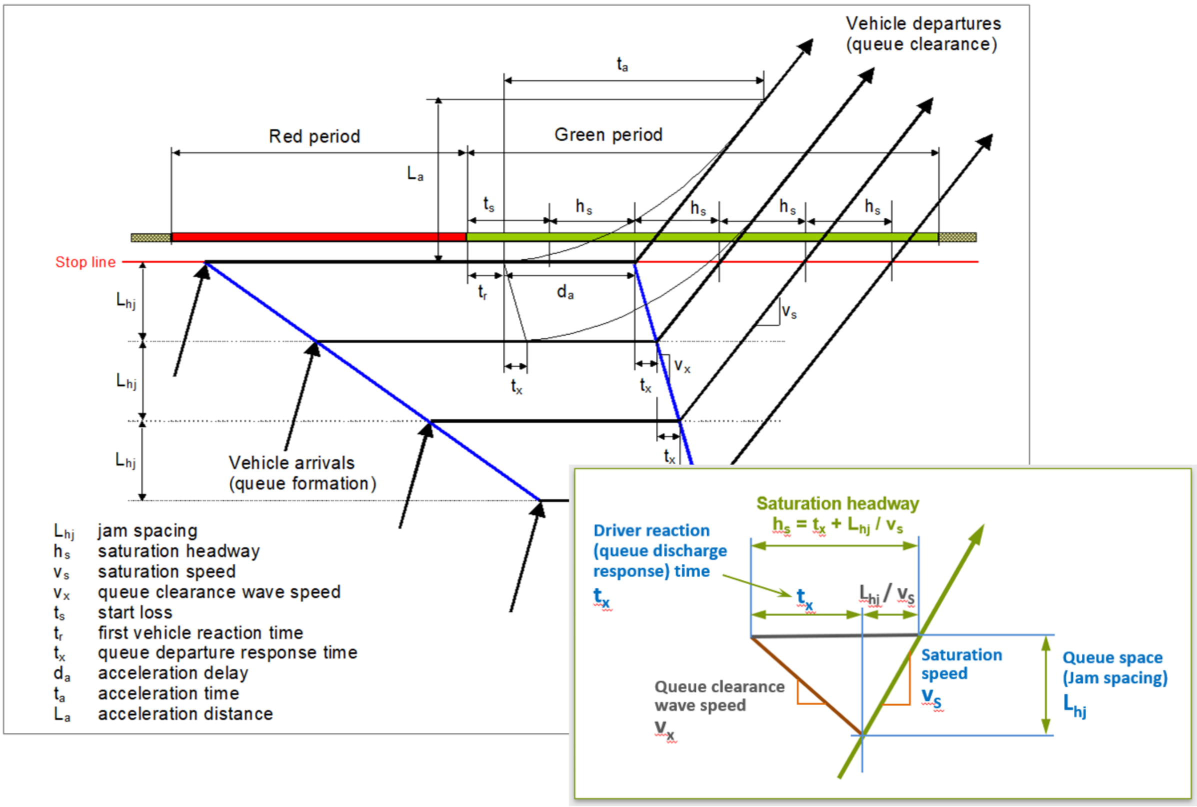


Figure 6 - Saturation headway as a function of driver reaction time, queue space and saturation speed

In *analytical models*, these are *saturation flows* for signalised intersections and *follow-up headway and critical gap* (gap acceptance) parameters for roundabouts and stop / give-way sign-controlled (priority) intersections. These parameters can be observed and used in calibrating analytical models. Importantly, analytical models such as SIDRA and the Highway Capacity Manual will estimate these key capacity parameters as a function of *road geometry and traffic flow conditions.*

In *micro-simulation models of intersections and networks*, capacity is not used generally, and the saturation flow parameter is not used for signals whereas the gap acceptance parameters may be used directly or indirectly. Research has shown that saturation flows (or saturation headways) at signals are directly related to three fundamental parameters, namely *driver reaction time* (queue discharge response time), *queue space* (jam density) and *saturation (queue discharge) speed* (Akçelik, Besley and Roper 1999). This is depicted in *Figure 6*. The follow-up headway parameter in gap acceptance is similar to saturation headway at signals.

The *driver reaction (queue discharge response) time*, *queue space* and *saturation speed* parameters estimated from saturation flow and follow-up headway parameters are given in the Driver Characteristics table of the Detailed Output report in SIDRA INTERSECTION.

In calibrating a micro-simulation model to achieve observed saturation flow or follow-up headway values, the parameters of the particular micro-simulation model corresponding to the driver reaction, queue space and saturation speed parameters could be used. This may be difficult task but theoretically it is possible. In gap acceptance modelling, micro-simulation may use a *conflict zone distance* in lieu of the critical gap parameter.

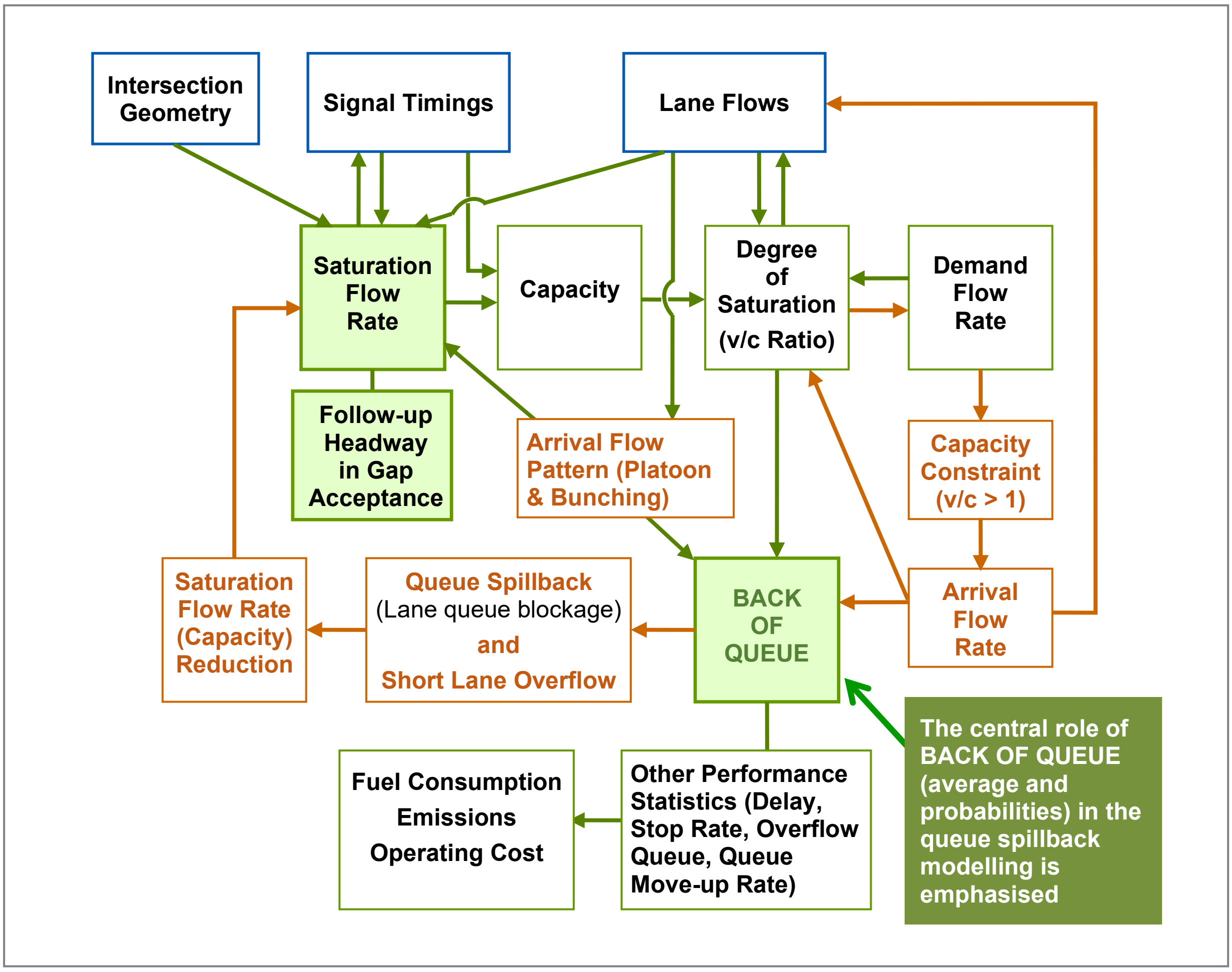


Figure 7 - The iterative capacity and performance estimation model for intersections and networks used in SIDRA INTERSECTION

Most importantly, the question should be asked if a micro-simulation or meso-simulation model:

(i) includes a process to estimate the fundamental parameters (*driver reaction time*, *queue space* and *saturation speed*) or the higher level parameters saturation or follow-up headway and critical gap that determine the capacity *as a function of road geometry and traffic flows*, and

(ii) allows the user to calibrate these parameters on the basis of observed parameters.

The same question applies to meso-simulation models that use individual vehicles as well.

The question should also be asked about the analytical models since not all analytical models estimate saturation flows and gap-acceptance parameters *as a function of road geometry and traffic flow.*

Unless good estimation and calibration methods are used in an analytical or simulation model to estimate or imply realistic capacity values, the estimates of delay, queue length, stop rate would not be reliable, especially even if "individual vehicles and their interactions" are simulated.

Figure 7 shows the iterative capacity and performance estimation model for intersections and networks used in SIDRA INTERSECTION.

The use of constant saturation flow values as input is not recommended. See *Point 7* in *Section 3.3*.

3.2 Are Intersection Models "simplistic"?

In the last row of Table 2.1 of the Austroads report, it is stated as a key feature of "Intersection models" that they are "*Simplistic calculation of intersection performance and operation*".

In Section 4.1 of the report, it is asserted that:

> "*Intersection analysis is typically viewed as the 'quick and easy' method of generating objective results for a given assessment. Intersection analysis generally uses simplistic calculations and assumptions, for example, inputs are based on average peak hour profiles and traffic flows are assumed to remain constant.*"

and

> "*Intersection analysis is typically only undertaken to determine performance of vehicles on the roadways. Performance of other modal types, such as pedestrians/cyclists/trams/heavy rail/etc, are generally not calibrated at the intersection analysis level due to their unique features. As intersection modelling generally uses the peak hour average, the finer details are unable to be modelled and are often discarded to simplify the analysis process.*"

These statements quoted from the Austroads report are erroneous as discussed below (underlining is our emphasis). They underrate traffic modelling in general and the software packages listed in the same row of Table 2.1 in particular.

Traffic and transport modelling deals with complex systems and therefore uses complex mathematical techniques whether it is analytical or simulation, and whether it is single intersection, small network or large network modelling. *Figure 7* above shows the complexity of the iterative method used in SIDRA for capacity and performance estimation for intersections and networks.

The issue of Peak Demand (Analysis) Period will be discussed first (*Section 3.2.1*), followed by the discussion of the erroneous and inconsistent assertions made in the Austroads report about pedestrians and vehicle classes (bicycles, buses, trams / light rail) in intersection modelling (*Section 3.2.1*). These discussions are important as the issues discussed seem to be the main reason for qualifying intersection modelling as simplistic.

3.2.1 Peak Demand (Analysis) Period

The claim in the Austroads report that "intersection models use *average peak hour profiles* with *constant traffic flows*" is surprising. The authors of the Austroads report should give specific reference to such models (software packages) which have this limitation.

The Austroads report identifies SIDRA as the most widely used software for intersection analysis in Australia and New Zealand. The SIDRA user guide and the supporting research publications make it clear that demand volumes for peaking are modelled either (i) by specifying hourly (or longer period) demand volumes but allowing for peaking within the hour by specifying a ***Peak Flow Factor, PFF*** (traditionally called Peak Hour Factor, PHF), or (ii) by specifying the demand volumes for a ***shorter peak period*** if the volume counts are available. In either case, the analysis is done for the *peak flow period*.

SIDRA uses default peak flow periods of ***30 minutes*** for the Standard Left software setup (applicable to Australia and New Zealand) or ***15 minutes*** for the HCM software setup (applicable to US as specified in the Highway Capacity Manual).

In the VOLUMES Excel utility for SIDRA, a *Peak Flow Period* sheet is provided for learning about this concept. *Figure 8* shows examples of a low peaking condition with a long peak period (Peak Flow Factor of 0.95) and a high peaking condition with a short peak period (Peak Flow Factor of 0.80) for a given average flow rate. Note that non-peak periods are also shown in this application.

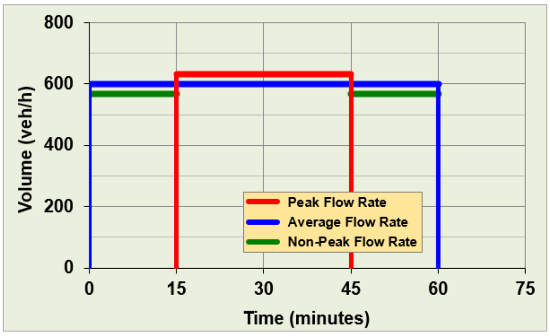
It is well known that, without modelling of peaking, high demand conditions cannot be modelled accurately. Research into the model of peaking using a single flow period (Akçelik and Rouphail 1993) concluded that:

> "It is found that the average delay to vehicles arriving in the Peak Flow Period appears to be a reasonable estimate for the corresponding average delay in the Total Flow Period (based on average delay calculated for all flow periods). The paper concludes that single-period analysis is adequate provided that the Peak Flow Period is determined with due attention to peaking in the Total Flow Period, and the use of PFF (PHF) parameter appears to be sufficient for this purpose even when oversaturation persists beyond the Total Flow Period. On the other hand, the use of the average degree of saturation with no consideration of peaking can lead to significant underestimation of delay, particularly when operating at or near capacity conditions. These findings are confirmed by comparing the model results with other models found in the literature."

Analytical models are capable of modelling congestion affects with the analysis of a single peak flow period. On the other hand, micro-simulation using individual vehicles needs to use multiple flow period modelling. The reason is explained below.

For oversaturated conditions, the SIDRA delay is the average delay to vehicles *arriving* during a given flow period (analysis period) including the delay experienced after the end of the flow period until the departure of the last vehicle arriving during the flow period (which happens after the flow period). This corresponds to the *path-trace* (instrumented car) survey method of measuring delays. There is a significant difference between this method and the method which measures the delay experienced by vehicles in the queue during the analysis period only. This corresponds to the *queue-sampling* survey method which involves counting the number of vehicles in the queue at regular intervals, e.g. every 5 or 10 seconds.

Input Parameters		
Total Flow Period (unit time for volumes) (mins)	T_f	60
Peak Flow Period (mins)	T_p	30
Peak Flow Factor (q_a / q_p)	PFF	0.950
Volume count for T_f (per unit time)	V_T	600
Calculated Parameters		
Peak Time Factor (T_p/T_f)	PTF	0.500
Average flow rate for T_f (veh/h)	q_a	600
Peak Flow Rate (average flow rate for T_p (veh/h)	q_p	632
Non-Peak Flow Rate (veh/h)	q_n	568



Input Parameters		
Total Flow Period (unit time for volumes) (mins)	T_f	60
Peak Flow Period (mins)	T_p	15
Peak Flow Factor (q_a / q_p)	PFF	0.800
Volume count for T_f (per unit time)	V_T	600
Calculated Parameters		
Peak Time Factor (T_p/T_f)	PTF	0.250
Average flow rate for T_f (veh/h)	q_a	600
Peak Flow Rate (average flow rate for T_p (veh/h)	q_p	750
Non-Peak Flow Rate (veh/h)	q_n	550

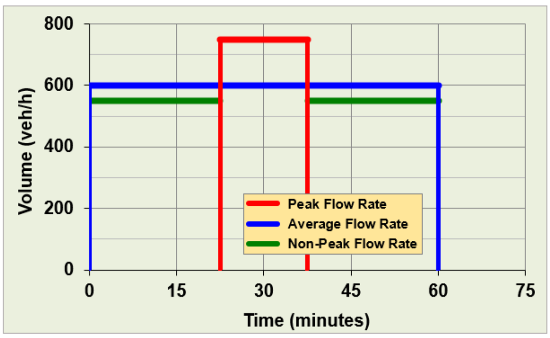


Figure 8 - Low peaking and high peaking examples

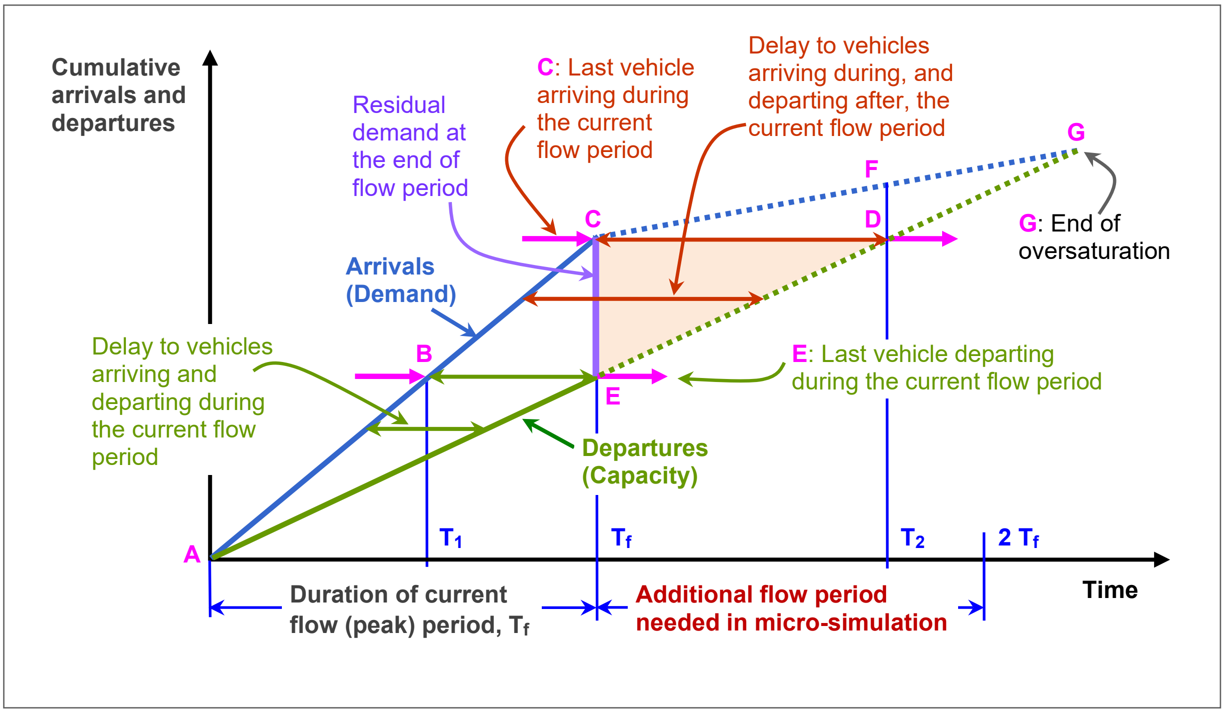


Figure 9 - Measuring delays experienced by vehicles in oversaturated conditions

Delays obtained using the path-trace method agree with the queue sampling method of measurement for low to medium degrees of saturation (v/c ratios), but the difference between the two methods is significant for high degrees of saturation and for oversaturated conditions (degree of saturation > 1) in particular.

In a micro-simulation model, delay experienced by vehicles that still remain in the queue at the end of the flow (analysis) period can only be measured by simulating an additional flow period. On the other hand, analytical model is able to determine this delay without processing an additional flow period. *Figure 9* shows a *deterministic oversaturation model* chosen as a simple model to explain this.

In *Figure 9*:

- Delays experienced by individual vehicles are represented by horizontal lines between the cumulative arrival (demand) and departure (capacity) lines.
- The flow period starts at point A with no residual demand and finishes at point C (time T_f) with a residual demand CE (vehicles).
- The total delay experienced by vehicles arriving during the first flow period consists of:
  - the total delay represented by area ACE which can be measured by queue sampling, and
  - the total delay represented by area CDE which is experienced by vehicles arriving after point B (at time T_1) and departing after the current flow period (during time T_f to T_2).

As indicated in *Figure 9*, an additional simulation period is needed to measure the total delay represented by area CDE. Otherwise, the average delay estimated for *vehicles arriving* during the flow period (T_f) would be underestimated. On the other hand, an analytical model like SIDRA can simply calculate this projected delay. This makes the analytical models *simpler* to use but *that does not mean they are simplistic models*!

If the residual demand (CE) at the end of the flow period (T_f) is larger, a micro-simulation model would need to simulate more than two simulation periods since it would take longer for the last vehicle arriving during the flow period to depart from the queue (time T_2 would be greater than 2 T_f. as represented by line CD).

The capability to calculate the oversaturation delays experienced by vehicles by analysing a single flow (peak) period (as explained using *Figure 9*) is related to the *time-dependent* structure of analytical models. This method calculates larger delays and queue lengths if the demand rate in the flow period lasts longer. This model has been around for a long time (e.g. see Akçelik 1980, 1981) and is included in the SIDRA and most analytical software packages erroneously listed as "Intersection Models" in Table 2.1 of the Austroads report. For more detailed discussion of this subject, refer to Rouphail and Akçelik (1992).

Time-dependence of demand means that micro-simulation and meso-simulation models using individual vehicles cannot correct the issue raised here by extending the length of the simulation period for modelling a single flow period. Longer simulation times used to obtain settled results in simulation works for undersaturated conditions but, if applied to model oversaturated conditions, would cause ever increasing queues and delays and would fail to produce realistic performance results.

Another issue with micro-simulation and meso-simulation models is that, by using the queue sampling method, it is not possible to estimate the delay to *vehicles arriving during a given flow period* since the total delay measured in subsequent flow periods will include the delays to vehicles arriving in those periods as well. This can be observed as area CDF in the example shown in *Figure 9* (total delay measured during the period from T_f to T_2 is area CEDF).

Variable demand modelling (demand profiling) is useful in modelling *existing traffic conditions* with very high demand leading to persistent congestion for long periods (Yumlu, Moridpour and Akçelik 2014, Lay 2019). Related discussions are given in Section 3.5.1 ("*the increasing level of congestion has led to extended peak periods (two-hour, four-hour) being modelled*") and Section 3.5.5 (*Demand profiling*) of the Austroads report.

Analytical intersection and network models are well capable of variable demand modelling (demand profiling). Performance models allowing for variable demand modelling have been used in some UK software, and are included in the US Highway Capacity Manual (TRB 2016). A model for this purpose was formulated by the first author some years ago and included in an extended form of the "*Akcelik function*" used in macro-analytical strategic transport modelling (Akçelik 2002, 2003a, 2006). The model has not yet been included in the SIDRA INTERSECTION software because of the lack of user demand for this feature, but it will be included in a future version for heavy congestion modelling.

The following statement in the Austroads report Section 4.1 is an interesting coincidence:

> "*As intersection modelling generally uses the peak hour average, the finer details are unable to be modelled and are often discarded to simplify the analysis process. For example, schools often have a* <u>*short intense peak associated with finishing times where queues and delays can be significant*</u>*. However, when the traffic volumes are evaluated at a peak hour, the extent of queues and delays are reduced.* "

Contrary to the assertion that intersection modelling discards the finer details to simplify the analysis process, a SIDRA user case of long queues developing on a roundabout leg during school finishing times was successfully modelled in a training workshop. It was only possible to do this by using the 15-minute peak volumes. Long queues developed not only because of high peaking of demand in a short period but also because of the resulting unbalanced flow conditions on roundabout approaches (queues developed on another approach, not on the approach with the demand surge). In this case, average hourly volumes would hide the conditions of not only high peaking but also unbalanced flows. The simplified diagram shown in *Figure 9* explains this situation where demand exceeds capacity in the 15-minute flow period analysed but is below capacity in the following 15-minute flow periods. In seeking solutions to such problems, analysing multiple flow periods would make little contribution.

3.2.2 Pedestrians and Vehicle Classes

The Austroads report Section 4.1 states: "*Intersection analysis is typically only undertaken to determine performance of vehicles on the roadways. Performance of other modal types, such as pedestrians/cyclists/trams/heavy rail/etc, are generally not calibrated at the intersection analysis level due to their unique features.*", and in Section 4.3 (*Selecting the Model Extents*), it suggest that "*pedestrian crossings, pedestrian volumes, tram lines, bus jumps, train phases*" can be excluded from intersection analysis.

This assertion is not correct. The US Highway Capacity Manual (TRB 2016, Dowling, et al. 2008) gives a lot of emphasis to "multimodal analysis" (motorised vehicle, truck, pedestrian, cyclist and transit modes are introduced in Chapter 3). The SIDRA software has extensive treatment of pedestrians, and includes bicycles, buses and trams / light rail in "vehicle movement classes". Intersection and network modellers require that these traffic system elements are included in analyses with increasing levels of interest.

The Austroads report is inconsistent in relation to the statements in Section 4.1 and 4.3:

- it includes "*public transport, bicycle, pedestrian*" as intersection model elements in Table 2.3 (*Summary of modelling elements*) in Section 2,
- pedestrians are included as model elements in Table 4.1 (*Summary of intersection model elements*),
- buses and pedestrians are discussed in Section 4.5.2 (*Data Analysis*), and
- it discusses cyclists and pedestrians in the context of intersection modelling in Section 4.6.1:

  > "*As the impact of vehicle congestion becomes more apparent, an integrated transport approach is becoming increasingly appreciated. As such, models need to include not just vehicles but also consider the impacts by other modes such as walking, cycling, mopeds and motorbikes.*",

  and in Section 4.6.2:

  > "*Depending on the volume and frequency of the cyclist and pedestrian demand, at times, in the outer urban environments, these may be potentially discarded. Whereas, in the inner urban areas, the impact will be more noticeable and should be included in the analysis. In this situation it is important to include pedestrians and cyclists as defined user classes with their own operating characteristics*."

- it qualifies "*cycle and pedestrian volumes*" as "expected" in intersection analysis in Table 8.2 (*Required information items for each type of transport model*) in Section 8.

In SIDRA, variabilities in pedestrian, bicycle, bus, tram/ light rail and train volumes and signal phases are treated via features such as modelling of pedestrian actuation and minor phase actuation, and user input of phase frequency. Scenario analysis can be used in cases such as infrequent bus priority, tram and train phases at signals.

Pedestrian crossings should never be excluded from signalised intersection analysis due to the critical impact of pedestrian minimum walk and clearance time requirements on signals.

The following list of features and *Figure 10* are given here to indicate the extent of pedestrians in modelling intersections and networks in SIDRA:

- Modelling pedestrians at signalised intersections, signalised crossings, roundabouts, two-way sign control.
- Pedestrian zebra (unsignalised) crossings on slip lanes at intersections and at midblock locations.
- Staged, slip lane and diagonal crossings, and walk time extension at signalised intersections.
- Pedestrian movement and signal characteristics as input.
- Effect of pedestrians on capacity of vehicle movements at signalised and unsignalised intersections and midblock, including holding a red arrow for pedestrian protection at signalised intersections.
- Effect of pedestrians on intersection design and signal timing including pedestrian actuation effects.
- Pedestrian performance at signalised intersections (delay and queues).
- Output reports and displays for vehicles, pedestrians and persons.

The results for *persons* given in SIDRA output include the count of pedestrians, cyclists and people in cars, buses, trams, and so on according to vehicle occupancy characteristics, and optimum signal timings (for minimum delay, etc) are determined for persons not for vehicles.

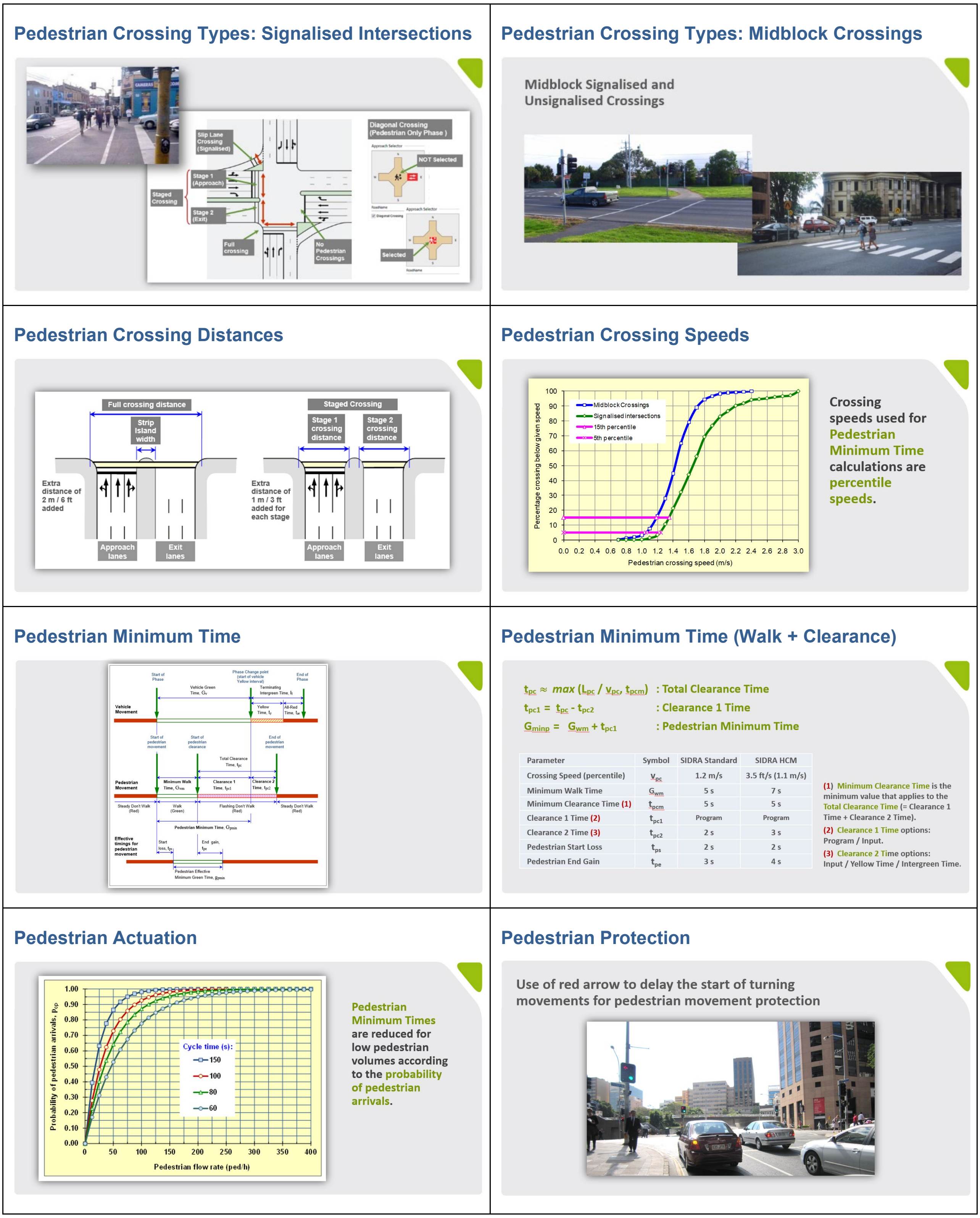


Figure 10 - Pedestrian analysis in SIDRA intersection modelling

3.3 Other Comments

In this section, comments on various aspects of the Austroads report Sections 3 and 4, and Appendices B, D and M are given.

In this section "the report" refers to the Austroads report being reviewed. Non-italic section, table and figure references are to those in the Austroads report. Section, table and figure references in italic font are to those in this review.

1. **Software processing and ease of setup** (Sections 4.2.3 and 4.3)

   In Section 4.2.3 of the report, UK software packages TRANSYT, ARCADY, PICADY & OSCADY are discussed stating that: "*These alternate software packages are less popular in Australia and New Zealand, but the underlying transport engineering principles remain the same. These alternate software packages often have niche strengths such as: faster processing, easier geometric setup, microscopic integration, etc*.".

   In Section 4.3, the report states that: "*Due to recent developments, growth in traffic (and understanding) and enhancements to software, intersection analysis tends to consider (aspects of) entire corridors. Generally, a corridor could consist of up to 10 intersections. Any higher and the intersection analysis tool would generally take too long to process or become unstable and any errors and/or assumptions would have a compounding effect.*".

   Evidence is required about faster processing in comparing these software packages, e.g. compare SIDRA INTERSECTION and LinSig for the same networks (geometry and congestion levels). Average processing time of a Site in SIDRA INTERSECTION is about one second. A 50-Site network with extensive queue spillback conditions took about 70 seconds to process with 10 iterations (unsettled results) and 140 seconds with 24 iterations (settled results as indicated by "Largest change in Lane Degrees of Saturation or Queue Storage Ratios for the last three Network Iterations: 0.5%, 0.4%, 0.3%").

   The authors are familiar with ARCADY for modelling single roundabouts. It uses an *approach-based* roundabout capacity model which is based on UK (TRL) roundabout research. The model uses roundabout geometry parameters only with no driver behaviour (gap acceptance) modelling. It may be easier to set up as it lacks a lot of detail about roundabout geometry (entry and circulating lane details) and driver behaviour modelling (Chard 1997, Akçelik 1997). Refer to many articles by the first author assessing the capacity model used in ARCADY and comparing with the SIDRA roundabout capacity model which is based on roundabout research carried out in Australia (Akçelik 2009, 2011a, 2012a, 2017b).

2. **Unsignalised intersections** (Section 4.3)

   The report suggests that "*When assessing traffic signal coordination, traffic signal network models might exclude unsignalised intersections, carparks and/or driveways. This is because they generally would not impact on coordination of traffic* ".

   This statement is not true since flows entering from midblock points cause deterioration of signal coordination effectiveness due to arrivals during the red period at the downstream signals. When these entry points are not modelled directly, *midblock inflows* need to be modelled for the same effect. When unsignalised intersections are modelled between signalised intersections, the software should be able model platoon progression between signals on the major road of the unsignalised intersection, and also needs to be able to carry out signal offset calculations. These capabilities are included in SIDRA INTERSECTION.

3. **Impacts of downstream queuing or short lanes** (Section 4.3)

   The report states that "*Generally, intersection analysis cannot model impacts from downstream queuing or short lanes, as the analysis is based on saturation flow at the stop line only.*".

   This is an incorrect statement as the SIDRA network model includes queue spillback modelling (effect of downstream queue blockage) and the SIDRA intersection model includes short lane modelling with fairly complex structures of multiple short lanes (see *Figure 7* in *Section 3.1*). Also see the next point.

4. **Relation of downstream impacts to throughput vs demand** (Section 4.6.2)

   The report states: "*Exit blocking (or blocking back) refers to traffic at the stop line that has a green signal but cannot proceed through the intersection or when full saturation flow is impeded … it is important to identify the source of this incident and understand the amount of traffic that is being blocked. The model should be developed to* *<u>ensure that the demand is modelled rather than the throughput</u>* …".

   This statement appears to be not clear about throughput as the *capacity without exit blockage* or as the *reduced capacity with blockage*. Oversaturated conditions can occur with or without exit blockage, and the demand flow as measured at the back of queue is higher than throughput under these conditions. On the other hand, it is possible to have exit blockage but the reduced capacity resulting from the exit blockage can still be larger than the demand (undersaturated case), and therefore throughput would be equal to the demand flow rate.

5. **Lane disciplines** (Table 3.1 in Section 3.3 and Table 4.1 in Section 4.4)

   Lane disciplines, i.e. allocation of turning movements by vehicle class to available lanes should be added as a key intersection and network model element in these tables. This is relevant to specification of exclusive and shared lanes for Left, Through, Right and U-turn movements, bus lanes, bicycle lanes, HOV lanes, HVs not allowed to use a lane, and so on.

6. **Saturation flow estimation** (Sections 4.6.1 and 8.5.5)

   Section 4.6.1 of the report gives a poor definition of saturation flow ("*a measure of the maximum volume of traffic over time in a traffic lane*" and gives a limited list of factors that affect saturation flow. It refers to *measuring* saturation flow but does not discuss the model capability to *estimate* saturation flow (see the discussion in *Section 3.1*).

   Saturation flow rate is the maximum departure (queue discharge) flow rate achieved during the green period at traffic signals (Akçelik 1981a, Akçelik, Besley and Roper 1999, Akçelik and Besley 2002; TRB 2016, Akcelik 2017a). A definition consistent with this is given in Section 8.5.5 of the Austroads report.

   Extensive discussion of the subject of saturation flow is given in Section 8.1.2 of the SIDRA user guide. The factors taken into account for estimating saturation flows include:

   - area type (ideal, average to poor; includes considerations such as visibility and speed limit),
   - lane width,
   - grade,
   - parking manoeuvres,
   - buses stopping,
   - vehicle movement class (light vehicles, heavy vehicles, buses, large trucks, trams / light rail, bicycles, user defined vehicle movement classes) using passenger car equivalents,
   - turning vehicle effects,
   - short lanes,
   - gap acceptance characteristics for opposed movements (filter right turns, slip lane movements, turn on red),
   - pedestrian interference (lost time or saturation flow reduction),
   - downstream queue blockage in network modelling.

   Saturation speed, driver response time and queue space as important related parameters are discussed in *Section 3.1* (see *Figure 6*).

   Austroads (2020) guide AGTM03-20 (Guide to Traffic Management Part 3: Transport Study and Analysis Methods) includes detailed discussions on the subject of saturation flows.

In Section 8.5.5 (subsections *Sampling techniques, Sample frame and size, Analysis and reporting procedures*), the Austroads report goes into technical details about saturation flows that are doubtful. It does not refer to well-established saturation flow survey methods (Akcelik 1981, TRB 2016), it does not discuss the related *start loss* and *end gain* parameters, and mixes the PCU factor use with saturation flow surveys in a simplistic and vague manner. All this is out of place and should be removed from this modelling guide for project managers.

7. **Saturation flow as input** (Section B.8.2)

   The report quotes the (RMS 2013) Traffic Modelling Guidelines: "*It should be noted that LinSig uses saturation flow as an input. Whilst SIDRA is capable of using saturation flow as an input also, it is not recommended, instead SIDRA should be calibrated individually using the available options*."

   This advice is strongly supported. Refer to the discussion on saturation flow in *Section 3.1*.

8. **PCU values and start loss** (Section B.8.1)

   The statements of the report for the recommended PCU values as "*MRWA uses 7.35 m and NSW uses 6.25 m, whilst the software default is 5.75 m*" should be examined since the quoted values are more like *queue space* values.

   The report refers to "*lane start displacement*" which sounds like "start loss" (a commonly used term in analytical modelling). As such, its definition as "*the time it takes for vehicles stopped at an intersection to regain posted free-flow speed (assuming no existing downstream blockage)*" is not correct. This text should be revised.

9. **Weaving and merging** (Section 4.5.4)

   While Table 4.1 of the report includes "*Lane weaving*" as an intersection model element, Section 4.5.4 of the report states that "… *traffic signal networks since the popular analysis tools used in Australia and New Zealand are typically based on mathematical formulas. These tools cannot accurately determine the impact of weaving and merging at congested intersections or the compounding effects of queuing once the queues extend beyond adjacent intersections*."

   The SIDRA lane-based network model determines and reports "midblock lane changes". Currently, it does not specifically identify and model the weaving movements but it is capable of doing so. Note that analytical weaving models exist for freeway segments in the US Highway Capacity Manual (TRB 2016).

   Analytical merging models (priority merging and zipper merging) have been included Version 9 of SIDRA INTERSECTION.

   Queue blockage modelling has been discussed in *Points 5 and 6* above.

10. **Short merging departure lane** (Section 4.6.1)

    The report states: "*a signalised intersection with a short merging departure lane may have 100% utilisation in the base scenario, but if the future scenario increases the green time, the lane utilisation may reduce. Situations like this are often overlooked and require careful consideration*.".

    This is not overlooked in practice as most SIDRA modellers pay attention to lane underutilisation of the approach lanes due to the short exit merging lanes. The SIDRA model estimates underutilisation as a function of the exit short lane length (e.g. around 30-40% for a 60 m exit short lane.). In Version 9, exit short lane merging delays are modelled. The suggestion of 100% lane utilisation for a short merging departure lane seems out of place.

11. **Arrival patterns in signal coordination** (Section 4.6.3)

    The statement "*The traffic signal coordination within networks affects the arrival rate of traffic and the generation of queues and delays.*" in Section 4.6.3 (Traffic signal timing) of the report is not correct. Coordination does not affect the arrival flow rate. It only affects the arrival pattern. The statement should be corrected to refer to "*arrival pattern of traffic*" or "*arrival rate of traffic during the signal cycle*".

12. **Model scenarios** (Section 4.8.1)

While the report states that "*Most model parameters set in the validated base model should generally not be altered in the development of the proposed scenarios, but simply carried forward*", it correctly warns "*However, it is important to note that the driver behaviour that occurs in the base scenarios could change in the proposed scenarios if there is an increase or decrease in capacity resulting from changes to geometric arrangements, signal phasing, timing and/or anticipated modal shifts.* "

The warning is correct. However, the relevance of the warning depends very much on whether the model has the capability to estimate the key parameters affected by these changes. For example, does the model include estimation of key saturation flow and gap acceptance (follow-up headway and critical gap) parameters for changes in changes in geometry, demand flows and congestion levels?

An *analytical model* which requires saturation flow rates as constant input values will not be sensitive to any such changes, and using values calibrated for existing conditions would not be expected to be valid in modelling future conditions.

Similarly, a *simulation model* which does not change the driver response, queue space and saturation speed parameters as a function of future changes in geometry, demand flows and congestion levels would have similar limitations for future scenario analysis.

In SIDRA INTERSECTION, the recommended method is to calibrate the basic parameters rather than specifying constant input values representing the base case so that the estimation method applies for future scenarios. For example, "basic saturation flow in through car units" should be adjusted so that the "saturation flow in vehicles per hour" estimated by the model matches the observed saturation flow for the base case, and the saturation flow estimation should be allowed to use all the factors listed in *Point 6* above for the future year scenarios.

The capacity estimation subject for analytical and simulation models has been discussed in detail in *Section 3.1*.

13. **Degree of saturation, delay and level of service** (Section 4.9.1)

Section 4.9.1 (Performance measures) of the report seems to have mixed up the Level of Service (LOS) based on degree of saturation (Table 4.3) vs delay (Table 4.4), and LOS for intersections vs uninterrupted conditions.

In Table 4.3, the header (*Summary of DOS criteria using delay*) and footnote (*Source: SIDRA Trip User Guide*) are wrong. The header should read "*Summary of LOS criteria using degree of saturation*" and the footer should read " *Source: SIDRA INTERSECTION User Guide*".

After discussing the degree of saturation (DOS) as a performance measure and presenting Table 4.3 as a Level of Service (LOS) scheme based on degree of saturation, the report goes on to describe level of service categories quoted from the Austroads (2020) guide AGTM03-20 (Guide to Traffic Management Part 3: Transport Study and Analysis Methods), Section 6.2.2. This is a serious mistake that misleads the readers since the LOS descriptions given here are for *uninterrupted flow conditions*. This is taken from AGTM03-09, Section 3.2.2 which makes it clear that these LOS categories are for uninterrupted flow facilities (e.g. freeways) and are taken from Highway Capacity Manual 2000 edition. These documents are superseded. Also note that LOS categories for uninterrupted flows are based on density rather than degree of saturation in the HCM as shown in Figures 4.1, 5.4 and 5.5 of AGTM03-20.

Therefore, the use of Table 4.3 vs Table 4.4 for different LOS criteria should be clarified and the text describing level of service categories given in Section 4.9.1 of the report should be removed. Table 4.4 is consistent with the LOS categories for intersections given in Table 7.7 in AGTM03-20 and used in SIDRA.

14. **Queue length** (Sections 4.6.2, 4.9.1, 8.5.4, B.8.2)

In Section 4.6.2, the report states: "*Although queue lengths are generally used to validate traffic models, the issues with both the queue calculation within traffic models and accurate on-site measurement is a common issue …*", and in Section 4.9.1: "*… determining queue lengths can be a difficult task. Despite the complexity and limitation, queue lengths can be used for model validation.*"

In this context, it would be useful to discuss different queue length definitions that can be used in models, and the need for the field surveys to match the definition used in the model used. The report acknowledges this ("*software packages may each calculate queue lengths using different criteria and methodologies which add a further level of complexity*") but does not clearly define which queue length definition it is using.

In SIDRA, *back of queue*, *queue at the start of green period*, and *cycle-average queue* are included in output (see *Figure 11*). While back of queue is emphasised for modelling short lane capacity, exit blockage (queue spillback) and so on, queue at the start of green period is easier to survey. The importance of calibrating the model for average value of the chosen queue length measure, rather than percentile queue values should also be emphasised. A queue length survey method is provided in the SIDRA user guide.

In Section 8.5.4, the Austroads report seems to be using the term "*maximum queue length*" to mean back of queue ("*the maximum length of the queue occurs at the point where an arriving vehicle is no longer delayed by the back of the discharging queue*") but the term could be understood as the largest (100th percentile) queue length observed.

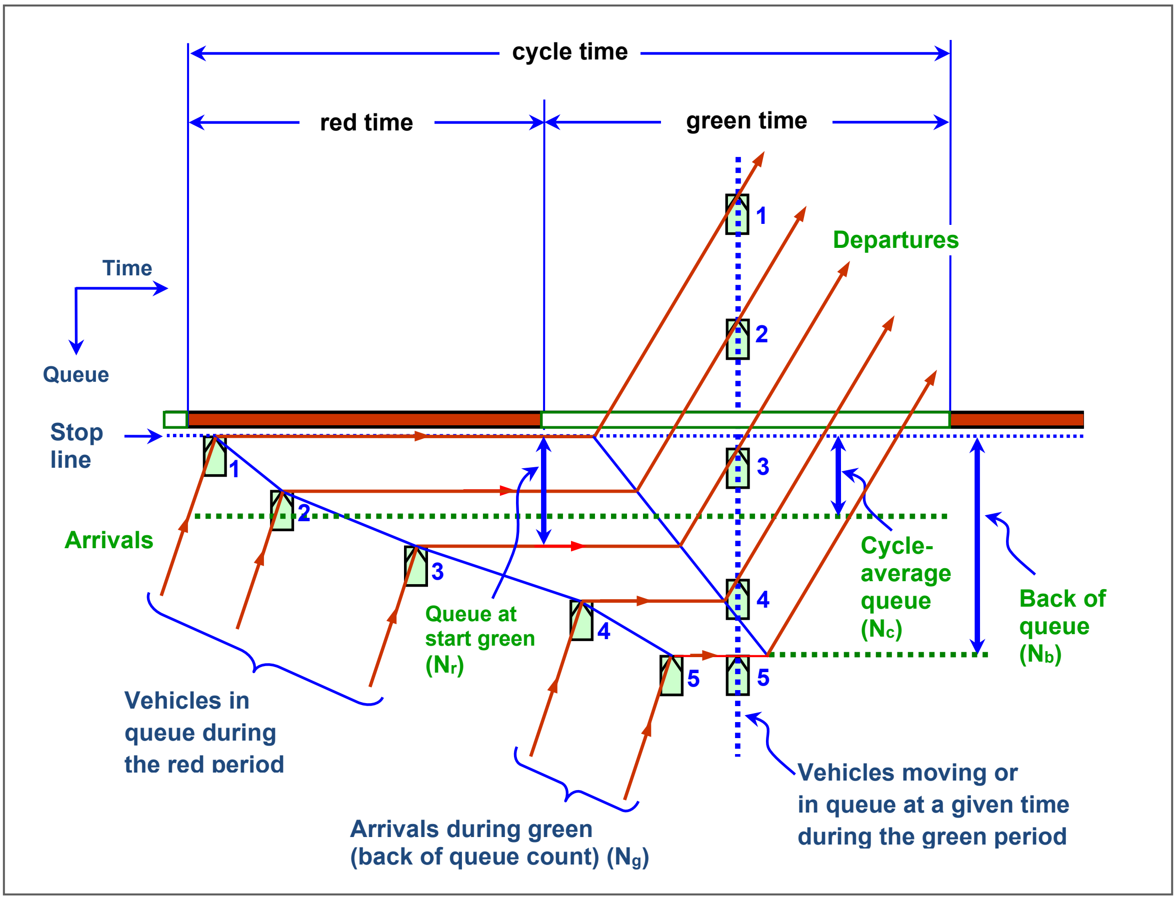


Figure 11 - Different queue length definitions used in SIDRA

15. **Practical degree of saturation and congestion** (Section 4.7)

    In Section 4.7 (Base case model calibration and validation), the report states: "*Traditionally, intersection analysis expects that the traffic demand would be serviced by the intersection capacity within the model time period, and therefore the DOS for analysis at the stop line would be less than 100% (or 1.0).* " and "*... in instances where the complexity of an intersection model outweighs its benefits to the study, more data intensive and capable tools such as simulation models should be considered.*".

    It would be useful to mention that the *practical capacity* is used in intersection analysis as a simple measure of acceptable performance. The corresponding *practical degrees of saturation* vary according to the intersection control. In SIDRA, default values of these are set as 90% for signals, 85% for roundabouts and 80% for sign (priority) control. This is accepted in Austroads (2020) guide AGTM03-20 (Guide to Traffic Management Part 3: Transport Study and Analysis Methods), Section 4.2.4.

    The quote from RMS (2013) modelling guidelines refers to the "practical operating capacity" at 90% for "new intersection designs".

    The suggestion to use simulation for congested conditions is misplaced. Simulation models raise analysis issues with oversaturated conditions due to the effect of time-dependent nature of demands on queue build up and decay. Refer to detailed discussions in *Sections 3.1 and 3.2* of this review.

16. **Unreleased trips** (Section B.7.2)

    The report quotes an earlier version of Austroads (2020) guide AGTM03-20 (Guide to Traffic Management Part 3: Transport Study and Analysis Methods) on the issue of latent demand which is a limitation of microsimulation modelling of congested conditions. This is given in Section 8.3 of AGTM03-20:

    > "*Another critical problem is <u>unreleased trips (also called latent demand)</u>, a common phenomenon associate with microsimulation modelling in congested conditions. It describes those vehicles which are unable to enter the modelled network, typically due to localised congestion near their point of release. Because these vehicles sit outside of the modelled network for some of (and occasionally all of) the simulation period, the unrealised potential travel distance and travel time relating to their desired trips are not fully reflected in the various metrics typically produced by modern microsimulation packages (i.e. vehicle hours travelled (VHT), vehicle kilometres travelled (VKT), number of stops, fuel consumption and emissions). As a result, incorrect inferences can be drawn from the results of modelling runs (which may represent different peak periods, modelled years or options) where different levels of <u>latent demand</u> exist. <u>In order to permit modelling results to be used credibly and effectively for project selection, justification, optimisation and prioritisation, it is imperative that latent demand be addressed so as to ensure 'like with like' comparability across different scenarios</u>.*"

    The issue of *unreleased vehicles* does not exist in analytical modelling since it does not rely on the ability of individual vehicles to enter the network. The SIDRA user guide, Section 9.1 states:

    > "*There are no <u>unreleased vehicles</u> in SIDRA network analysis. The issue of individual vehicles not being able to enter from the origin zones into the simulated network is specific to microsimulation modelling. In SIDRA INTERSECTION analytical modelling, the effect of congestion on delays, travel times, queues and so on are taken into account fully in accordance with the demand flow rates on "external approaches" of the network as specified by the user and any oversaturation (demand higher than capacity) estimated by the model for approach lanes at network entry. Therefore, issues related to unreleased vehicles are not relevant to "analytical modelling" used in SIDRA INTERSECTION.*"

    The use of the term *latent demand* to describe *unreleased trips in microsimulation* is confusing. Latent demand is "*currently desired demand for travel that is not realised because of one or more constraints, such as poor network connectivity or congestion. This is related to the concept of induced demand*" as stated in the report under review. Unreleased trips are not latent demand, but rather they are related to a methodological limitation of microsimulation related to not having enough queue storage at external links (connecting to a source) when queues extend to blocking entry of vehicles emerging from the source. It is recommended that the terminology is clarified in AGTM03-20 and the Austroads report under review by using only the term "unreleased trips' or "unreleased vehicles" in relation to the microsimulation issue.

17. **Corridor models** (Section 4.2.3)

    In relation to *corridor / multi-intersection / local area / small network models*, refer to the proposed system of model categories given in *Table 1* and *Figure 1 (Section 2.2.1).* Also see the summary of model category and hierarchy systems given in various modelling guidelines (*Section 2.2.3)*.

18. **Integrated modelling** (Sections 5.2 and 5.3)

    As mentioned in Section 2.2.1, it is recommended that Figure 5.1 in Section 5.2.2 of the report is modified to replace "SIMULATION MODEL" in the middle box to "NETWORK MODEL" in line with the proposed changes in *Table 1* and *Figure 1*. This is shown in *Figure 12*.

    At the same time, it is recommended that all references to "*simulation model*" is replaced by "*network model*" in Sections 5.2 and 5.3 (and elsewhere in the report) as relevant including Table 5.2 (*Common challenges and possible solutions*). For example, the second point in the text below Figure 5.1: "*The ~~simulation~~ network model provides more detailed traffic volume outputs to feed into an intersection model. It also has the ability to inform the likely intersection configuration and operations from a network wide perspective that can be tested at an even more detailed level in the intersection model.* ".

    These changes would reflect the reality that analytical network models are also capable of traffic assignment, e.g. as in SATURN software, and would avoid inconsistent categorisation that leads the statements like "*iterating between an intersection model and simulation model*". This would make more sense if it was "*iterating between an intersection model and network model*".

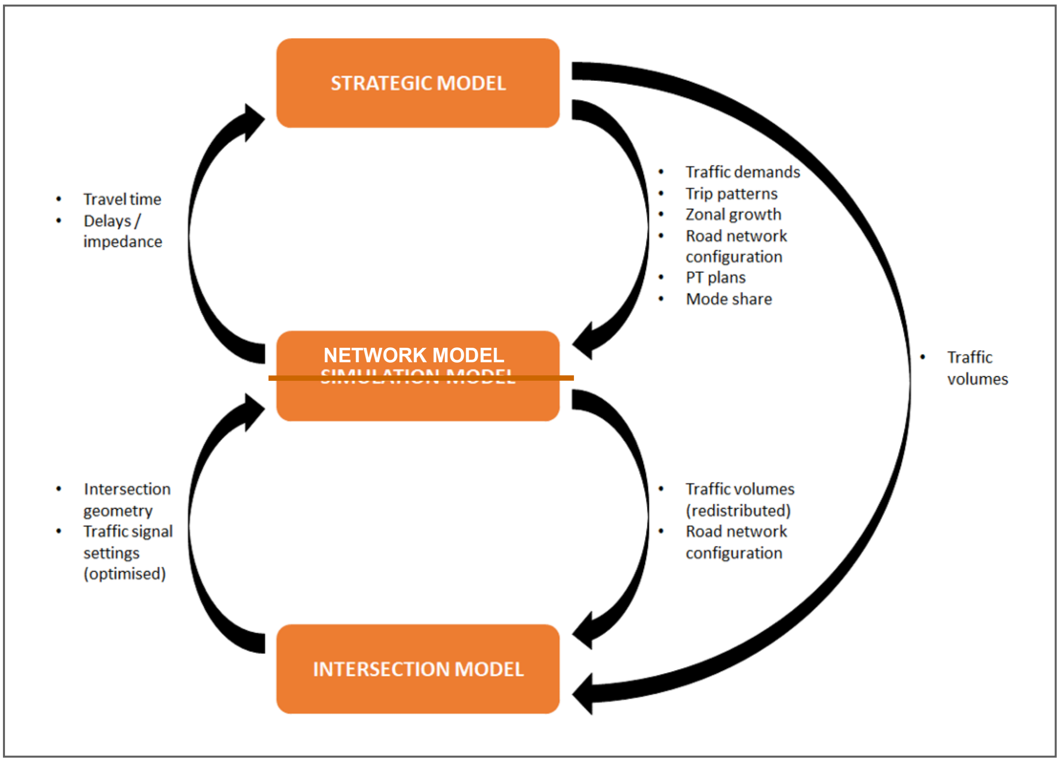


Figure 12 - Integrated modelling interdependencies
proposed modified version of Austroads AP-R621-20, Figure 5.1

19. **Mesoscopic modelling** (Section B.6.1)

In Appendix B, Section B.6, the Austroads report refers to an earlier version of Austroads (2020) guide ***AGTM03-20*** (Guide to Traffic Management Part 3: Transport Study and Analysis Methods) in discussing mesoscopic modelling.

AGTM03-20, Section 8 discusses modelling guidelines including a discussion of "major categories of modelling". In Section 8.1.1, it describes "*Mesoscopic models, also known as macrosimulation, are a type of simulation where vehicles are represented as a traffic stream or platoon*." This is in line with the proposed system of model categories given in Section 2.2 of this review (see *Table 1*) although it is recommended that AGTM03-20, Section 8 and Appendix M are revised in view of this review.

In Appendix M, Table M1 of AGTM03-20, the software packages TRANSYT, SATURN, SYNCHRO and LinSig are listed as examples of mesoscopic models. It is recommended that SIDRA INTERSECTION is also included in this group in Table M1 <u>as a more detailed lane-based network model</u> as discussed in *Section 2.2.2* which is capable of "*simulation of signalised road network, with traffic signal optimisation*" stated in the table for TRANSYT, and "*A traffic signal optimisation tool for arterials and networks, using time-space analysis and platoon dispersion models*" stated for SYNCHRO, as well as being capable of capacity constraint and queue spillback for congested network modelling.

In discussing mesoscopic models in Appendix B, Section B.6, the Austroads report (AP-R621-20) states "*the specification of modelling technologies specified in the 2017 Austroads Guide* (now AGTM03-20) is *somewhat different from modern conventional language and as such the importance of redefining the various modelling techniques is re-iterated …", and* "*Earlier versions of what was termed mesoscopic modelling were actually closer to being macroscopic models, with functions used to determine intersection delay and queueing … More recently, the term mesoscopic modelling has also been used to define a simplified simulation model*." Thus, it dismisses the use of the mentioned analytical software packages mentioned above as mesoscopic models and places them as "Intersection models" in Table 2.1.

Table 1 of this review recognises the role of these analytical packages as both intersection and network modelling tools with macroscopic, mesoscopic and microscopic analysis features.

The following recommendation of the Austroads report for further work on mesoscopic models is fully supported: "*While the development and level of accuracy of these models can be generally stated as being between macroscopic and microscopic models, further exploration into this topic is considered important for Austroads to consider due to its popularity in the current market, as well as lack of detailed and descriptive analysis in current guidelines.*".

20. **Microscopic modelling** (Section B.7)

The report states: "*The Austroads guidelines on microsimulation modelling (Austroads, 2006) also note some areas requiring improvement in microsimulation technology (such as in relation to overtaking, flexibility in driver behaviour, and the operation of roundabouts). <u>These issues have been addressed in subsequent software development</u>.*".

It is interesting that the report makes a blanket statement which may give the impression that the limitations of microsimulation modelling discussed in Section 2.3 of the Austroads (2006) report AP-R286-06 (*The Use and Application of Microsimulation Traffic Model*) have been resolved.

The authors do not agree with the statement of the report in the last paragraph of Section B.7.1 which sounds like the advice in AP-R286-06 is outdated.

It is doubtful that all microsimulation modelling limitations have been resolved in all software packages. Some basic limitations are related to the difficulty of model calibration and lack of capacity estimation algorithms as discussed in *Section 3.1* of this review. This relates to the point "*microsimulation applications or models require calibration, validation and verification or auditing which, if overlooked, could make the model useless*" in report AP-R286-06.

In Section B.7.2, the report argues for "*a more flexible approach to calibration and validation than the approach recommended by Austroads* (AP-R286-06)" stating "*e.g. large area network with multiple available routes is less strict than a small area or long corridor*". This invites the question whether "*a microsimulation model with less strict calibration for a large network*" is more accurate than an analytical network model if the latter has the advantage of less effort for a better level of calibration.

Also refer to Akçelik and Besley (2001a).

21. **Adoption of a single system of model classification** (Section B.11)

    In Table B.10, the report recommends that Austroads should consider "*... as part of its review of modelling guidelines, whether it may be of benefit for it to promote the adoption of a single system of model classification. Such a system could assist in clarifying the intent and scope of modelling needed and would help to target advice to particular applications and so improve the quality and consistency of Australian practice.* "

    This recommendation is supported in view of the issues raised and the classification system proposed in this review. The discussions presented in this review (including Points 15, 16 and 17 in this section) should be taken into account in the future work recommended in Table B.10.

22. **Modelling technique selection** (Appendix D)

    Table D.1 (*Modelling Technique Selection Worksheet*) in Appendix D of the report is based on Table A.1 given in Austroads (2010) report AP-R350-10 (Guidelines for Selecting Techniques for the Modelling of Network Operations), Appendix A.

    Although the Austroads report, Section 2.5 states that Table D.1 "*has been reproduced*" from AP-R350-10, it has been modified by changing the column headers giving the false impression that the original table uses the model categories presented in Table 2.1 of the report.

AP-R350-10, Appendix A1

Step 3: Review of elements of the traffic system (select from list key aspects to be considered by the model, add if not on list)	4A: Technique assessment			
	Macro-model	Micro-model	Macro-sim	Micro-sim

AP-R621-20, Appendix D.1

Step 3: Review of elements of the traffic system (select from list key aspects to be considered by the model, add if not on list)	**Step 4A: Technique assessment**			
	Strategic modelling	**Meso-scopic modelling**	**Micro-scopic modelling**	**Inter-section modelling**

There are several general issues about Table D.1:

(i) The ratings given in the *Intersection modelling* column of the table need a major revision in view of the detailed discussions presented in *Sections 2 and 3* of this review. A short list of ratings in Table 2.1 of the report that are not agreed with are listed in *Table 3*. The "Intersection Modelling" column in *Table 4* shows modified ratings. The "Small Area Modelling" column is added with applicable ratings shown.

(ii) The columns of Table D.1 reflect the model categories given in Table 2.1 of the report which leads to biased assessments, especially considering that the software packages listed against the intersection category shown in Table 2.1 are all network models.

(iii) "*Network Representation*" group of Table D.1 appears to be applied to the "*Intersection modelling*" column in Table D.1 whereas many elements in this group are not applicable to single intersection modelling. This would be rectified if separate columns are used for *Intersection Modelling* and *Small Areas Modelling* as shown in *Table 3*.

It is therefore recommended that either Appendix D should be removed from the report, or a new version of the table should be prepared with columns corresponding to the proposed model categories shown in *Table 1* of this review (*Section 2.2*), namely

- *Strategic Transport Models*
- *Large Area Traffic Models*
- *Intersection and Small Area Traffic Models.*

If a new version of the table is prepared, a major revision of the ratings should be undertaken with consideration to the revised model categorisation and the progress with modelling capabilities taken place during the last decade (*Table 3* given in Section 2.3 of this review and *Table 4* given below should be used in this revision).

However, the authors of this review recommend removal of Table D.1 (Modelling Technique Selection Worksheet). Their experience is that this table was not particularly useful in practice since practitioners choose modelling software rather than modelling techniques. A selection guideline to select software (such as a more detailed version of *Table 3* given in *Section 2.3*) might be more useful.

On the other hand, traffic modelling software packages continually extend the traffic modelling techniques they employ and tend to use hybrid modelling. At the same time, an evaluation table / worksheet is not likely to assess the relative extent, quality and ease of use of particular techniques employed in alternative software packages.

A possibility is to conduct regular surveys of software developers asking them to respond to questions about software features and modelling techniques employed by way of self-assessment (UTM 2013, 2015).

With this approach, the modelling guidelines and modelling software project managers can focus on input and output specification in the context of their specific project purposes and modelling experts can then determine the appropriate modelling software for the particular analysis they need.

Table 4 Modelling Technique Selection Worksheet - Recommended changes to Table D.1 of the Austroads report (selected rows and columns)

S: Suitable (or mostly suitable). **P**: Partially suitable (i.e. with some limitations or approximations).
U: Unsuitable (or mostly unsuitable). **NA**: Not applicable.

	Model elements	**Intersection Modelling**	**Small Area Modelling**
Demand representation (input)	Origin-destination (small area or corridor)	~~U~~ NA	S
	Hourly traffic volume **(1)**	~~S~~ P	P
	Period traffic volume (> 1 h, with peaking) **(1)**	~~U~~ P	P
	Time varying (variable) demand (e.g. 15-minute periods)	~~U~~ S	S
	Person trips	~~U~~ P	S
	Passenger car units **(2)**	~~S~~ Delete this row.	
	Classified vehicle units	~~P~~ S	S
	Motorcycle	~~P~~ S	S
	Bicycle	~~P~~ S	S
	Pedestrian	~~P~~ S	S
Network representation (input)	Cycling lanes	~~P~~ S	S
	Pedestrian facilities	~~P~~ S	S
	~~Bus lines~~ Buses	~~U~~ S	S
	Trams / Light Rail	~~U~~ S	S
	Coordinated traffic control	~~U~~ NA	S
	Ramp metering **(3)**	~~U~~ P	P
Geographic and temporal scope (input)	Expressway / Freeway	~~U~~ P	P
	Small area/network	~~U~~ NA	S
	Corridor	~~U~~ NA	S
	Immediate (i.e. routes will change)	~~U~~ NA	S
	Operational level (i.e. no change in travel patterns)	S	S
Model functionality (input)	Time-of-day measures	~~U~~ S	S
	Gridlock / highly saturated conditions	~~U~~ S	S
	Temporary blockages	~~U~~ S	S
	Public transport schemes	~~U~~ S	S
Indicators (output)	Travel time	~~U~~ S	S
	Vehicle hours travelled (VHT)	~~U~~ S	S
	Volume	~~U~~ NA	S
	Origin-destination demand	~~U~~ NA	S
	Vehicle kilometres travelled (VKT)	~~P~~ S	S
	Emissions / Fuel (considering stop-and-go)	P	P
	Emissions / Fuel (considering drive cycles) **(4)**	S	S
	Journey distance	~~U~~ S	S
	Vehicle occupancy / Persons	~~U~~ S	S
	Number of stops	~~P~~ S	S
	Travel time reliability	~~U~~ P	P

(1) Modelling of peak hour with constant demand is not recommended. Modelling longer than one hour with shorter peak is possible but uncommon. Variable demand modelling is possible.

(2) Raw traffic volume input data are not in passenger car units (pcus). Input in pcus leads to anomalies in model performance estimates. Refer to the SIDRA user guide for discussion.

(3) On-ramp traffic can be modelled.

(4) Refer to detailed description of drive cycles (four-mode elemental model) in *Section 2.2.2*.

23. **Examples of network model outputs** (Appendix E)

It is recommended that the title of Appendix E is changed from "Examples of Simulation Model Outputs " to "Examples of Network Model Outputs", and it would be great if a SIDRA output example such as the one shown in *Figure 13* is included.

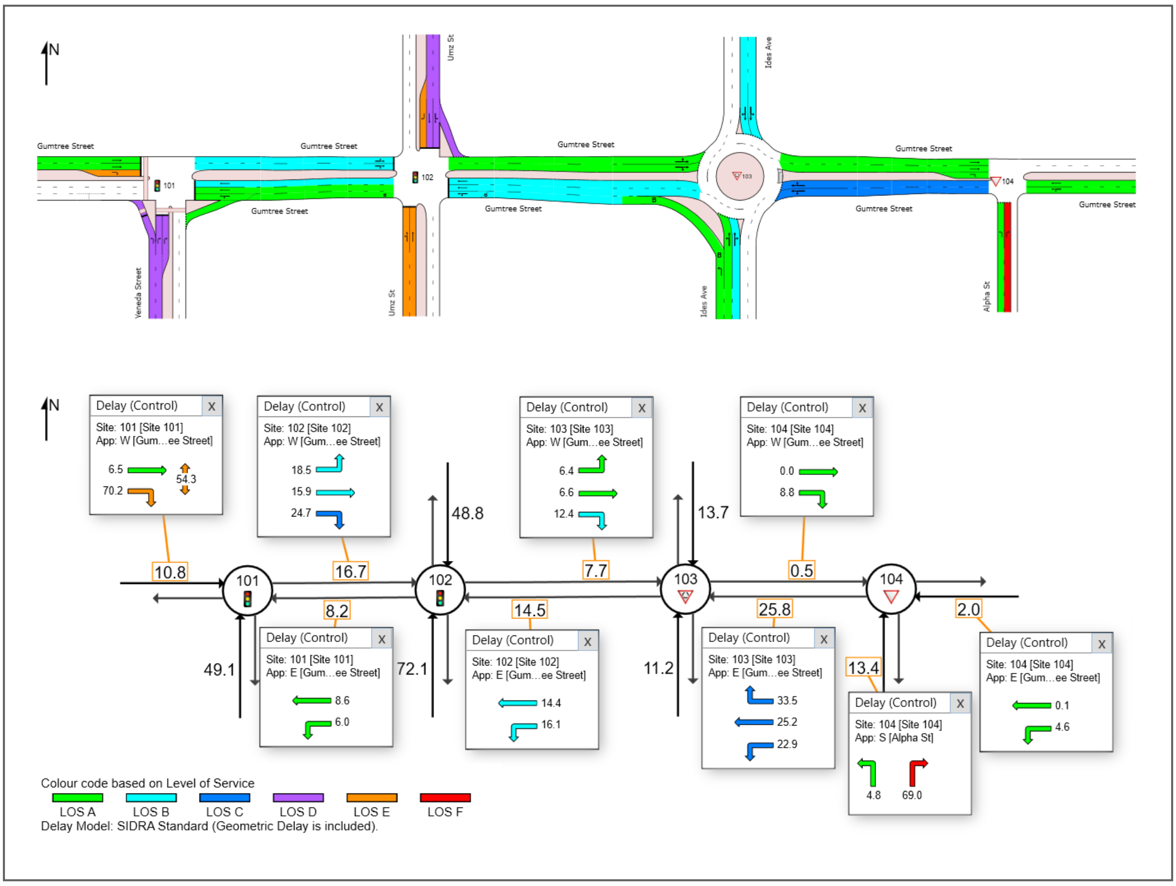


Figure 13 - Lane level of service display and movement delay display (SIDRA INTERSECTION)

4. Recommendations

This technical note has addressed the subject of guidance to traffic and transport modelling project managers and presented a critical review of the Austroads Report AP-R621-20 (Building Transport Modelling Management Capability). The conclusions and recommendations for an urgent revision of the report under review are summarised below.

Non-italic section, table and figure references are to those in the Austroads report under review. Section, table and figure references in italic font are to those in this review report.

1. **Model Categories and Hierarchy** (*Section 2.2.1*)

   It is recommended that the proposed system of model categories presented in *Table 1* is adopted and the related changes are applied to Table 2.1, Figures 2.3 and 5.1, and the text throughout the Austroads report.

   The proposed framework for categorising traffic and transport models is based on clear definitions of categories using consistent criteria:

   - ***Model Type*** identified by the type of *area* and the *network size* as a rough guide:
     - *Strategic Transport Models*: Very large networks (city scale, regional scale).
     - *Large Area Traffic Models*: Medium to Large networks (up to 30-100 intersections).
     - *Intersection and Small Area Traffic Models*: Single intersection and small Networks (up to 10-20 intersections).
   - ***Model Level*** identified by the level of detail determined according to the scale of the model:
     - *Macroscopic*: Large-scale model with more aggregate elements.
     - *Mesoscopic*: Intermediate scale and level of detail between microscopic and macroscopic.
     - *Microscopic*: Small scale model with detailed elements.
   - ***Modelling Technique*** contrasted as analytical or simulation:
     - *Simulation Model*: Modelling of traffic moving in a network as individual vehicles or as groups (small packs, platoons) of vehicles.
     - *Analytical Model*: This term refers to algorithmic models that combine mathematical model elements based on a combination of traffic theory and empirical derivations).

2. **Traffic Movements and Road Geometry** (*Section 2.2.2*)

   The Macroscopic / Mesoscopic / Microscopic categories of *Model Level* should be determined according to both ***traffic movements*** (modelling individual vehicles, vehicle paths / drive cycles, signal platoons / bunching, traffic flows, speed-flow relations) and ***road geometry*** (approaches, lane groups, lanes, lane segments). This recognises the importance of not only vehicle-to-vehicle (movement-to-movement) interactions but also vehicle-road geometry interactions. The difference between ***lane-based***, ***link-based*** and ***approach-based*** models can be understood only by due consideration to this aspect of model level of detail.

3. **Modelling Guidelines** (*Section 2.2.3*)

   Two modelling guidelines, namely Main Roads Western Australia *Operational Modelling Guidelines* (MRWA 2018) and the New Zealand Transport Agency *Transport Model Development Guidelines* (NZTA 2019) are recommended for close attention in the revision of the report under review.

   In categorising the models on the basis of *geographic coverage* and *purpose of modelling* rather than *model detail* (macroscopic, microscopic, mesoscopic) and *modelling technique* (simulation, analytical), these are in line with the categorisation structure proposed in this review.

4. **Assessing Software Packages** (*Section 2.3*)

The report under review forces groups of software packages into boxes in an inconsistent model category scheme. This creates misleading impressions especially for those listed in the last row labelled as *Intersection Models*, particularly in view of the erroneous assertion of "*Simplistic calculation of intersection performance and operation.*". Most software packages listed in Table 2.1 of the Austroads report have capabilities for modelling *intersections and networks,* use a mixture of *analytical and simulation modelling techniques*, and involve *macroscopic, mesoscopic and microscopic levels of detail*. Therefore, the relationship between model categories and software packages is a complicated one as indicated in *Table 1* of this review.

It is recommended that the listing of software packages is removed from the table of model categorisation as shown in Table 2 of this review.

A separate table such as the one shown in *Table 3* of this review could be prepared for the assessment of applicable model categories and key model features applying to individual software packages. This would help with the selection of software packages for the specific purposes of traffic and transport modelling projects.

5. **Modelling Technique Selection** (*Section 3.3*)

Table D.1 (*Modelling Technique Selection Worksheet*) in Appendix D of the report under review is problematic. It is recommended that either it is removed from the report, or a new version of the table is prepared. If a new version of the table is prepared, a major revision of the ratings should be undertaken with consideration to the revised model categorisation and the progress with modelling capabilities taken place during the last decade.

Since the selection of modelling software rather than modelling techniques is more relevant in practice, software assessment guidelines would be more useful as discussed in the previous point.

On the other hand, traffic modelling software packages continually extend the traffic modelling techniques they employ and tend to use hybrid modelling. Therefore, an evaluation table / worksheet is not likely to assess the relative extent, quality and ease of use of particular techniques employed in alternative software packages. A possibility is to conduct regular surveys of software developers asking them to respond to questions about software features and modelling techniques employed by way of self-assessment.

With this approach, the modelling guidelines and modelling software project managers can focus on input and output specification in the context of their specific project purposes and modelling experts can then determine the appropriate modelling software for the particular analysis they need.

6. **Model Estimation of Key Capacity Parameters** (*Section 3.1*)

The report under review gives a lot of emphasis on demand modelling but not enough on capacity modelling, and it ignores important calibration issues that need to be discussed in relation to microsimulation models. In relation to *model calibration*, the question "*Where is capacity in simulation?*" should be asked to establish the difference between analytical and simulation models.

In *analytical intersection and network traffic models*, capacity is the key parameter used in estimating degree of saturation (v/c ratio), delay, queue length, stop rate, and so on. The methods used to estimate the key parameters of *capacity* as a function of *road geometry*, *traffic flows (demand)* as well as *signal timings* (cycle time, green time) for signalised intersections, are based on well-established traffic theory and empirical methods.

In *analytical models*, these key parameters for capacity estimation are *saturation flows* for signalised intersections and *follow-up headway and critical gap* (gap acceptance) parameters for roundabouts and stop / give-way sign-controlled (priority) intersections. These parameters can be observed and used in calibrating analytical models.

In *micro-simulation models of intersections and networks*, capacity is not used generally, and the saturation flow parameter is not used for signals whereas the gap acceptance parameters may be used directly or indirectly. Saturation flows are directly related to three fundamental parameters, namely *driver reaction time* (queue discharge response time), *queue space* (jam density) and *saturation (queue discharge) speed*.

In calibrating a micro-simulation model to achieve observed saturation flow or follow-up headway values, the parameters of the particular micro-simulation model corresponding to the driver reaction, queue space and saturation speed parameters could be used. This may be difficult task but it is theoretically possible.

Unless good estimation and calibration methods are used in an analytical or simulation model to estimate or imply realistic capacity values, the estimates of delay, queue length, stop rate would not be reliable.

It is recommended that the report under review should discuss this subject in explaining the calibration of analytical and simulation models. In traffic modelling using simulation or analytical models in general, the use of constant capacity, saturation flow and gap acceptance parameters is not recommended.

7. **Peak Demand (Analysis) Period** (*Section 3.2.1*)

It is recommended that the erroneous statements such as "*Intersection analysis generally uses simplistic calculations and assumptions, for example, inputs are based on <u>average peak hour profiles</u> and <u>traffic flows are assumed to remain constant</u>.*" given repeatedly in the report under review are corrected. This is discussed in detail in *Section 3.2.1* of this review.

It is important to note that, for oversaturated conditions, the SIDRA delay is the average delay to vehicles *arriving* during a given flow period *including the delay experienced after the end of the flow period* until the departure of the last vehicle arriving during the flow period (which happens after the flow period). This allows analytical models to model congestion affects with the analysis of a single peak flow period whereas microsimulation using individual vehicles needs to use multiple flow period modelling.

8. **Pedestrians and Vehicle Classes** (*Section 3.2.2*)

It is recommended that the erroneous statements in the report under review suggesting that "*Intersection analysis is typically only undertaken to determine performance of vehicles on the roadways. Performance of other modal types, such as pedestrians/cyclists/trams/heavy rail/etc, are generally not calibrated at the intersection analysis level due to their unique features.*", and "*pedestrian crossings, pedestrian volumes, tram lines, bus jumps, train phases*" can be excluded from intersection analysis.

The report is inconsistent in relation to these statements as it includes "*public transport, bicycle, pedestrian*" as intersection model elements in Table 2.3 (*Summary of modelling elements*) in Section 2, includes *pedestrians* as model elements in Table 4.1 (*Summary of intersection model elements*), discusses buses and pedestrians are discussed in Section 4.5.2 (*Data Analysis*), discusses cyclists and pedestrians in the context of intersection modelling in Section 4.6.1, and qualifies "*cycle and pedestrian volumes*" as "expected" in intersection analysis in Table 8.2.

In SIDRA, variabilities in pedestrian, bicycle, bus, tram/ light rail and train volumes and signal phases are treated via features such as modelling of pedestrian actuation and minor phase actuation, and user input of phase frequency. Scenario analysis can be used in cases such as infrequent bus priority, tram and train phases at signals.

Pedestrian crossings should never be excluded from signalised intersection analysis due to the critical impact of pedestrian minimum walk and clearance time requirements on signals.

9. **Comments on Various Aspects of the Report Under Review** (*Section 3.3*)

   It is recommended that the following aspects of the report under review should be revised to correct various incorrect or inconsistent statements and address various comments for improvement as discussed in *Section 3.3*:

   - Software processing and ease of setup.
   - Unsignalised intersections.
   - Impacts of downstream queuing or short lanes, and
     relation of downstream impacts - to throughput vs demand.
   - Lane disciplines.
   - Saturation flow estimation, saturation flow as input, start loss and pcu values.
   - Weaving and merging, short merging departure lane.
   - Degree of saturation, delay, level of service.
   - Queue length.
   - Practical degree of saturation and congestion.
   - Arrival patterns in signal coordination.
   - Unreleased trips.
   - Model scenarios.
   - Corridor models.
   - Integrated modelling.
   - Mesoscopic modelling.
   - Microscopic modelling.
   - Adoption of a single system of model classification.
   - Examples of network model outputs.

10. **Research on Microscopic and Mesoscopic Modelling** (*Section xxx*)

    Research is recommended to compare capacity and performance estimates from different microscopic and mesoscopic (simulation and analytical) network modelling methods listed below as well as any other methods and software packages available:

    - Individual vehicle simulation, e.g. AIMSUN, VISSIM.
    - Analytical time-step (second-by-second) *lane-based* platoon movement where platoons move along network lanes with lane changes (SIDRA INTERSECTION).
    - Analytical time-step (second-by-second) *link-based* platoon movement where platoons move along network links, i.e. aggregate lane groups (SATURN, TRANSYT, LinSig,).

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https://www.vicroads.vic.gov.au/-/media/files/technical-documents-new/miscellaneous-guidelines/transport-modelling-guidelines-volume-5-intersection-modelling-june-2020.ashx

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Appendix A - Model Comparison (Extract from SIDRA INTERSECTION User Guide)

The material in this appendix is reproduced from:

AKCELIK & ASSOCIATES (2020). *SIDRA INTERSECTION 9 User Guide.* Akcelik and Associates Pty Ltd, Melbourne, Australia.

Model Comparison

Model calibration effort may involve comparison of traffic models offered by different software packages, for example SIDRA INTERSECTION (a micro-analytical model) and various microsimulation models. In this effort, various issues need to be recognized.

Firstly, users of microsimulation models should not assume that a more detailed model involving individual vehicles will necessarily result in reduced model error (*Figure 2.6.3*). This is because, it is likely that, while *model specification error* may decrease with increased model detail (complexity), the total *measurement error* will increase due to the increased model complexity (more variables each with an associated degree of measurement error). This consideration applies to all models, simulation or analytical.

Akçelik and Besley (2001a) discussed the compatibility between microsimulation methods and established analytical techniques that are used in traffic engineering, considering several key components of traffic models:

(i) capacity analysis;

(ii) estimation of lane flows at intersection approaches, and relating lane underutilisation at closely spaced intersections to lane change implications between intersections (Akçelik 2013, 2014a,b, 2015, 2016b,c);

(iii) modelling of queue discharge (saturation) flow rate, queue discharge speed and other queue discharge parameters at signalised intersections, and relating them to the general queuing, acceleration and car-following models used in microsimulation; and

(iv) modelling of gap acceptance situations at all types of traffic facilities, e.g. permitted or filter turns (right-turn or left-turn) at signalised intersections, minor movements at stop or give-way / yield signs, traffic entering unsignalised roundabouts, and freeway and other traffic merging situations.

In model comparison, the parameters of each model in relation to the above components need particular attention. Also importantly, the *consistency of definitions and measurement methods* for traffic performance variables such as delay (stopped, geometric, etc.) and queue length (cycle average, back of queue, etc.) must be ensured in comparing models as in comparing model estimates with values observed in the field (*Section 2.6.3*).

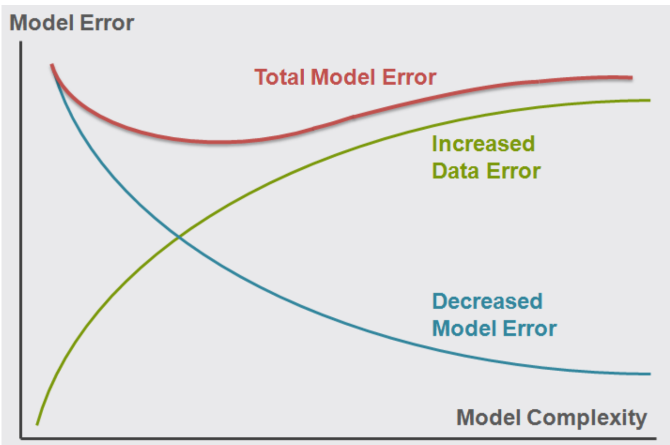


Figure 2.6.3 - Model error vs model complexity

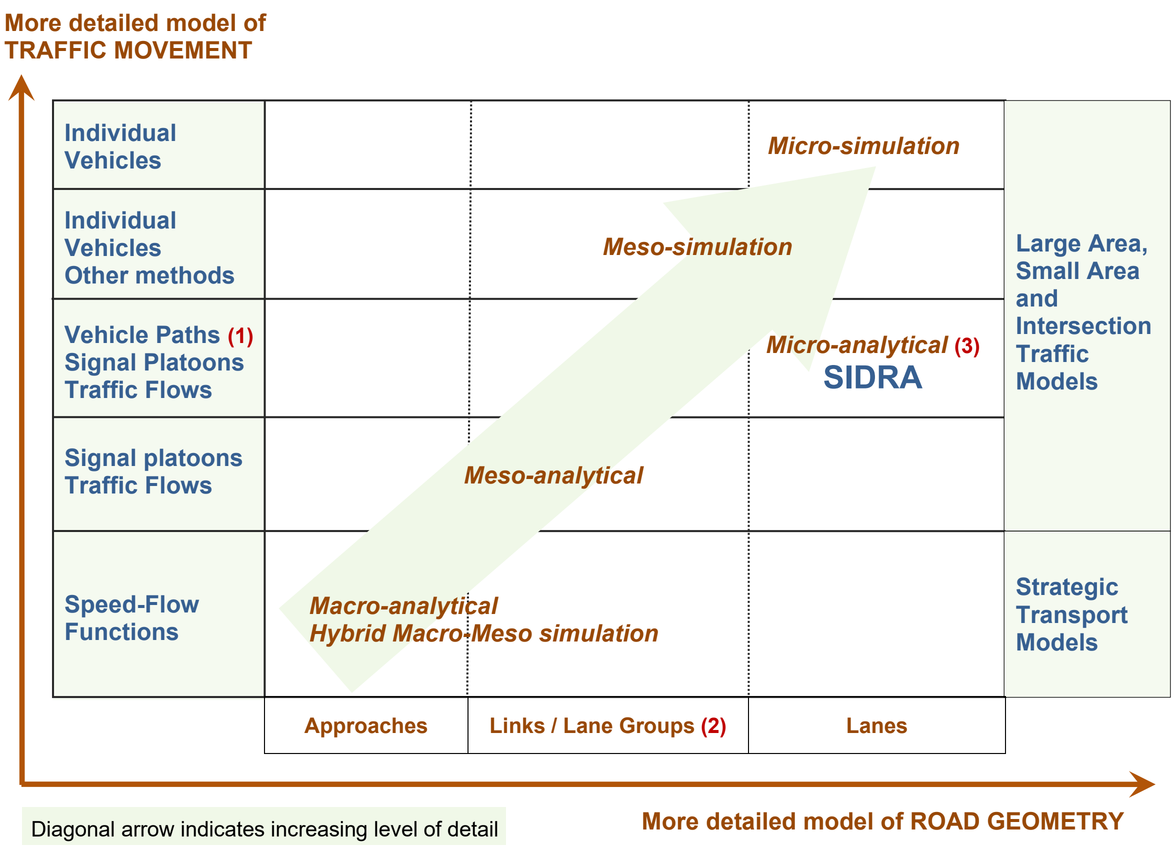
The *Driver Characteristics* table in the Detailed Output report includes the *saturation speed*, *saturation headway and spacing*, *average queue space* and *driver response time* parameters which may be helpful for calibrating microsimulation models for closer results to SIDRA INTERSECTION estimates.

The *SCATS Parameters* table in the Detailed Output report include SCATS system parameters derived using the saturation speed parameter (maximum flow, occupancy and space time at saturation).

A general framework for road traffic models

It is useful to understand how various traffic models relate to each other and to the real-life system. For this purpose, a general framework for classification of road traffic models is presented in *Figure 2.6.4*. This two-dimensional framework considers the nature and level of detail offered by a traffic model in representing road geometry and traffic elements. The focus is on the movement of vehicle traffic.

Contrasting models as macroscopic vs microsimulation, deterministic vs microsimulation, empirical vs theoretical, empirical vs analytical, etc are not valid ways of qualifying models. Models never fall into clear-cut categories, but there is a spectrum (continuum) of models. The framework presented here may be helpful to understand that analytical models or simulation models can be microscopic or macroscopic (and in between).



(1) **Drive cycle** (four-mode elemental) method is used to model ***vehicle paths***, i.e. speed-time traces consisting of acceleration, deceleration, cruise and idling elements (modelled using initial and final speeds, acceleration and deceleration times and distances, and idling times).

(2) **Link / Lane Group** is a set of lanes used by a movement or a number of movements with shared lanes including different movement classes in shared lanes.

(3) **SIDRA INTERSECTION** is considered to be a ***micro-analytical model*** due to being a lane-based model like microsimulation models, including detailed modelling of vehicle paths (using drive cycles) and modelling lane-based second-by second platoon patterns for signalised intersection networks.

Figure 2.6.4 - A general framework for road traffic models

For the purpose of the framework presented in *Figure 2.6.4*, the *analytical* models are defined as algorithmic models that use direct mathematical computations to determine system states, and simulation models as those that use various rules (mostly in the form of mathematical equations) for movement of vehicles in a system (individually or in platoons). Accordingly:

(iii) a simulation model can be macroscopic, mesoscopic or microscopic,

(iv) an analytical model can be macroscopic, mesoscopic or microscopic, and

(v) a simulation model can be deterministic or stochastic.

The US Highway Capacity Manual Edition 6 (HCM 6), Chapter 9 (Glossary and Symbols) defines an *analytical model* as "*A model based on traffic flow theory, combined with the use of field measures of driver behaviour, resulting in an analytical formulation of the relationship between field measures and performance measures such as capacity and delay.* ", and it defines a *microscopic model* as "*A mathematical model that captures the movement of individual vehicles and their car-following, lane-choice and gap-acceptance decisions at small intervals, usually by simulation*." The latter will be interpreted as definition of "microsimulation" and it is noted that the definition does not apply to our qualification of the SIDRA INTERSECTION as a *micro-analytical* model.

Analytical traffic models such as SIDRA INTERSECTION usually incorporate stochastic elements (e.g. overflow queue models for traffic at intersections) although each application of the model may produce the same outcome (deterministic). The distinction "stochastic vs deterministic" does not necessarily imply model quality since it is possible to randomise parameters of traffic elements at every level of detail (individual vehicle. platoon, traffic flow, etc).

It should also be noted an analytical model such as SIDRA INTERSECTION that use an algorithmic *iterative approximation method* to solve complex analytical problems, especially in the case of network modelling, does not necessarily produce the same outcome, e.g. the results may differ according to the number of iterations and stopping conditions used.

Contrasting models as "empirical vs theoretical" (as frequently done in the literature in relation to roundabout capacity models) represents a simplistic view since most models have basis in traffic behaviour theory and are empirical at the same time. However, the term "empirical model" is usually used to mean "based on statistical analysis of field data without any direct basis in traffic theory".

The framework presented *Figure 2.6.4* is limited to vehicle traffic. The issues of different vehicle types (movement classes) and driver types are further considerations in this context. Different modes of traffic (pedestrians, cyclists, public transport) could be added as a third dimension to this framework, each with its own special considerations. For example, for pedestrians, drive cycles are not applicable, and pathways rather than lanes would be relevant.

Appendix B - Traffic Model Hierarchy from Guide to Fuel Consumption Analysis for Urban Traffic Management (SR 32)

ARRB Special Report 32 (Bowyer, Akçelik and Biggs 1985) discussed traffic model hierarchy in some detail with examples of software packages available at the time. One of the objectives of the report was stated as:

"*This report provides a guide to assist the traffic manager in selecting techniques which are appropriate to the various traffic management contexts, and presents a comprehensive guide to the use of techniques for fuel consumption analysis in urban traffic systems*."

GUIDE TO FUEL CONSUMPTION ANALYSES

TABLE III

SELECTED TRAFFIC MODELS APPROPRIATE TO PARTICULAR TRAFFIC-TRANSPORT SYSTEM CONTEXTS

Traffic — Transport System Context			*Selected Traffic Models*		
System Scale	*Travel Demand Variables*	*System Supply Description*	*Name*	*Estimated Traffic Variables*	*Model Features*
Macro	Destinations modes, routes	Travel costs specified for travel links	UTPS[1]	Link volumes and travel costs	Travel analyses and system evaluation
			LATM[2]	Traffic demand, delay and queues on traffic links	Dynamic trip assignment and intersection delay estimation
Macro/Meso	Routes	Travel time specified for traffic links			
			SATURN[3]	Traffic demand, delay, queue time, stops, on traffic movements	Trip assignment, interfaced to a detailed traffic model (TRANSYT-like)
		Explicit description of intersections and their interactions	TRANSYT[4]	Travel time, delay, stops on traffic movements	Analytic estimation of delays, stops and queue lengths in a network
Micro/Meso	Constant Demand				
		Explicit description of vehicle movements	SCATSIM[5]	Instantaneous velocity of individual vehicles	Event simulation in a signal network
Micro	Constant Demand	Detailed description of individual intersection and movement interactions	SIDRA[6]	Delay, stops, queue lengths, travel time on traffic movements	Analytic estimation of capacity and traffic performance for movements at a single intersection
		Explicit description of vehicle movements	MULTSIM[7]	Instantaneous velocity of individual vehicles	event simulation;
			INSECT[8]		event simulation; priority control intersections only

References:

(1) UMTA (1977)
(2) Taylor (1980)
(3) Bolland, Hall and van Vliet (1979)
(4) Vincent, Mitchell and Robertson (1980)
(5) Negus and Fehon (1982)
(6) Akcelik and Besley (1984)
(7) Gipps and Wilson (1980)
(8) Nairn and Partners (1983*a*)

ARRB SR 32, 1985 25

Figure B.1 - Traffic Model Hierarchy presented in ARRB Special Report 32 (Bowyer, Akçelik and Biggs 1985)

Appendix C - NZTA Guidelines Section 3 - Purpose Categories

The material in this appendix is reproduced from:

NZTA (2019). *Transport Model Development Guidelines.* 1st Edition. Waka Kotahi New Zealand Transport Agency. Wellington, New Zealand.

SECTION 3 - PURPOSE CATEGORIES

This section broadly defines seven categories which are based on the intended purpose for which the model would be applied and geographic coverage – two elements which are generally interrelated. The categories are not specific to any particular modelling software or technique. These categories and definitions should not be considered absolute and some crossover may exist for certain study areas/projects. These categories have been defined to create a suitable range for the target levels of comparison criteria.

The reason for separating calibration and validation targets into categories is that it is not feasible to develop a single model which covers a wide range of transport assessment purposes (model applications), particularly as geographic coverage and traffic volume levels increase. Therefore models typically need to be designed and developed to achieve a calibration level which is suitable to their intended purpose.

3.1 IDENTIFYING MODEL PURPOSE

When initiating the development of a new model, the adaptation or upgrade of an existing model, or the application of an existing model to a new project, it is important that an explicit statement of the purpose is made. This must identify clearly what the model is designed to do and what it is to be used for. In particular, this requires a careful definition of the problem statement to be addressed and a clear understanding of what questions the model is designed to answer. This will also require the level of confidence that the model is required to deliver to be defined.

It is expected higher levels of confidence will be demanded where the applications of the model are envisaged to support activities involving larger levels of expenditure. In practice larger levels of expenditure are likely to relate to larger schemes and as such larger and more complex models. This would appear to produce a contradiction; larger more complex models are likely to have correspondingly lower levels of calibration and validation (as per the scaled calibration/validation targets based on the categories defined below) unless significant investment is placed in the model development. A level of pragmatism is anticipated in relation to project expenditure and model confidence, eg a balance of investiture in the model development to achieve a level of confidence appropriate to the risk and expenditure of the project.

The reason for separating calibration and validation targets into categories, and for making a clear statement around the purpose of the model application as outlined above, is that it is generally not feasible to develop a single model which covers a wide range of transport assessment purposes (model applications), particularly as geographic coverage and traffic volume levels increase. Due to this, models typically need to be designed and developed to achieve a validation/calibration level which is suitable to their intended purpose.

Applications of models, particularly subsequent to an initial base model development or update, also require consideration of purpose and calibration/validation level appropriateness. This ranges from being as straightforward as simply considering/confirming that the application fits within stated purposes and achieved levels of the base model, through to considering the need for updating the calibration/ validation levels or model for the intended application.

3.2 LIST OF CATEGORIES

PURPOSE TYPE A: Regional transportation assessments.

Regional transportation assessment purposes require representation of land-use activities, demographics etc. Purposes include the assessment of strategic impacts of land-use changes, larger scale transport and PT projects, and the effects of policy changes on wider regions. These models are typically 3, 4 or more stage or activity based model.

PURPOSE TYPE B: Strategic network assessments.

A strategic network assessment is likely to be focused on strategic links such as motorway corridors, the state highway, and/or the arterial route network across a wider geographic area. Assessments include major transport infrastructure changes, eg large scale motorway schemes, bridges. These models are commonly 'traffic assignment' models.

PURPOSE TYPE C: Urban area assessments.

Urban area assessments focus on the operation of urban conurbations, city centres, and other urban style environments. This is a potentially wide range of applications which may include local authority planning, development strategy, urban traffic management and road schemes, infrastructure and policy change assessments, ITS etc. These models are typically of varying form.

MODEL TYPE D: Transport Agency scheme assessment / project evaluation (within area of influence/focus).

This category, and associated guidance, could be applied to any road controlling authority scheme/ project at their discretion. Could be a model or models of any form and scale. Where larger, eg regional, models are applied to a scheme within sub-region of the model, criteria/target levels in this guide relate to the area of influence/area of focus of the assessment.

PURPOSE TYPE E: Small area with limited route choice/corridor assessment.

Assessment focussed on an urban area with limited route choice, commuter corridors, smaller towns, and rural areas. Applications and assessment may be similar to larger urban area models but are likely to be focused more on traffic management testing than transport planning.

PURPOSE TYPE F: Single intersection/short corridor assessment.

Intersection or short corridor (around 3 intersections) assessments commonly focus on the performance of movements and approaches at intersections under different design layouts and/or traffic conditions (growth, development scenarios etc).

PURPOSE TYPE G: Special case high flow/high speed/ multi-lane corridors assessment.

Assessment and analysis of high flow, high speed, and/or multilane corridors such as motorways may require special treatment, eg detailed data collection and higher levels of model calibration and validation. Testing may include detailed motorway design, ITS, incident management, lane management, the effects of 'soft' policies etc.

3.3 APPLICATION TO PROJECTS

The categories above have been defined based on the purposes for which the models tend to be developed and geographic coverage. Figure 4 below gives an indication of how the purposes, and the models associated with them, overlap and apply to transport projects.

This should not be considered as a guide to selecting a modelling approach for a project, it is provided to offer further information on the purpose categories. The application of the model classifications to different projects has been broadly graded as:

FIGURE 4: LIKELY PROJECT APPLICATION OF PURPOSE CATEGORIES

PROJECT APPLICATION	PURPOSE CATEGORY						
	A: REGIONAL	B: STRATEGIC NETWORK	C: URBAN AREA	D: NZ TRANSPORT AGENCY LARGE PROJECT	E: SMALL AREA /CORRIDOR	F: INTERSECTION / SHORT CORRIDOR	G: HIGH FLOW, SPEED, MULTI LANE
AREA DEMAND RESPONSES, LAND-USE/TRANSPORT PLANNING, POLICY INVESTIGATION	S	N	N	N	N	N	N
LARGER TRANSPORT SCHEME FEASIBILITY, SCOPING STUDY	S	S	P	P	N	N	S[5]
LOCAL AUTHORITY TRANSPORT INTERVENTION & LAND-USE PLANNING	S	S	S	P	P	P	N
OPTION TESTING, DESIGN REFINEMENT, ECONOMICS	P	P	P	S	S	S	S
DEVELOPMENT FORECASTINGS AND/OR IMPACTS	P	P	P	S	S	S	S
DETAILED DESIGN, TRAFFIC MANAGEMENT	N	N	P	P	S	S	S
ITS, INCIDENT MANAGEMENT, ACTIVE MODE DESIGN AND IMPACT	N	N	P	P	S	S	S

Purpose category D (Transport Agency scheme/ project assessment), and by association the application of this guideline to Transport Agency projects, is principally applicable to 'large' NZ Transport Agency projects[6]. Section 1.7 above defines 'large' projects as costing over $5m for the purposes of this guideline and refines the definition into three classes based around investment. It is anticipated that application of target comparison criteria as defined in the chapters below is likely to include greater rigour for higher project classes, i.e. with greater investment and associated risk to Transport Agency. This can be achieved through consideration of the criteria adjacent to purpose category D.

5 Assumes model type-G has been built to cover an appropriate area of influence of the scheme.

6 This distinction could also apply to other road controlling authority projects.

Appendix D - Information on Austroads Traffic Management Guides Useful for SIDRA INTERSECTION Users

This appendix is provided for SIDRA users to provide references to the parts of the Austroads Traffic Management Guides that include information directly relevant to the use of the **SIDRA INTERSECTION** software. Some parts of the Austroads Traffic Management Guide refer to the SIDRA INTERSECTION software using the older names "**SIDRA**" or "**aaSIDRA**".

Table D.1 - Information useful for SIDRA INTERSECTION users in relevant Austroads Traffic Management Guides

Austroads Guide	**Guide Title**	**Information**
AGTM02-20 (2020) Guide to Traffic Management ***Part 2***	*Traffic Theory Concepts*	Unfortunately, this Guide does not cover many aspects of modelling introduced in SIDRA INTERSECTION during last few decades, for example Cowan's bunched exponential headway distribution.
AGTM03-20 (2020) Guide to Traffic Management ***Part 3***	*Transport Study and Analysis Methods*	A key document for SIDRA INTERSECTION. Appendices on traffic surveys.
AGTM04-20 (2020) Guide to Traffic Management ***Part 4***	*Network Management Strategies*	Section 5.4 and Commentary 2 discuss network performance measures and Levels of Service.
AGTM05-20 (2020) Guide to Traffic Management ***Part 5***	*Link Management*	Lane management (Section 6).
AGTM06-20 (2020) Guide to Traffic Management ***Part 6***	*Intersections, Interchanges and Crossings Management*	A key document for SIDRA INTERSECTION. Useful for intersection design generally. Includes discussions on selection of intersection type, roundabouts, signalised and unsignalised intersections, interchanges, and so on.
AGTM09-20 (2020) Guide to Traffic Management ***Part 9***	*Transport Control Systems - Strategies and Operations*	Section 6, Appendices E, G and I, and Commentaries 6 to 13 on traffic signals are directly relevant to SIDRA INTERSECTION users.
AGTM10-20 (2020) Guide to Traffic Management ***Part 10***	*Transport Control - Types of Devices*	Traffic Signals including signal displays, location of signal faces, and so on (Section 10).
AGTM12-19 (20109) Guide to Traffic Management ***Part 12***	*Traffic Impacts of Developments*	Relevant to SIDRA INTERSECTION use in the context of traffic impact assessments.

Appendix E - Model Categories in the Austroads Report

Table 1 given in *Section 2* of this technical note is the proposed modified version of Table 2.1 of the Austroads report. *Table E.1* presented in this appendix shows the details of the changes made to Table 2.1 of the Austroads report in preparing *Table 1*. Crossed text and brown colour text are indicative of the changes made. A copy of the original Table 2.1 of the Austroads report is shown in *Figure 1*.

Table E.1 - Model categories: Changes to Table 2.1 of the Austroads report

~~Model level~~ **Model Type**	~~Sub-category~~ **Model Level**	~~Other terminology~~ **Modelling Technique**	**Key model features**	**Examples of software packages**
Strategic Transport Models	**Macroscopic**~~,~~ ~~Demand, Multimodal, Highway Assignment~~	Macro-analytical model Hybrid Macro-Meso simulation model * ~~Macroscopic analytical model~~	Very Large Networks (city scale, regional scale) Estimation of trips between origins and destinations at specific time periods. Estimation of mode choice and route choice. Estimation of link, route, area and network travel statistics. Constant link capacities assumed. Demand modelling, multimodal analysis, highway assignment	**Macro-analytical** • Aimsun • Cube Voyager • EMME • OmniTRANS • QRS II • STRADA • TRACKS • TransCAD • PTV Visum
Large Area Traffic Models ~~Simulation Models~~	**Mesoscopic** ~~models~~	Meso-simulation model Meso-analytical model Link-based and lane-based simulation and analytical modelling of road geometry, traffic flows and signal platoons. ~~Operational model, Traffic flow model~~ ~~Analytical model, Empirical model, Corridor model,~~ Signal optimisation. ~~Model~~	Medium to Large Networks (up to 30-100 intersections). Simplified simulation of *individual vehicles* ~~by~~ and other methods of the propagation of flow in discrete time intervals along a sequence of links. Models are likely to encompass all intersection control types (Signals, Roundabouts, Give-way and Stop Controlled, Uninterrupted). Constant capacity parameters. Multimodal analysis. Vehicle classes and pedestrians. Static and Dynamic traffic assignment.	**Meso-simulation** • Aimsun • Cube Avenue • Dynameq • OmniTRANS • ~~SATURN~~ • PTV Visum/Vissim **Analytical (Meso / Micro)** • LinSig • SCATES • SIDRA • SATURN • TRANSYT • TRANSYT-7F • PTV Vistro • SYNCHRO
Intersection and Small Area Traffic Models ~~Intersection Models~~	**Microscopic** ~~models~~	Micro-simulation model Micro-analytical model Detailed lane-based simulation and analytical modelling of road geometry, traffic flows, drive cycles and signal platoons.	Single Intersection and Small Networks (up to 10-20 intersections). Detailed lane-based simulation of individual vehicles ~~and their interactions with each other~~. Models are often restricted to specific intersection control types (Signals, Roundabouts, Give-way and Stop Controlled, Uninterrupted). Capacity parameters estimated or constant. Multimodal analysis. Vehicle classes and pedestrians. Static and Dynamic traffic assignment. ~~Simplistic calculation of intersection performance and operation.~~ ~~Static traffic assignment.~~	**Micro-simulation** • Aimsun • Commuter • CORSIM • Cube Dynasim • Paramics • SUMO • SYNCHRO (SimTraffic) • PTV Vissim

* Aimsun Newsletter, Jul 2020: " We're introducing the ***hybrid macro-meso simulator*** - now you can model *individual vehicles* at a *city scale and at a regional scale* for unparalleled understanding of strategic rerouting."

Key changes in the table are shown in this colour. Arrows show most relevant relationships between the Model Type and model Level.

Table 2.1: Modelling categories[1]

Model level	Sub-category	Other terminology	Key model features	Examples of software packages[3]
Strategic Model [2]	Macroscopic, Demand, Multimodal, Highway Assignment	Macroscopic analytical model	Estimation of trips between origins and destinations at specific time periods. Estimation of mode choice and route choice. Estimation of link, route, area and network travel statistics.	• Aimsun • Cube Voyager • EMME • OmniTRNAS • QRS II • STRADA • TRACKS • TransCAD • PTV Visum
Simulation Models[2]	Mesoscopic models	Macrosimulation model, Operational model, Traffic flow model	Simplified simulation of individual vehicles by the propagation of flow in discrete time intervals along a sequence of links. Static and Dynamic traffic assignment.	• Aimsun • Cube Avenue • Dynameq • OmniTRANS • SATURN • PTV Visum/Vissim
	Microscopic models	Microsimulation model, Operational model, Traffic model	Detailed simulation of individual vehicles and their interactions with each other. Static and Dynamic traffic assignment.	• Aimsun • Commuter • CORSIM • Cube Dynasim • Paramics • SUMO • SYNCHRO • PTV Vissim
Intersection Models	Intersection models	Microscopic model, Analytical model, Empirical model, Corridor model, Signal optimisation model	Simplistic calculation of intersection performance and operation. Static traffic assignment.	• LinSig • SCATES • SIDRA • TRANSYT • TRANSYT-7F • PTV Vistro

[1] Other modelling techniques, such as pedestrian modelling, are not covered in these guidelines.

[2] While strategic models are not discussed in these guidelines, they have been included in this table for added context. The ATAP, 2016 publication should be referred to for advice on strategic models.

[3] There are numerous other software packages in the market that can be categorised in each model level. This table is only intended to provide an indication of the more commonly used software packages.

Figure E.1 - Model categories: original Table 2.1 of the Austroads report