

SIDRA Model Extensions for the Highway Capacity Manual

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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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Summary

This technical note collates information about the SIDRA model extensions offered for the US Highway Capacity Manual (HCM). It also includes information about the SIDRA research contributions to the HCM, and further information about the SIDRA INTERSECTION software relevant to the HCM. SIDRA INTERSECTION software complements the US Highway Capacity Manual (HCM) as an advanced intersection and network analysis tool. SIDRA and HCM use common fundamental traffic modeling principles. However, unlike other software packages, SIDRA INTERSECTION does not claim to be a simple replication of the HCM procedures. Instead, it offers significant extensions to the capabilities of HCM.

General SIDRA model extensions to HCM that apply to all intersection types include multi-modal and lane-based modeling, consistent back-of-queue modeling, analysis of stops and emissions, lane-based network analysis with lane blockage and midblock lane changes, approach and exit short lane modeling, and Site and Network templates for easy setup including alternative intersections and interchanges.

SIDRA model extensions to HCM for roundabout analysis include a geometry-sensitive capacity model, capacity constraint applied to oversaturated lanes, an unbalanced flow model, metering signal assessment, turbo roundabout, upstream signal effects, geometric delay back of queue and numerous performance measures .

SIDRA model extensions to HCM for traffic signal analysis include common control group timing, a unique critical movement identification method, green split priority, a behaviour-sensitive Right/Left Turn On Red model, analysis for multiple phase sequences, and lane-based platoon progression.

SIDRA model extensions to HCM for sign control analysis include modeling of two-way yield (give way) sign control, lane-based sign control analysis, and extensive general model extensions.

SIDRA research contributions to the HCM include second term of the HCM delay equation based on the model developed by Akçelik, a back of queue model developed for signalized intersections and actuated signal analysis method used in HCM 2000, the effect of Akçelik's early work and the SIDRA software on the signal timing and capacity analysis methods used in HCM 1985 and later editions, bunched exponential model of arrival headway distribution used in the actuated signal model, progression factor for queue length and related performance statistics for signalized intersections used in HCM 2000, and a number of papers presented detailed assessments of the HCM roundabout capacity models included in HCM 2010 and HCM Edition 6.

1 Introduction

SIDRA INTERSECTION software complements the Highway Capacity Manual (HCM) as an **advanced intersection and network analysis tool**. SIDRA and HCM use **common fundamental traffic modeling principles** and the HCM setup in SIDRA is calibrated using the HCM model parameters.

Unlike other software packages, SIDRA INTERSECTION does not claim to be a simple replication of the HCM procedures. Instead, **it offers significant extensions to the capabilities of HCM**. The following is a selection of these.

This is in line with the Highway Capacity Manual acknowledgement of the need to use alternative models in view of various shortcomings of the HCM.

With the release of new **HCM Edition 7**, SIDRA INTERSECTION continues its compatibility with, and extensions to, the HCM analytical approach to traffic modeling.

Sections 2 to 5 give lists of SIDRA model extensions offered for the HCM. *Section 6* gives a list of SIDRA research contributions to the HCM. *Sections 7 and 8* give further information about the SIDRA INTERSECTION software relevant to the HCM.

Most references given in the two *REFERENCES* sections (separate lists for model extensions and research contributions) are available for download from <https://www.sidrasolutions.com/publications>.

2 Extensions to HCM for roundabout analysis

SIDRA INTERSECTION includes a full implementation of the roundabout capacity models described in **HCM Edition 6** and **HCM 2010** in addition to the **SIDRA Standard (HCM) model** calibrated to match the HCM Edition 6 model as well as the **HCM 6 Extended Roundabout Capacity Model**.

Roundabout Capacity Model in **HCM Edition 7** is the same as the model in HCM Edition 6. Therefore, SIDRA INTERSECTION continues to use the name "**HCM 6 Roundabout Capacity Model**".

The roundabout capacity model is the only analysis method in the HCM which uses **lane-by-lane analysis**, and as such it is best implemented by SIDRA INTERSECTION which has been using a lane-based model for all types of intersection since the 1984 and for networks since 2013.

According to the US Transportation Research Board document "Roundabout Practices", SIDRA INTERSECTION is the **most widely-used software tool in the USA** for roundabout capacity and performance analysis.

Roundabout capacity and performance models in SIDRA INTERSECTION have been developed as part of an **integrated performance modeling framework** developed considering **all types of intersection** allows comparison of roundabout design with signalised and sign-controlled intersections in one package using **consistent methodology**.

Numerous articles comparing the features of SIDRA Standard (HCM), HCM Edition 6 and, and the UK TRL model implemented in the RODEL and ARCADY software can be found on the web page <https://www.sidrasolutions.com/publications>.

The features compared include methodology, model level of detail (lane-based or approach-based), parameters used in the model to represent driver behaviour and roundabout geometry, and model calibration methods.

See the following TRB presentation for **detailed information about SIDRA roundabout analysis**:

AKÇELIK, R. (2024). SIDRA Multimodal Capacity and Performance Analysis for Roundabouts. Presentation at TRB 103rd Annual Meeting, Session 3068: Multimodal Operations and Capacity of Roundabouts in the US and Beyond, Washington D.C., USA, January 2024.

Available for download from:

<https://www.sidrasolutions.com/learn/publications/sidra-multimodal-capacity-and-performance-analysis-roundabouts>



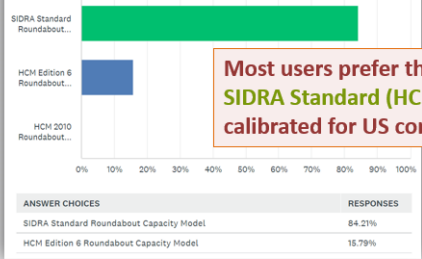
Source: ITE Journal

The most popular roundabout analysis software in the USA

According to the TRB document **Roundabout Practices, A Synthesis of Highway Practice (NCHRP SYNTHESIS 488)**, SIDRA INTERSECTION is the **most widely-used software tool in the USA** for roundabout analysis.

[Download from <https://www.nap.edu>]

If you are using a US HCM software setup of SIDRA INTERSECTION, which roundabout capacity model option do you use for roundabout analysis?



ANSWER CHOICES	RESPONSES
SIDRA Standard Roundabout Capacity Model	84.21%
HCM Edition 6 Roundabout Capacity Model	15.79%
HCM 2010 Roundabout Capacity Model	0%

Refer to:
<https://www.sidrasolutions.com/software/sidra-intersection/features/roundabouts/most-widely-used-software-tool-usa>

Powerful extensions to the HCM roundabout models offered by SIDRA INTERSECTION to help you enhance your roundabout design capabilities are listed below.

- **SIDRA Standard (HCM) Roundabout Capacity Model** option:
 - **sensitive to roundabout geometry** (roundabout size, circulating road width, entry radius and angle, short lanes, etc.),
 - **critical gap and follow-up headway reduction** with increasing demand flows in **design life analysis** (drivers accept shorter headways when experiencing longer delays), and
 - the HCM setup in SIDRA **calibrated to match the HCM** roundabout capacity model.

- Unique **HCM Extended Roundabout Capacity Model** option in addition to the **original HCM roundabout capacity model**. This option enables better calibration by specifying parameter values that distinguish different lane configurations including separate parameters for bypass lanes.
- Models for **roundabout corridors and networks** (where signals, sign-controlled intersections and pedestrian crossings are located close to roundabouts) allow for **lane blockage (queue spillback)** and **midblock lane changes**.

Roundabout Corridors and Networks with all types of intersections, interchanges and pedestrian crossings

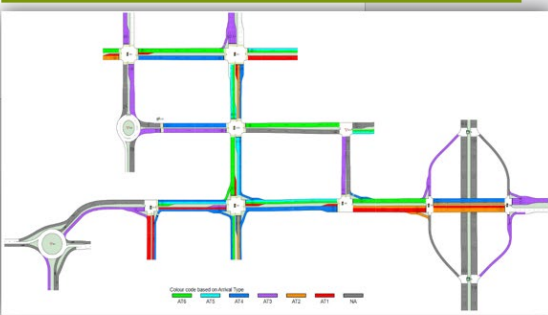
Lane-based Network model
Up to 50 Sites

- Lane Blockage
- Capacity Constraint
- Midblock Lane Changes

Example: Roundabout interchange with signalized intersection



Example: Lane-based signal coordination display



LEVEL OF SERVICE
Net Network: N315 Roundabout Corridor with Signals

Colour code based on Level of Service

Level of Service	Colour
LOS A	Green
LOS B	Yellow
LOS C	Orange
LOS D	Red
LOS E	Dark Red
LOS F	Black

Colour code based on Signal Type

Signal Type	Colour
AT1	Green
AT2	Yellow
AT3	Orange
AT4	Red
AT5	Dark Red
AT6	Black

- Unique method to assess the effectiveness of **roundabout metering signals**.

Roundabout Metering Signals

Roundabout Metering Signals CASE STUDY:
Nepean Hwy – McDonald St, Melbourne, Australia, AM Peak

Congestion caused by **UNBALANCED flow patterns** at roundabouts can be alleviated using metering signals

AKÇELİK, R., SMIT, R. and BESLEY, M. (2014). **Recalibration of a vehicle power model for fuel and emission estimation and its effect on assessment of alternative intersection treatments**. Paper presented at the TRB 4th International Roundabout Conference, Seattle, WA, USA.
www.sidrasolutions.com/publications

Red and Yellow aspects



Metered Approach: McDonald St

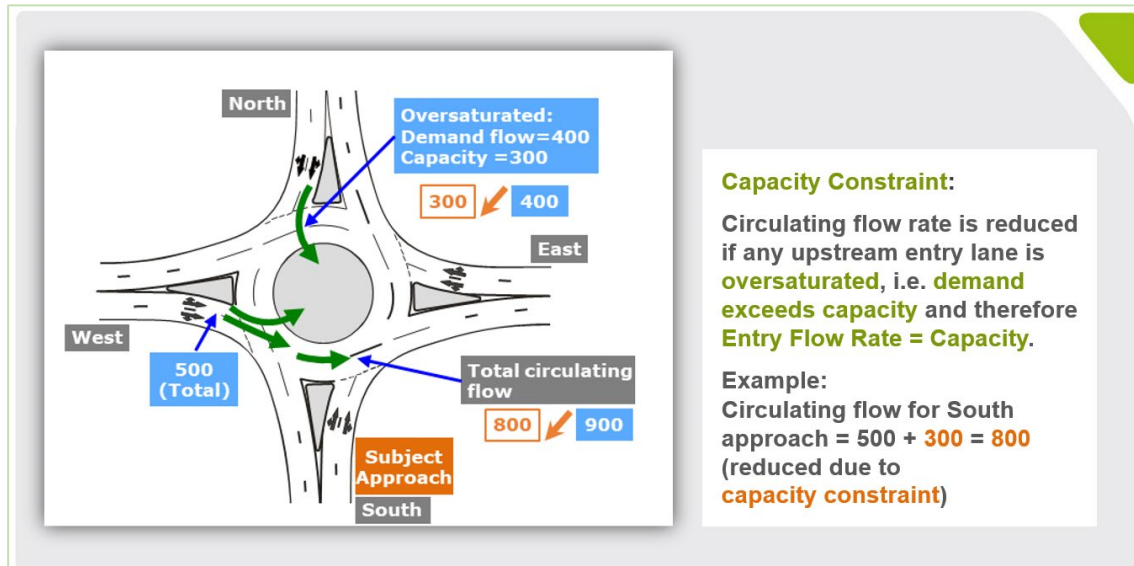


Controlling Approach: Nepean Hwy SE



Photos modified for driving on the RIGHT-HAND side of the road

- Roundabouts with **any configuration**, and roundabouts with **more than two entry and circulating lanes**.
- **Capacity constraint** applied to oversaturated entry lanes as an essential requirement for roundabout capacity and performance analysis.



- Modeling of **unbalanced flows** under heavy demand conditions. The method used treats the roundabout as an **interactive system** rather than a series of T intersections.
- **Effect of upstream traffic signals** on downstream roundabout capacity taken into account by determining **extra bunching in circulating flows**.
- **Entry and circulating lane flow rates** calculated allowing for **lane under-utilisation** including the **effect of exit short lanes**.
- **Approach short lane capacity** with excess queues overflowing into adjacent lanes.
- **Effect of Heavy Vehicles and other Movement Classes** on capacity taken into account using separate factors for **entry flows (Gap Acceptance Factor)** and circulating flows (**Opposing Vehicle Factors**).
- Option to include **Geometric Delay** using estimated **negotiation speeds and distances**, and **acceleration and deceleration distances and times**.
- **Model Calibration Factor** and **Environment Factor** parameters for **easy calibration** of the roundabout capacity models. **SIDRA Standard (HCM)** roundabout capacity model option uses default Environment Factors of 1.05 for single-lane roundabouts and 1.20 for two-lane roundabouts to match the lower capacity estimates based on US roundabout research.
- Easy setup of roundabout geometry configuration using the **Add New Site** function for 1-lane and 2-lane roundabouts (unsignalised), roundabouts with metering signals, turbo roundabouts (new in Version 10), and using **Site Templates (18 different roundabouts available)**.

3 Extensions to HCM for traffic signal analysis

SIDRA was first developed traffic signal analysis software implementing Dr Rahmi Akçelik's well-known **Research Report ARR 123 (Traffic Signals: Capacity and Timing Analysis)**. This was published by the Australian Road Research Board in 1981 and had a strong influence on signal analysis methods in the 1985 Highway Capacity Manual.

Signal timing analysis methods in the current version of SIDRA INTERSECTION cover an extensive area of application including single intersections, interchanges and networks, pretimed, actuated and semi-actuated signals, variable phasing, pedestrian and minor vehicle phase actuation, turn on red, yield-controlled and continuous bypass lanes, and so on.

Network signal timing methods are available to determine cycle time, green times and signal offsets for coordination of signalised intersections controlled by **separate signal controllers** as well as **Common Control Group** timings for intersections running under a single signal controller. The program determines Signal Offsets for Network Routes defined by the user.

When the HCM Software Setup is used in SIDRA INTERSECTION, signals phase sequences use **NEMA phase numbering scheme**.

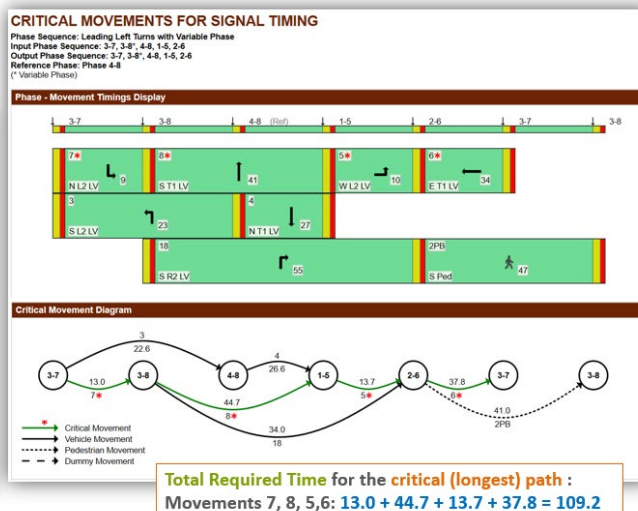
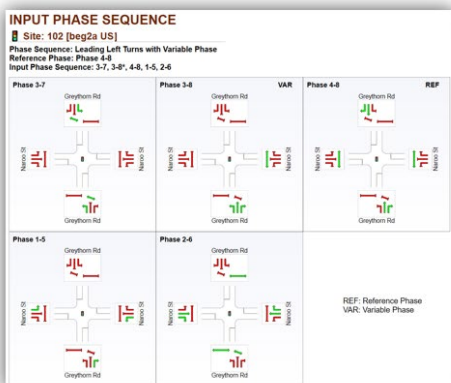
SIDRA signal timing analysis

The **basic elements of SIDRA** signal timing analysis:

- **Unique Critical Movement Identification method** (example in next slide)
- Use of **Target Degrees of Saturation (v/c Ratios)** for **Required Green Times** in **EQUISAT** and **ACTUATED** signal timings
- **Green Split Priority** method for **coordinated** and **user-specified priority** movements, and
- **Multiple Green Periods** for phasing requirements related to **complex intersection geometry**, **signal control** and **multimodal traffic analysis** (new in SIDRA INTERSECTION 10: **more than 2 green periods**)

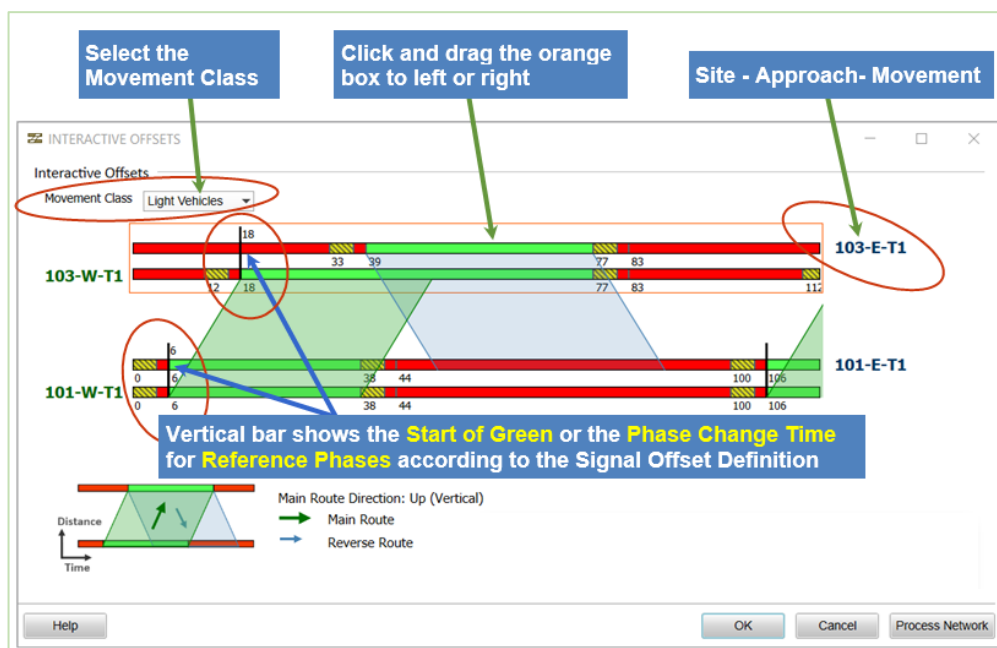


Critical Movement Identification (using critical path method)



In addition to the general model extensions to HCM, the following features offer advanced signal timing methods.

- Signal timing analysis for **Common Control Groups** (intersection and interchange signals running under a single signal controller).
- Unique **Critical Movement Identification** algorithm.
- **Green Split Priority** for coordinated or user-specified priority movements.
- Use of **Target Degrees of Saturation (v/c ratios)** for **EQUISAT** and **ACTUATED** signal timing methods.
- Optimum signal timings for intersections, interchanges and networks.
- **Right Turn On Red** capacity model sensitive to driver behavior and blocking of turning vehicles in shared lanes.
- **Multiple green periods** modelled for signal timing and performance calculations.
- Analysis for **multiple phase sequences** with variable phase sequence analysis.
- Effect of **pedestrian actuation** on signal timings.
- Unique lane-based second-by-second **platoon movements** method using the SIDRA lane-based network model with **midblock lane changes**.
- **Interactive Offsets** function allows the user to modify Offsets manually towards achieving desired two-way progression.



- **Extra bunching** determined by the program automatically for signal platoons from an upstream intersection arriving at downstream roundabouts and sign-controlled intersections for estimating the effect of upstream signals.
- Output options to show "**displayed signal timings**" or "**effective signal timings**" for vehicle and pedestrian movements in **Movement Timing** and **Time - Distance** displays. **Displayed timings** are signal timings (red, green, yellow, flashing don't walk) as drivers see them as opposed to **effective timings** used in capacity and performance calculations.

4 Extensions to HCM sign control analysis

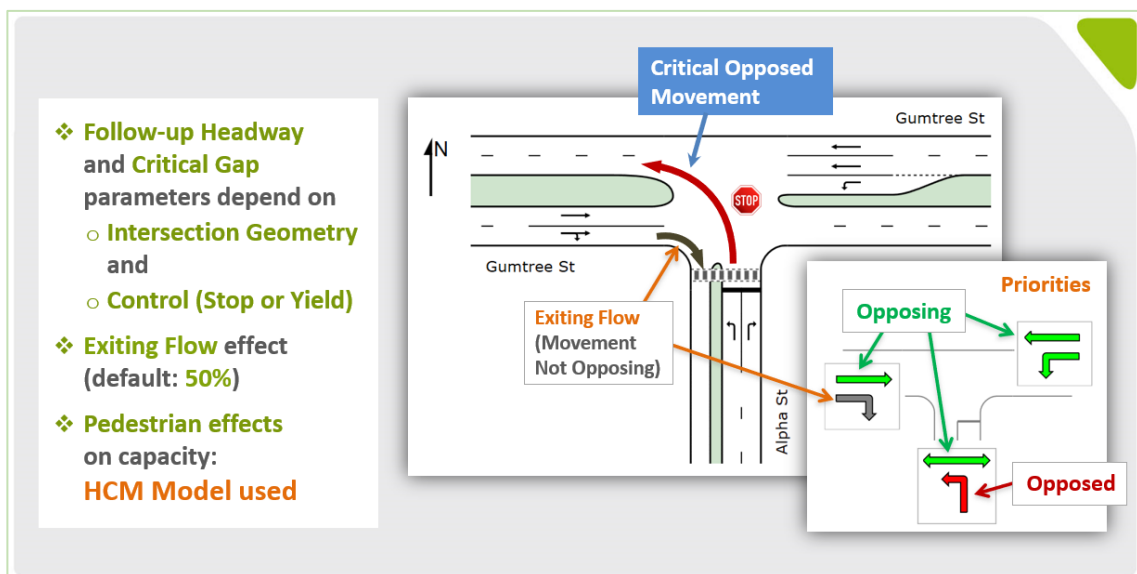
SIDRA INTERSECTION and HCM include the following important **common aspects** of **Two Way Sign Control (TWSC)** capacity and performance models in:

- **consistent values of Critical Gap (Headway) and Follow-up Headway parameters** for gap acceptance modeling (some minor differences may exist),
- **capacity and delay equations** (the HCM equations are used in the HCM software setup of SIDRA by default but they are applied to lanes rather than movements), and
- the same method for basic **shared lane capacity**.

However, because the SIDRA capacity and performance model for TWSC intersections is a **lane-based** model compared with the HCM **lane-group based** model, some differences exist between the SIDRA and HCM methods for TWSC intersections (discussed in detail in the SIDRA INTERSECTION User Guide).

HCM TWSC method is limited to **Stop Sign Control** while SIDRA INTERSECTION includes modeling of **Yield (Give Way) Sign Control**.

For the AWSC model in SIDRA INTERSECTION, specifying the **Departure Headway** parameter determined from the HCM method as input is recommended.



5 General model extensions to HCM

The following features apply to analysis of all types of intersections (traffic signals, roundabouts, sign control) as well as interchanges and networks consisting of these intersection types.

- **Multi-modal and lane-based** modeling of all intersection types and networks with different **Vehicle Movement Classes** (Buses, Bicycles, Light and Heavy Vehicles, Large Trucks) that can be assigned to specific approach lanes and signal phases, and **separate performance output for Buses, Bicycles, Light and Heavy Vehicles, Large Trucks, Trams / Light Rail, Pedestrians, Persons**.

Multi-modal and lane-based modeling (general feature)

Combined with the **lane-based** method, multi-modal approach allows:

- modeling of **Bus priority and Bicycle lanes and special Bus and Bicycle signals**, and similar capabilities,
- more detailed analysis including **gap acceptance model by Movement Class**, and
- **separate performance output by**
 - Movement Class,
 - Pedestrians, and
 - Persons.

Vehicle movements by Movement Class as a basis of all data and modeling for vehicle movements:

- Light Vehicles
- Heavy Vehicles
- Buses
- Bicycles
- Large Trucks
- Light Rail / Trams
- Six **User-Defined Movement Classes**



- **Lane-based network analysis** with:
 - **lane blockage (queue spillback)** based on **back of queue probabilities**, and
 - **midblock lane changes**.

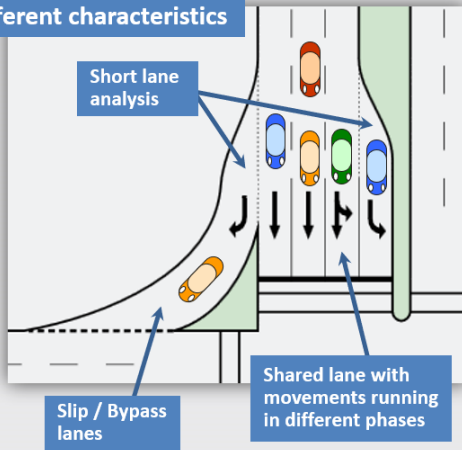
LANE-BASED Methodology

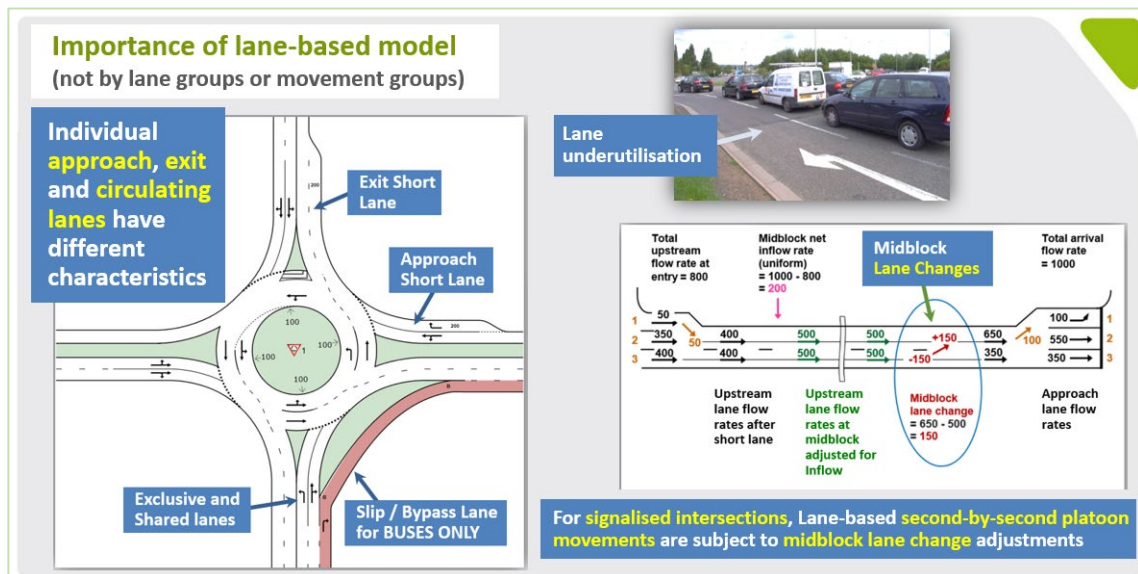
Input >> MODEL >> Output

Important for

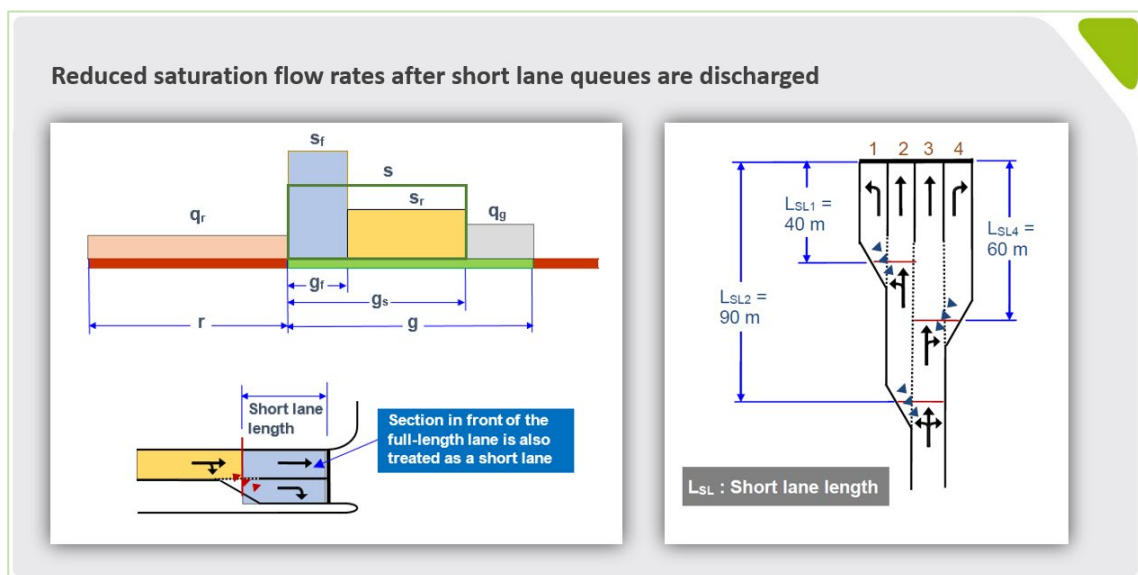
- **INTERSECTIONS**
- **General:**
unequal lane flows, de facto exclusive lanes, short lanes, slip/bypass lanes
- **Roundabouts:**
unequal circulating lane flows, dominant and subdominant lanes
- **NETWORKS**
Lane queues, queue spillback, signal platoon arrival and departure patterns, midblock lane changes.

Individual lanes have different characteristics



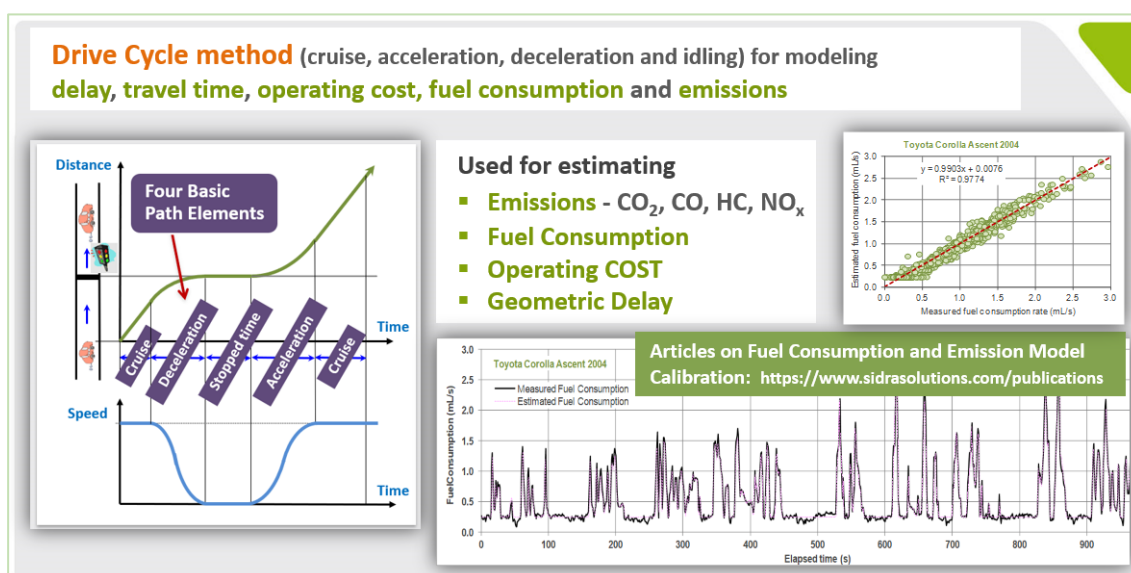


- Short lane modeling including multiple approach short lane combinations and exit short lanes with merging and effect on approach lane use.



- **Back of queue model** for roundabouts and two-way sign control consistent with the HCM back of queue model for signalized intersections. Important for **network lane blockage (queue spillback)** and **approach short lane** modeling.
- Performance models include **stops** (effective stop rate and queue move-up rate), **number of cycles to clear**, **proportion queued**, **overflow queue** and **queue at the start of green (or acceptable gap)** for all types of intersections and networks.

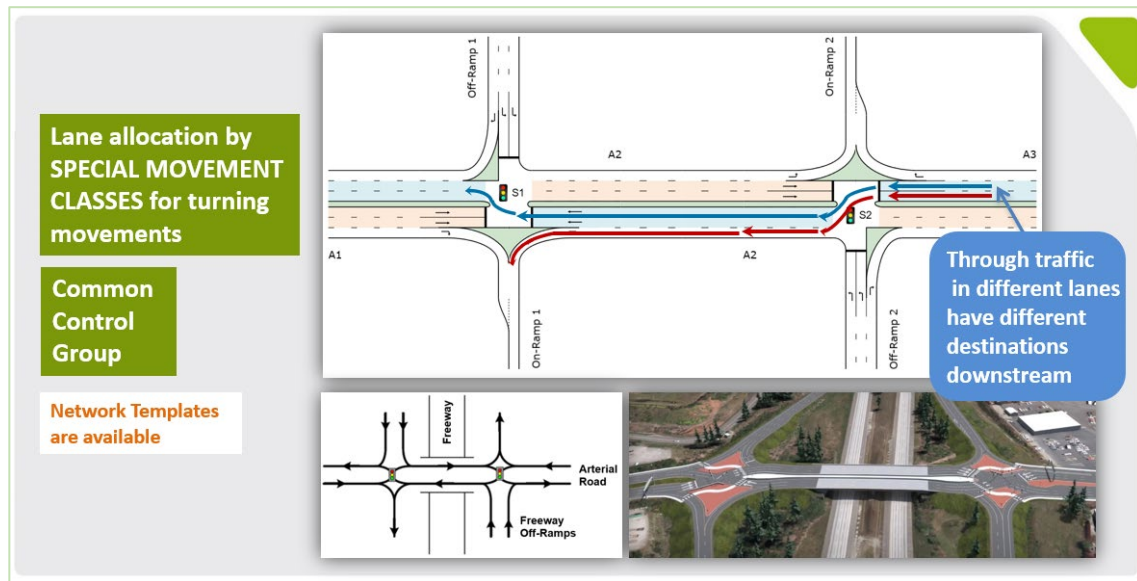
- **SIDRA performance models** include the following basic differences from the HCM models:
 - performance models based on **overflow queue concept**,
 - **first-term equations** for all cases including **multiple green periods** based on **analytical formulations** (graphics based queue accumulation polygons in HCM), and allowing for randomness,
 - **second-term equations** allowing for no **overflow queue** effects below a **variable limit v/c ratio** (degree of saturation).
 - the effects of **initial queued demand** included in the **second-term equations** (in a separate third term in HCM).
- **SIDRA drive cycle method** (cruise, acceleration, deceleration and idling) allows for detailed modeling of delay and travel time components as well as **operating cost, fuel consumption** and **emission** estimation.



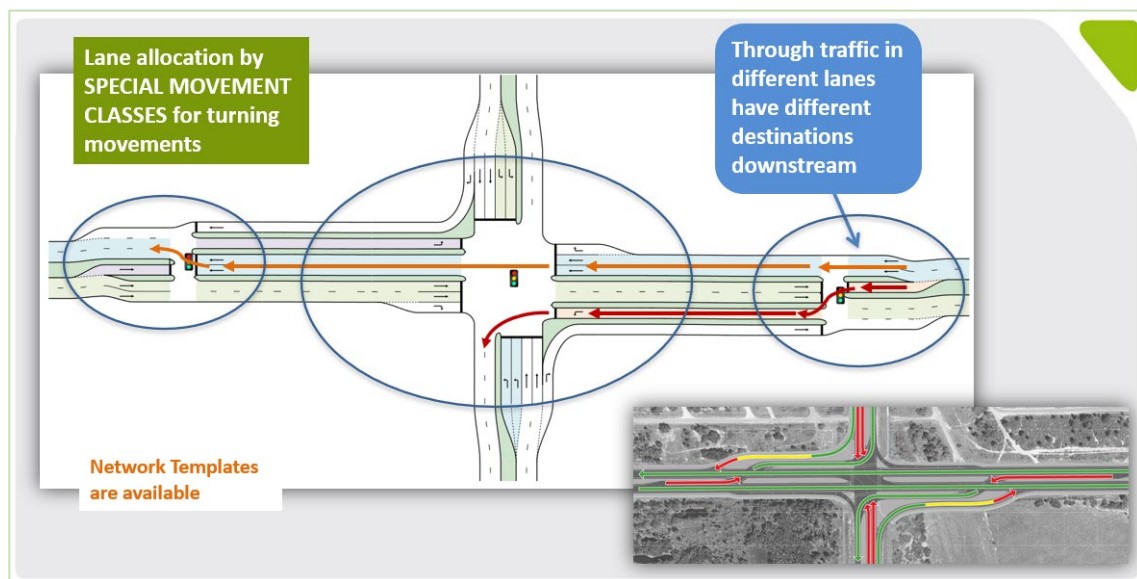
- **Network templates** for easy setup including **alternative intersections and interchanges**. The list of SIDRA Network Templates and two examples are given in figures below.

Alternative Intersections Continuous Flow Intersection (CFI) P-Turn Restricted Crossing U-Turn (RCUT)	Roundabouts Double Teardrop Roundabout. Roundabout with Signalised Pedestrian Crossings Roundabout with Zebra Pedestrian Crossings
Interchanges Divergabout Diverging Diamond Interchange (DDI) Double Roundabout Interchange (DRI) Signalised Diamond Interchange (SDI) Unsignalised Diamond Interchange (UDI)	Staged Crossings Staged Crossing at Four-Way Intersection Staged Crossing at T-Intersection (3 Types)
Paired Intersections Wide-Median Intersection Signalised Roundabouts	Staggered T - Signals Staggered T - Unsignalised

Diverging Diamond Interchange (DDI)



Continuous Flow Intersection (CFI)



6 SIDRA research contributions to HCM

Dr Rahmi Akçelik's research made a number of direct and indirect contributions to the development of various editions of the Highway Capacity Manual. Dr Akçelik served as a member of the US Transportation Research Board (TRB) Committee on Highway Capacity and Quality of Service and its subcommittees, and Committee on Traffic Signal Systems.

The following is a summary of Dr Akçelik's contributions. See the References section below.

- The **second term of the HCM delay equation** (Chapters 19, 20, 21, 22) is based on the model developed by Akçelik (Roess 1983; Roess, Prassas and McShane 2019; Akçelik 1980, 1981, 1988). An anomaly in the earlier HCM delay equation was corrected in the HCM 2000 edition.

1. The **second term of the HCM delay equation** is based on the model developed by Akçelik. See [Roess \(1983\)](#), [Roess, Prassas and McShane \(2019\)](#); [Akçelik \(1980, 1981, 1988, 1990\)](#).
HCM Edition 7: Chapters 19, 20, 21, 22.

$$d_2 = 900 T \left[(X_A - 1) + \sqrt{(X_A - 1)^2 + \frac{8 k I X_A}{c_A T}} \right] \quad \text{Equation 19-26}$$

Notes:

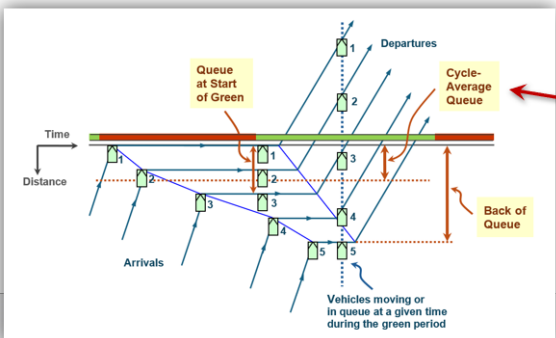
- The **second term of the queue length equation** is similar to the delay equation.
- An anomaly in the **earlier HCM delay equation** was corrected in HCM 2000 edition.

- The second term of the queue length equation is similar to the delay equation. A **back of queue model** developed for signalized intersections was used in HCM 2000 edition (Akçelik 1998, 2001). Refer to Chapter 16, Appendix G in HCM 2000.

In Chapter 31 of HCM Edition 7, the second-term of the **back of queue equation for signals** appears to be calculated from a **deterministic oversaturation model** which would underestimate oversaturation delay near capacity.

For **roundabouts and sign control**, HCM calculates the **cycle-average queue** as the product of the delay and arrival flow rate.

A **back of queue model** developed for **signalized intersections** was used in HCM 2000 edition. Refer to Chapter 16, Appendix G in HCM 2000. See Akçelik (1998, 2001).
HCM Edition 7: Chapter 31 (Sections 3 and 4).

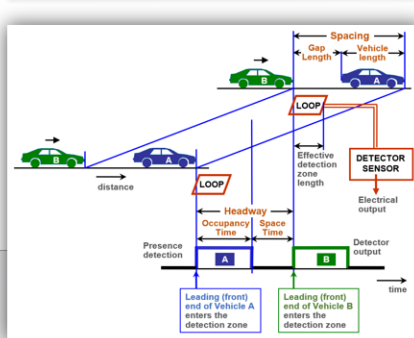


Notes:

- For roundabouts and sign control, HCM calculates the **cycle-average queue** as the product of the delay and arrival flow rate.
- Cycle-average queue is also applicable to **signalized intersections**.

- Actuated signal analysis method** developed jointly by Prof. Courage and Dr Akçelik was used in HCM 2000 (Akçelik 1994, 1995; Courage and Akçelik 1994; Courage, et al 1996). Refer to Chapter 16, Appendix B in HCM 2000.

Actuated signal analysis method developed jointly by **Prof. Courage and Dr Akçelik** was used in HCM 2000. Refer to Chapter 16, Appendix B in HCM 2000.
 See Akçelik (1994, 1995); Courage and Akçelik (1994); Courage, et al (1996).
HCM Edition 7: Chapters 19 (Section 2), 31 (Section 2).

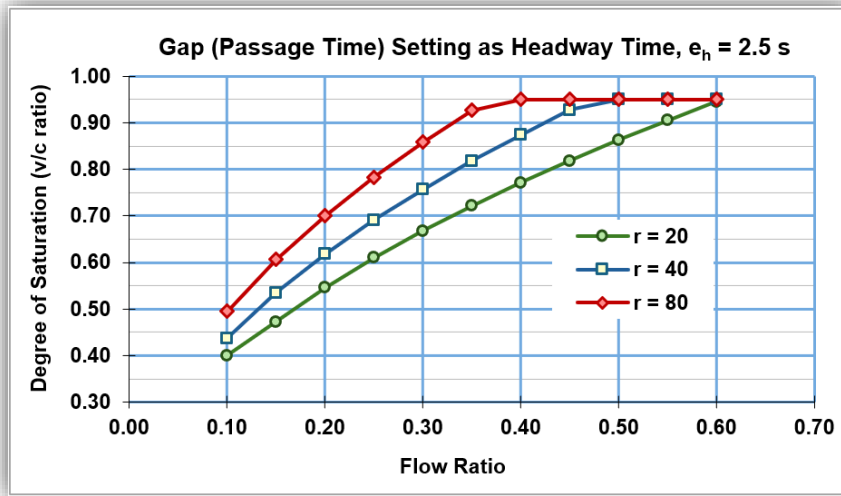


Note:

- Dr Akçelik's early work and the SIDRA software affected the signal timing methods in HCM generally. See Roess (1983); Roess, et al (2019); Akçelik (1980, 1981, 1988, 1990).

- Dr Akçelik's early work including the research report **ARR No. 123** (Traffic Signals: Capacity and Timing Analysis) and the SIDRA software affected the signal timing analysis methods at the same time as the capacity analysis methods used in HCM 1985 and later editions (Roess 1983; Roess, Prassas and McShane 2019; Akçelik 1980, 1981, 1988, 1990).

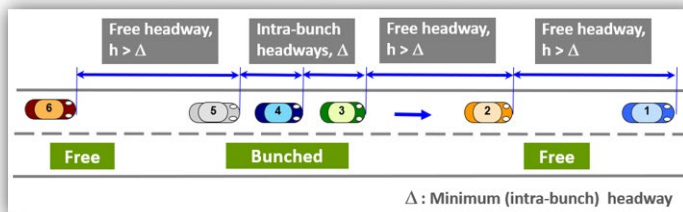
- SIDRA actuated signal analysis method differs from the HCM method in using "target v/c ratios" estimated for actuated signal operation (Akçelik, Chung and Besley 1997).



- Bunched exponential model of arrival headway distribution** was used in the actuated signal model (Akçelik and Chung 1994; Akçelik 2007).

Bunched exponential model of arrival headway distribution is used in the actuated signal model. See Akçelik and Chung (1994); Akçelik (2007).

HCM Edition 7: 31 (Section 2).



Note:

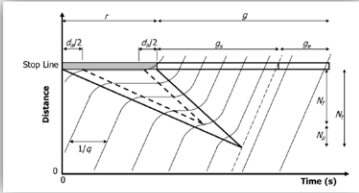
The HCM roundabout and TWSC capacity equations are based on simple negative exponential model of arrival headway distributions.

- **Progression Factor for Queue Length** and related performance statistics for signalized intersections were used in HCM 2000 (Akçelik 1995, 1996, 2001). Refer to Chapter 16, Appendix G in HCM 2000.

Progression Factor (PF_2) for Queue Length and related performance statistics for signalized intersections was used in HCM 2000. Refer to Chapter 16, Appendix G in HCM 2000. See Akçelik (1995, 1996, 2001).

HCM Edition 7: Chapter 19 (Section 3), Chapter 31 (Section 5)

Exhibit 31-20 (HCM Edition 7, Chapter 31, Section 4))



Note:

Is this "Progression Adjustment Factor, PF_2 " used in the HCM back of queue model for signalized intersections? Author could not find it in Chapters 19 and 31 (there is only PF for delay; PF_2 was used in HCM 2000).

If it is true, this means that progression effects on back of queue length are not taken into account in the HCM.

- A number of papers presented detailed assessments of the HCM roundabout capacity models included in HCM 2010 and HCM Edition 6 (Akçelik 2011, 2017; Akçelik, et al 2022).

In particular, Akçelik, et al (2022) assessed the basic exponential and linear model forms used in practice for roundabout capacity estimation using the **HCM single-lane roundabout capacity research data**. These assessments demonstrated the non-linear characteristic of roundabout capacity data as a function of the circulating flow, and **supported the HCM exponential roundabout capacity model over the linear model form**.

Akçelik, et al (2022) and Akçelik (2022) applied a **simplified SIDRA geometry method** for estimating the parameters of the HCM (Siegloch) exponential roundabout capacity model. This method estimated the gap acceptance parameters follow-up headway, t_f and critical gap (headway), t_c as a function of **inscribed diameter, entry radius and entry angle**. Results were promising when applied to the HCM single-lane roundabout capacity research data.

These papers are available for download from:

<https://www.sidrasolutions.com/publications>.

7 HCM methods used in SIDRA INTERSECTION

Various HCM models or methods are used **in all software setups** of SIDRA INTERSECTION. These include:

- the HCM Level of Service method and criteria,
- the effects of adjacent parking manoeuvres and bus stops on saturation flow rates at signalised intersections,
- the effect of grade at sign-controlled intersections,
- the delay and queue progression factors for signal coordination effects, and
- pedestrian effects on capacity at signals, roundabouts and sign-controlled intersections.

These models are adopted with some changes as required for the **lane-based** models used in SIDRA INTERSECTION.

8 SIDRA HCM Software Setup

The Highway Capacity Manual (HCM) **Software Setup** in SIDRA INTERSECTION offers options for US Customary and Metric units. SIDRA model extensions to HCM are available in both software setups.

The HCM and SIDRA INTERSECTION capacity and performance models are compatible in their basic structures and principles.

Making use of this compatibility, the HCM Software Setup in SIDRA INTERSECTION is based on the calibration of most model parameters using the HCM defaults as applicable.

SIDRA INTERSECTION includes facilities to allow the user to choose between the **HCM** and **SIDRA Standard (HCM)** model options including **Roundabout Capacity Model** options (SIDRA Standard (HCM), HCM 6, HCM 6 Extended Model, HCM 2010), **HCM Delay and Queue Model** options, and options to include **Geometric Delay** and apply the **SIDRA Model for Unbalanced Conditions**. Note that HCM Edition 7 uses the HCM 6 roundabout capacity model.

Detailed explanations related to all aspects of the HCM version of SIDRA INTERSECTION are included in the SIDRA INTERSECTION User Guide.

More detailed information can be found in research papers and reports listed in the References section. Many of these reports are available for download from <https://www.sidrasolutions.com/publications>.

9 Conclusion

Various extensions to the US Highway Capacity Manual are presented in this document.

Considering that SIDRA and HCM use common fundamental traffic modeling principles, it is recommended that various SIDRA model extensions described here are considered for future improvements to the Highway Capacity Manual.

Author

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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*.

REFERENCES - SIDRA Model Extensions

Available for download from <https://www.sidrasolutions.com/publications>.

AKÇELIK, R. (1988). The Highway Capacity Manual delay formula for signalised intersections. *ITE Journal*, 58(3), pp 23-27.

AKÇELIK, R. (1990). SIDRA for the Highway Capacity Manual. Compendium of Technical Papers, 60th Annual Meeting of the Institute of Transportation Engineers, pp 210–219.

AKÇELIK, R. (1997). Lane-By-Lane Modelling of Unequal Lane use and Flares at Roundabouts and Signalised Intersections: The SIDRA Solution. *Traffic Engineering + Control*, 38 (7/8), pp 388-399.

AKÇELIK, R. (2003). A Roundabout Case Study Comparing Capacity Estimates from Alternative Analytical Models. Paper presented at the 2nd Urban Street Symposium, Anaheim, California, USA, July 2003. Revised 15 Jun 2004.

AKÇELIK, R. (2004). Roundabouts with Unbalanced Flow Patterns. Paper presented at the ITE 2004 Annual Meeting, Lake Buena Vista, Florida, USA, Aug 2004. Updated: 6 May 2005.

AKÇELIK, R. (2005). Roundabout Model Calibration Issues and a Case Study. Paper presented at the TRB National Roundabout Conference, Vail, Colorado, USA, May 2005. Updated: 3 June 2005.

AKÇELIK, R. (2011). Some Common and Differing Aspects of Alternative Models for Roundabout Capacity and Performance Estimation. Paper presented at the International Roundabout Conference, Transportation Research Board, Carmel, Indiana, USA, May 2011.

AKÇELIK, R. (2011). ROUNDABOUTS - Comments on the SIDRA INTERSECTION Model and the TRL (UK) Linear Regression Model. Akcelik and Associates Pty Ltd, Melbourne, Australia.

- AKÇELIK, R. (2011). Roundabout Metering Signals: Capacity, Performance and Timing. Paper presented at the 6th International Symposium on Highway Capacity and Quality of Service, Transportation Research Board, Stockholm, Sweden, June 2011.
- AKÇELIK, R. (2012). An Improved Method for Estimating Sign-Controlled Intersection Capacity. Paper presented at the New Zealand Modelling User Group NZMUGS 2012 Conference, Auckland, Sep 2012.
- AKÇELIK, R. (2012). Issues in Performance Assessment of Sign-Controlled Intersections. Paper presented at the 25th ARRB Conference, Perth, Australia, Sep 2012.
- AKÇELIK, R. (2013). Lane-Based Micro-Analytical Model of a Roundabout Corridor. Paper presented at the CITE 2013 Annual Meeting, Calgary, Alberta, Canada, Apr 2013.
- AKÇELIK, R. (2014). Modelling Queue Spillback and Nearby Signal Effects in a Roundabout Corridor. Paper presented at the TRB 4th International Roundabout Conference, Seattle, WA, USA, Apr 2014.
- AKÇELIK, R. (2014). A New Lane-Based Model for Platooned Patterns at Closely-Spaced Signalised Intersections. Paper presented at the 26th ARRB Conference, Sydney, Australia, Oct 2014.
- AKÇELIK, R. (2015). Modelling Signal Platoon Patterns by Approach Lane use and Movement Class. Presentation at the 21st International Conference on Urban transport and the Environment (URBAN TRANSPORT 2015), Valencia, Spain, Jun 2015.
- AKÇELIK, R. (2015). Development of Network Signal Timing Methodology in SIDRA INTERSECTION. Presentation at the New Zealand Modelling Use Group Conference (NZMUGS 2015), Auckland, New Zealand, Sep 2015.
- AKÇELIK, R. (2016). Recent Innovations and Applications in SIDRA INTERSECTION: Lane-Based Network Model. Presentation at the AITPM Transport Modelling Workshop (AITPM 2016 Conference), Sydney, July 2016.
- AKÇELIK, R. (2016). Comparing Lane Based and Lane-Group Based Models of Signalised Intersection Networks. Paper presented at the TRB 7th International Symposium on Highway Capacity and Quality of Service (International Symposium on Enhancing Highway Performance (ISEHP)), Berlin, Germany, Jun 2016. Full paper published in Transportation Research Procedia, Vol 15, 2016, pp. 208-219.
- AKÇELIK, R. (2017). Roundabout Model Comparison Table. Akcelik and Associates Pty Ltd, Melbourne, Australia.
- AKÇELIK, R. (2017). An Assessment of the Highway Capacity Manual Edition 6 Roundabout Capacity Model. Paper presented at the 5th International Roundabout Conference, Transportation Research Board, Green Bay, Wisconsin, USA, May 2017.
- AKÇELIK, R. (2018). Gap Acceptance Cycles for Modelling Roundabout Capacity and Performance. Paper presented at the 15th Scientific and Technical Conference, Transport Systems - Theory and Practice, Silesian University of Technology, Katowice, Poland, 17-19 September 2018.
- AKÇELIK, R. (2022). Intersection Level of Service and Performance Discrepancies. Paper presented at the 6th International Symposium on Highway Geometric Design, Amsterdam.

- AKÇELIK, R. (2024). SIDRA Multimodal Capacity and Performance Analysis for Roundabouts. Presentation at *TRB 103rd Annual Meeting, Session 3068: Multimodal Operations and Capacity of Roundabouts in the US and Beyond*, Washington D.C., USA, January 2024.
- AKÇELIK, R. and BESLEY, M. (2015). Alternative Intersection Analysis Using SIDRA INTERSECTION. Presentation at the ITEANZ Innovative Intersections Seminar, Melbourne, Australia, Nov 2015.
- AKÇELIK, R. and BESLEY, M. (2018). Comparing Common Control Group treatment and signal coordination of intersections with separate controllers. Presentation at the 28th International ARRB Conference, Brisbane, Apr 2018.
- AKÇELIK, R. and BESLEY, M. (2022). HCM 6 Extended Roundabout Capacity Model in SIDRA INTERSECTION. Presentation at *TRB 6th International Conference on Roundabouts*, Monterey, California, USA, 15-18 May 22.
- AKÇELIK, R., SHIRKE, C., BESLEY, M., ESPADA, I. and BILLINGHURST, D. (2022). A Comparative Analysis of Exponential and Linear Roundabout Capacity Models Using HCM Research Data. Technical Note. Akcelik & Associates Pty Ltd, Melbourne, Australia. Also: Presentation at *TRB 6th International Conference on Roundabouts*, Monterey, California, USA, 15-18 May 22.

REFERENCES - SIDRA Research Contributions

- Available for download from <https://www.sidrasolutions.com/publications>.
- AKÇELIK, R. (1980). *Time-Dependent Expressions for Delay, Stop Rate and Queue Length at Traffic Signals*. Internal Report AIR 367-1. Australian Road Research Board, Vermont South, Australia.
- AKÇELIK, R. (1981). *Traffic Signals: Capacity and Timing Analysis*. Australian Road Research Board. Research Report ARR No. 123 (6th reprint: 1995).
- AKÇELIK, R. (1988). The Highway Capacity Manual delay formula for signalised intersections. *ITE Journal*, 58(3), pp 23-27.
- AKÇELIK, R. (1990). SIDRA for the Highway Capacity Manual. *Compendium of Technical Papers, ITE Annual Meeting*, pp 210–219.
- AKÇELIK, R. (1994). Estimation of green times and cycle time for vehicle-actuated signals. *Transportation Research Record* 1457, pp 63-72.
- AKÇELIK, R. (1995). *Signal Timing Analysis for Vehicle-Actuated Control*. Working Paper WD TE 95/007. ARRB Transport Research Ltd, Vermont South, Australia.
- AKÇELIK, R. (1995). *Extension of the Highway Capacity Manual Progression Factor Method for Platooned Arrivals*. Research Report ARR No. 276. ARRB Transport Research Ltd, Vermont South, Australia. (Previously WD TE 95/010 and WD TO 95/011).
- AKÇELIK, R. (1996). Progression factor for queue length and other queue-related statistics. *Transportation Research Record* 1555, pp 99-104.

AKÇELİK, R. (1998). *A Queue Model for HCM 2000*. Technical Note. ARRB Transport Research Ltd, Vermont South, Australia.

AKÇELİK, R. (2001). HCM 2000 Back of Queue Model for Signalised Intersections. Technical Report. Akcelik and Associates Pty Ltd, Melbourne, Australia.

AKÇELİK, R. (2001). Progression Factors in the HCM 2000 Queue and Delay Models for Traffic Signals. Technical Report. Akcelik and Associates Pty Ltd, Melbourne, Australia

AKÇELİK, R. (2007). A Review of Gap-Acceptance Capacity Models. Paper presented at the 29th Conference of Australian Institutes of Transport Research (CAITR 2007), Adelaide, December 2007. Updated: 21 March 2022.

AKÇELİK, R. (2011). An assessment of the Highway Capacity Manual 2010 roundabout capacity model. *International Roundabout Conference*, Transportation Research Board, Carmel, Indiana, USA.

AKÇELİK, R. (2017). An assessment of the Highway Capacity Manual Edition 6 roundabout capacity model. *5th International Roundabout Conference*, Transportation Research Board, Green Bay, Wisconsin, USA.

AKÇELİK, R. (2022). Searching for a gap acceptance theory basis for linear capacity models. Technical Note. Akcelik & Associates Pty Ltd, Melbourne, Australia.

AKÇELİK, R. and CHUNG, E. (1994). Calibration of the Bunched Exponential Distribution of Arrival Headways. *Road and Transport Research* 3 (1), pp 42-59.

AKÇELİK, R., CHUNG, E. and BESLEY M. (1997). Recent Research on Actuated Signal Timing and Performance Evaluation and its Application in SIDRA 5. *Compendium of Technical Papers* (CD). 67th Annual Meeting of the Institution of Transportation Engineers, Boston, USA.

AKÇELİK, R., SHIRKE, C., BESLEY, M., ESPADA, I. and BILLINGHURST, D. (2022). A Comparative Analysis of Exponential and Linear Roundabout Capacity Models Using HCM Research Data. Technical Note. Akcelik & Associates Pty Ltd, Melbourne, Australia. Also: Presentation at *TRB 6th International Conference on Roundabouts*, Monterey, California, USA, 15-18 May 22.

COURAGE, K.G. and AKÇELİK, R. (1994). *A Computational Framework for Modelling Traffic-Actuated Controller Operations*. NCHRP Project 3-48, Working Paper 348-1.

COURAGE, K.G., FAMBRO, D.B., Akçelik, R., LIN, P-S., ANWAR, M. and VILORIA, F. (1996). *Capacity Analysis of Traffic Actuated Intersections*. NCHRP Project 3-48 Final Report Prepared for National Cooperative Highway Research Program, Transportation Research Board, National Research Council.

ROESS, R.P. (1983). Efforts towards the Third Edition of the "Highway Capacity Manual. *Traffic Engineering + Control*, 24 (8), pp 351-355.

ROESS, R.P., PRASSAS, E.S. and MCSHANE, W.R. (2019). *Traffic Engineering*. Pearson Education, NJ, USA. Fifth Edition.

