Modeling High-Capacity **Multi-Lane Roundabouts**

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Abstract

RODEL and SIDRA are two of the most common macroscopic roundabout operational analysis tools being used in the United States. One significant drawback of the macroscopic tools is that they cannot address complex interactions between roundabouts being analyzed and any adjacent intersections.

Analysis of interaction between the operations of closely spaced intersections becomes critical in urban settings where peak-hour traffic volumes are high. Only microscopic traffic modeling tools can analyze such interactions. However, due to a large set of parameters that affect driver behavior in microscopic traffic modeling tools, the application and acceptability of roundabout analysis results still is not predominant.

This paper attempts to provide some guidelines for multi-lane roundabout operational analysis using the popular microscopic traffic simulation tool, VISSIM. Comparison of results from VISSIM to those from RODEL and SIDRA also is provided.

1. Introduction

Roundabouts as a choice of intersection control are becoming increasingly popular in the United States. The recent rise in roundabout related research and publications also is indicative of the increased interest in using roundabouts as an alternative to traditional intersection designs.

While there are established guidelines for the design and operational analysis of signalized intersections in the United States, guidelines for the design and analysis of roundabouts are still being developed.

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Introduction *(Continued)*

When compared to traditional signalized intersection controls, numerous advantages related to traffic operations and safety are being associated with modern roundabouts. However, very few studies have documented analysis procedures and challenges encountered when modeling roundabouts. Even fewer studies have contributed to the safety analysis of roundabouts in the United States. Several agencies are, however, treating roundabouts as an innovative solution to solve traffic congestion in severely congested urban corridors. A deeper understanding and analysis of operations at roundabouts would be helpful to designers and planners when justifying them as a solution.

Single-lane and two-lane roundabouts are the most common types of roundabouts in the United States. Some studies *(1, 2)* have provided analysis results for single-lane and two-lane roundabouts. The National Cooperative Highway Research Program (NCHRP) Report 572: *Roundabouts in the United States (3)* is the only study known to the author that documents operational analysis results for multi-lane roundabouts in the United States.

RODEL and SIDRA are the two most commonly used macroscopic roundabout operational analysis tools in the United States. One significant drawback of these macroscopic tools is that they cannot address complex interactions between the roundabouts being analyzed and any adjacent intersections.

Analysis of interaction between the operations of closely spaced intersections becomes critical in an urban setting where peak-hour traffic volumes are high. It is important to study such interactions in tight urban corridors where queues from adjacent

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intersections can disrupt traffic flow. Only microscopic traffic modeling tools can analyze such interactions.

Multi-lane roundabouts with varying circulatory lanes are usually designed to address distinctive origin-destination patterns. To accommodate complex origin-destination patterns, engineers typically attempt to incorporate lane changes into a design through signing and striping.

Origin-destination patterns that span across several intersections cannot be captured in isolated intersection analysis. Lane changing due to such complex patterns – and the resulting impacts on traffic operations and capacity – can be estimated using microscopic tools. However, due to a large set of parameters that affect driver behavior in the microscopic models, their application and the acceptability of results is not predominant.

This paper aims to provide guidelines for multi-lane roundabout operational analysis using the popular microscopic traffic simulation tool VISSIM. The intention is to identify some key parameters, the impact of which practitioners should be aware of before analyzing and recommending roundabouts as solutions.

A case study is used to compare results from VISSIM to those from RODEL and SIDRA. The author's intention is not to propose the use of a particular tool for roundabout analysis in the United States. Instead, the purpose is to provide guidelines that make the best use of the three widely used roundabout analysis tools. In the process, some common issues encountered while estimating capacity and operational effectiveness of roundabouts also are addressed.

2. Literature Review

Waddell *(4)* provides a comprehensive literature review focusing on the history of roundabouts and the analysis tools used. He provides useful recommendations to practitioners – the most notable being the necessity to eliminate bias when it comes to deciding on the tool used to study roundabouts. Waddell also observed that roundabouts have been in use for more than 50 years all over the world and that the United States need not reinvent the concepts of a roundabout.

NCHRP Synthesis 264 *(5)* is the first major effort in documenting modern roundabouts practice in the United States. This report was followed by an FHWA publication, *Roundabouts: An Informational Guide (6)*. This guide summarizes several topics of interest for transportation professionals who intend to design and recommend roundabouts in the United States.

Kyte et al. *(7)* summarized the characteristics of more than 300 modern roundabouts in the United States. The authors' summary provides useful insight about the status of roundabouts in the United States.

About 30 percent of the 300 roundabouts studied by the authors were newly constructed intersections and about 61 percent were converted to a roundabout from some form of stop-control.

The important statistic to be noted, however, is that only 9 percent of the 300 roundabouts studied were converted from signalized intersections. The low percentage – when compared to the 30 percent and 61 percent – might be indicative of the resistance traffic engineering professionals encounter when roundabouts are proposed as alternative solutions to signalized intersections.

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Literature Review *(Continued)*

In addition, a summary of gap acceptance behavior in the form of accepted and rejected gaps also is provided. It is evident from the summary provided that comprehensive operational analysis of roundabouts in the United States is still nascent.

The findings of Kyte et al. *(7)* are also summarized in the NCHRP Report 572: *Roundabouts in the United States (3)*. This report also provides a comprehensive evaluation of the operational characteristics of the roundabouts studied as part of the NCHRP Project 3-65. The report states that both RODEL and SIDRA result in higher estimates of capacity if default parameters are used. However, it is not clear if this overestimation is the result of driver unfamiliarity with roundabouts in the United States.

If the default parameters are modified to reflect observed critical gaps and follow-up headway times, both tools provide capacity estimates that are well below those provided with un-calibrated parameters. The summary also suggests that there is a need for better analysis to estimate driver behavior in the presence of trucks and other heavy vehicles. According to this report, exiting vehicles tend to have some influence on the capacity of roundabouts in the United States.

Açkelik authored several *(8, 9)* informative papers on roundabout analysis. Much of his work is dedicated towards providing guidelines to users of SIDRA. Some of his papers also compare the RODEL to SIDRA under different traffic-demand conditions.

Kinzel et al., *(1)* studied operations of a single-lane roundabout using SimTraffic and VISSIM under hypothetical traffic demand situations. Comparison of results from HCS methodology and SIDRA to SimTraffic and VISSIM also were provided. The authors used different gap acceptance parameters to study the effect on roundabout operations. The study serves as a useful

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guideline, but is limited to estimation of a few parameters based on trial and error.

Although there are several other noteworthy contributions to roundabout literature, there are very few that document the procedures and challenges encountered when modeling roundabouts in microscopic models.

3. Background & Study Area

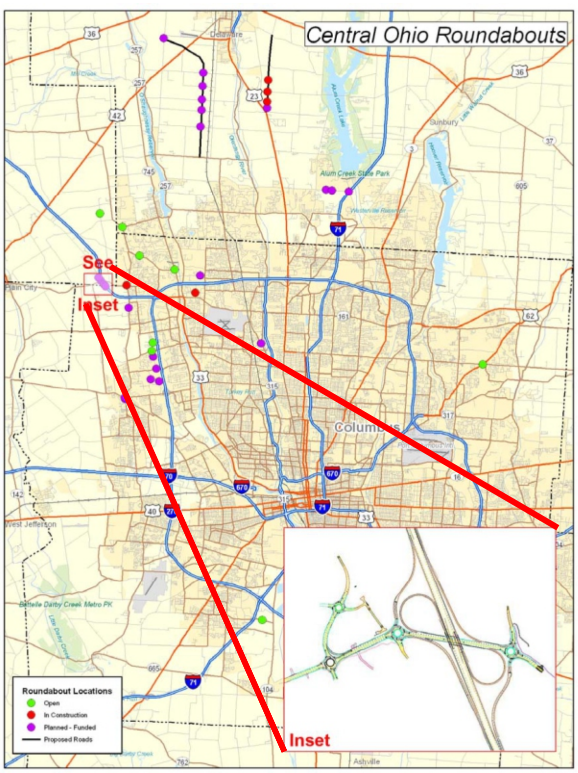

Figure 1 – Roundabouts in Central Ohio with study area as inset

The City of Dublin is a high-growth suburb of the City of Columbus, Ohio. According to the Mid-Ohio Regional Planning Commission, the population of the city increased by approximately 91 percent from 1990 to 2000. Based on the year 2000 statistics, the two largest segments of the City of Dublin's population fell into the age brackets of 25-44 (34 percent) and 0-19 (33 percent). This suggests that the driving population of this city is likely to increase significantly in the future.

Several existing signalized intersections in this city are failing due to high traffic during the peak hours. To alleviate congestion during peak hours, the City is considering roundabouts as an alternative to signalizing some of the high-volume intersections. In addition, roundabouts are being considered as preferred solutions for new arterial intersections. Several of the proposed designs for these intersections are multi-lane roundabouts with varying circulatory lanes. The City is adopting a staged construction of these multi-lane roundabouts to minimize driver confusion and maximize safety.

Figure 1 summarizes the location of roundabouts in Central Ohio. An inset for the study area is also shown in this figure.

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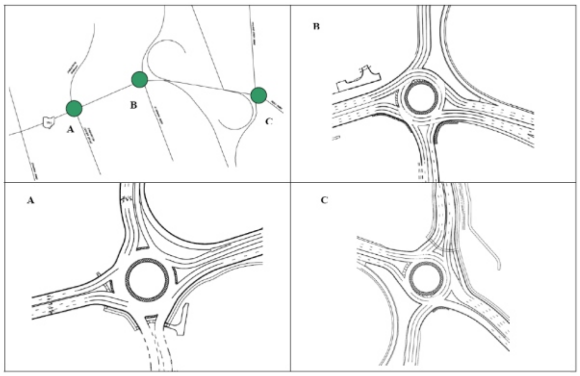
Background & Study Area *(Continued)*



A. Intersection of SR 161 and Industrial Parkway
B. Intersection of SR 161 and US 33 EB Ramp Terminal
C. Intersection of Post Rd, Hyland-Croy Rd, US33/SR 161 WB Ramp Terminal

Figure 2 – Detailed view of multi-lane roundabouts in the study area

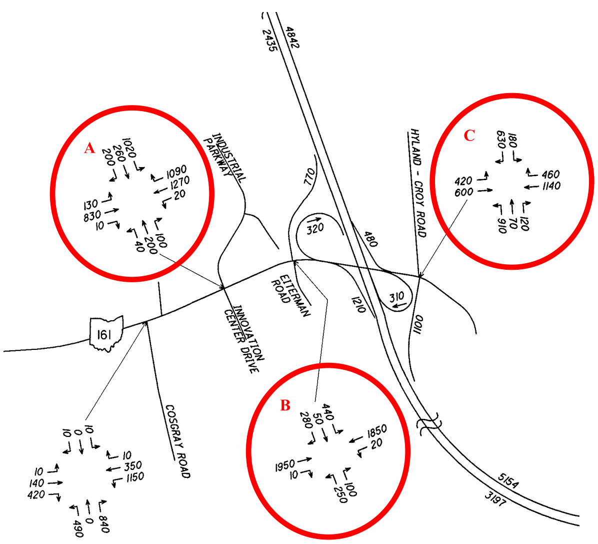


Figure 3 – Traffic projections for the design year 2030

Note that several roundabouts identified in this figure are still in the planning or construction stages, illustrating the increased interest in roundabouts. Of all the roundabouts shown in Figure 1, the roundabouts in the City of Dublin's jurisdiction have the central character of serving high traffic volumes.

The study area currently is configured as a diamond interchange. A centerline of the proposed layout of the interchange, a partial-clover, is shown in the top left corner of **Figure 2** and a detailed view of each multi-lane roundabout, identified by the letters A, B and C, is shown in the other three quadrants of the figure.

Traffic volumes for the design year 2030 were estimated using the existing counts, current and future model Average Daily Traffic (ADTs) from the regional travel demand model. The procedure outlined in the NCHRP 255 report was used for this purpose.

The projected traffic volumes for 2030 P.M. peak hours are shown in **Figure 3**. These volumes also were certified by the Ohio Department of Transportation for use in the Interchange Modification Study. The unique nature of the traffic demand in this region creates a scenario of unbalanced traffic demands at all three roundabouts during the peak hours.

Although the entire study area was modeled in VISSIM, the roundabout at the intersection of SR 161 and Industrial Parkway (Roundabout A in Figures 2 and 3) is selected for illustrating the model development process due to its unique geometry. In this configuration, SR 161 has an east-west orientation and Industrial Parkway has a north-south orientation.

4. Software Tools Used: An Overview

Operational analysis of the proposed roundabouts in the study area was conducted using three different tools: RODEL, SIDRA, and VISSIM. RODEL and SIDRA were primarily used to determine whether a roundabout was a feasible solution. VISSIM was used to supplement the results of RODEL/SIDRA by including intersections adjacent to the roundabouts and to model the roundabouts as a system of intersections as opposed to isolated intersections.

RODEL

RODEL is an empirical software tool for analysis of roundabouts. The model is based on actual observations of field data in the United Kingdom. Regression equations were developed for capacity estimates based on these observations. The variable central to these regression equations is associated with roundabout geometry. Hence capacity estimates from RODEL are largely dependent on roundabout geometry. RODEL can provide only a limited number of output measures. The new version of RODEL, which is currently under development, is supposed to include more parameters and features which can be calibrated to alter the capacity estimates.

SIDRA

The macro analytic tool SIDRA can be used for both signalized intersection and roundabout analysis, although it is mostly used for roundabout analysis in the United States. It can model individual lanes on approaches and, using a lane utilization factor, can account for uneven lane usage on the approaches. In addition, SIDRA uses exclusive gap acceptance parameters to

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Software Tools Used *(Continued)*

individual lanes on approaches and, using a lane utilization factor, can account for uneven lane usage on the approaches. In addition, SIDRA uses exclusive gap acceptance parameters to model driver behavior at the entrance of roundabouts. Driver behavior is also sensitive to geometry and flow levels. Essentially, several parameters can be adjusted to modify capacity estimates of SIDRA. Moreover, the input entry screen of SIDRA is much more user-friendly than that of RODEL.

VISSIM

VISSIM is a stochastic microscopic simulation model developed by PTV AG, Germany *(10)*. It uses the Wiedemann psycho-physical car following logic to model traffic on the road network. It is a time-step and behavior-based simulation tool developed to model urban traffic and public transit operations. The inputs in VISSIM include lane assignments and geometries, travel demands, distributions of vehicle speeds, acceleration and deceleration, and signal control timing plans. The model is capable of producing measures of effectiveness commonly used in the traffic engineering profession such as total delay, stopped-time delay, stops, queue lengths, fuel emissions, and fuel consumption. VISSIM provides a good platform for the analysis of roundabouts due to the amount of flexibility incorporated into the model structure.

5. Modeling Procedure

The modeling procedure outlined has the following major steps:

- Use RODEL for initial analysis and to generate a rough estimate of capacity

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Modeling Procedure *(Continued)*

- Use SIDRA to refine the roundabout designs generated by RODEL
- Select roundabout designs for further analysis in VISSIM
- Import Microstation/CADD drawings into VISSIM and code the VISSIM base network
- Modify VISSIM parameters for gap acceptance

These steps are explained in more detail in the following sections.

5.1 Model Development in RODEL

Of the three tools identified above, RODEL provides the easiest and quickest way to estimate capacity. Therefore, RODEL was used to assess whether or not roundabouts are feasible solutions. The initial roundabout concept tested in RODEL is based on the traffic demand that is expected to be served by the assumed design. This initial design was further refined to account for any abnormal volume to capacity ratios or delays.

Based on the traffic demands projected for the intersection of SR 161 and Industrial Parkway, shown in Figure 3, a basic roundabout concept can be synthesized. The heavy westbound right-turn traffic suggests a right-turn bypass for the movement. The magnitude of the southbound left turns suggests a minimum of two lanes for the movement and another lane for

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the southbound through/right-turn movements. Using such inferences, several roundabout concepts were generated and tested for operational effectiveness.

Note that the operational measures from RODEL obtained in this manner are very rough because the current version of RODEL is "blind" to the concept of lane assignments on the approaches to the roundabout.

Due to this lack of lane-assignment knowledge, RODEL distributes all the vehicles evenly on different lanes of the roundabout. This could pose significant problems in the form of overestimation of capacity as documented widely in the literature. The advantage, however, is that roundabout analysis using this software could be conducted within hours for several design concepts.

5.2 Model Development & Design Refinement Using SIDRA

Any designs that produce reasonable measures using RODEL can be carried forward for further analysis in SIDRA. As noted earlier, SIDRA accounts for lane assignments and lane utilization, which should provide more insight into the layout of the roundabout. Considerable changes to capacity estimates can be expected by adjusting lane assignments. SIDRA generates a roundabout graphic based on the geometry and the lane assignments. This graphic should be visualized for each scenario

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Design Refinement Using SIDRA *(Continued)*

to ensure that no major issues would be encountered in the integration of the roundabout with the adjacent network.

Uneven lane usage tends to reduce intersection capacity. It is imperative to investigate and understand the factors behind uneven lane usage prior to planning any new or improved design.

Drivers familiar with the design and capacity constraints have a tendency to be selective about lane choice at an intersection. This behavior is evident in the peak hours when traffic demand is the highest of the day. Particular attention must be paid to origin-destination information when deciding lane usage at a roundabout. Incorrect estimation of lane usage may result in inefficient operations both at the roundabout and at any immediate upstream or downstream intersections to the roundabout. The origin-destination pattern at the subject roundabout did not reveal any reason for uneven lane usage; hence the lane utilization factor was left at 100 percent for all the lanes.

An innovative procedure to estimate the effect of upstream signals on roundabout operations is available in SIDRA. The parameter "extra bunching" can be used to emulate the effects of any upstream signals on roundabouts. This parameter is specified in the model as a percentage of the traffic demand on the approach. The parameter can be varied by approach, but is constant for all the lanes on the approach. Because of this, there is a possibility that the effect of any system improvement treatments at the upstream intersection that guides vehicles into their desired lanes prior to entering the approaches of a roundabout will be lost.

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Design Refinement Using SIDRA *(Continued)*

The SIDRA manual *(11)* provides rough guidelines for the "extra bunching" parameter based on the roundabout's proximity to any upstream signal. Its value specified as a percentage has a default value of 0 with a range of -50 to 50. Per the manual's guidelines, as the distance to the nearest upstream intersection increases, the effect of the "extra bunching" factor diminishes.

Although this methodology is a generic approximation of platoon dispersion concepts, it serves as a useful tool in adjusting the capacity of roundabouts. As the upstream intersections to the roundabout at Industrial Parkway and SR 161 are also roundabouts, the extra bunching factor was set at 0.

The environmental factor also affects the follow-up and critical gap models. The environmental factor is a global parameter and applies to all approaches of the roundabout. It essentially quantifies driver aggressiveness. Lower environmental factors result in more aggressive driver behavior. An environmental factor of 1.0 was used to analyze the roundabout at Industrial Parkway and SR 161. However, an environmental factor of 1.2 is being recommended by the developers of SIDRA to match the lower capacity estimates based on the findings of NCHRP 3-65 research on US roundabouts.

5.3 Model Development in VISSIM

In contrast to the ease and quickness of the roundabout model development process in RODEL or SIDRA, the model development process is lengthy and time consuming using

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Model Development in VISSM *(Continued)*

VISSIM and usually has some prerequisites. The most important prerequisite for VISSIM is a good base map showing an accurate design of the roundabout to scale. The preferred roundabout design developed, based on an analysis using SIDRA, has to be designed to scale using CADD-based software and then imported into VISSIM for network coding.

In addition to an accurate geometry, roundabout operations in VISSIM are affected by speed restrictions, acceleration/ deceleration values, car following and gap acceptance behavior. Of these important attributes, a general idea about the design speed is usually available based on roundabout design criteria. Several guidelines that relate design speeds to roundabout radius are provided in *Roundabouts: An Information Guide (3)*.

As with any microscopic traffic simulation tool, VISSIM relies on several parameters to model traffic on transportation networks. As noted in an earlier work by the author *(12)*, model parameters in VISSIM can be classified as following:

- Car-following parameters
- Lane-changing parameters
- Kinetic parameters
- Vehicle parameters

Car-following and lane-change parameters directly affect the driving behavior of vehicles in the model. Kinetic parameters typically include parameters associated with desired speed, desired acceleration, maximum acceleration, maximum deceleration, etc. Finally, vehicle models describe attributes associated with each vehicle type modeled. Some of the parameters affect the models' performance on a global scale

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while some of them have a local effect. In addition to these factors, the gap acceptance parameters as defined by priority rules (described later) dictate the capacity and operations at a roundabout in VISSIM.

Once the network geometry was accurately coded in VISSIM, it was ensured that lane changing is prohibited within the circulating section of the roundabout. Lane-changing prohibitions can significantly influence roundabout operations in VISSIM. It is critical to ensure that this is done correctly for multi-lane roundabouts.

Due to the prohibition of lane changes within the roundabout, vehicles must be guided into their desired lanes before they enter the roundabout. Adjusting the "look ahead distance" parameter on the connectors can ensure this behavior. However, as the network modeled in VISSIM included four very closely spaced intersections, this parameter was varied based on visualization of the simulation until a realistic animation was observed.

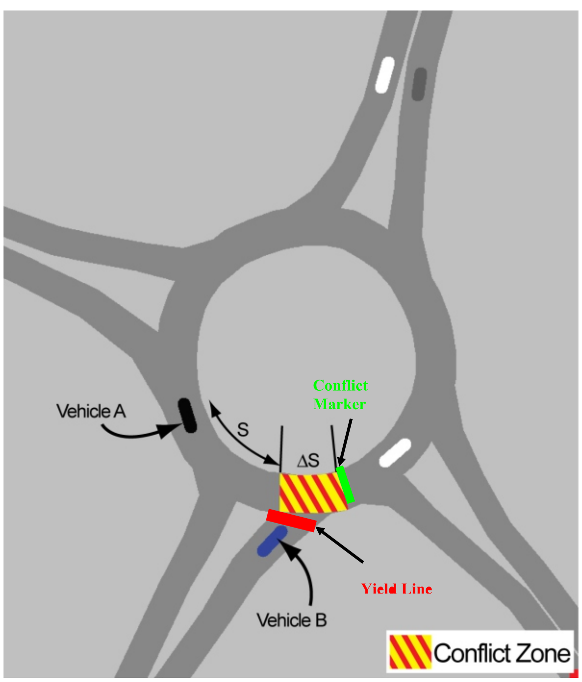

Figure 4 – Representative conflict zone in VISSIM for single-lane roundabout

5.3.1 Priority Rules

The network element termed as "Priority Rule" governs the gap acceptance behavior in VISSIM. Each priority rule consists of the location of the yield point, the location of the conflict point, minimum headway (distance), minimum gap time and maximum speed of the vehicle on the major road. These attributes of the priority rules are illustrated in **Figure 4**.

Minimum headway is typically defined as the length of the conflict area (ΔS in Figure 4). If the headway at any point of

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Priority Rules *(Continued)*

simulation is less than the minimum headway, the priority rule goes into effect and stops vehicles on the minor road at the yield point (Red Line in Figure 4) until the conflict is resolved.

The current gap time at any point of simulation is calculated based on the current speed of a vehicle approaching the conflict marker (Green Line in Figure 4) on the major road. For instance, if the distance (S + ΔS, in Figure 4) between the conflict marker and Vehicle A on the major road is 100 feet and, if this vehicle is traveling at a speed of 34 mph (~50 fps), the current gap time is calculated as:

$$\textbf{Current Gap Time} = \frac{S + \Delta S}{\text{Speed (A)}} \quad \text{or } (100/50 = 2 \text{ Seconds})$$

where Speed (A) is the speed of Vehicle A.

In this instance, if the user-defined value of minimum gap time is less than two seconds, then the priority rule gets activated and stops any vehicle on the minor road until the conflict is resolved. In practice, both the minimum headway and minimum gap times are used to effectively model drivers' behavior at roundabouts. Several examples eliciting appropriate use of priority rules are provided in the VISSIM user manual *(9)*.

The critical differences between coding a single-lane roundabout and multi-lane roundabouts in VISSIM are shown in **Figure 5**. The concepts described above can easily be expanded to multi-lane roundabouts. However, due to variations in circulatory lanes of multi-lane roundabouts and the use of staggered stop lines in the design, multiple priority rules must be used for each approach to the roundabout. Moreover, it is a good practice to code different priority rules for different vehicle classes. This feature can also be utilized to model the aggressiveness of

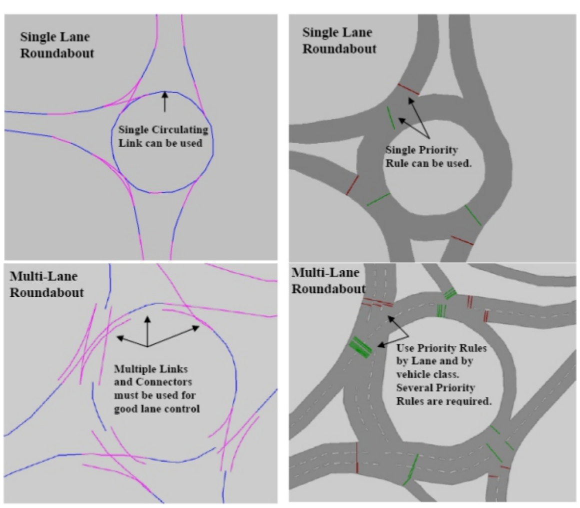

Figure 5 – Differences between single and multi-lane roundabouts in VISSIM

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drivers at the entry point of multi-lane approaches. In essence, several priority rules can be used in combination to achieve desired driver behavior at the entry point of a multi-lane roundabout.

Trial-and-error methods often are used to determine the parameter values for priority rules. Although such procedures supply quick answers for single-lane roundabouts, it becomes prohibitive to blindly adjust those parameters for several priority rules of multi-lane roundabouts. It is therefore beneficial to start with a ballpark estimate of the priority rule parameters when modeling multi-lane roundabouts.

Based on the definition of priority rules, at any point of a simulation run, the vehicle's kinetic variables in terms of speed and acceleration significantly affect gap acceptance in addition to the user-defined minimum gap time and maximum headway values. In turn, the minimum gap time for priority rules can be estimated from the speed limits and acceleration values. The procedure to estimate priority rule parameters is illustrated in the following two sections.

5.3.1.2 **Estimation of Priority Rule Parameters** Based on Speed Variables

VISSIM provides users with several cumulative distribution functions for different speed categories. A cumulative distribution function returns the probability that the parameter being described by it is less than a certain value. Each speed

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Priority Rule Parameters *(Continued)*

distribution curve has a minimum and maximum value; users can define intermediate nodes to adjust the shape and orientation of the cumulative distribution function for speed.

The general practice is to use curves that have a small range and include the posted speed limit. A more appropriate way is to ensure that the chosen speed distribution curve reflects the conditions observed in the field. An ideal methodology to estimate the speed distribution of vehicles traveling on a particular roadway is to measure the actual speeds under free-flowing conditions and to use the data to estimate the curves.

Free-flow speeds are rarely achieved in urban areas with tight intersection spacing and intersection controls. However, under free-flowing conditions, one would expect the speeds of vehicles on a particular roadway section to be centered on the posted speed limit. The desired speed distributions in VISSIM should hence be defined so that they represent a range of values with a mean close to the posted speed limits.

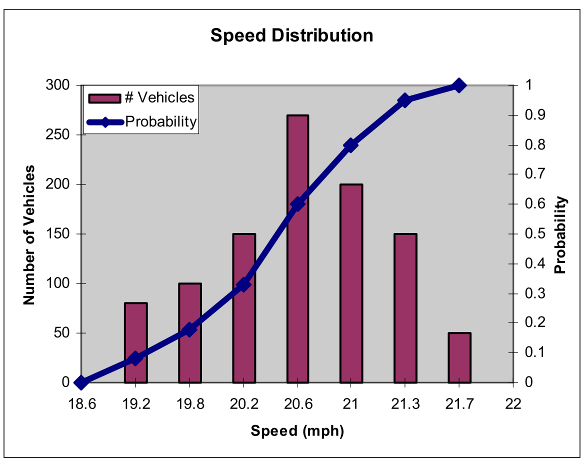

Figure 6 – Speed distribution in VISSIM

A representative cumulative distribution curve for speed distribution in VISSIM is shown in **Figure 6**. The line shown in this figure represents cumulative speed distribution for the speeds ranging between 18.6 and 21.7 mph. Such a curve could be used for a posted speed limit of 20 mph. If 1,000 vehicles travel on this section of the road, the number of vehicles that are expected to travel at speeds less than a certain value can be computed using the probabilities and speeds shown on the curve. These calculations are represented as histograms in the same figure. It is evident from the profile of the histograms that the speeds for this section have an approximate normal distribution.

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Priority Rule Parameters *(Continued)*

Priority rule estimation based on speed data is illustrated using the speed profile shown in Figure 6 and the conceptual single-lane roundabout shown in Figure 4. The radius of the inscribed circle of the roundabout shown in Figure 4 is 60 feet. The speed limit within the roundabout is set at 20 mph and the cumulative distribution curve as defined in Figure 6 was used to set this limit.

The conflict zone shown in Figure 4 essentially implies that either vehicle A or vehicle B can occupy it at any given time. As noted earlier, the time taken by vehicle A to go past the conflict zone can be calculated as:

$$\text{Current Gap Time} = \frac{S + \Delta S}{\text{Speed (A)}}$$

where Speed (A) is the current speed of the vehicle A on the major road.

For example, if a user wants to code a behavior where vehicles are prevented from entering the roundabout when a vehicle from the nearest approach to the left has already entered it, the minimum gap time can be computed as follows:

Vehicle A would have just entered the roundabout and the driver of vehicle B is waiting for vehicle A to go past the conflict zone. The worst possible scenario in such a case would be that vehicle A is traveling at the maximum speed of 21.7 mph (~32 fps) as permitted by the speed distribution curve and vehicle B had just arrived at the yield line.

$$S + \Delta S = \frac{2 \times \pi \times R}{4} \quad \text{(Estimated as one-fourth the circumference of the roundabout)}$$

where R is the radius of the roundabout.

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Priority Rule Parameters *(Continued)*

$$\textbf{Minimum Gap Time} = \frac{S + \Delta S}{\text{Speed (A)}} \text{ or } \frac{2 \times \pi \times 60}{4 \times 32} = 2.9 \text{ seconds}$$

As calculated above, the 2.9 seconds gap time would result in a conservative gap acceptance behavior. The actual value of the distance (S + ΔS) can be measured directly from the model to obtain a better estimate of minimum gap time. The minimum gap time can be estimated in a similar fashion for every lane on the multi-lane roundabouts. For the subject area, several priority rules were estimated using such simplistic procedures and then adjusted to achieve desirable yielding behavior at the entries of the roundabouts.

5.3.2 VISSIM: Other Model Refinements

5.3.2.1 Simulation Resolution

Simulation resolution, which has a range of 1 to 10, specifies the number of times a vehicle's position is updated within one simulation second. A value of 10 implies that a vehicle's position will be calculated and updated 10 times every simulation second, based on its current speed and acceleration parameters. A value of 1 implies that a vehicle's position will be calculated and updated only once for every simulation second.

As noted previously, priority rules are the most critical elements for roundabout analysis using VISSIM. To ensure that all the priority rules are being conformed to, a simulation resolution of 10 should be used. This also aids in improving the visualization

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as vehicle movements appear smooth and not discrete as observed with a simulation resolution of 1.

5.3.2.2 Reduced Speed Areas

In VISSIM, it is a common practice to use reduced speed areas for temporary speed reduction on a vehicle's path. For instance, reduced speed areas can be used to control speed on the circulating links of a roundabout. This practice should be avoided for multi-lane roundabout analysis using VISSIM. This is because reduced speed areas in VISSIM are modeled as slow moving vehicles. Since the number of observed vehicles in the driver behavior is two, vehicles do not see more than two actual vehicles or network elements modeled as vehicles. It is therefore recommended to use desired speed decision bars to model lower speeds before vehicles reach the roundabout.

5.3.2.3 Multiple Model Runs

Multiple runs must be performed in VISSIM to account for its stochastic nature. Different random speeds will generate different inter-arrival gap times of vehicles into the network. Measures of effectiveness generated by VISSIM will vary between the runs. An average of all the runs for each measure of effectiveness must be reported for comparison.

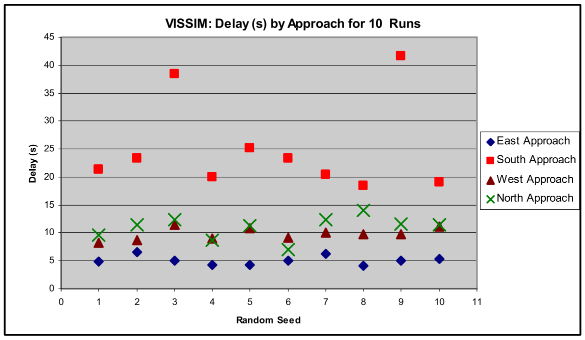

Figure 7 – VISSIM: Delay measurements for 10 simulation runs

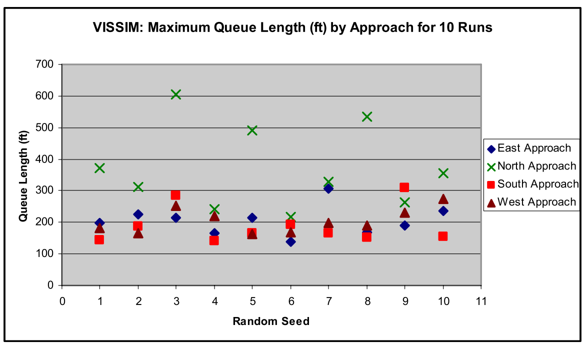

Figure 8 – VISSIM: Maximum queue length measurements for 10 simulation runs

6. Results & Some Observations

Several roundabout alternatives were considered for each intersection in the study area identified in Figures 1 and 2. Analysis results of only the preferred roundabout design at Industrial Parkway and SR 161 (Roundabout A in Figures 2 and 3) are presented in the interest of space.

The modeling procedure described in the earlier sections was used to develop models in RODEL, SIDRA and VISSIM. From the analysis conducted for several different conceptual alternatives, it was observed that any alternative that performed poorly (V/C > 0.85 for any approach) in RODEL also performed poorly in SIDRA.

Ten simulation runs were performed in VISSIM for the entire study corridor. **Figures 7 and 8** illustrate the delay and maximum queue lengths observed for the 10 simulation runs performed using VISSIM. The two outliers for delay on the south leg (Runs 3 and 9) were further investigated for model inconsistency and unusual lane changes, which could have contributed to the excessive observed delay. No such inconsistencies were found.

Table 1 summarizes results from operational analyses of the preferred roundabout concept using the three software

Approach	Delay (s)			V/C			Maximum Queue (ft)		
	RODEL	SIDRA	VISSIM*	RODEL	SIDRA	VISSIM	RODEL**	SIDRA	VISSIM*
North	4.2	14.4	11	0.63	0.61	NA	40	129	372
West	2.4	8.4	9.81	0.4	0.51	NA	20	107	204
South	4.8	11.7	25.14	0.32	0.38	NA	0	67	190
East	4.2	5.7	5.1	0.59	0.57	NA	20	109	205

* Average of 10 Simulation Runs is reported in this table
** RODEL reports queue lengths in vehicles. This was converted to feet assuming 20 feet per vehicle

Table1 – Roundabout analysis results

(Continued ▶)

programs. The results suggest that the roundabout as analyzed would work really well for the traffic demand shown in Figure 3. This is indicated by good saturation flow rates, minimal delays and short queues.

RODEL reported lower delays and queue lengths for all the approaches. Delay results from VISSIM and SIDRA were more or less comparable for three approaches. However, the south approach in VISSIM showed much higher delay than RODEL or SIDRA. This was the case even with the exclusion of the two outliers identified earlier. The animation observed in VISSIM indicated good car-following, lane changing and yielding behavior for the approach. Further investigation revealed that the delay definitions and the distance over which delays are measured could be different between the programs.

Table 1 also summarizes volume to capacity ratios and maximum queue lengths observed on the approaches to the roundabout. It should also be observed that saturation ratios are not provided for VISSIM as they are not computed by the program. However, it has to be noted that both RODEL and SIDRA provided very reasonable volume to capacity ratios for the subject roundabouts.

RODEL reported minimal or no queues on the approaches to the roundabout, which appeared unrealistic considering the volumes serviced by the roundabout. The queue lengths observed in VISSIM were higher than both SIDRA and RODEL. However, the main purpose of the VISSIM model was to ensure that these queues did not spill back onto adjacent intersections. The maximum queues and the visual animation confirmed that the queues did not spill back onto adjacent intersections proving that the roundabouts worked well as a system. The differences

(Continued ▶)

in the queue lengths predicted by the three programs could also be partly attributed to the different definitions used by the programs.

7. Summary & Conclusions

This paper summarized the efforts to develop practical models to test operations at alternative roundabout configurations proposed at the site described. Isolated intersection analysis conducted in RODEL and SIDRA was further supplemented with a site-wide VISSIM model. A methodology to estimate gap times required by the VISSIM model was described. The approach adopted provided realistic animation results.

There seems to be a growing debate in the transportation community regarding the accuracy of the available programs for roundabout analysis. Although the tools mentioned in this paper have differences and provided different results, they were used in combination to successfully demonstrate that roundabouts are a good solution for the study site. The modeling procedure outlined in this paper tries to take advantage of the merits of each program.

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