Simulating Roundabouts With VISSIM

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Abstract. The purpose of this paper is to inform traffic engineers about the power and flexibility that VISSIM offers in analyzing roundabouts. Typically, traffic engineers use “static” analysis software (such as aaSIDRA) to analyze the expected traffic operations at roundabouts. There are certain projects, however, where traffic simulation should be considered to assess the traffic operations of roundabout alternatives. The “static” software packages can only analyze individual intersections as independent entities and thus ignore the system impacts of roundabouts.

Traffic simulation is increasingly being used to assess traffic operations along many different types of roadway networks. From highways to arterial streets, traffic simulation enables the engineer as well as the public to visualize traffic operations. Roundabouts, however, have unique operational characteristics that some existing simulation packages do not currently model very well. VISSIM has considerable flexibility and can simulate many of these characteristics.

HDR recently used VISSIM to analyze traffic operations for two very different roundabout projects. The first project included the analysis of six proposed two-lane roundabouts along Missouri Avenue in St. Robert, Missouri, while the other project included the analysis of a proposed “dumbbell” arrangement along Missouri Route 367 just outside the City of St. Louis, Missouri. VISSIM was used on both projects due to its excellent graphical capabilities and its ability to model roundabouts through user-defined parameters. The following VISSIM features and their importance in effectively simulating roundabouts will be covered in the paper:

- Link and connectors
- Routing Decisions
- Reduced Speed Zones
- Priority Rules

What’s The Big Deal About Roundabouts?

As traffic volumes increase along America’s roadways, so does congestion. In some cases however, the use of roundabouts instead of the typical signalized intersection can actually reduce congestion and delay. In addition to roundabouts’ potential congestion benefits, they have also been known to reduce accidents when compared to traditional signalized intersection configurations. Since roundabouts have been successfully implemented across the U.S. in recent years, their application is gaining interest in many communities. This increased interest has lead to the need to have flexible tools that adequately analyze the numerous roundabout configurations and their associated impact on nearby intersections.

Simulation and Roundabouts: Why and What Makes Them Complex?

With the increase of traffic simulation as a tool for comparing one roadway alternative to another, one should understand the complexities in simulating roundabouts. One benefit that simulation adds to an analysis is the ability to determine impacts of closely spaced intersections and their effects on each other. aaSIDRA is typcially used to analyze roundabouts on a macroscopic level. If roundabouts and closely spaced intersections are included in an analysis, traffic simulation may be needed to accurately assess the interaction between the roundabout and nearby intersections. Just as some simulation models simulate freeways better than others, there are simulation packages that can model roundabouts better than others. VISSIM provides a flexible platform with several user-definable features that allow the user to more realistically model the traffic operations of roundabouts.

Unlike the modeling of four-way stop-controlled or signalized intersections, roundabouts are based more on the ability of drivers to accept or deny gaps. At stop signs, all vehicles must stop. After stopping, the right-of-way is assigned based on arrival order. At traffic signals, vehicles are assigned the right-of-way based on the signal display. In both of these cases, the work load (decision making process) on the driver is *generally* less than that of a roundabout. At roundabouts, almost the opposite is true. As vehicles approach the roundabout, they are supposed to only yield to those vehicles actually in the roundabout. If vehicles are approaching the roundabout on the opposite approach, but are not in the roundabout, then other vehicles are not required to yield. Simulating this type of driving behavior requires the ability to control *gap* and *headway* parameters on a link-by-link basis. VISSIM has the ability to control gaps and headways on a lane-by-lane basis to more accurately simulate these types of operations present at roundabouts.

Since roundabouts also are round, as their name suggests, they can present some car-following behavior problems for some simulation models. For example, many simulation models have difficulty simulating traffic operations when short links (e.g., closely spaced intersections, roundabout entries) exist in a network. Another benefit that VISSIM incorporates is that roadway networks consist of a link-connector structure instead of a link-node structure. This enables VISSIM to simulate short links without affecting the behavior of drivers as they proceed through small links.

The above paragraphs briefly describe just a few features within VISSIM that allow roundabouts to be simulated more accurately than other models. In order to gain a better understanding of VISSIM, the next section provides a brief description of how vehicles are simulated and the car-following model used within VISSIM. The remainder of the paper provides more detail on the coding of roundabouts within VISSIM and what can be done to more accurately simulate them.

General VISSIM Model Structure

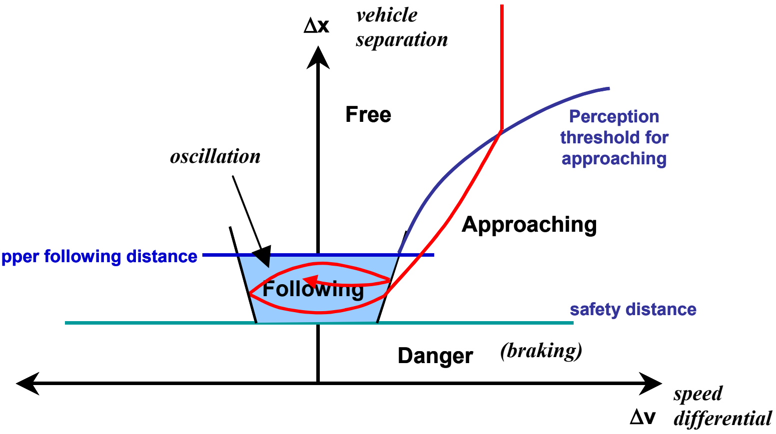
VISSIM (1,2,3,4) is a microscopic, time-step and behavior-based simulation model developed to analyze the full range of functionally classified roadways and public transportation operations. VISSIM can model integrated roadway networks found in a typical corridor as well as various modes consisting of general purpose traffic, buses, light rail, heavy rail, trucks, pedestrians, and bicyclists. In terms of operations, VISSIM is extremely flexible. It has the capability of being able to model complicated intelligent transportation system control strategies (e.g., ramp metering, transit signal priority, dynamic lane control signals, etc.) to modeling the backing of vehicles. The model was developed at the University of Karlsruhe, Germany during the early 1970s. Commercial distribution of VISSIM began in 1993 by PTV AG, who along with Innovative Transportation Concepts, Inc. in North America continue to develop, distribute and maintain VISSIM today.

VISSIM is unique in the manner in which the roadway network geometry is coded. Links and connectors are used to build any network of functional roadway classification (*4*). This approach enables the user to control vehicle paths as well as the interaction of vehicles within intersections. The link-node structure of other simulation models provides little, if any, flexibility for the user to control traffic operations within the intersection (i.e., node). With VISSIM it is possible to model any kind of intersection (or sequence/network of intersections) with a precision down to one millimeter!

The traffic flow model in VISSIM is a discrete, stochastic, time-step based microscopic model with driver-vehicle-units as single entities. The model contains a psycho-physical car following model and a rule-based algorithm for lateral movements. The model is based on the continued work of Wiedemann (*1,4*). The basic idea of the Wiedemann model is the assumption that a driver can be in one of four driving modes (see Figure 1):

Free driving is the mode in which the vehicle is not influenced by preceding vehicles. In this mode the driver seeks to reach and maintain his individually desired speed. In reality, the free driving speed cannot be held constant. Rather, it oscillates around the desired speed due to imperfect throttle control (*4*).

Figure 1 – Driving Modes within VISSIM



Approaching is the mode in which a vehicle goes through the process of adapting his speed to the lower speed of a preceding vehicle. While approaching, a driver applies deceleration so that the speed differential of the two vehicles is zero in the moment he reaches his desired safety distance (*4*).

Following is the mode in which a driver follows a preceding car without any conscious acceleration or deceleration. He keeps the safety distance more or less constant, but again due to imperfect throttle control and imperfect estimation, the speed difference oscillates around zero (*4*).

Braking is the mode in which the driver applies medium to high deceleration rates when the distance falls below the desired safety distance. This can happen if the preceding car changes speed abruptly, of if a third car changes lanes in front of the observed driver (*4*).

For each mode, the acceleration is described as a result of speed, speed difference, distance and the individual driver and vehicle characteristics (*4*). The driver switches from one mode to another as soon as he/she reaches a certain threshold that can be expressed as a combination of speed difference and distance. The ability to perceive speed differences and to estimate distances varies among the driving population, as well as the desired speeds and safety distances. Because of the combination of psychological aspects and physiological restrictions of the driver's perception, the model is referred to as a psycho-physical car-following model.

As stated above, vehicle speeds play an important role within the traffic flow model of VISSIM. Desired speeds within VISSIM are coded in three separate manners. The first is when vehicles enter the network. Each vehicle is assigned its own unique speed within a range based on an *empirical curve* defined by the user. The empirical curve can be defined to match field data (e.g., S-curves from speed studies) or assumptions can be used such as the posted speed limit. Vehicles oscillate around their desired speed until traffic conditions, speed zones, or roadway geometry requires them to change speeds. Speed zones are coded using *desired speed decisions*. Vehicles will not change speeds until they pass over the desired speed decision line. To capture the influence of roadway geometry (e.g., curves are intersection turning movements) on speeds, VISSIM uses *reduced speed areas*. The user defines the area where vehicles need to reduce speeds and then assigns a speed distribution to that area. Vehicles begin to decelerate for the reduced speed area in advance of reaching it. This behavior is similar to a motorist desiring to make a right turn who begins to decelerate before arriving at the point where he needs to turn. After passing over the reduced speed area vehicles begin to accelerate back to their previous desired speed. All speed distributions used in VISSIM can be vehicle-type-dependent. For example, the user may use slower turning speeds for trucks as opposed to cars.

Detailed Coding of Roundabouts Within VISSIM

With a better understanding of how VISSIM works, the user can begin to understand how the features of VISSIM can be used to accurately simulate operations at roundabouts. The two projects that are being used in this paper differ: one of them included single-lane roundabouts, while the other included two-lane roundabouts. The simulation of two-lane roundabouts can be rather complex when compared to that of single-lane roundabouts. There are more opportunities for vehicle conflicts circulating inside the roundabout. This is true not only in the real world but within the simulation model as well. Each of the following VISSIM features and their use in simulating roundabouts will be discussed in the following sections.

- Link and Connectors
- Routing Decisions
- Priority Rules
- Reduced Speed Zones

Two of these features, link-connectors and priority rules, are directly related to how vehicles enter/exit the roundabout. Two others, routing decisions and reduced speed zones, more accurately simulate lane choice and speed within the roundabout.

LINKS AND CONNECTORS – BUILDING THE ROUNDABOUT GEOMETRY

The coding of roadway networks within VISSIM, as discussed above, is rather different from most other traffic simulation models. CORSIM and SimTraffic, for example, rely on series of links and nodes to form roadway networks, in contrast to VISSIM's link-and-connector approach. The approach that VISSIM has allows for greater flexibility when compared to the other models. This flexibility allows the user to code the roadway network depicting several roundabout features, such as flared approaches and bypass lanes. The following provides a brief description of links and connectors within VISSIM.

Links are used to build the major roadway segments. When the number of lanes change, a new link is required. A number of attributes can also be assigned to links including driver behavior (car-following and lane-changing), number of lanes, lane widths, lane restrictions and gradient. Because VISSIM does not use the traditional link and node approach, a link within VISSIM can have several internal inflection points, as depicted in Figure 2, without affecting how the model simulates traffic flow through the link. As links become less than 150 feet in length (necessary to replicate curvature at a roundabout), the traffic flow model within CORSIM and SimTraffic begins to have problems simulating traffic flow. This usually leads to car-following logic difficulties that make modeling a roundabout very difficult.

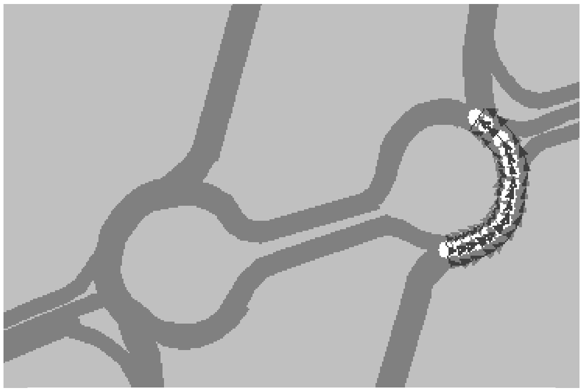


Figure 2 – VISSIM Curved Link

Connectors are used to connect links. They are the primary feature used to create an intersection and control the path of vehicles through the intersection. Connectors can be thought of as "ramps" onto links. An important consequence of this is that as vehicles travel onto a connector, it is possible that a vehicle on a link (possibly coded underneath the connector) may not recognize that there is a conflicting vehicle on the connector. This can lead to what looks like collisions when viewing the simulation, but rather vehicles are really going under or over each other in the model's universe. Most of the other connector features are very similar to links with the exception of their influence on lane-changing behavior. The user can specify a lane-change look-back distance from the connector and an emergency stop distance. The lane-change distance defines the distance at which vehicles will begin to attempt to change lanes. The emergency stop distance defines the last possible position for a vehicle to change lanes.

The ***Route 367*** project included a proposed expressway with one-way outer roads on each side of the expressway. This paper focuses on one particular proposed alternative that consisted of a "dumbbell" arrangement with two "teardrop" roundabouts located at the intersections of the cross-street and frontage road. Route 367 itself actually travels beneath the cross street in-between the roundabouts. Figure 3 depicts the "dumbbell" roundabouts along the cross-street. The frontage road consists of two travel lanes (NB on the right and SB on the left), while the cross-street consisted of one travel lane in each direction. The link-connector (blue centerlines are links and pink are connectors) structure of VISSIM allowed for very detailed lane alignments and curvature approaching the roundabout, as well as within the roundabout itself.

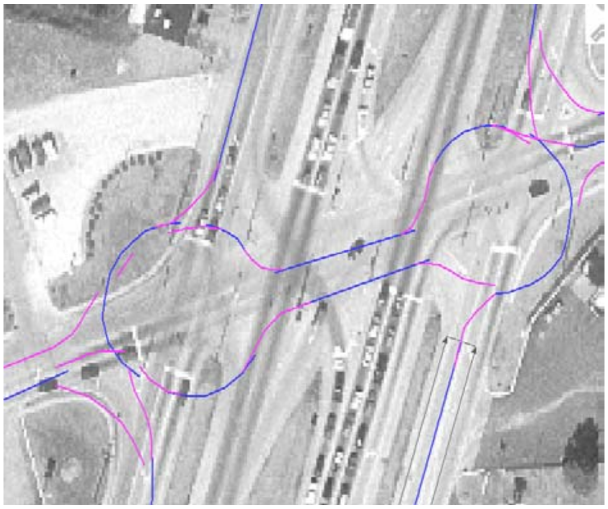


Figure 3 – Link-Connector Structure of One-Lane Roundabouts

The proposed roundabouts along ***Missouri Avenue*** consisted of two-lane configurations. The modeling of two lane roundabouts is somewhat more complex than one-lane roundabouts. In terms of the layout of the roundabout, however, they are fairly straightforward. Figure 4 depicts a screen shot of the link-connector structure coded within VISSIM. What makes this particular coding of a roundabout unique is the ability to model the inside circle as one large link with only one connector. This can help reduce the number of visual collisions that may occur, as discussed above, by using the least number of links that require connectors.

Figure 4 – Link-Connector Structure of Two-Lane Roundabouts

ROUTING DECISIONS—CONTROLLING THE VOLUMES AND PATHS THROUGH ROUNDABOUTS

One of the most powerful features within VISSIM is the coding of routing decisions. Routing decisions allow the user to "route" traffic through an intersection by movement and, if needed by lane. Routes can extend through one intersection or an unlimited number of intersections. Routing decisions consist of a routing decision point and any number of destination points. The user defines the volume on each route as either a percentage of the total volume passing the routing decision point or the actual volume on each route.

The use of routing decisions enables traffic to be routed through a roundabout based on the proposed lane geometry of the roundabout. From an operational point of view, this can make a big difference in the analysis of the expected roundabout operations. Along each approach of the roundabout, routing decisions are coded to define where vehicles will exit the roundabout and the portion of vehicles that will use that exit. Routing decisions can also control the lane selection as vehicles travel through a roundabout. This control (combined with the lane-change distance setting) is extremely important to reflect the influence of closely spaced intersections and how most motorists select their desired lane in advance of their downstream destination.

Routing decisions are sometimes used to more accurately simulate traffic through a multi-lane roundabout. Since multi-lane roundabouts have more than one circulating lane, the opportunity exists for vehicles to make movements from lanes where a particular movement is not allowed. For example, Figure 5 depicts one of the ***Missouri Avenue*** roundabouts where northbound left-turning vehicles were only allowed to turn from the inside lane of the roundabout. Within VISSIM this can be simulated by coding a *connector* over a link (Figure 6) and then using this connector to create a route that forces vehicles turning left to use the inside lane. If preferred, the user could force this routing decision to make this occur prior to entering the roundabout if desired.

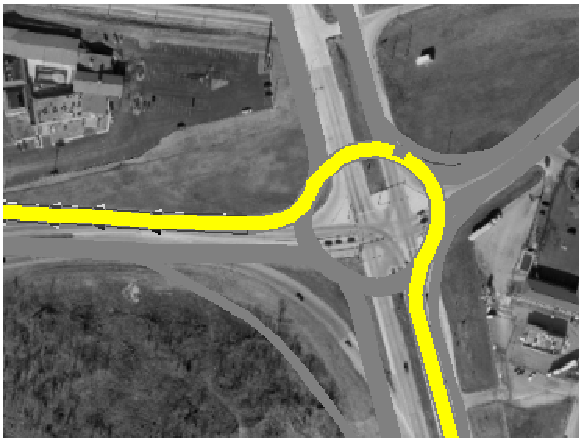


Figure 5 – Routing Decision Within Multi-Lane Roundabout

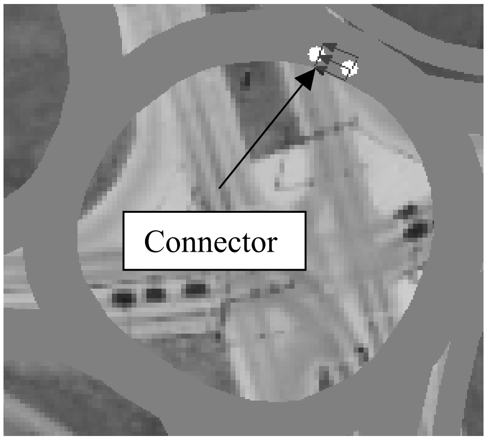
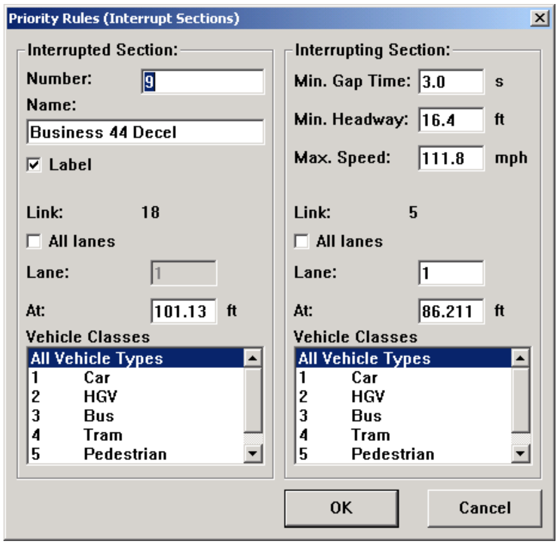


Figure 6 – Connector Used With Routing Decisions to Model Lane Choice

PRIORITY RULES— HOW AND WHEN VEHICLES CAN ENTER A ROUNDABOUT

Within VISSIM, acceptable gaps that drivers take are controlled by “priority rules”. The coding of “priority rules” within VISSIM provides great flexibility that allows traffic flow within a roundabout to be simulated closely to what might be expected in the real world. A priority rule consists of one stop line and one or more conflict markers that are associated with the stop line. They are used to control the conditions under which vehicles can enter the roundabout. Depending on the current conditions at the conflict marker(s), the stop line controls whether vehicles can cross the stop line or not. Two conditions need to be satisfied before a vehicle can cross a stop line: minimum headway (distance) and minimum gap time. For the purposes of simulating roundabouts, a combination of both should be used to accurately model driver behavior. Figure 7 depicts a screen shot of the input screen used for coding priority rules within VISSIM. Note the ability to input priority rules based on travel lane and/or by vehicle type.


Priority Rules (Interrupt Sections)

Interrupted Section:
Number: 9
Name: Business 44 Decel
☑ Label
Link: 18
☐ All lanes
Lane: 1
At: 101.13 ft
Vehicle Classes
All Vehicle Types
1 Car
2 HGV
3 Bus
4 Tram
5 Pedestrian

Interrupting Section:
Min. Gap Time: 3.0 s
Min. Headway: 16.4 ft
Max. Speed: 111.8 mph
Link: 5
☐ All lanes
Lane: 1
At: 86.211 ft
Vehicle Classes
All Vehicle Types
1 Car
2 HGV
3 Bus
4 Tram
5 Pedestrian

Figure 7 – VISSIM Priority Rule Input Screen

Priority rules consist of placing at least two bars across a set number of travel lanes. One is placed on the "interrupted" (red) section and one is placed on the "interrupting" (green) section. In one-lane roundabouts, such as those coded along ***Route 367***, only one priority rule is required on each approach to the roundabout, as depicted in Figure 8.

Two-lane roundabouts, on the other hand, require more priority rules than one-lane roundabouts. Figure 9 depicts one of the two-lane roundabouts along ***Missouri Avenue***. Two-lane roundabouts should be coded with two or more "interrupting" sections that correspond to the "interrupted" section. This allows VISSIM to help prevent vehicles from entering the roundabout as vehicles travel inside the roundabout. The criss-cross lines are coded to minimize crossovers that may occur as vehicles exit the roundabout in front of another vehicle that is routed to travel through the roundabout. Sometimes the placement of priority rules is based on trial and error by viewing the animation file produced by VISSIM. Furthermore, priority rules can be vehicle-dependent. Thus, different gap-acceptance times can be defined for different vehicle types such as trucks and buses.

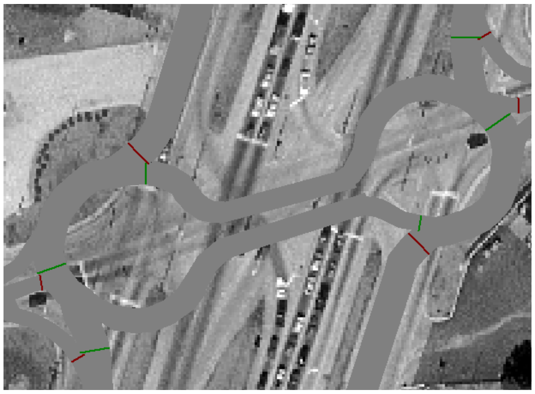


Figure 8 – Priority Rules for One-Lane Roundabouts

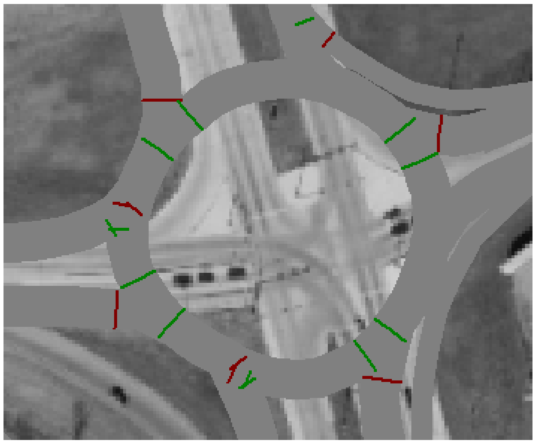


Figure 9 – Priority Rules for Two-Lane Roundabouts

REDUCED SPEED ZONES — CONTROLLING VEHICLE SPEEDS WITHIN ROUNDABOUTS

VISSIM also enables the user to control vehicles within a roundabout through the use of reduced speed zones. Simply stated, reduced speed zones force vehicles to decelerate from their desired speed to a speed coded on a reduced speed zone. As discussed earlier, vehicles within VISSIM attempt to travel at their desired speed. They will continue to do so unless they encounter a reduced speed zone or some other form of speed reduction. Typically, the recommended travel speeds within roundabouts range from 20 to 25 mph.

Reduced speed zones within VISSIM should be placed so that vehicles travel over the beginning of the speed zone as they enter the roundabout (or shortly thereafter). Vehicles will decelerate to the coded speed just prior to the beginning of the reduced speed zone. It is important to allow vehicles to enter the beginning of the reduced speed zone to effectively allow the vehicle to "activate" the coded reduced speed. Figure 10 depicts an incorrect way to code a reduced speed zone, while Figure 11 ***(Route 367)*** and 12 ***(Missouri Avenue)*** depict the correct way to code reduced speed zones. The correct placement of reduced speed zones enables vehicles to realistically travel at speeds typically observed within roundabouts.

Figure 10 – An Incorrect Way to Code Reduced Speed Zones

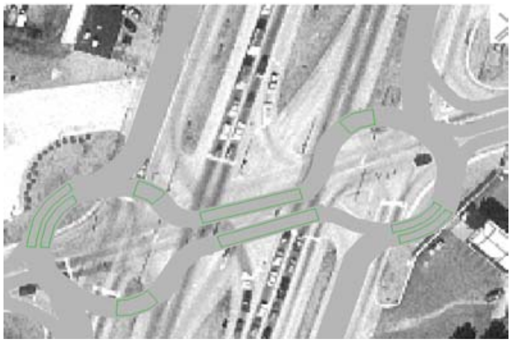


Figure 11 – Reduced Speed Zones for One-Lane Roundabouts

Figure 12 – Reduced Speed Zones for Two-Lane Roundabouts

Summary

As traffic simulation proves to be a viable tool for analyzing traffic operations along proposed roadway networks, it is becoming important to be able to simulate "non-traditional" alternatives that may be proposed. Roundabouts have been gaining popularity as an alternative to the traditional signalized intersection. In terms of traffic simulation, roundabouts typically require detailed coding due to their non-traditional driving rules.

Several features within VISSIM allow the user to more accurately simulate traffic operations of roundabouts. The paper discussed some of the detailed coding required to accurately model both one-lane and two-lane roundabouts. A discussion of the traffic flow characteristics within VISSIM was also briefly described to provide some insight on how VISSIM simulates vehicles and driver behavior. The following bullet points highlight the four key factors within VISSIM that enable roundabouts to be realistically simulated.

- *Link and Connectors* – This feature is related to the geometric coding used for roundabouts. The placement of links and connectors not only allows the user to graphically depict the curvature of a roundabout, but also to assist in modeling lane choice through a roundabout.
- *Routing Decisions* – This feature allows VISSIM to "route" traffic through the roundabout using the correct lane or lanes that will be signed or marked in the field.
- *Priority Rules* – This feature provides VISSIM with the ability to accurately reflect gap acceptance at roundabouts. The user has almost unlimited choices on where priority rules can be coded. VISSIM allows the coding of time headways as well as distance headways.
- *Reduced Speed Zones* – This feature controls the speed that vehicles traverse through the roundabout. Typically speeds within roundabouts should range from 20 to 25 mph.

In summary, simulating roundabouts using VISSIM can provide a reasonable assessment of how a proposed roundabout may operate. Simulating roundabouts allows the user to gain a better understanding of the overall roadway network. The flexibility of VISSIM allows the user to code many different roadway scenarios (i.e. closely spaced intersections), while at the same time providing the means to fine-tune driver behavior through lane choice and travel speed. The intent of this paper has been to provide some insight into the challenges that simulating roundabouts poses and the ability to overcome these challenges using VISSIM.

References

1. Wiedemann, R. and Reiter, U. *Microscopic Traffic Simulation, The Simulation System—Mission*, University of Karlsruhe, Germany, 1974.
2. Hoyer, R. and Fellendorf, M. *Parametrization of Microscopic Traffic Flow Models Through Image Processing*, 8th IFAC Symposium on Transportation Systems, Chania, Greece, June 1997.
3. Fellendorf, M. *Public Transport Priority within SCATS – A Simulation Case Study in Dublin,* Institute of Transportation Engineers, 67th Annual Meeting, Boston, August 1997.
4. VISSIM 3.70 User Manual, PTV AG, Karlsruhe, Germany, April 2003.

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