1 Introduction

The purpose of this document is to outline the process and standards associated with developing and applying VISSIM microsimulation models for the analysis of roundabouts. Modeling roundabouts in VISSIM requires diligence and trained staff, as model assumptions may substantially affect the traffic operations and the performance measures. The guidelines provided here establish best practices for modeling roundabouts in VISSIM and ensure consistent and reproducible application of the roundabout microsimulation models for MassDOT. It should be noted that the information contained in this document is specifically developed for the VISSIM microsimulation software, and is not transferable to other microsimulation tools. All examples and associated discussion focus on VISSIM-specific parameters and VISSIM network objects. The guidelines are organized as follows:

- General VISSIM guidance,
- Roundabout modeling guidance,
- Roundabout calibration,
- Data collection and performance measures, and
- Peer review checklist.

2 General VISSIM Guidance

2.1 Simulation Parameters

This section provides guidance related to the simulation parameters that should be included in the models.

2.1.1 Simulation Resolution

Simulation resolution is the number of times the position of a vehicle will be calculated within one simulated second (ranging from 1 to 10). The input parameter of one will result in the vehicles moving once per simulation second while an input parameter of 10 will result in the position of the vehicle being calculated 10 times per simulation second, thus making vehicles move more smoothly throughout the network. The change of simulation speed is inversely proportional to the number of time steps. A simulation resolution of 10 time steps per second is recommended for all simulation analyses.

2.1.2 Network "Warm-up" Period

"Warm-up" period is the time before the system reaches equilibrium for the simulation period, or more specifically when the number of vehicles in the network levels out (vehicles entering the network balance vehicles exiting). No performance measures should be collected from simulation models until after the warm-up period. Depending on the network size, warm-up times will vary from one model to another. A rule of thumb to identify the appropriate warm-up time is to select at least twice the estimated longest travel time within the network during free-flow conditions. For example, if the longest path to traverse the network takes approximately 7.5 minutes at the free-flow speed, the warm-up time should be set at 15 minutes.

2.1.3 Simulation Run Time

For models where congestion and queues can be cleared within the peak hour (e.g., 8 AM – 9 AM), a 60-minute simulation run time is typically sufficient to collect simulation outputs (excluding warm-up period). For networks where there is significant oversaturation and queues extend beyond the peak hour, a longer simulation run time should be considered to include the effects of residual queues (i.e., unserved vehicles) within the network. It is also important to note that future year analyses might experience congestion that is not observed under the existing (or baseline) conditions. Therefore, the analyst needs to take expected congestion levels into account during the selection of temporal limits. Where it is not feasible to conduct preliminary analysis to determine the extent of queues, local knowledge (e.g., anticipated growth in the study area and potential bottleneck locations) along with sketch-level tools, HCM approaches, and other planning tools will be the key factors for the selection of temporal limits.

2.2 Number of Simulation Runs

The simulation models will be run multiple times with different random seeds to minimize the impact of the stochastic nature of the model on the results. It is recommended that the analyst will start with an initial set of ten simulation runs with different random seeds to collect model outputs. After the first ten runs, the standard deviation for the selected system performance measure should be entered into the following equation to determine the necessary number of simulation runs[1]:

$$n = \left(\frac{s * t_{\frac{\alpha}{2}}}{\mu * \varepsilon}\right)^2 \tag{1}$$

Where:

[1] FHWA, Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software

n is the required number of simulation runs
s is the standard deviation of the system performance measure (e.g., speed) based on previously conducted simulation runs
$t_{\alpha/2}$ is the critical value of a two-sided Student's t-statistic at the confidence level of α and n-1 degrees of freedom. An α of 5% is typical, corresponding to a t-value of 1.96
μ is the mean of the system performance measure
ε is the tolerable error, specified as a fraction of μ. A 10% error is desired.

2.3 North America Vehicle Models

All VISSIM models should begin with the example file "NorthAmericanDefault.inpx", which is provided with each VISSIM installation. This file contains a vehicle fleet mix for passenger cars, as well as heavy vehicles that is representative for travel conditions in the U.S. The default file contains typical vehicles seen on American roadways, including mini vans, sport utility vehicles, and pick-up trucks, as opposed to the more European vehicle fleet contained in a new VISSIM file. For heavy vehicles, the NorthAmericanDefault file contains all standard AASHTO truck classes. The use of this file is highly recommended to adequately reflect vehicle sizes typical in the U.S., get reasonable capacity estimates, and result in visualizations representative of U.S. vehicles. The analyst may customize the relative percentages of different passenger car and truck types in the "2D/3D Model Distribution" parameter set in VISSIM. Truck percentages should be specified in the "Vehicle Distribution" setting to match local conditions.

3 Roundabout Modeling Guidance

Geometric elements and general design principles including speeds, alignment of approaches and entries, and yielding behaviors are considerably different between a single lane roundabout and a multilane roundabout. As a result, this section first presents modeling guidance for single lane roundabouts. Additional modeling guidance for multilane roundabouts are given in the subsequent section. The last section in this chapter will focus on multimodal modeling guidance, which will be applicable to both single land and multilane roundabouts.

3.1 Single Lane Roundabout

This section provides guidance for single lane roundabouts with a focus on three key modeling elements in VISSIM: (1) links and connectors, (2) speed control, and (3) yielding behavior.

3.1.1 Links and Connectors

A roundabout should be laid out such that continuous links follow the trajectory of the primary movements from approach through exit. The minor street links are terminated just prior to the roundabout, with connectors being used to connect entry lanes to the appropriate circulating lanes. Additional links for pedestrian crosswalks and cycle tracks/bike lanes should be modeled where appropriate. All connectors should be kept as short as possible, and should avoid excessive overlap with the upstream or downstream links. Long connectors for the entry and exit links result in large conflict areas, which in turn may lead to challenges with respect to the yielding behavior. A typical roundabout layout is shown in **Figure 1**.

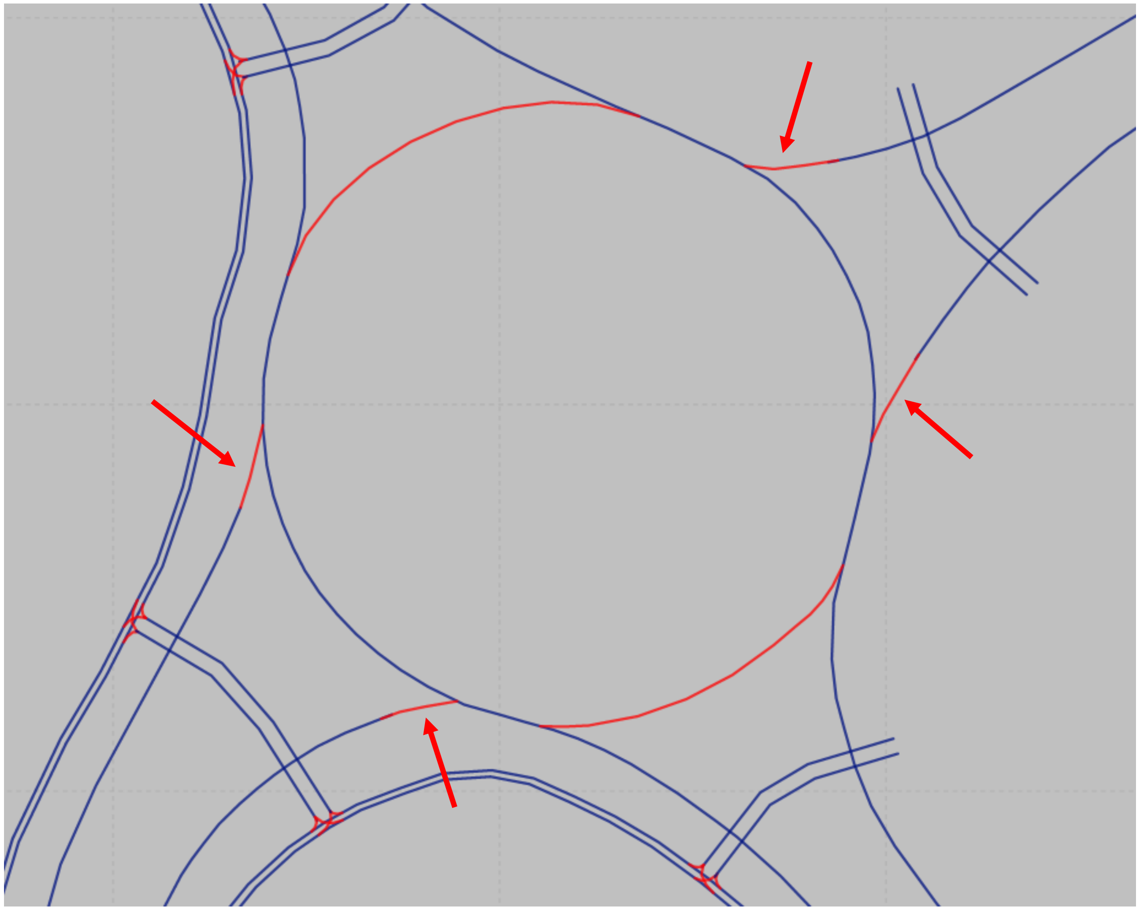


Figure 1: Coding Lanes and Connectors for Roundabouts in VISSIM

3.1.2 Speed Control

Coding approach, entering, and circulating speeds appropriately in VISSIM is critical to developing a realistic model that can accurately represent field conditions and prevent models from producing unrealistic or misleading results. Approach, entering, and circulating speeds are typically controlled by the geometry of a roundabout including horizontal curvature and pavement widths. **Figure 2** illustrates how an analyst should use desired speed decisions and reduced speed areas to code approach, entry, circulating, and exit speeds in VISSIM.

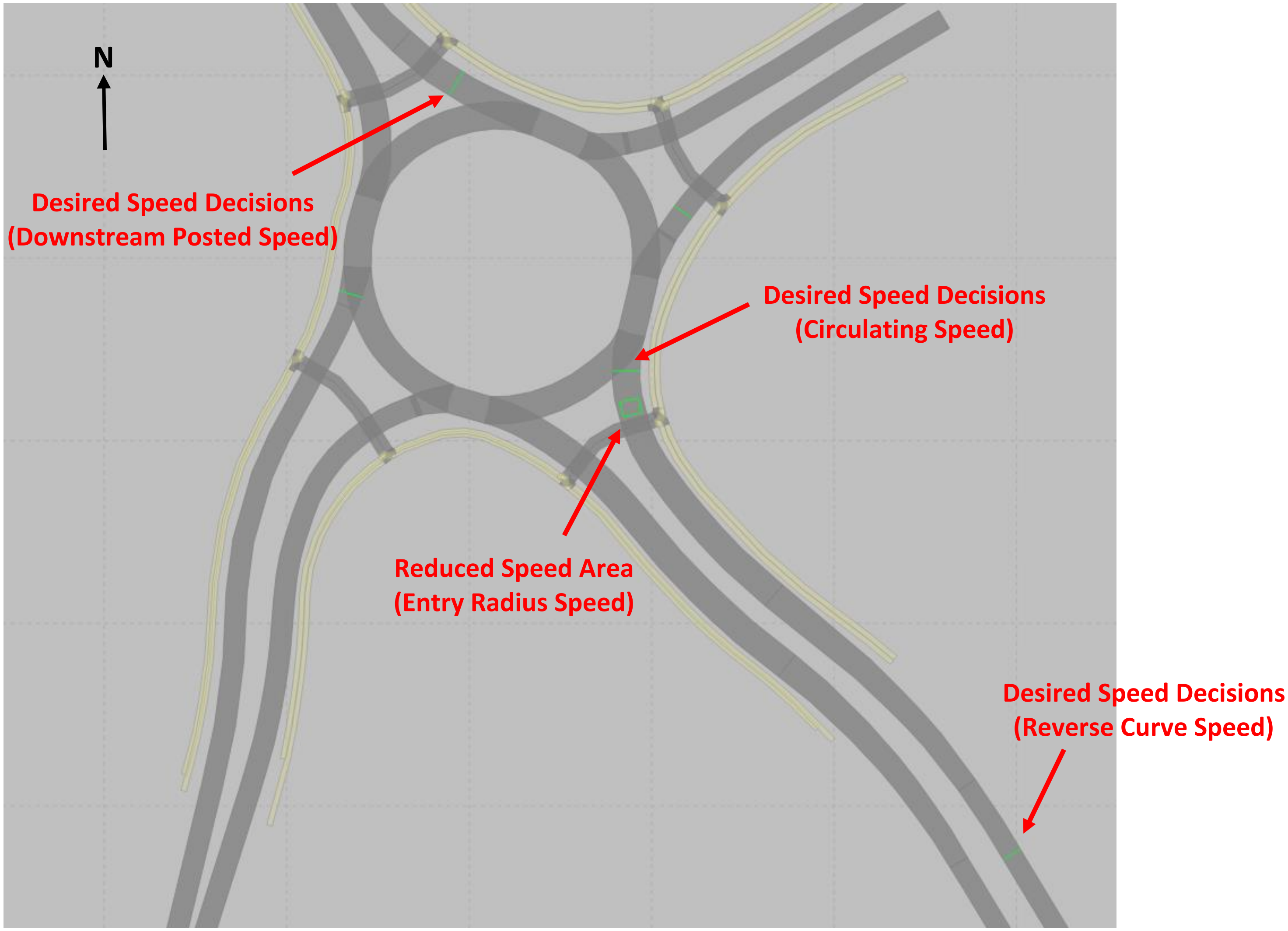
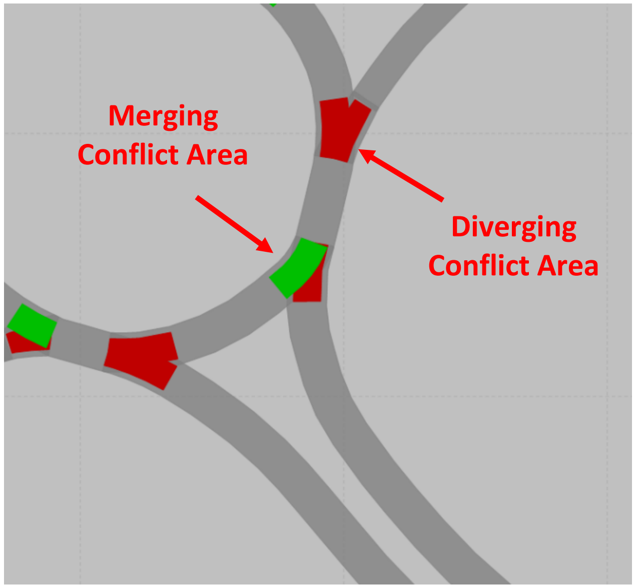


Figure 2: Coding Desired Speed Decisions and Reduced Speed Areas for Modeling Roundabout Speed Control in VISSIM

In the figure, a vehicle approaching the roundabout from the south-east, first encounters a desired speed decision that adjusts the vehicle speed to the design speed of the reverse curvature (use to slow vehicles before reaching the roundabout). A reduced speed area at the entry then reduces vehicle speeds further to the entering design speed of the roundabout (e.g. the "R1" speed). Since reduced speed areas are "look-ahead" features in VISSIM, vehicles will have slowed down to the R1 speed by the time they reach the reduced speed area. The length of the reduced speed area is thus reduced to the apex of the curve (approximately 5-10 feet). Immediately following the reduced speed area, a desired speed decision assigns the circulating speed (e.g. the "R2" speed) to vehicles. Vehicles maintain that speed until they exit the roundabout, and pass another desired speed decision at the downstream posted speed. Note that no reduced speed areas should be used inside the roundabout.

3.1.3 Yielding Behavior

Yielding behavior in VISSIM can be modeled either through "conflict areas" or through "priority rules". Conflict areas are generally preferred for roundabouts, as they take into account vehicle characteristics such as vehicle length (truck vs. passenger car) and acceleration/deceleration behavior. The illustration of the merge and diverge conflict areas are shown in **Figure 3**. A merging conflict area is used to control vehicle yielding upon roundabout entry. A diverging conflict area is used to control conflicts at the exit (for example due to spillback from a downstream crosswalk).



While conflict areas are generally preferred for managing conflicts at roundabouts, recent research[2] indicates that using priority rules can result in more consistent and repeatable gap acceptance behavior in certain cases. Priority rules can also be beneficial when modeling pedestrian crossings or transit movements through roundabouts. If the decision is to use priority rules, it is highly recommended for the analyst to follow the guidance provided in the referenced paper.[2]

Whether conflict areas or priority rules are used, VISSIM's default gap-acceptance parameters (e.g., Front Gap, Minimum Gap, etc.) should be calibrated to match field-observed roundabout entry capacities, or the recommended values given in the Highway Capacity Manual (HCM) 6th Edition. All gap acceptance behavior should initially be calibrated visually, before conducting a more detailed calibration as discussed in Section 4.

[2] Calibration of VISSIM Roundabout Model: A Critical Gap and Follow-up Headway Approach, Li et al., TRB 2013.

3.2 Multilane Roundabouts

This section provides VISSIM modeling guidance for multilane lane roundabouts with a focus on links/connectors, speed control, yielding behavior, lane change assumptions, and heavy vehicles in multilane roundabouts.

3.2.1 Links and Connectors

Similar to the single lane roundabouts, links and connectors in VISSIM should follow the trajectory of the primary movements from approach through exit. Side street links are terminated upstream of the roundabouts, and connectors are used to complete those movements. Furthermore, short connectors are recommended for the entry and exit links as discussed in Section 3.1.1.

Special consideration for multilane roundabouts is needed for sites with spiral pavement markings, where circulating traffic is guided from an inside lane to the outside lane through markings prior to exiting. For these cases, the VISSIM connectors are configured to follow the markings (**Figure 4**).

Figure 4: Modeling of Spiral Pavement Markings for Multilane Roundabouts in VISSIM

3.2.2 Speed Control

In order to model approach, entering, circulating, and exit speeds accurately in a multilane roundabout, the recommended desired speed decisions and reduced speed areas shown in **Figure 2** should be used by the analyst. For roundabouts with a right-turn bypass lane (or right-turn slip lane), speeds may be slightly different than the roundabout entry and exit speeds (depending on the radius of the right-turn bypass lane), and thus different desired speed decisions and reduced speed areas may be required for those movements.

3.2.3 Yielding Behavior

With multilane roundabouts, in addition to merging and diverging conflicts displayed in **Figure 3**, crossing conflicts need to be coded in the simulation. Crossing conflicts apply for entry lanes crossing multiple circulating/exiting lanes as a continuous link. **Figure 5** illustrates how to code a crossing conflict in VISSIM for multilane roundabouts through conflict areas. As previously discussed, whether the analyst uses conflict areas or priority rules in VISSIM to model crossing conflicts, proper calibration of the model should be performed. Detailed calibration information is discussed in Section 4.

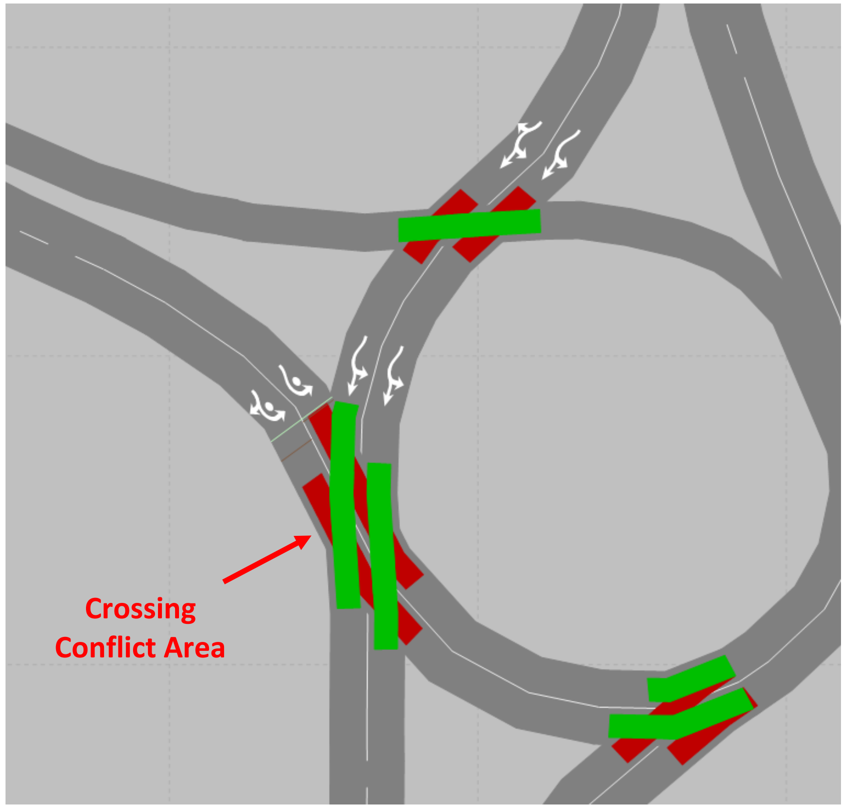


Figure 5: Coding Crossing Conflict for Multilane Roundabouts in VISSIM

3.2.4 Lane Change Assumptions

For correctly modeling multi-lane roundabouts, no lane changes should be allowed within the circulating lanes, other than those dictated by spiral markings. Therefore, all multi-lane links and connectors in the roundabout should be configured with the “no lane change” link/connector parameter to prevent road changes within the circulatory roadway. **Figure 6** shows the start and end location for the no lane change assumption for modeling multilane roundabouts. For long, continuous links through the roundabout, the link may need to be “split” to allow the no-lane change zone to be restricted to just the circle.

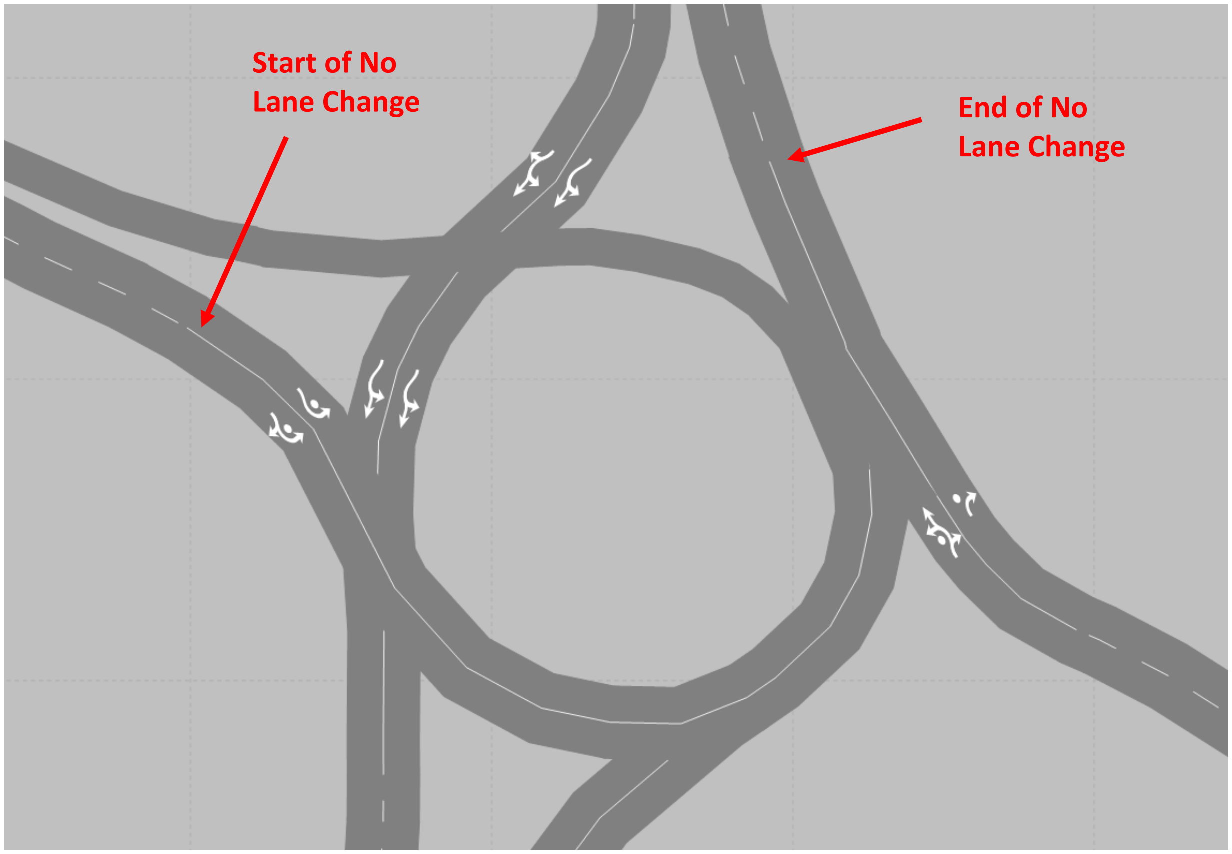


Figure 6: Start and End of No Lane Change in VISSIM for Modeling Multilane Roundabouts

In addition, the default emergency stop distance from turn connectors should be modified to avoid vehicles getting stuck in the roundabout and ensure drivers change to the appropriate lane prior to the roundabout. **Figure 7** shows the calculation for the emergency stop distance. **Figure 8** illustrates how to adjust emergency stop distance for connectors in VISSIM.

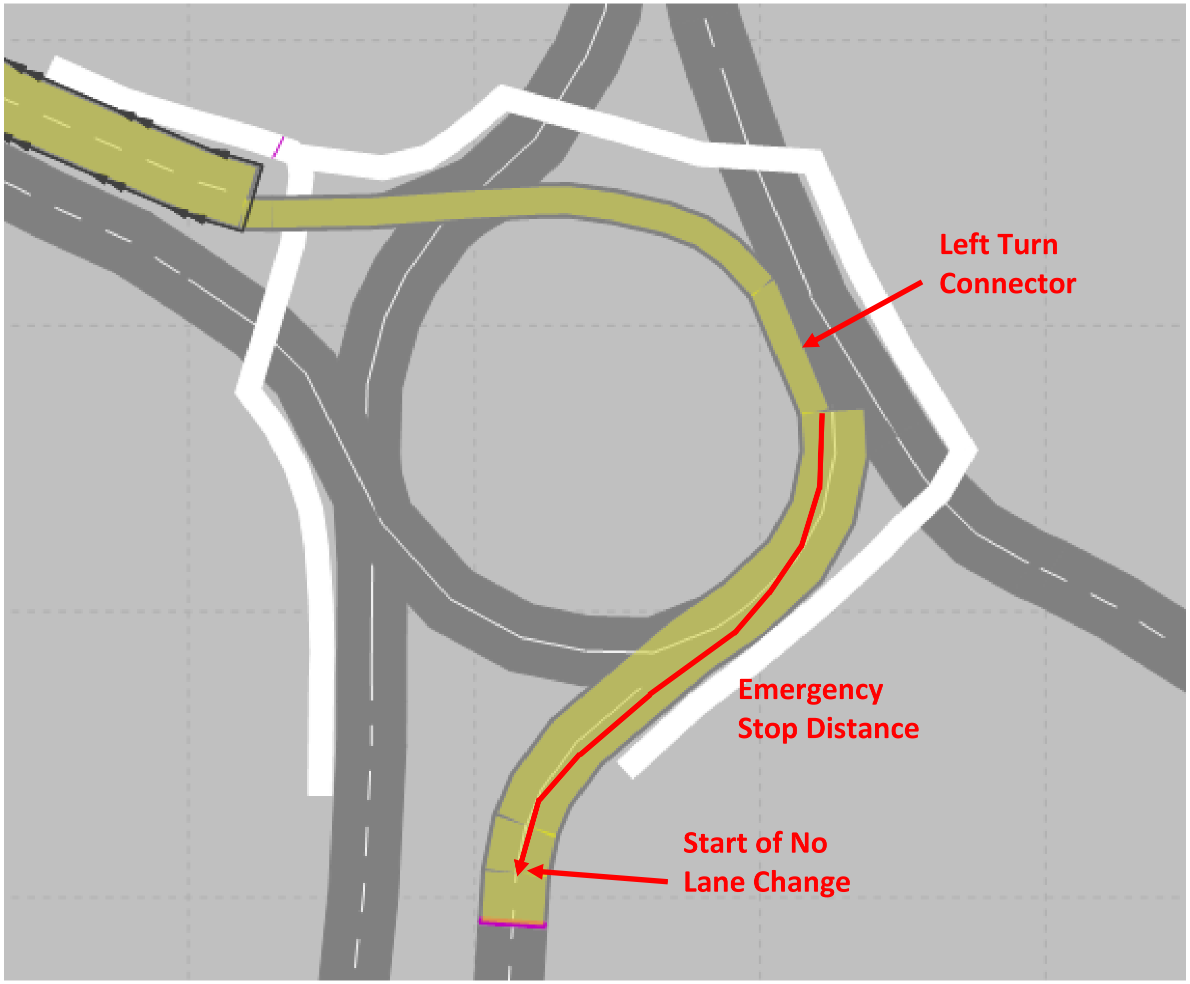


Figure 7: Emergency Stop Distance Calculation for Modeling Lane Change in Multilane Roundabouts

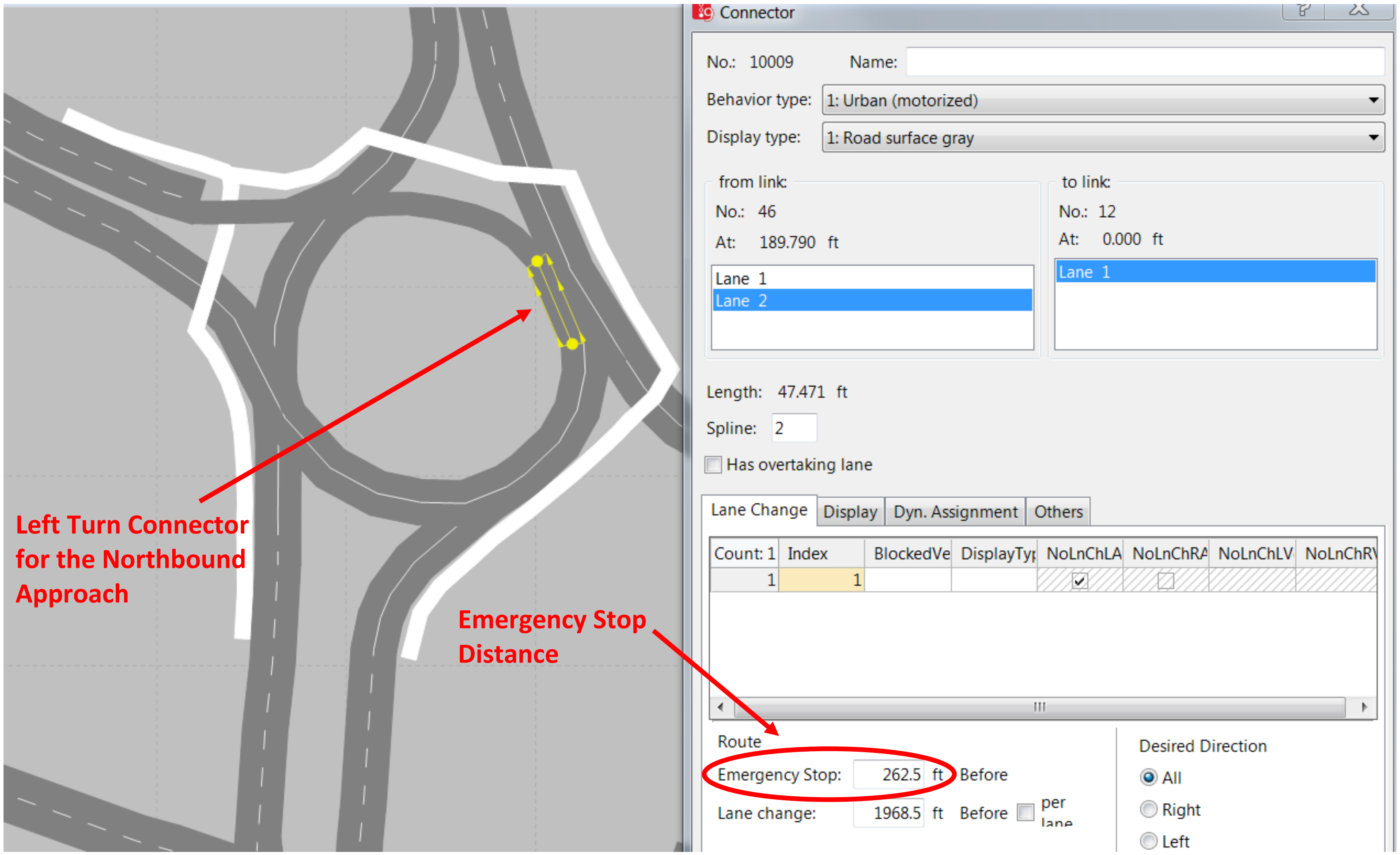


Figure 8: Adjustment of Emergency Stop Distance in VISSIM for Connectors

3.2.5 Heavy Vehicles in Multilane Roundabouts

In a multilane roundabout, large vehicles (e.g., vehicles with trailers) may need extra room to complete their turn in a roundabout, which may require oversize vehicles to straddle both lanes. As a result, drivers avoid driving next to large vehicles in a multilane roundabout. By default, VISSIM is unable to capture the behavior of not passing an oversize vehicle in the roundabout, as vehicles would still drive through a roundabout even when both lanes are occupied, as illustrated **Figure 9** through a 3D screenshot taken from the simulation. This results in unrealistic behavior and may lead to inaccurate operational results.

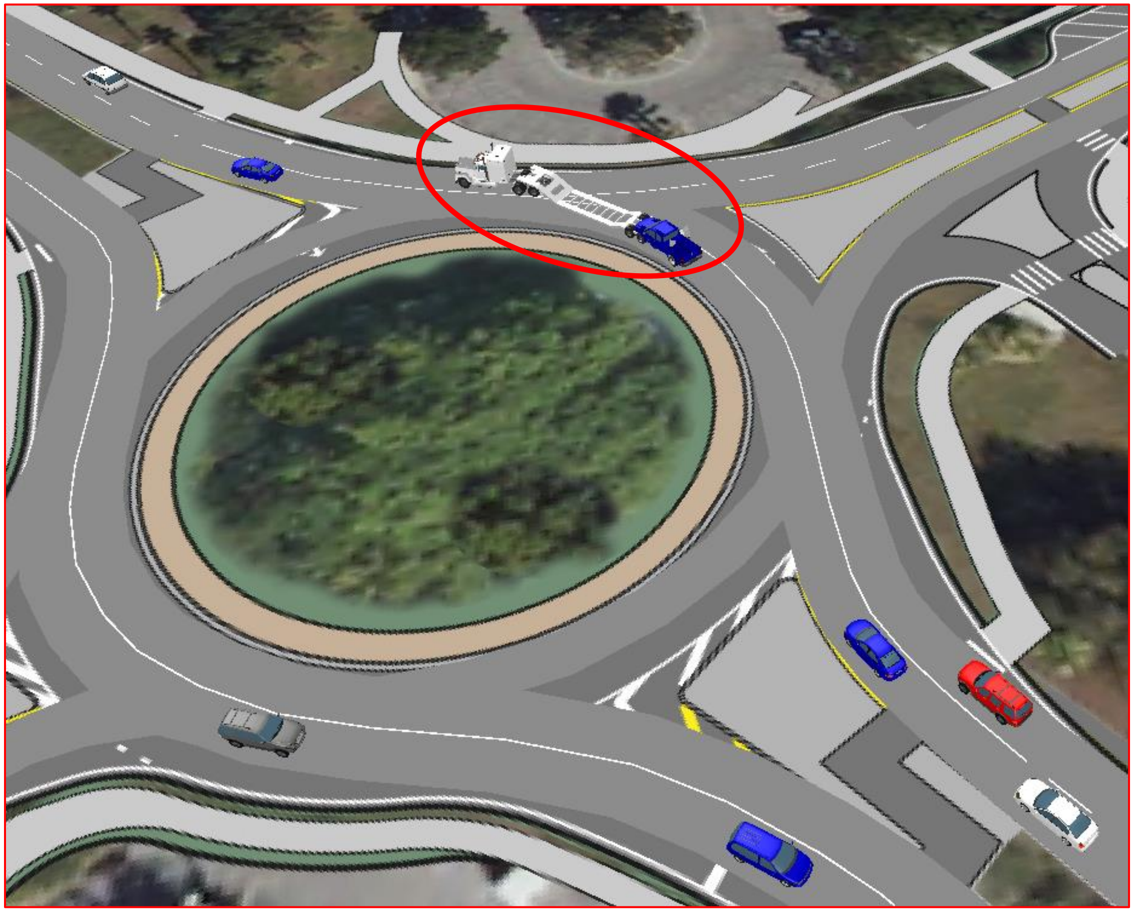


Figure 9: VISSIM's Limitation of Modeling No Passing of an Oversize Vehicle in a Multilane Roundabout

Figure 10 illustrates how to accurately incorporate truck effects on a multilane roundabout as well as the resulting behavior. It should be noted that the 3D screenshots shown in both figures are taken exactly at the same simulation timestep.

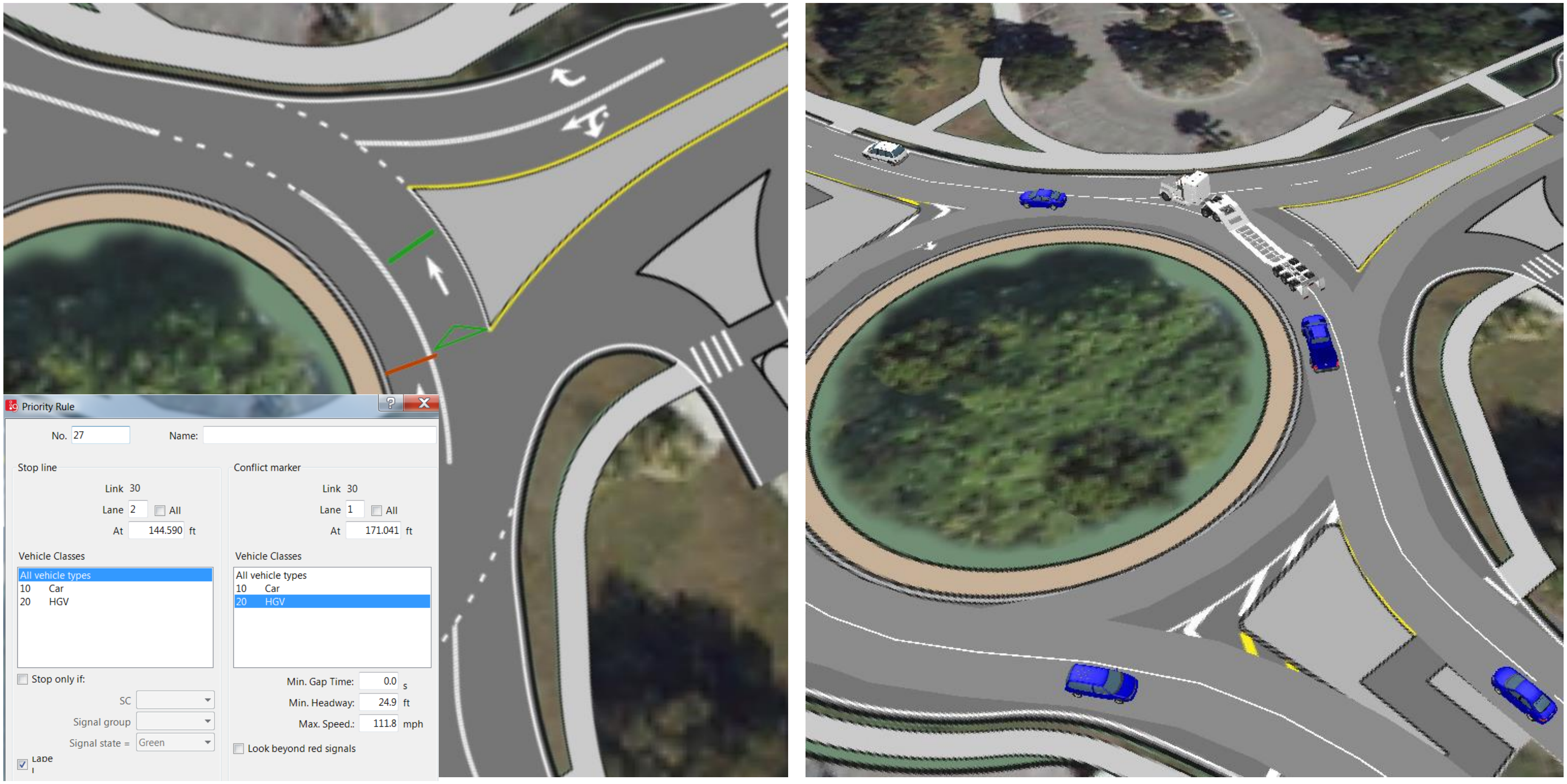


Figure 10: Using Priority Rules to Model No Passing of an Oversize Vehicle in a Multilane Roundabout

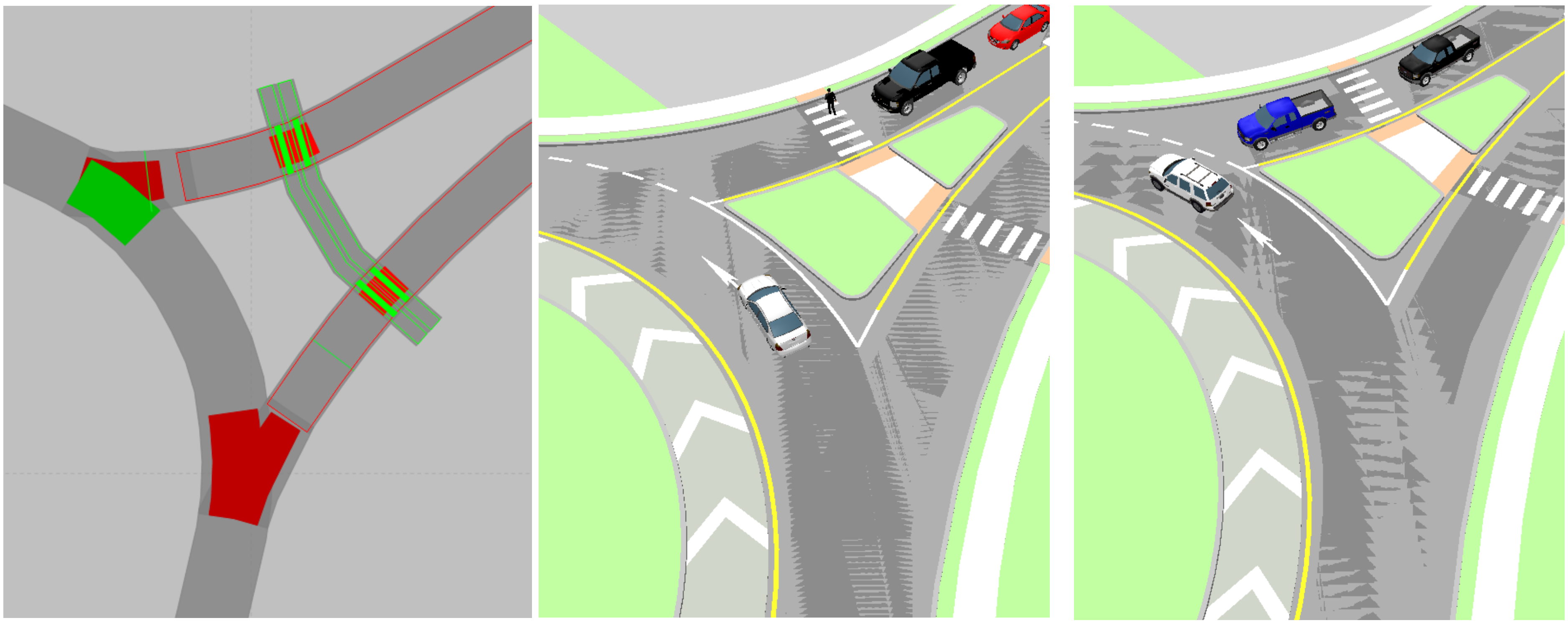
3.3 Multimodal Modeling

This section discusses modeling of multimodal users with a focus on pedestrian and bicycles, as well as modeling multimodal treatments for roundabouts including raised crosswalks and pedestrian hybrid beacons.

3.3.1 Pedestrians and Yielding Behavior

The coding of crosswalks in VISSIM along with the yielding behavior to pedestrians are shown in

Figure 11. In the example provided below, conflict areas are used to model yielding (**Figure 11a**), which also prevents vehicles from blocking the



8a. Coding yielding behavior through conflict areas ***8b. Vehicles yielding to pedestrians in the crosswalk***

crosswalk as shown in **Figure 11c**.

Figure 11: Modeling Pedestrians and Yielding Behavior in a Roundabout using Conflict Areas in VISSIM

In the example show, conflict areas are configured such that all vehicles yield to pedestrians at entry and exit leg crossings. While this is certainly desirable, roundabout yielding is often less than 100%, which may require a different modeling approach. Further, an evaluation of a pedestrian crossing treatment, such as a Rectangular Rapid-Flashing Beacons, requires an alternate coding approach to allow the analyst to specify a percentage of yielding, as well as an increase in that percentage after the treatment is in place. To specify a percentage of yielding below 100%, and to model the effects of crossing treatments, the use of priority rules is recommended to provide more control over the percentage of drivers yielding.

In the example provided in **Figure 12**, priority rules are used to have “yielding” vehicles yield to pedestrians waiting at the crosswalk landing area as well as pedestrians that are already in the crosswalk. Note that only the distance setting of the priority rules is used (**Figure 12a**), with the gap time set to zero. A second priority rule is used to make pedestrians yield to vehicles that are close to the crosswalk or about to pass the crosswalk (**Figure 12b**). For pedestrians, the gap time setting of priority rules is used to allow pedestrians to also cross in gaps between vehicles. Note that for pedestrians, the distance parameter of priority rules is set to zero. If desired, multiple “types” of pedestrians could be modeled to accept more or less aggressive gaps.

12a. Vehicle Priority Rules

12b. Pedestrian Priority Rules

Figure 12:Modeling Pedestrians and Yielding Behavior in a Roundabout using Priority Rules

3.3.2 Bicycles in Roundabouts

At roundabouts, bicycles may be accommodated through protected bike lanes, shared lanes, or multi-use paths. As a result, modeling bicycles in VISSIM are dependent on the type of facility provided for cyclists. This section provides guidance on modeling bicycles in roundabouts using VISSIM.

3.3.2.1 Multi-use Paths

Multi-use paths are coded as separate links and connectors that are shared by bicycles and pedestrians. Bicycle speeds should be adjusted on a multi-use path to reflect cyclists slowing down for pedestrians. All conflict points for cyclists are modeled similar to pedestrians, with the consideration that gap acceptance times for cyclists may be shorter than for pedestrians.

3.3.2.2 On-street bike lanes

On-street bike lanes in VISSIM are modeled as a wide outside lane on the approach to the roundabout, and not as a separate link. The lane positioning algorithm in VISSIM should be specified for "right side rule", resulting in cyclists staying on the right-hand side. Overtaking within the same lane should be allowed for vehicles passing cyclists.

Generally, no bike lanes are provided within the circulating lane of a roundabout for safety reasons, and cyclists can traverse the roundabout either in a multi-use path, or claim the travel lanes. For multi-use paths, all bicycle routes should leave the roadway through a connector onto the multi-use path in advance of the roundabout. For cyclists remaining in the roundabout, the travel lane width should be reduced (no bike lane in circle), and the lane positioning for cyclists changed to "center". No passing of cyclists by vehicles should be allowed within the roundabout. The bike lane is continued after exiting the circle (wide outside lane, right-side rule, in-lane passing allowed).

3.3.2.3 Modeling Protected Bike Lanes

A protected bike lane should be modeled as a standalone link for cyclists, since physical separation is provided. All conflict points between the protected bike lane and either travel lanes or pedestrian sidewalks are controlled by conflict areas or priority rules as appropriate. Protected bike lanes may be continued through the roundabout using "protected intersection" concepts or may be terminated in advance of the roundabout similar to on-street bike lanes.

3.3.2.4 Shared Lanes

For many single-lane roundabouts, cyclists may be accommodated through shared lanes. In this case, cyclists are expected to claim the lane while traversing the roundabout, and no passing by vehicles is allowed. In VISSIM the lateral lane position of cyclists should be set to "center" and no within-lane passing should be allowed for vehicles.

4 Roundabout Calibration

The calibration of microsimulation traffic models is a key component to the success of the simulation modeling projects. Calibrating roundabout models is critical as assumptions related to VISSIM's driving behavior and gap-acceptance parameters may influence simulation results considerably. This section discusses the process for the calibration of roundabouts in VISSIM. First, key calibration parameters to be considered by the analyst are presented. Then, key calibration measures that can be extracted from VISSIM are presented.

4.1 Key Calibration Parameters

VISSIM's driver behavior model consists of car-following, gap acceptance, lane changing, lateral positioning, and signal control models. Among these five models, the car-following and gap acceptance models are the most critical for the calibration of roundabouts as the assumptions and parameters of these algorithms alter the follow-up headway and acceptable gap times.

Conceptually, a roundabout without conflicting traffic is controlled primarily by the car-following algorithm, and headway settings in the car following logic directly control follow-up times upon entering the roundabout. Conceptually, the car-following model controls the *intercept* of the roundabout capacity relationship when compared to field data or the HCM 6th Edition.

As entering vehicles have to yield to circulating traffic, the gap acceptance algorithm in VISSIM controls the capacity. Gap acceptance settings in the conflict area module controls how aggressive drivers are upon entering the circle, thereby directly impacting capacity. Conceptually, the gap acceptance model controls the *slope* of the roundabout capacity relationship when compared to field data or the HCM 6th Edition.

4.1.1 Car-Following Model

VISSIM uses two different car-following models; Wiedemann 74, more suitable for urban traffic; and Wiedemann 99, more suitable for freeway traffic. As a result, it is recommended that the Wiedemann 74 model is used for the roundabout analysis as the operations within a roundabout is similar to urban traffic behavior.

According to the Wiedemann 74 car-following model, the distance between two vehicles is calculated by the following model parameters:

- *Average standstill distance*: the average desired distance between two stopped vehicles, and
- *Additive and multiplicative part of safety distance*: parameters that affect the computation of the safety distance. The *additive* portion describes the fixed average headway; the *multiplicative* portion further adjusts the headway as a function of vehicle speed.

Based on the algorithm, changes in these model parameters affect the follow-up headway, and thus roundabout capacity. Specifically, an increase in the safety distance parameters will result in an increase safety distance (more space/time between vehicles), and thus a decrease in capacity (fewer vehicles per hour per lane). It is recommended that the analyst start with VISSIM's default parameters and make necessary adjustments to model parameters based on the selected calibration measures. Detailed guidance on the calibration measures is provided in Section 4.2.

Car following behavior should be calibrated from field data or capacity relationships in the HCM 6th Edition or local/state defaults. Car following primarily impacts the intercept of the capacity relationship, and the VISSIM results should be evaluated under periods of little or no conflicting volume. Field data may be derived from direct measurement of capacity (one-minute observations of vehicle queuing, expressed in flow rates of vehicle per hour), or inferred from measurements of saturation headway and follow-up times at roundabouts. More guidance is provided in the HCM 6th Edition or the FHWA Roundabout Informational Guide.

4.1.2 Yielding Behavior and Gap Acceptance

Yielding behavior influences the driving behavior of any vehicle at the approach entry and determines when a driver accepts (or rejects) a gap to safely enter the circulating traffic. The gap acceptance parameters in the conflict area or priority rule modules in VISSIM control the minimum size of an acceptable gap (priority rules), or the front-gap and rear-gap portion of the gap before/after a conflicting vehicle passes the conflict point (conflict areas). An increase in these gap acceptance values will result in more conservative yielding behavior, and therefore a reduction in capacity.

Gap acceptance behavior should be calibrated from field data or capacity relationships in the HCM 6th Edition or local/state defaults. Gap acceptance primarily impacts the slope of the capacity relationship, and the VISSIM results should be evaluated under periods of varying conflicting volume levels. Ideally, a capacity calibration experiment should be set up to gradually increase conflicting circulating flow, while keeping a high entering demand constant. Field data may be derived from direct measurement of capacity (one-minute observations of vehicle queuing, expressed in flow rates of vehicle per hour), or inferred from measurements of critical gap values at roundabouts. More guidance is provided in the HCM 6th Edition or the FHWA Roundabout Informational Guide.

4.2 Key Calibration Measures

This section discusses the main calibration parameters available in VISSIM that can be used during the calibration of roundabouts. The following measures are recommended to be used in VISSIM as part of the calibration process. It should be noted that typically the calibration of models is achieved by comparing measures obtained from VISSIM to field-measured data. However, in certain cases where roundabout field data may not be available (e.g. new designs), it is recommended for the analyst to rely on theoretical numbers outlined in the literature (e.g., Highway Capacity Manual (HCM) 6th Edition models) or field measured data from nearby roundabouts with similar roundabout design and driving behavior characteristics.

- Roundabout capacity,
- Travel time,
- Queue lengths, and
- Visual calibration.

4.2.1 Roundabout Capacity

Roundabout capacity is defined as the maximum flow rate that can be accommodated at a roundabout entry. The capacity of a roundabout depends on two factors: the circulating flow on the roundabout that conflicts with the entry flow, and the geometric elements of the roundabout.

In order to obtain the true capacity at any facility, the arriving traffic demand should be greater than the supply. Therefore, if the roundabout is under capacity, a hypothetical scenario should be created first in VISSIM by artificially increasing entry traffic volumes to ensure the model is oversaturated. Then, by varying the circulatory flow, the analyst can estimate maximum entry flows from VISSIM and compare the results to the theoretical capacity or nearby roundabouts, as discussed above. **Figure 13** provides an example where the roundabout right entry lane capacity was used as the measure to calibrate a multilane roundabout. In this example, the model was run with variable circulating volumes and the associated entry flow (capacity) was obtained from the model both for the right lane and the left lane. Then, the calculated capacity values from VISSIM with default parameters and adjusted parameters for calibration were compared to the HCM 6th Edition models for the multilane roundabout.

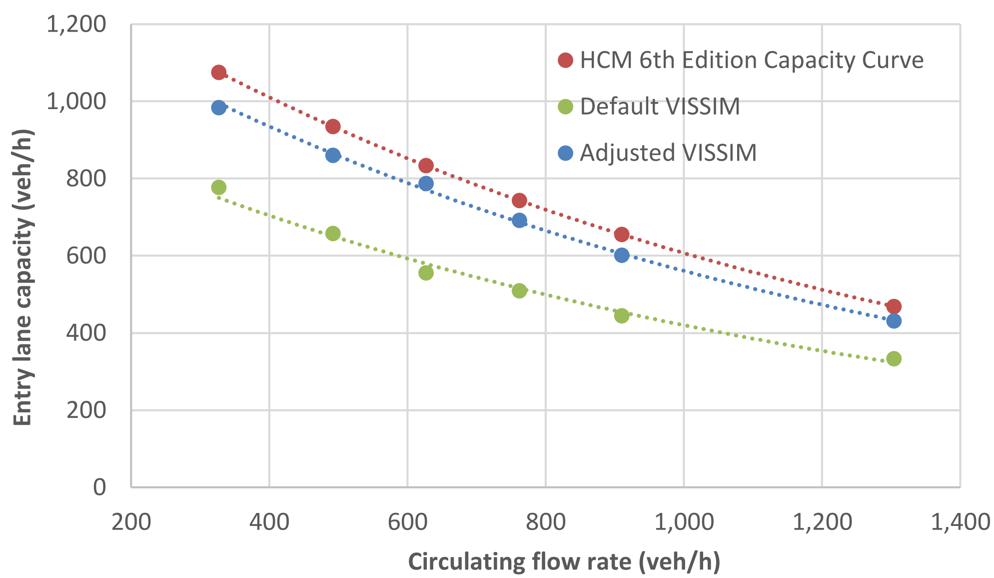


Figure 13: VISSIM Roundabout Capacity Calibration for a Multilane Roundabout using the HCM 6th Edition Model Values as the Theoretical Capacity

The figure indicates that while VISSIM's default parameters resulted in substantially lower entry lane capacity compared to the HCM 6th Edition capacity curve, the calibration adjustments in the default model parameters increased VISSIM's entry lane capacity considerably, resulting in a capacity curve that is almost identical to the HCM 6th Edition. In this example, it was concluded that the VISSIM model was calibrated since the two curves visually matched and the entry lane capacity difference between the HCM 6th Edition Curve and the adjusted VISSIM model was less than 10 percent for all circulating flow rate volumes. It should be noted that there is no national guidance related to calibration targets (i.e., thresholds where the differences between the model and the field, or a baseline model, are acceptable), however +/- 10 percent can be used as a rule of thumb for the capacity calibration target.

To obtain roundabout capacity, the analyst should define data collection points both for the circulating volume and the entry flow. Continuing from the same example provided above, **Figure 14** shows the location of data points used to collect right lane capacity, left lane capacity, and circulating volume. As previously described in Section 2.1.2, the data collection from the simulation should start after the "warm-up" period. For example, if the "warm-up" period is identified as 600 seconds and if the data will be collected over the peak hour, the analyst should set up the data collection period from 600 seconds to 4,200 seconds, in recording intervals of 60 seconds as shown below, consistent with the HCM capacity calculations, which are based on 1-minute observations.

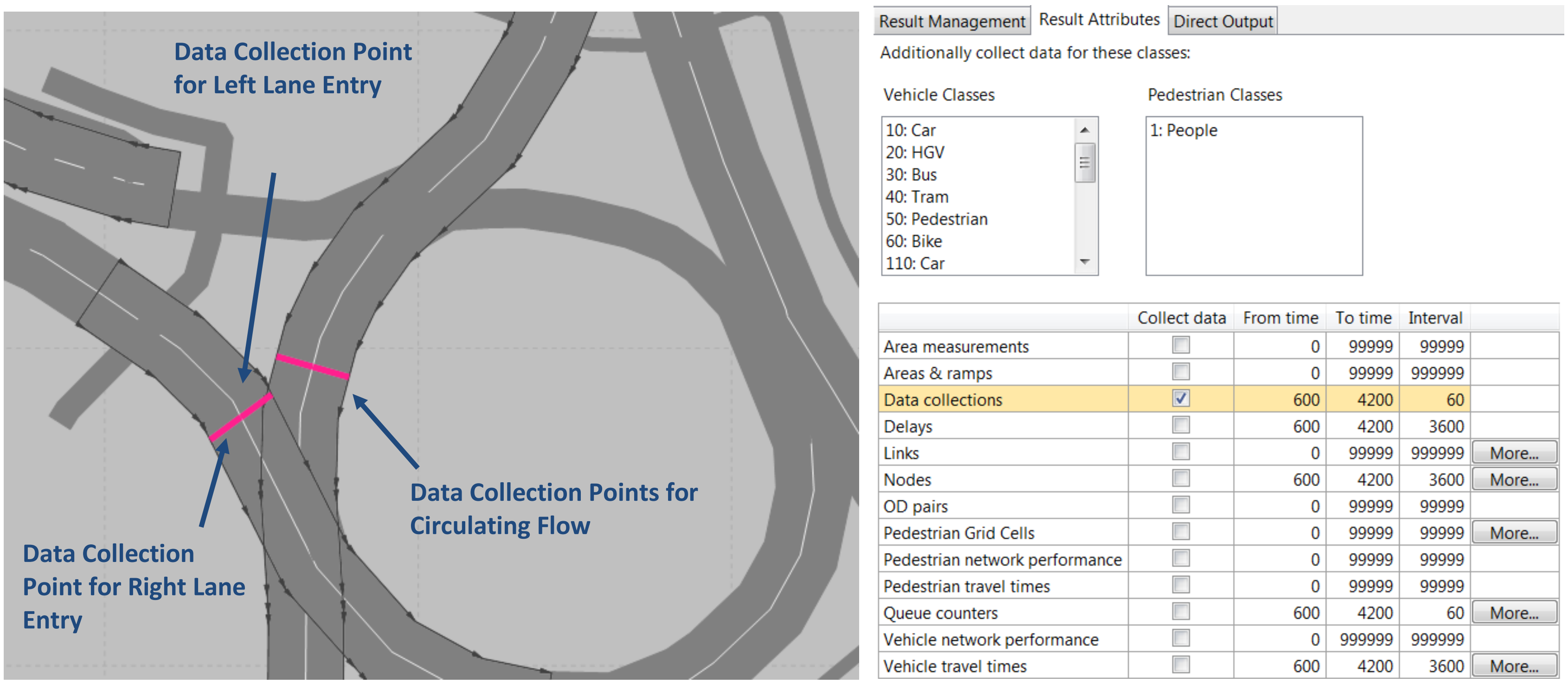


Figure 14: Data Collection Points to Measure Circulating Volume, Right Lane and Left Lane Entry Volumes for Roundabout Capacity Calibration

4.2.2 Travel Time

Travel time is another key metric that can be used for the calibration of roundabouts. For roundabouts that exist today (i.e., not a proposed design), field measured travel time should be compared to the travel times obtained from the VISSIM model. Field travel time data can be obtained through “floating car runs”. In addition, if available, other resources such as probe data or Bluetooth data can be used to collect field travel time runs, although those sources typically a more adequate for longer segments.

Calibration targets may vary according to the purpose for which the microsimulation model is being developed and the resources available to the analyst. Below provides an example of travel time calibration targets that were developed by Florida DOT.[3]

- *±1 minute (60 seconds) for routes with observed travel times ≤ 7 minutes (420 seconds)*
- *±15% for routes with observed travel times > 7 minutes (420 seconds)*

Figure 15 shows how to code vehicle travel time segments in VISSIM and describes the process to collect travel time results from the simulation model. The vehicle travel time in the given example is collected for the eastbound left approach over the peak hour, following a 600-seconds "warm-up" time. Data can be recorded in hourly (3600 seconds) or 15-minute (900 seconds) intervals, depending on how traffic conditions vary across the analysis period.

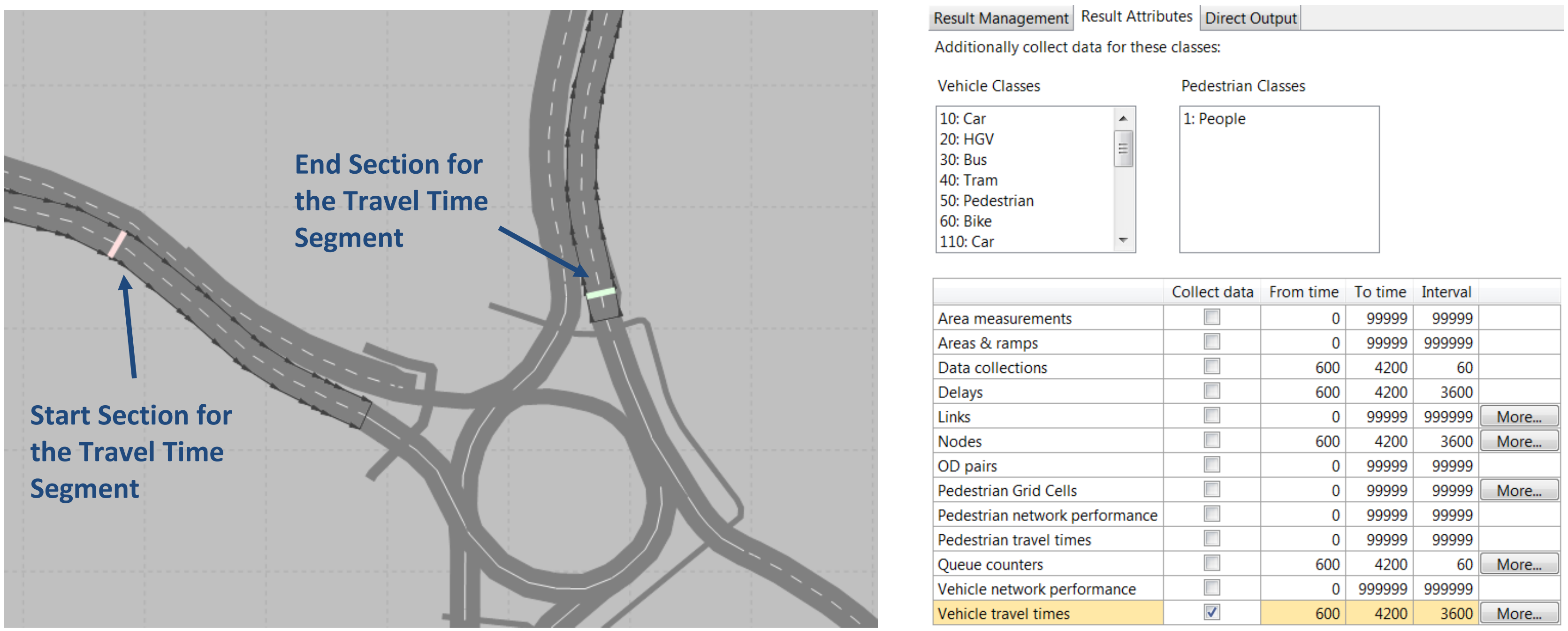


Figure 15: Defining Vehicle Travel Time Segments and Collecting Travel Times in VISSIM

[3] http://www.fdot.gov/planning/systems/programs/SM/intjus/pdfs/Traffic%20Analysis%20Handbook_March%202014.pdf

4.2.3 Queue Length

Similar to the field measured travel time data, queue length is another measure that can be used for the calibration of existing roundabouts. Queue lengths can be collected using standard traffic engineering techniques such as recording the back of queue lengths at set intervals (e.g., 30 seconds) at a roundabout entry. A longer interval may be required (e.g., 1 minute) if the queue is difficult to obtain at shorter intervals. The field collected queue lengths can then be compared to the queue length results obtain from the simulation. The recording interval of queue measurements in VISSIM should be set to match the recording interval of field data. The measure of interest is the "maximum back of queue" within the recording interval, NOT the average queue across that interval. Below provides an example of queue length calibration targets that were developed by Florida DOT:[3]

- *The difference between simulated and observed queue lengths to be within 20%.*

Queue lengths can be determined either using queue counters or node evaluation in VISSIM. Queue counters allow collecting queue data at any point in the VISSIM network and evaluated for any time interval. Node evaluation allows collecting various measures, including queue data, from roundabouts (or intersections) without having to define all sections manually, therefore generally preferred if multiple metrics are obtained from the simulation.

Figure 16 describes modeling queue counters in VISSIM and shows how queue data can be collected through queue counters. Similar to the previous examples, a "warm-up" period of 600 seconds and data collection period of 3600 seconds (peak hour) was assumed. The aggregation interval should be set to match the recording interval for the field data (e.g. 60 seconds). Section 5 provides additional information on the node evaluation.

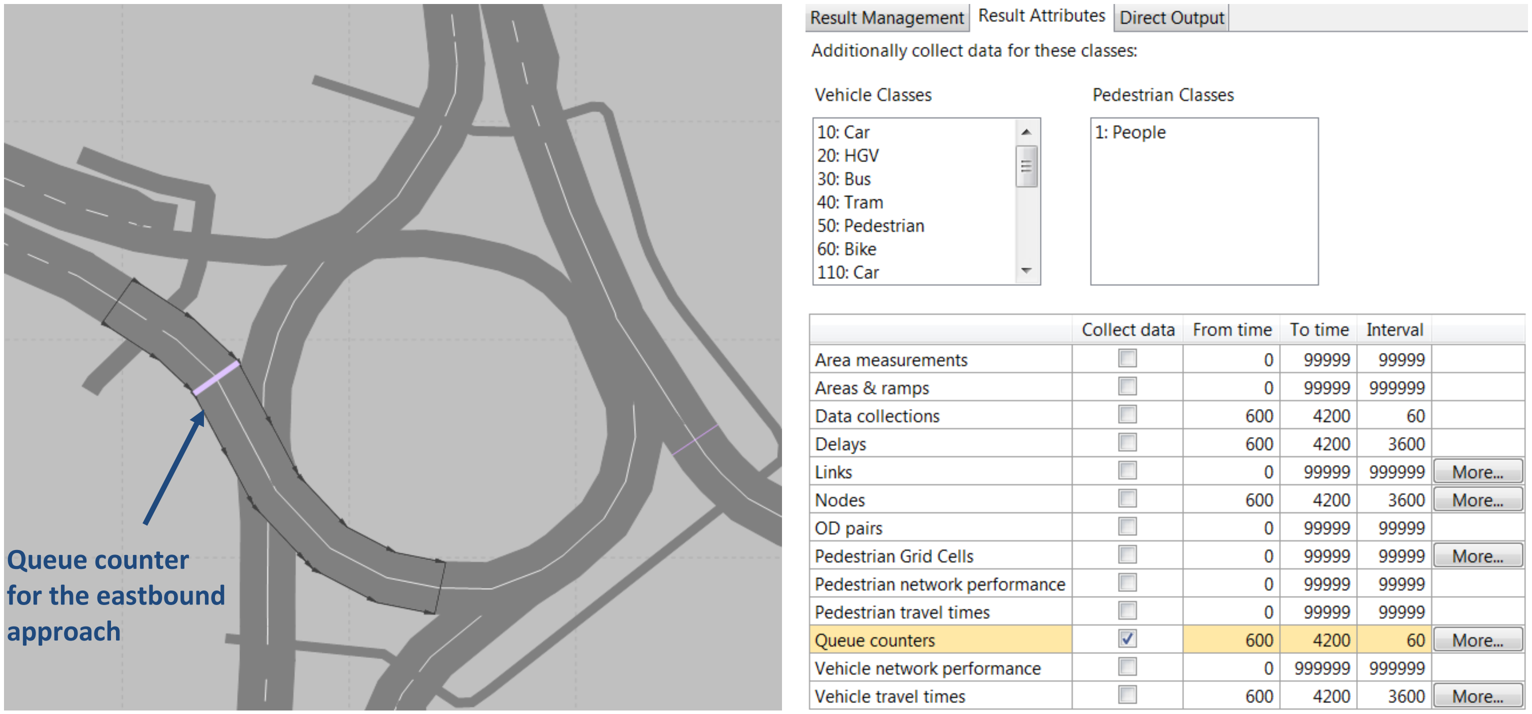


Figure 16: Modeling Queue Counters in VISSIM for Roundabout Queue Calibration

4.2.4 Visual Calibration

In addition to the quantitative measures listed above, performing visual calibration through analyst judgment is essential during the calibration process to ensure to ensure traffic operations are reasonable in the model. The visual calibration may include adjusting and fine tuning the following elements in VISSIM:

- Yielding behavior at the entry links,
- Vehicles getting stuck within the roundabout looking for lane change (applicable for multilane roundabouts),
- Approach, entering, circulating, and exit speeds, and
- Qualitative comparison of queue lengths and comparison with field data (if available) or macroscopic models.

5 Data Collection and Performance Measures

5.1 Key Operational Assessment Measures

The selection of performance measures for operational assessment should be closely tied to the overall objectives and goals of projects (e.g., mobility, reliability, overall system performance, etc.) along with performance standards (thresholds) used by agencies. The selection should be performed such that the findings can provide a complete picture of the analysis and support the decision-making process. The measures should be sensitive to the operating conditions both in the existing conditions and future year scenarios and be meaningful to stakeholders. To the extent possible, the selected measures should provide *multimodal system performance* rather than focusing on a single mode or a single facility. In addition, it is important to be aware of the limitations of the outputs that can be generated by VISSIM coupled with the limitations in available data.

Table 1 provides typical performance measures that can be obtained from VISSIM to conduct operational assessment of roundabouts. The measures were grouped into three key performance areas: *mobility*, *variability*, and *emissions*. While there are several measures that can be collected from VISSIM to analyze roundabouts, the analyst needs to identify the overall objectives of the project before selecting performance measures. This assures that measures are closely tied to the overall goals. For example, if the primary goal of building a roundabout is to improve delay, then the selected measures may include delay, travel time, and average/maximum queue. However, if the objective is to address oversaturation, then the measures should be able to capture the effects of a proposed roundabout on oversaturation such as vehicle throughput, latent (unserved) demand, and the length of congestion period.

Table 1: Typical VISSIM Performance Measures for the Operational Analysis of Roundabouts

Key Performance Area	Performance Measure
Mobility	Delay Level of service (LOS) Travel time Speed Average queue Maximum queue Vehicle throughput Latent (unserved) demand The length of congestion Pedestrian/bicycle delay Pedestrian crossing time
Variability	Extreme travel times Travel time standard deviation
Emissions	Total fuel consumption Number of stops Emissions (e.g., CO, NOx)

Delay, level of service, and queue lengths by approach and by movement are the most common metrics to measure the performance of roundabouts for vehicles, however VISSIM is unable create all these measures automatically and some post-processing will be required by the analyst. The easiest way to collect delay and queue length data is to use “Nodes” in VISSIM and utilize VISSIM’s node evaluation feature. Typically, one node is required for each roundabout or intersection. When the node is defined the first time in VISSIM, the analyst needs to ensure that “Use for evaluation” box is checked under the Node attributes. For details regarding how to define a node and edit node attributes, please refer to the PTV VISSIM User Manual.

Figure 17 shows an example of a node defined in VISSIM to measure roundabout performance as well as the Nodes checked box under Evaluation Configuration that is necessary to collect VISSIM outputs to obtain delay, level of service, queues, and other performance measures (e.g., emissions) where necessary. Similar to the previous examples, a “warm-up” time of 600 seconds and an evaluation period of 3,600 seconds (peak hour) is assumed in the below example.

For a link or movement to be included in the node evaluation, the link needs to cross the node boundary. This is important when wanting to include pedestrian and bicycle movement sin the node evaluation.

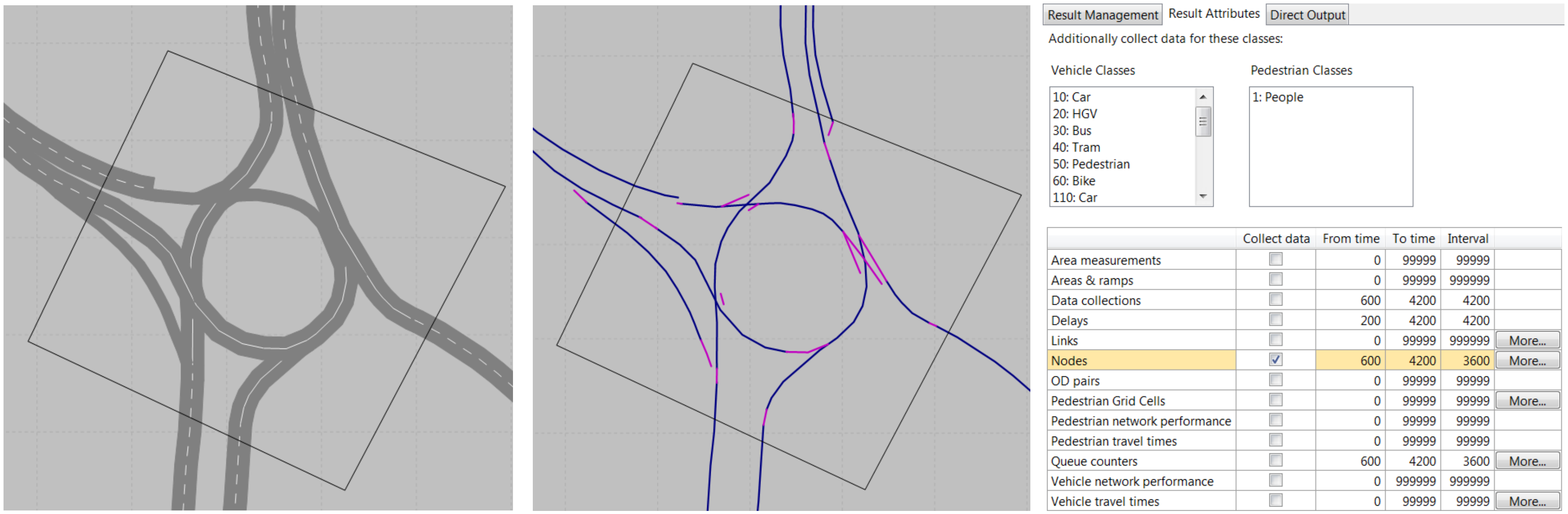


Figure 17: Defining Node in VISSIM for the Evaluation of Roundabouts

Node evaluation in VISSIM uses "start of delay segment", which assumes a certain distance from the node, from which delay time is measured. By default, VISSIM uses 328.1 feet for the delay segment start to collect delay time. While this value can be acceptable in certain cases, particularly when queues are short and bounded within 328.1 feet, under long queues and congested periods, the default delay segment start value will result in underreporting of delay as node evaluation will not be able to capture delay for vehicles beyond 328.1 feet from the roundabout.

As a result, it is critical for the analyst to increase delay segment start, especially when there are long queues, to more accurately capture roundabout delay. A rule of thumb that can be used for the delay segment start is 1,000 feet, which approximately corresponds to a vehicle queue of 40 vehicles. If the effect of congestion leads to even longer queues, then a higher delay segment start value should be defined in the simulation. **Figure 18** illustrates how to change the start of delay segment value in VISSIM. In this example, the default 328.1 feet was increased to 1,000 feet as shown below.

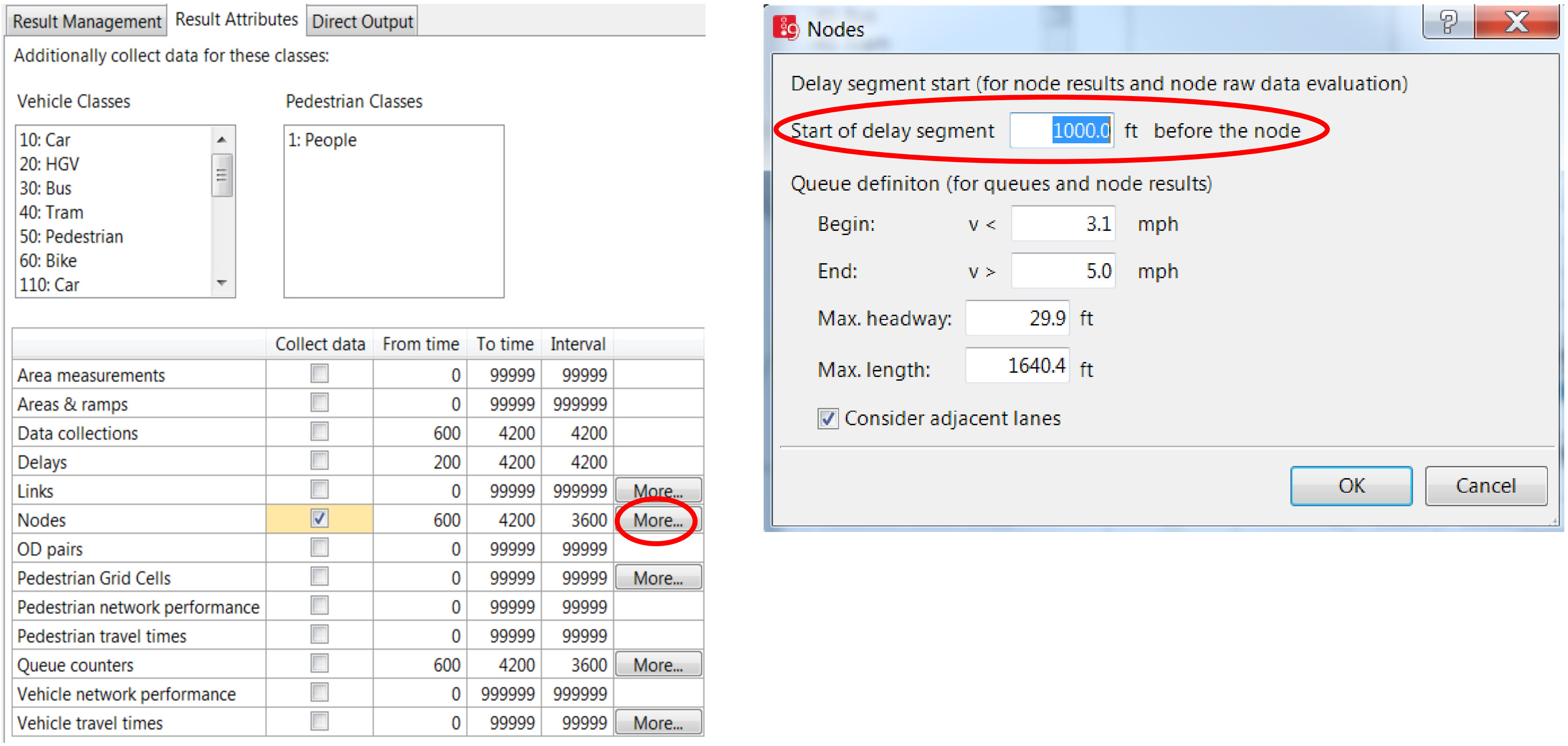


Figure 18: Changing Start of Delay Segment for Node Evaluation in VISSIM

The node evaluation will provide outputs (e.g., delay, queue length, stops, etc.) for each movement crossing the node boundary. Therefore, the analyst needs to post-process the outputs to aggregate approach delay for multiple movements. The approach delay should be calculated as the *volume-weighted sum* of individual movement delays. Total intersection delay and LOS can be calculated the same way, but is also included in the sum-average feature in the node results output. **Figure 19** provides node results example from a roundabout analyzed in VISSIM. The node sum of all movements and average performance across the node are shown as the bottom two rows in the table. All values can be exported to Excel for further processing. Additionally, VISSIM includes various built-in chart generation features to visualize the results.

Node Results

Select layout...

Cou	SimRun	TimeInt	Movement	Movement\Di	QLen	QLenMax	Vehs(All)	Pers(All)	LOS(All)	LOSVal(All)	VehDelay(All)	PersDelay(All)	StopDelay(All)
4	Average	600-4200	1: Damon Road Roundabout	S-E	0.39	46.36	77	77		1	3.75	3.75	0.48
4	Average	600-4200	1: Damon Road Roundabout	S-N	14.97	136.36	514	514		2	11.44	11.44	5.48
4	Average	600-4200	1: Damon Road Roundabout	S-N	0.23	35.47	13	13		1	0.00	0.00	0.00
4	Average	600-4200	1: Damon Road Roundabout	N-E	20.65	146.96	822	822		2	11.21	11.21	4.33
4	Average	600-4200	1: Damon Road Roundabout	S-N	0.21	16.20	10	10		2	9.31	9.31	7.15
4	Average	600-4200	1: Damon Road Roundabout	N-S	0.00	0.00	14	14		1	0.00	0.00	0.00
4	Average	600-4200	1: Damon Road Roundabout	N-S	0.06	27.98	4	4		1	0.00	0.00	0.00
4	Average	600-4200	1: Damon Road Roundabout	Total	4.56	157.93	2292	2292		1	6.93	6.93	2.83
4	Average	600-4200	2: Damon Road Roundabout	N-S	4.16	225.65	1239	1239		1	7.49	7.49	0.31

Figure 19: VISSIM Node Results Example

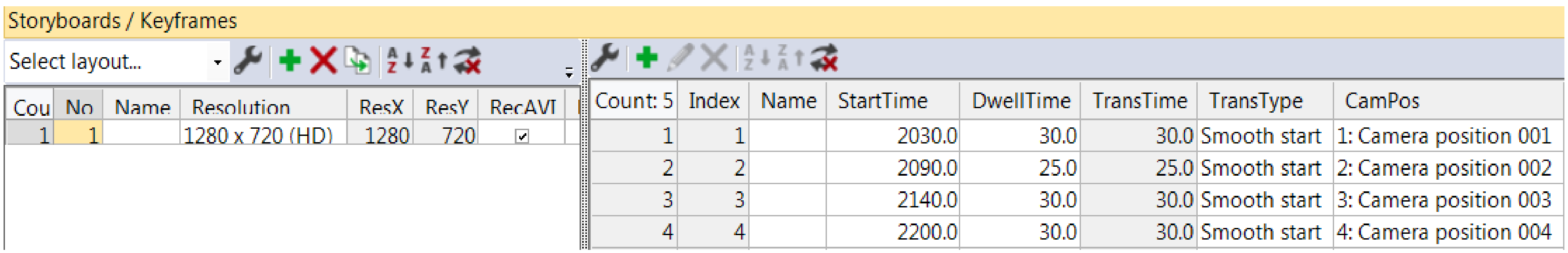
5.2 Visualization

In addition to providing an operational assessment of roundabout performance, there is a strong interest from agencies to use VISSIM as an animation/visualization tool. The following provides key steps to creating visually appealing roundabout animation in VISSIM:

1. Create a high-resolution file that can be used as the background map. VISSIM can support several different image file types such as AutoCAD, JPEG, Bitmap, etc. (please see PTV VISSIM User Manual for details).
2. Once the background map is inserted, the background map can be scaled and positioned (if necessary) so the network (i.e., links and connectors) can be developed on the background file. That way, the network will be overlaid exactly on the background map.
3. When the model is developed and ready to be recorded for animation/visualization, the analyst should turn off the object visibility for links. The reason for turning off the link visibility is to allow simulated vehicles to drive on the background image, which typically looks more realistic than the links created in VISSIM.
4. The next step to creating an animation is to set up camera positions (keyframes) with the network view of your choice. Multiple camera positions can be defined in VISSIM if the analyst creates an animation with different angles.
5. The final step before running the model and creating an animation is to define a storyboard with keyframes. A storyboard allows an analyst to define basic settings for recording of a simulation. For each camera position, it is typical to assign a camera position to each key frame. For each keyframe, a dwell time needs to be specified, which determines the amount of time the assigned camera to the keyframe will dwell in that position during recording. The transition time will be calculated by VISSIM automatically based on the start time of the previous keyframe, the dwell time, and the start time of the next keyframe.
   It is important to note that to record an animation, the analyst must define at least one key frame with a camera position and a dwell

time and assign it to a story board. **Figure 20** provides an example of a storyboard with four defined keyframes. The first keyframe starts at simulation time 2030 seconds with a dwell time of 30 seconds. Camera position 1 is assigned to this keyframe. Similarly, the next key frame starts at time 2090 seconds in the simulation, and therefore the transition time between the first keyframe and the second one is 30 seconds (2090 seconds minus 2060 seconds). For detailed information, please refer to the PTV VISSIM User Manual.

For successful animation recording, the analyst needs to specify a resulting file name and resolution, which impacts playback and file size. A video codec is used to compress the video file, while maintaining acceptable file quality. An uncompressed video file can quickly grow to several hundred megabytes. The preferred codec for VISSIM video recording is the XVID codec, which can be downloaded off the internet. The codec needs to be installed prior to launching VISSIM, and will then be automatically available in the storyboard menu.



Cou	No	Name	Resolution	ResX	ResY	RecAVI
1	1		1280 x 720 (HD)	1280	720	☑

Count: 5	Index	Name	StartTime	DwellTime	TransTime	TransType	CamPos
1	1		2030.0	30.0	30.0	Smooth start	1: Camera position 001
2	2		2090.0	25.0	25.0	Smooth start	2: Camera position 002
3	3		2140.0	30.0	30.0	Smooth start	3: Camera position 003
4	4		2200.0	30.0	30.0	Smooth start	4: Camera position 004

Figure 20: Storyboards/Keyframes Example in VISSIM to Create Animations/Visualizations

6 Peer Review Checklist

This section develops a process for reviewing roundabout simulation models involving evaluations by independent sub-consultants. **Table 2** summarizes key elements that should be considered at each step of the review for developing and analyzing roundabout simulation models in VISSIM.

Table 2: Roundabout VISSIM Simulation Peer Review Items

Model Element	Peer Review Item
Simulation parameters	• Review core simulation parameter settings including simulation period, simulation resolution, and number of simulation runs and determine if adjustments are needed • Ensure the number of runs selected and warm-up time are identified properly
Network coding	• Check whether all segments are coded in the network including pedestrian and bicycle network elements (e.g., crosswalks, protected bike lanes, etc.) • Check that geometric network elements (i.e., links and connectors) are coded properly • For multilane roundabouts, check coding of spiral markings
Speed Control	• Review approach, entering, and circulating speeds coded in VISSIM including reduced speed areas and desired speed decisions • Check that desired speed distributions (i.e., lower speed bound, upper speed bound, and speed distribution) defined in the model are realistic
Yielding Behavior	• Review yielding behavior for merge, diverge, and crossing (crossing conflicts are applicable for only multilane roundabouts) • Review yielding behavior to pedestrians and bicycles in a roundabout
Lane Change Assumptions	• For multilane roundabouts, check lane changes assumptions (i.e., start and end location for the no lane change)
Traffic Demand	• Check entry demand volumes and profiles (e.g., 15-minute profile, hourly profile, etc.) including pedestrian and bicycle volumes • Check the coding of the routing decisions to ensure routing decisions are consistent with the roundabout volumes • Check vehicle compositions and relative flow assumptions being used (vehicle types, vehicle occupancy, etc.) • Check the vehicle model distribution and make sure it is consistent with the vehicle fleet type based on the collected traffic data (e.g. North American Default)
Heavy Vehicles in Multilane Roundabouts	• Review no passing an oversize vehicle within a roundabout for multilane roundabouts
Multimodal Modeling	• Check the assumptions regarding bicycle lane termination • For bicycles in circle, check lateral lane position and overtaking rules • For pedestrian crossings, evaluate need for percent yielding less than 100% and consideration of pedestrian crossing treatments

Model Element	Peer Review Item
Calibration	• Review the calibration approach followed as well as the thresholds being used • Review driving behavior and link behavior types. If there are any adjustments to the default VISSIM parameters, check appropriateness of these adjustments • Review calibration results to determine whether calibration results meet the thresholds identified by the project team • Run simulation to conduct visual calibration of simulation models and identify anomalies • Review whether model adjustments for calibration are consistent across scenarios
Data Collection and Performance Measures	• Review the proposed data collection measures for calibration as well as for the assessment of roundabouts • Review whether MOEs are consistent across scenarios • Check the location of proposed data collection points coded in the model • Review data collection start time as well as data collection duration period for the selected MOEs to make sure the data collection period does not include warm-up time • If Node Evaluation is used, review start of delay segment for Node Evaluation to determine whether the default value of 328.1 feet was used in VISSIM. If the network experiences long queues and congestion, suggest increasing this value to incorporate vehicles getting delay beyond 328.1 from the node.