

Some Guidelines for Selecting Microsimulation Models for Interchange Traffic Operational Analysis

By

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ABSTRACT

There are several commercially available traffic simulation packages that are able to model the full range of interchange ramp terminals. Each of these packages has pros and cons for simulating various types of interchanges and traffic control plans. Previous research has studied specific simulators in terms of their capabilities for simulating single urban point interchanges (SPUIs) and diamond interchanges. There is no guidance provided however on how to generally select appropriate simulators based on their capabilities and internal algorithms for analyzing specific interchange design and control scenarios. This paper focuses on identifying the elements that should be available in a simulator in order to evaluate a specific interchange scenario (including type, geometry and traffic control characteristics). The paper does not identify all the specific packages that are appropriate for a specific scenario because these evolve constantly; even though the current version of a package may not support a particular function, future versions of that package may incorporate it. Thus, identifying the most appropriate package would very quickly become obsolete. It is up to the analyst to examine whether a particular characteristic or algorithm is present in a specific package.

To accomplish this, three simulators were selected and studied: AIMSUN, CORSIM and VISSIM. Data from two interchanges (one SPUI and one diamond interchange) at Arizona were obtained and used in the assessment of these packages. The model parameters and assumptions are examined for each model. Simulation is conducted first by using default parameter values followed by a calibration process to adjust parameters related to driver behavior, vehicle performance, and others. In conclusion, several elements are identified as critical in simulating interchanges, which fall in the following categories: 1) the capability of representation of specific geometric characteristics; 2) the capability of simulating specific signal control plans; 3) calibration needs and accuracy in comparison to field conditions; and 4) the extraction of specific performance measures from the simulator.

1. INTRODUCTION

Traffic simulation is a computer-based system that models the dynamic traffic flows over a time horizon for a given facility (1). Traffic simulation models can be applied to study complex situations when analytic approaches may not be appropriate or to test alternative scenarios in the computer, without altering the actual system, which may be very costly and/or unsafe. Because of these major advantages, simulation has become an essential tool in traffic operational analysis.

Interchanges are critical components of the highway network. They provide the connection between various highway facilities (i.e., freeway-arterial, arterial-arterial, etc.) and thus their safe and efficient operation is essential. There are various types of interchanges including the diamond interchange, the Single Point Urban Interchange (SPUI), etc. The operation of an interchange with two closely-spaced intersections is complicated due to the existence of interacting queues, intensive weaving, and unbalanced lane utilization due to heavy turning movements. Thus, their signalization presents some major challenges for which the use of analytical and empirical models is often not suitable. In such cases, simulation modeling is a better approach, however there is no guidance available on what characteristics and algorithms should a simulator have for modeling interchanges. This paper focuses on identifying some

elements and algorithms that should be available in a simulator in order to evaluate a specific interchange scenario (including type, geometry and traffic control characteristics). The paper does not identify all the specific packages that are appropriate for a specific scenario because these evolve constantly; even though the current version of a package may not support a particular function, future versions of that package may incorporate it. Thus, identifying the most appropriate package would very quickly become obsolete. It is up to the analyst to examine whether a particular characteristic or algorithm is present in a specific package.

There are a variety of simulation tools available for studying interchanges. The function and capabilities of these models differ widely, and selection of the most appropriate model for a given case would depend on a variety of factors, including the characteristics and requirements of the site/interchange, the objectives of the study, ease of use and familiarity of the user with a given model. In this research, three widely used traffic simulation packages, namely, AIMSUN, CORSIM and VISSIM were selected for evaluation and comparison. There are other packages that are also capable of simulating interchanges; these three are used in this study because a) the researchers are familiar with them, and b) because they are representative of the wide variety of commercially available microscopic and stochastic traffic simulators. All three models are microscopic and stochastic. They all provide in their output the following performance measures: Delay, Average Travel Time, Speed on a Segment/Link, Number of Stops and Average Queue, although their exact definitions differ between models.

Past research (e.g., 2, 3, 4 etc.) has applied simulation tools on evaluating several aspects of interchange operations, focusing on the selection of an appropriate interchange type and performance measures output comparison of each model. There is no study conducted to investigate the important and unique elements required for simulating interchanges and no guidance provided on how to assess the capabilities of simulation packages. The calibration process is not explicitly addressed in previous research on interchanges. There are several papers however that deal more generally with the calibration of traffic simulators (e.g., 5, 6, 7, etc.)

The main objective of this research is to evaluate the capabilities of three commercially available simulation models with an extensive assessment on calibration parameters, and identify these elements that are critical in the simulation of specific interchange scenarios. These elements include geometric layout characteristics, signalization, calibration needs, output performance measures provided and accuracy of the results relative to field-measured values. Unsignalized interchanges are not considered in this paper.

To achieve this objective, data from two interchanges (one diamond interchange and one SPUI) at Arizona are obtained. The model parameters and assumptions are examined for each model. In simulating these two interchanges, several issues were identified that pertain to each package regarding their capabilities and limitations. Simulation is conducted first by using default parameter values. This is followed by a calibration process to adjust parameters related to driver behavior, vehicle performance, and others. Delay was selected as the performance measure to be used in the comparison of simulation output.

The following section gives an overview of past research and a short description of each simulation package considered in this study. Section 3 discusses the field data assembly, the

sample size determination for simulation runs and the research methodology. Section 4 discusses the simulation with default values, while section 5 deals with the calibration of each model. Simulation assumptions, inputs and results are also presented in these sections. Conclusions and recommendations are provided in the last section.

2. LITERATURE REVIEW

There are several studies in the literature on the evaluation of various simulation models for simulating interchange ramp terminals. Radwan and Hatton (2) assessed five programs in terms of their abilities to simulate two types of interchanges: SPUI and conventional diamond interchange. Garber and Fontaine (3) developed guidelines for preliminary selection of the optimum interchange type at a location based on synthesizing the results of literature review, survey, operational analysis by CORSIM and accident analysis. Selinger and Sharp (4) developed a workflow to select an interchange configuration between SPUIs and tight urban diamond interchanges with the use of SYNCHRO, PASSER III and CORSIM in sequence. Past research has not identified which elements and algorithms should be incorporated in a simulator so that it can adequately evaluate a specific interchange. Calibration parameters related to interchanges have not been examined and evaluated, however there are several papers that have discussed calibration of traffic simulators more generally.

Milam and Choa (5) presented an initial set of recommended guidelines for the calibration and validation of simulation models based on literature survey, interviews with practitioners and simulation results from successful projects. The guidelines discussed the calibration of model parameters, traffic flow characteristics and drivers' behavior. Hourdakakis and Michalopoulos (6) developed a calibration process for freeway simulation based on volume, speed calibration and the specific purpose of the simulation. In each stage of calibration, the global parameters (e.g., vehicle characteristics, etc.) are calibrated first followed by local calibration (e.g., speed limits of sections). Park and Schneeberger (7) discussed VISSIM calibration for a coordinated actuated signal system. The importance of statistical tests and simulation visualization were addressed in the paper.

The three simulation packages selected, namely CORSIM, VISSIM and AIMSUN, are stochastic and microscopic simulation models, and can simulate arterial and freeway operations, and a wide variety of highway geometric characteristics, traffic control and signalization functions. CORSIM (8) was developed by the Federal Highway Administration (FHWA) in the mid-1970s. AIMSUN (9) was developed by TSS (Transportation Simulation Systems) in Spain. Both AIMSUN and CORSIM networks are based on a link-node representation. VISSIM (10) was developed by PTV AG, Germany. It employs links and connectors to form its network, rather than nodes and links.

3. METHODOLOGY

3.1 Overview

The main objective of this research is to evaluate the capabilities of several commercially available simulation models, assess their calibration parameters, and identify elements that are critical in the simulation of specific interchanges. These elements include geometric layout

characteristics, signalization, output performance measures provided and accuracy of the results relative to field measured values. To achieve this objective, field data from two interchange sites (one SPUI and one diamond interchange) are first assembled and input into each simulator. For each site, the input data for simulation are classified into four types: 1) geometric characteristics; 2) signal timing plan and signal controller settings; 3) traffic demand; 4) other features such as vehicle and driver characteristics and free-flow speed. For calibration purposes, control delay by movement was obtained for the two sites. Next, simulation is conducted for these two sites by each simulator, and results are compared in two stages: pre-calibration and post-calibration. Calibration is the process by which model parameters are adjusted so that the selected performance measure(s) are in agreement with field measurements. The pre-calibration stage involves the comparison of the simulation output when the default values of each parameter (other than the available input data) are used. The comparison of the pre-calibration results to the field data provides an indication of calibration requirements for each simulator. If the results are not reasonable approximations of the field delay, the simulation model is calibrated to replicate field conditions at the two sites, as closely as possible. The post-calibration results are also compared to the field results, to assess the calibration capabilities of the models as well as their accuracy in replicating field conditions at interchanges.

3.2 Performance Measures

As indicated above, control delay was measured in the field at the two study sites, using the current Highway Capacity Manual (HCM, 2000) (I) methodology. Each simulator however defines delay in a different manner. The following paragraphs summarize definitions of delay:

Field-Measured Control Delay (HCM 2000):

Control Delay (sec/veh) is defined in the HCM (p. 5-3) as follows: “The component of delay that results when a control signal causes a lane group to reduce speed or to stop; it is measured by comparison with the uncontrolled condition.” The technique provided in Appendix A of Chapter 16 (HCM 2000) allows for measurement of “time-in-queue” and provides correction factors for consideration of acceleration and deceleration – related delay.

CORSIM:

Control Delay (sec/veh) is defined as the difference between the actual travel time and the travel time if constantly moving at the vehicle’s operating speed prior to deceleration. This operating speed is lower than free-flow speed, to account for traffic interactions.

VISSIM:

Average Total Delay (sec/veh) is defined as the difference between the desired travel time and actual travel time. The desired travel time is obtained by a user-defined desired speed distribution. This distribution can be specified for each approach, movement, and vehicle type.

AIMSUN:

Delay Time (sec/veh) is the average delay time per vehicle, which is the difference between the expected travel time (time it would take to traverse the section under ideal conditions) and the travel time.

As shown above, the exact definitions of delay among models differ. Total delay, as defined in VISSIM and AIMSUN, includes delay due to factors other than the traffic signal (for example mid-block delays.) Control delay focuses on the delay due to the presence of a signal (or other control.) To obtain control delay as defined in the HCM 2000 from a simulator, several runs need to be performed with and without the traffic signal, to obtain the differences in delay due to the signalization (which is the definition of control delay). Another way to estimate control delay is based on time-in-queue as defined in the HCM 2000. Users can obtain it from VISSIM, where time-in-queue is readily available, or other models if they can provide time-in-queue in their output. In this study, we do not attempt to obtain control delay from each of the simulators, because the focus of the paper is the process of calibration, rather than its result. Practitioners that are interested in calibrating a specific model to field data however should compare performance measures defined in the field and in the simulator in the exact same manner.

3.3 Assembly of Field Data

The field data of two sites obtained from Arizona DOT were employed to evaluate the three models: SPUI – Dunlap/I-17, and Diamond Interchange – Indian/I-17, Arizona. Figure 1(a) and 1(b) show the geometry layout of the SPUI and the diamond interchange, respectively. The average free-flow speeds were obtained from videotapes of the study sites. It was also determined from the videotapes that both the diamond interchange and the SPUI had approximately 2% heavy vehicles. The signalization of SPUI employs an actuated four-phase signal plan. It accommodates movements of all four through movements (arterials and frontage roads) and four left turning movements (ramps to arterials and arterials to ramps). The duration of yellow (i.e., 3.9s) and all-red clearance interval (i.e., 2.3 ~6.5s) is long. The diamond interchange is operated by a dual-ring actuated NEMA controller. The signal plan follows a Lead-Lead three-phase signal scheme. Arterial through movement phase has longer duration of minimum and maximum green time than other phases. Pedestrian signal phase can be recalled during arterial and ramp phases at both interchanges. Dual entry is activated in left turn phase for the diamond interchange and in arterial phase for the SPUI.

The control delay measured at the two sites is based on the HCM 2000, Chapter 16, Appendix A technique. Equation A16-1 of the HCM 2000 was used to convert “time in queue” into control delay, as specified in that document. In this field study, the correction factor used to account for acceleration and deceleration – related delay (which is not directly measured by this technique) is 5 sec.

4. SIMULATION OF SELECTED SITES

The required sample size is established to achieve a predetermined precision in the output measures. The confidence level selected is 95 percent, and the tolerance ± 1.5 seconds. The required sample size was estimated for each of the three models, and the maximum required sample size was selected from these three. Thus ten runs were conducted for each model.

4.1 Pre-Calibration (Default Parameter Values)

4.1.1 Overview of Assumptions and Model Inputs

Operations at the two sites were simulated for sixty minutes using each of the three simulators. Each simulator employs a series of different input variables. The researchers evaluated the various model inputs and assumptions to ensure that the models replicate as closely as possible the field operations. For input data not currently available (e.g., car-following parameters) the simulators' default values were used. The following paragraphs provide information on input assumptions, and other model use issues encountered in each model.

CORSIM 5.2 Analysis

SPUI:

Simulation of the SPUI was complicated by the fact that the site has frontage roads. Thus, this SPUI was simulated with three nodes (1, 2, 3), as indicated in the node/link diagram of Figure 2. Nodes 4, 5, 11 and 12 represent the frontage road traffic, while nodes 18 and 19 represent the arterial traffic. The middle node/intersection (1) represents the actual signalized intersection. Two “dummy” nodes (2 and 3) had to be inserted to accurately replicate the geometry of the site, however in the field these two nodes are not actual intersections. Traffic flow through these is regulated by the signalization of node 1, to accommodate the off-ramp movements. The difficulty in simulating this configuration is that, because CORSIM attaches a controller to each node rather than assigning a controller to a set of movements in two or more nodes, it is impossible to add detectors in links arriving to nodes 2 and 3 to actuate the controller of node 1. Thus, pretimed control only could be used to simulate this site in CORSIM.

The possibility of using one node only (and eliminating nodes 2 and 3) to represent the SPUI intersection was also investigated. This configuration however would result in routing all traffic through node 1, and combining the frontage road through movements and left turning movements into the same link, which would significantly alter the actual demands and thus the actuation pattern of the controller at node 1.

Diamond Interchange:

Simulation of the diamond interchange in CORSIM was somewhat simpler than that of the SPUI. Two nodes were used to represent the two signalized intersections. The geometric layout of the diamond interchange can be well represented in CORSIM. As in the simulation of the SPUI however, actuated control could not be simulated accurately at this site, because CORSIM attaches a controller to each node rather than assigning a controller to a set of movements in two or more nodes. Thus, pretimed control only could be used to simulate this site in CORSIM.

VISSIM 4.1.2 Analysis:

SPUI:

VISSIM may simulate a wide variety of vehicle types. In this project the default traffic composition was used, which consists of: car 1 (26%), car 2 (18%), car 3 (18%), car 4 (18%), car 5 (16%), car 6 (2%). The percent of heavy vehicles was determined in the field as 2%. The

characteristics of each type of vehicle (i.e., maximum acceleration, maximum deceleration, etc.) are the default values provided by VISSIM. Urban driver behavior was assumed. One of the input requirements for VISSIM is desired speed distribution for each approach. It was assumed desired speeds are those prevalent under low demand conditions, and they were obtained from the videotapes by collecting speed data during low demand conditions. For each approach, speeds were collected for vehicles that were uninhibited by other traffic and by traffic control (i.e., speeds were collected at low flows, and when the approach had the green).

VISSIM has the capability to simulate a controller that can control more than one intersections, thus actuated control at this site can be simulated. In general, however, actuated control in VISSIM was very difficult to program, as it required programming, rather than simple data entry.

Diamond Interchange:

The assumptions used in the simulation of the diamond interchange were the same as those used for the SPUI. Field-measured speed distributions were also obtained from the videotapes of this site for each approach.

AIMSUN 4.1.2 Analysis:

SPUI:

AIMSUN requires the field-measured free-flow speed for each section and turning movement, which were obtained from the videotapes. Vehicle types used include the categories “Car” and “Truck”. Their characteristics (i.e., maximum desired speed, maximum desired speed, maximum acceleration, speed acceptance, etc.) used were the default values provided by AIMSUN. AIMSUN has the capability to simulate a controller that can control more than one intersections, thus actuated control at this site can be simulated. The controller function in AIMSUN provides a function to group a set of signal groups of different intersections into a single group.

Diamond Interchange

The assumptions used were the same as for the SPUI, except that the maximum desired speed for trucks was changed to 62 mph, to better reflect the field-measured free flow speeds.

4.1.2 Pre-Calibrated Results

The results reported in this study use the definitions of delay as provided by each model. Table 1 presents the delay simulation results for the SPUI and the diamond interchange, respectively.

For the SPUI, CORSIM does not directly provide the EB and WB left turn delay because these turns are defined as diagonal movements due to the SPUI configuration. However the delay for these diagonal turns can be calculated using the weighted discharge flows of the link if necessary. CORSIM gave higher delays than field conditions, particularly on the ramps (NB and SB through and left turn movements). VISSIM generally underestimated delays. AIMSUN results appear to be closer to the field conditions, and the slightly higher delays could be due to the differences in the delay definitions.

Pre-calibration results show that with the use of default values all three models underestimate delays at this diamond interchange. The differences are actually larger than indicated here, since the field-measured control delay does not incorporate all components of delay (such as mid-block delays.) These however are included in the delay obtained from the three simulators.

4.2 Calibration

4.2.1 Calibrated Parameters

As described above, in the pre-calibration evaluation each simulator's default values were used for parameters not available from the field data. These parameters describe vehicles, drivers, and traffic model (e.g., car-following, lane changing) characteristics. In the calibration process these parameters were adjusted so that the simulator output performance measure (in this case delay) is as close as possible to the respective field observations. As shown above, before calibration was performed all packages underestimated delays at the diamond interchange. Thus, in this case, the calibration process attempts to increase the delays by modifying several parameters used in the models. For the SPUI, the simulators will also be adjusted accordingly. The following section presents the parameters modified from their default values in each model:

CORSIM

Maneuver Time: SPUI: 1s, Diamond: 8s, (default: 3s)

This is the minimum amount of time after a lane change is initiated before another lane change can commence. It can take values ranging from 1 to 8 sec.

Mean Reaction Time: SPUI: 1s, Diamond: 3s, (default: 1s)

This represents the amount of time required for a driver to begin to apply braking after his or her leader has begun a sudden deceleration. The range is 0.1 to 3.0 sec.

Start-up Lost Time:

SPUI: 2.0s (default: 2.0s)

Diamond: EB/WB External link: 5s; Internal link: 3s; SB/NB: 5s

This value is the delay experienced by all lead vehicles in queues, when responding to a phase change from red to green (also called startup loss). Minimum and maximum acceptable values are 0.5 and 9.9 sec, respectively.

The start-up lost time is defined link by link.

Queue Discharge Headway (same as the HCM 2000 saturation headway):

SPUI: 1.5s, (default: 1.8s)

Diamond: EB/WB External link: 4.5s; Internal link: 2.5s; SB: 6s; NB: 7s

The mean time-gap (headway) between vehicles discharging from a standing queue is entered here. This value applies only to those vehicles which were fourth in queue or further upstream.

Minimum and maximum acceptable values are 1.4 and 9.9 sec, respectively. This headway is defined link by link.

Free-Flow Speed:

This represents the desired, unimpeded mean free-flow speed. This value must be attained by traffic in the absence of any impedance due to other vehicles, pedestrians, or control devices. Minimum and maximum acceptable values are 10 mph and 65 mph

Diamond:

Arterial: 45mph

Ramp: 35mph

SPUI:

Arterial: WB: 45mph; EB: 35mph Ramp: 35mph; left turning: 30mph

Maximum Acceleration Rate: SPUI: 15ft/s^2 , Diamond: 7ft/s^2

The rates can be input as a function of speed every 10 ft/sec. However, we used constant maximum acceleration rate.

Leading Vehicle Deceleration Rate: SPUI: 10ft/s^2 , Diamond: 15ft/s^2 (default: 12ft/s^2)

This is the "panic" deceleration rate applied by the leader vehicle to determine the lane changer's required deceleration for a safe stop. As the values of this parameter increases, the deceleration required for a lane changer to stop safely also increases and the likelihood that a given lane changing opportunity will be accepted decreases. Its value ranges from 10 to 15ft/s^2 .

Follower Vehicle Deceleration Rate: SPUI: 10ft/s^2 , Diamond 15ft/s^2 (default: 12ft/s^2)

This is the "panic" deceleration rate applied by the follower vehicle to determine the lane changer's required deceleration for a safe stop. As the values of this parameter increases, the deceleration required for a lane changer to stop safely also increases, and the likelihood that a given lane changing opportunity will be accepted decreases. Its value ranges from 10 to 15ft/s^2 .

VISSIM

Maximum Acceleration Rate:

Minimum: Passenger car: SPUI: 0ft/s^2 , Diamond: 0ft/s^2

Heavy vehicle: SPUI: 0ft/s^2 , Diamond: 0ft/s^2

Maximum: Passenger car: SPUI: 11.5ft/s^2 , Diamond: 7ft/s^2

Heavy vehicle: SPUI: 8.2ft/s^2 , Diamond: 5ft/s^2

Maximum acceleration rates in VISSIM vary as a function of speed, and distributions are input for each vehicle type.

Desired Speed of Vehicles:

A vehicle travels at its desired speed (with a small stochastic variation called oscillation) if other vehicles do not hinder it. Stochastic distributions of desired speeds are defined for each vehicle type within each traffic composition. Different entrance links can be associated with different traffic composition by vehicle input attributes in the model. The distributions of minimum and

maximum desired vehicle speeds for passenger cars and heavy vehicles were modified as follows,

Ramps:

Minimum: Diamond: 30;

Maximum: Diamond: 40;

Arterials:

Minimum: Diamond: 35;

Maximum: Diamond: 45;

Saturation Flow Rate

The two parameters of Additive Part of Desired Safety Distance (BX_ADD) and Multiplic. Part of Desired Safety Distance (BX_MULT) determine the saturation flow rate for VISSIM. The mathematical relationship between these two parameters and saturation flow rate is not revealed in the documentation, however, it shows the trend of the relationship. With the increase of BX_ADD and BX_MULT, the saturation flow rate is reduced. The values for BX_ADD and BX_MULT were input as follows:

BX_ADD: Diamond: 4 ft; SPUI: 3 ft (default: 2 ft)

BX_MULT: Diamond: 6 ft; SPUI: 4 ft (default: 3 ft)

Detector:

VISSIM models each type of detector in the same way. As soon as a vehicle reaches the detector element with its front and leaves it with its tail, a message impulse is transmitted to signal controllers. Signal actuation is sensitive to the detector location (i.e., distance to stop-line). In this study detectors were placed to yield minimum green time for the corresponding phase.

AIMSUN

Driver's Reaction Time: SPUI: 0.75s, Diamond: 1s, (default: 0.75s)

This is the time it takes a driver to react to speed changes in the preceding vehicle. It is used in the car-following model. For implementation reasons it is also taken as the simulation step or cycle. Increasing the reaction time increases the overall delay, because vehicles become more "sluggish".

Response Time at Stop: SPUI: 0.75s, Diamond: 2s, (default: 1s)

This is the time it takes for a stopped vehicle to react to the acceleration of the vehicle in front, or to a traffic light changing to green. Similarly to the driver's reaction time, increasing this parameter increases overall delay.

Vehicle Maximum Desired Speeds:

This set of inputs defines the distributions of the maximum speeds for each type of vehicle (i.e., passenger cars, trucks, etc.) present in the traffic stream. Decreasing these speeds results in a decrease of travel time delay. The distribution of maximum desired speeds for passenger cars was selected to be as follows for both the SPUI and the diamond:

Mean: 50mph
 Deviation: 10 mph
 Minimum: 40mph
 Maximum: 60mph

Vehicle Maximum Acceleration:

This set of inputs defines distributions of the maximum acceleration that each vehicle type can achieve under any circumstance. This acceleration is used in the Gipps car-following model that AIMSUN employs. The distribution of maximum acceleration for passenger cars was entered as follows:

Mean: SPUI: 9.19 ft/s^2 , Diamond: 7 ft/s^2 (default: 9.19 ft/s^2)
 Deviation: SPUI: 0 ft/s^2 , Diamond: 0 ft/s^2 (default: 0 ft/s^2)
 Minimum Value: SPUI: 9.19 ft/s^2 , Diamond: 7 ft/s^2 (default: 9.19 ft/s^2)
 Maximum Value: SPUI: 9.19 ft/s^2 , Diamond: 7 ft/s^2 (default: 9.19 ft/s^2)

Vehicle Speed Limit Acceptance Parameter:

This parameter ($\theta > 0$) can be interpreted as the “level of goodness” of the drivers or the degree of acceptance of speed limits. $\theta > 1$ means that the vehicle will be assigned as maximum speed for a section a value greater than the speed limit while $\theta < 1$ means that the vehicle will be assigned a lower speed than the speed limit. The distribution of the vehicle speed acceptance parameter for passenger cars was modified as follows:

Mean: SPUI: 1, Diamond 1.1, (default: 1)
 Deviation: SPUI: 1, Diamond: 0, (default: 0)
 Minimum: SPUI: 1, Diamond: 1, (default: 1)
 Maximum: SPUI: 1, Diamond: 1.2, (default: 1)

Speed Limit of Links (Sections)

It is the maximum allowed speed for the vehicles traveling through a section. Depending on the value of the Vehicle Speed Limit Acceptance Parameter, each vehicle may or may not follow the speed limit recommendations. The values entered are as follows for both the SPUI and the diamond:

Arterials: 45mph (default: 31mph)
 Ramp: 35 mph (default: 37 mph)

Speed Limit of Turning:

It is the maximum speed at which a vehicle will travel when making a turn. Depending on the value of the Vehicle Speed Limit Acceptance Parameter, each vehicle may or may not follow the speed limit recommendations. The values entered are as follows for both the SPUI and the diamond:

Arterials: Through: 45 mph	Right turning: 40mph	Left turning: 40mph
Ramps: Through: 35mph	Right turning: 40mph	Left turning: 35mph

Defaults:

Arterials: Trough: 31 mph	Right turning: 16mph	Left turning: 10mph
Ramps: Through: 37mph	Right turning: 23mph	Left turning: 34mph

4.2.2 Calibrated Results

Table 2 provides the calibrated results of each model (average of 10 runs) and the field delay results for the SPUI and the diamond interchange, respectively.

For the SPUI, after calibration, CORSIM delays are decreased for each approach. However, delays for left turnings in NB and SB are still higher than the field measurements. This is because CORSIM has to model the SPUI network as three closely-spaced nodes/controllers, where the NB and SB left turning vehicles are only discharged by the middle node and proportionally have less green time than other movements. The VISSIM calibration increased the WB and EB left-turning delays and resulted in values comparable to the observed data. However, the calibration did not improve much the results for the arterial through movements. The AIMSUN results are the closest to the field observations.

The calibration of CORSIM model at the diamond interchange increased the delay of each approach; note however that to achieve this, the values for start-up lost time and queue discharge headway had to increase dramatically in each link. The table lists both travel time delay and control delay results from CORSIM, to demonstrate the difference in values between travel time delay and control delay in that model. The VISSIM calibration results show that predicted delays in ramps (NB and SB approach) are fairly close to the field measurements, while arterial (EB and WB approach) delays cannot be highly improved by the calibration process. The AIMSUN results indicate that the delays obtained by the model for three of the approaches is very close to the field data, however for the fourth approach (WB) the predicted delay is significantly lower. The fact that the field delay for the WB approach is much higher than that of the EB approach is puzzling given that the two have similar demands and similar signal phasing/timing allocations. It may be that the site has some unique characteristics not typically captured in a data collection, or that the field data obtained are erroneous in some way.

5. CONCLUSIONS

In this study three traffic models, namely, AIMSUN, CORSIM and VISSIM were employed to analyze the operations of a diamond interchange and a SPUI at Arizona. The two interchanges are considerably different in terms of operational conditions and geometric characteristics, while the simulation models are different from each other in input requirements, output of operational performances and capabilities in evaluating interchanges' operations. An extensive investigation was conducted into how the network is represented, the demand is specified, the traffic control is defined, and what and how traffic behavior is modeled. As a result of this investigation, the following were identified as important considerations in the selection and use of an appropriate simulation model for a specific type of interchange.

- 1) Regarding the capability of representing geometric layout:

All three models are capable of representing urban streets and freeways including ramps. However, an initial investigation of the values of saturation flow rates prevalent in AIMSUN

revealed that the simulator does not explicitly account for differences between left-turning, through, and right turning movements, and all three have very similar saturation headway values. Generally factors such as turning radius and lane width are not considered explicitly in any of the three simulators tested. In the case of CORSIM the saturation flow rate is an input. In this case, one can use the HCM 2000 to estimate the expected saturation flow rates based on the prevailing geometry and traffic stream characteristics. In conclusion, if the effects of highway geometry changes are to be investigated (or if saturation flow rates are of interest) the package selected should be one that incorporates algorithms that consider such changes directly, and particularly the effects of geometry on vehicle and driver performance. Existing simulation packages incorporate very few highway design elements in their algorithms, and the most frequently considered element is grade.

2) Regarding the capability of simulating signal controls:

An issue related to geometry but mostly affecting signal control is that a SPUI cannot be easily represented in CORSIM when frontage roads exist. SPUI is operated by one intersection/controller that accommodates all four turning movements and through movements including frontage roads. However, CORSIM has to use three nodes/controllers to represent the entire SPUI, while in the field only the middle node represents the actual signalized intersection. In CORSIM two “dummy” nodes had to be added for accurately replicating the geometry of the site (Figure 2, nodes 2 and 3). For this SPUI actuated control cannot be accurately simulated because the controller in node 1 cannot control the movements approaching the “dummy” nodes. In this case, only pre-timed control can be simulated with CORSIM. In conclusion, to simulate an interchange with actuated control where there is one controller for two or more intersections, most appropriate simulators are those that do not define each controller as belonging to a single node only.

Another issue regarding signal control is that the simulator should have the capability to explicitly analyze the start-up lost time of discharging vehicles at the green onset, and also consider the effects of a downstream queue on lost time and saturation flow rates. Our experiment on vehicle discharge headways showed that there is no lost time difference (or saturation flow difference) in the presence of a downstream queue and blockage. The queue discharge behavior is not affected by downstream conditions, while field studies have shown that to be the case (11). Generally the operation of closely-spaced intersections and the driver behavior around them should be investigated and addressed in simulation packages.

3) Regarding calibration needs and accuracy in comparison to field conditions:

Each simulator defines and uses various parameters in very different ways, thus it is extremely difficult to compare the results provided by the various simulators. This study has shown that delays resulting from the pre-calibrated simulations, using their respective default values deviate widely from field measures. In the calibration process, several parameters were modified in each model to approximate the field measurements of delay. Calibration showed (particularly for AIMSUN) that the vehicle reaction time has a significant effect on the output. This value is also the “simulation step”, and although not specifically discussed in all simulators’ documentation, the simulated performance measures very much depend on its value.

Each model uses a different term and definition for obtaining the speed under very low demand conditions (desired speed, free-flow speed, maximum speed, etc.) The value of this speed is very important, particularly if the travel time delay is estimated as a deviation from this value.

Another important calibration factor is familiarity of drivers with the facility. AIMSUN provides a function called look-ahead model to simulate vehicles that has knowledge of the next following two turns. VISSIM defines the number of vehicles ahead and look-ahead distance that a vehicle can see forward in order to react to other vehicles. Such look-ahead models are important in positioning vehicles and it is a critical component when considering interchanges, particularly when it consists of closely-spaced intersections. For simulators that do not contain such a function and under heavy demands, it could be that a large percentage of simulated vehicles cannot reach their intended destinations. Some packages “remove” vehicles from the simulator when they have to wait for a long time to reach their destination. Such an approach may result in erroneous performance measures predicted by the simulator. It is recommended that particularly for interchanges, and to the extent the simulator allows for it, familiarity with the facility is assumed to avoid this problem.

As shown in the calibration process, parameters in a simulator can be adjusted to a large extent to approximate given performance measures values. Even though such a process provides flexibility, users should use caution and modify values within a reasonable range. Guidance from simulation package developers on calibration of specific parameters would be very useful in overcoming this difficulty.

4) Regarding performance measures:

In terms of provision of performance measures, a simulator should be capable of providing the necessary performance measures for different interchange types. All three simulators produce a variety of performance measures including Delay, Travel Time, Speed, Number of Stops, Average Queue and Maximum Queues, etc. However, their exact definitions differ among models. For example, in CORSIM a vehicle is considered to be in a queue when its acceleration is less than 2 ft/second², while in VISSIM, the user can define when a vehicle is part of a queue. In comparing performance measures between the field and simulation results, the exact same definition should be used to the extent possible. Simulator manuals typically provide definitions for all performance measures obtained. A feature that provides additional user flexibility is the provision of virtual detectors in the simulator. Such a tool can be used to obtain additional performance measures, and also to obtain information tailored to each user’s needs, and to the application at hand.

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FIGURE 2. SPUI (Dunlap/I-17, Arizona) CORSIM Input Network

TABLE 1. Pre-calibrated Simulation Results for the SPUI and the Diamond Interchange

			Field	CORSIM	VISSIM	AIMSUN
			Measured Control Delay (sec/veh)	Control Delay (sec/veh)	Travel Time Delay (sec/veh)	Travel Time Delay (sec/veh)
SPUI	WB	LT	47	a	22.7	45.9
		TH	34.9	41.85	7.9	35.4
		RT				
	EB	LT	38.6	a	12.3	45
		TH	24.7	44.62	12.7	39
		RT				
	SB	LT	34.2	65.61	11.8	47.5
		TH	34.8	66.25	16.9	49
		RT				
	NB	LT	40.7	63.93	13.9	45.6
		TH	34.4	64.44	10.4	49.4
		RT				
Diamond Interchange	WB	LT	40.9	14.94	8.7	27.3
		TH				
		RT				
	EB	LT	27.9	11.01	9.1	16
		TH				
		RT				
	SB	LT	36.5	18.76	28.8	8.8
		TH				
		RT				
	NB	LT	37.2	13.63	20.4	16.5
		TH				
		RT				

- a. CORSIM does not directly provide the diagonal turn delays. These can be calculated however by the weighted discharge flows.

TABLE 2. Calibrated Simulation Results for the SPUI and the Diamond Interchange

			Field	CORSIM	VISSIM	AISMUN
			Measured Control Delay (sec/veh)	Control Delay (sec/veh)	Travel Time Delay (sec/veh)	Travel Time Delay (sec/veh)
SPUI	WB	LT	47	a	44.4	45.8
		TH	34.9	35.9	9.3	35.9
		RT				
	EB	LT	38.6	a	39.5	46.5
		TH	24.7	39.6	11.5	36.2
		RT				
	SB	LT	34.2	58.9	20.5	36.8
		TH	34.8	41.7	18.0	43.8
		RT				
	NB	LT	40.7	59.1	21.3	39.5
		TH	34.4	23.4	31.2	42.6
		RT				
Diamond Interchange	WB	LT	40.9	29.3 / 26.3	13.1	28.8
		TH				
		RT				
	EB	LT	27.9	29.4 / 25.2	16.9	28.8
		TH				
		RT				
	SB	LT	36.5	30.6 / 28	30.7	35.4
		TH				
		RT				
	NB	LT	37.2	25.8 / 23.3	26.7	40.3
		TH				
		RT				

- a. CORSIM does not directly provide the diagonal turn delays. The delays can be calculated by the weighted discharge flows.

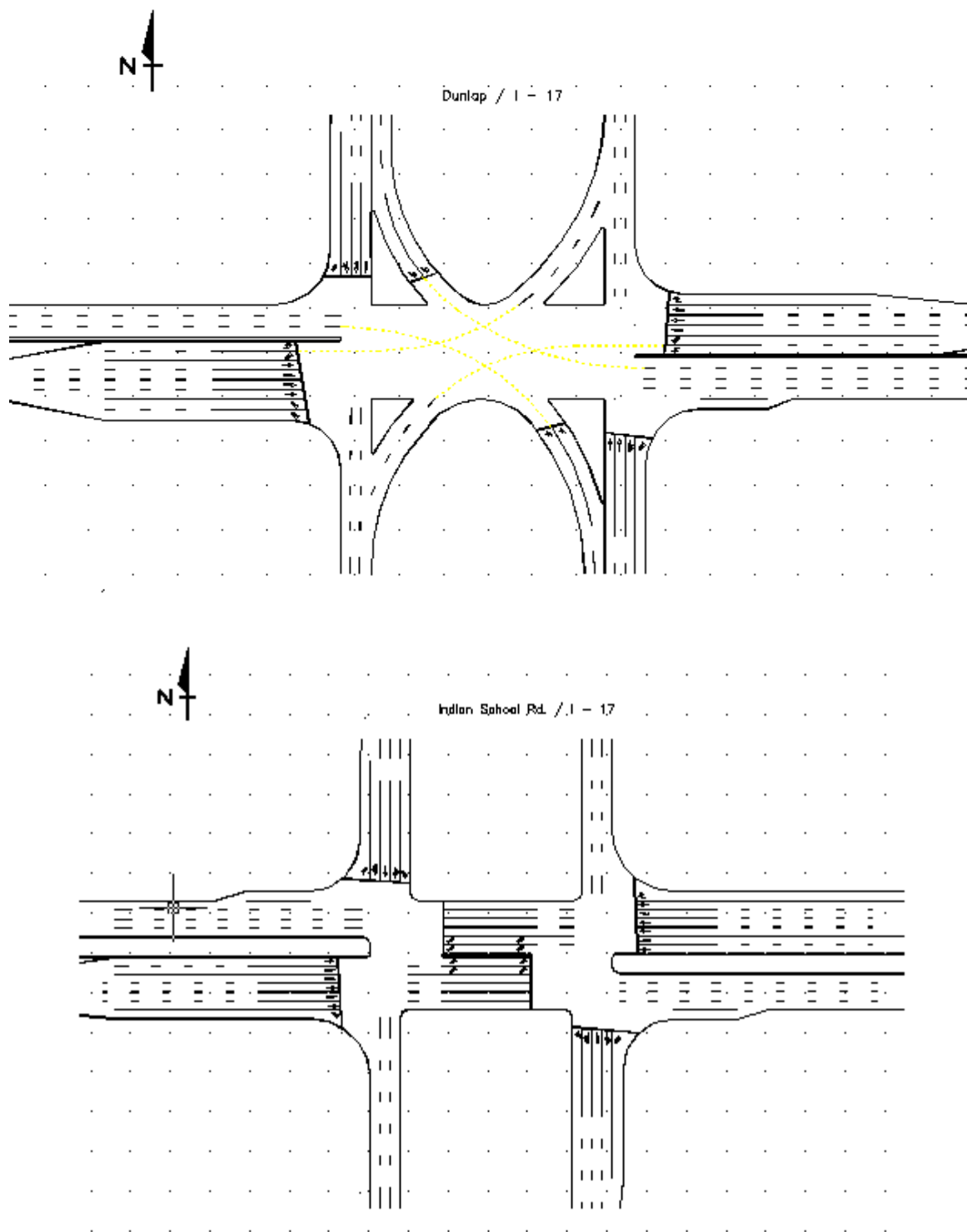


FIGURE 1. Geometric Layout for the (a) SPUI (Dunlap/I-17, Arizona), and (b) Diamond interchange (Indian/I-17, Arizona)

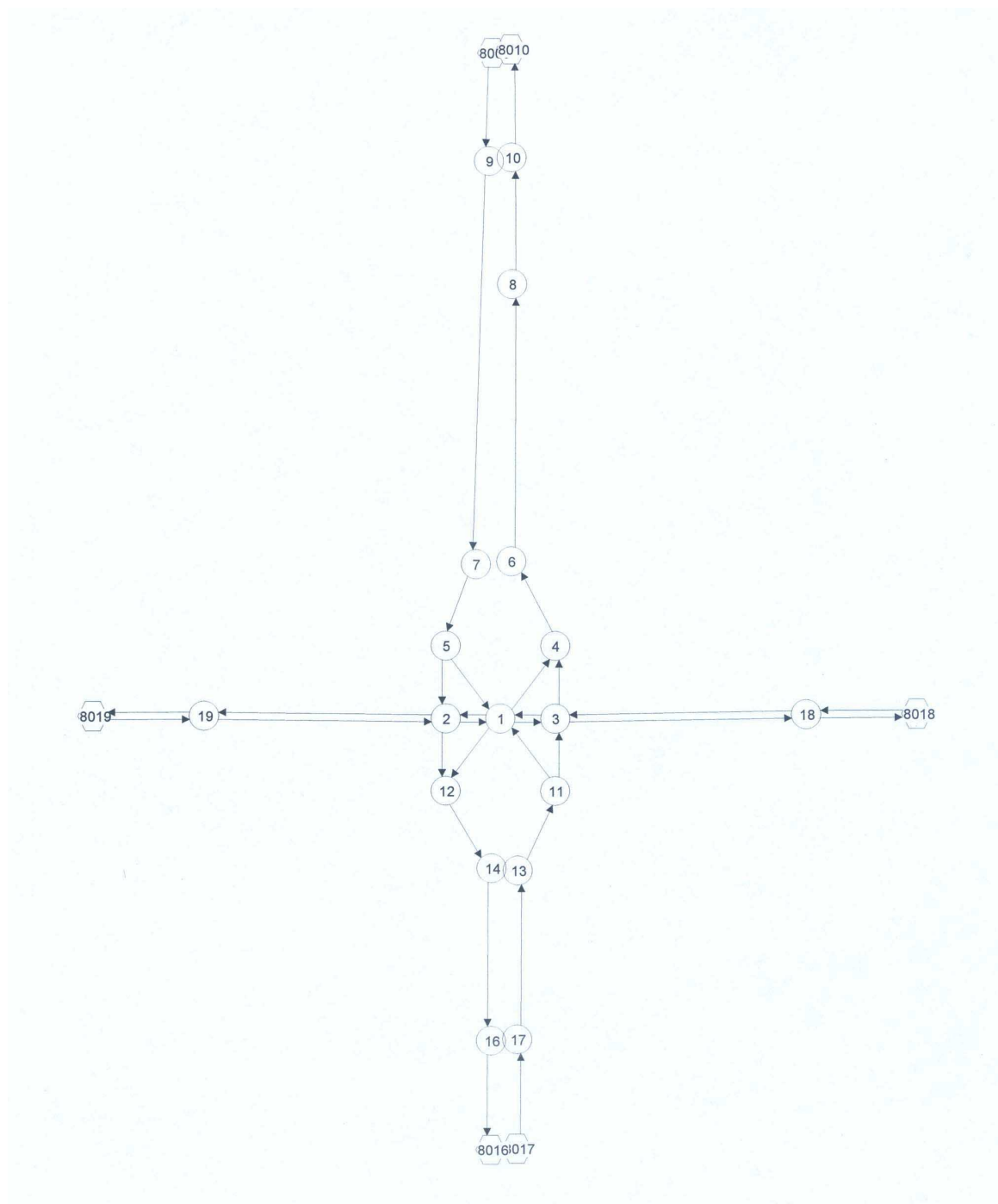


FIGURE 2. SPUI (Dunlap/I-17, Arizona) CORSIM Input Network