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Comparison of SimTraffic and VISSIM Microscopic Traffic Simulation Tools in Modeling Roundabouts

Khaled Shaaban[a], Inhi Kim[b]*

[a]Qatar University, Doha, Qatar University
[b]Monash University, Clayton, Victoria, Australia

Abstract

SimTraffic and VISSIM are two microscopic traffic simulation tools that are capable of modeling arterial roads with signalized intersections and roundabouts. This study compares the performance of the two simulation tools in modeling dual lane and triple lane roundabouts under different scenarios such as traffic volume, proportion of left turning movement, and proportion of trucks in the traffic flow. The two simulation tools did not show statistically significant difference in general. However; in the case of high traffic volumes, VISSIM showed higher average delays than those from SimTraffic compared to nearly identical results in the case of low traffic volumes.

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Keywords: Multilane roundabouts; Microsimulation; Transport modeling; SimTraffic; VISSIM; Sensitivity analysis

1. Introduction

In order to address roundabout designs, the need for microsimulation modeling has been considered by traffic professionals in order to have an advanced understanding of an overview of traffic and to identify current problems and suggest possible immediate solutions[1]. It also helps test alternative traffic operating systems in a simulated environment, which provides a platform for performance comparison of varying solutions for decision-making[2].

* Corresponding author. Tel.: +974-4403-4185; fax: +974-4403-4172.
E-mail address: kshaaban@qu.edu.qa

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Furthermore, Shaaban and Radwan[3] also believed that simulation modeling could save users huge amounts of time, effort and money and also ensure safety by not interrupting real-world traffic conditions if the calibration of the traffic micro-simulation is done logically in conducting the analysis of a transport system.

Kinzel and Trueblood[4] categorized software packages into two categories based on the method of calculation. One is a deterministic model. The other is a stochastic model. The former evaluates roundabout performance based on the relationship between traffic flow and capacity along with operational properties such as delay and queues[5]. The latter analyzes roundabouts based on probability in relation to randomness of traffic phenomenon[6,7].

Deterministic models can be drilled down into two models[8]. One is a statistical model (empirical model). The other is an analytical model (semi-probabilistic model). The statistical model is a regression model developed from field data. This model represents the relationship between the capacity for each direction and the circulating flow rate. The software package RODEL was developed in the United Kingdom by modifying a typical regression model for roundabout capacity estimation[9]. SIDRA is a well-known gap-acceptance model that predicts the approach capacity at a roundabout. This model determines the number of times that gaps are larger than the minimum headway as well as the number of vehicles entering the circular flows based on the follow-up headway[5].

The Highway Capacity Manual (HCM)[10] contains a stochastic simulation model that can integrate the statistical model and the analytical model. Besides a regression model and a gap-acceptance model, microscopic simulation can also predict roundabout performance. A core algorithm behind the microscopic simulation is based on the car-following theory and lane-changing logic. Some of the existing microscopic traffic simulation models include SimTraffic, VISSIM, AIMSUN, CUBE Dynasim, and others. In this study, VISSIM and SimTraffic were compared in terms of their operational measurement.

This paper starts with Past Work that introduces the use of traffic simulations in roundabouts through comprehensive literature reviews and includes a research gap. Data comprising a combination of 240 scenarios are tested for data analysis after being calibrated, and results from the two packages are compared in the next section. The last section provides a summary and some limitation of this study.

2. Past work

Some studies have investigated single lane roundabouts using simulations. Gallelli and Vaiana[8] tested three separate scenarios; width of the splitter island, external roundabout radius, and width of the circulatory roadway by comparing approach delays from VISSIM. They concluded that the microsimulation results were greatly influenced by geometric variables. Al-Ghandour and Rasdorf[11] also used VISSIM to identify the relationship between average delay and circulating conflict volumes in a roundabout and a slip lane volume and found that they were related exponentially up to saturation point. Deshpande and Eadavalli[12], evaluated a single lane roundabout based on delay and queue length by using four traffic simulations packages, namely; SIDRA, RODEL, VISSIM, and SimTraffic. They insisted that most models including HCM 2010 were not able to mimic well the effects of imbalance in approach volumes.

On the other hand, research on multi-lane roundabouts has been conducted by many researchers. Chen and Lee[9] compared three simulation packages including VISSIM, RODEL, and SIDRA with NCHRP Report 572 and concluded that all three simulation packages overestimated capacities and SIDRA and VISSIM underestimated delays and queue lengths while RODEL overestimated compared to NCHRP Report 572. Later Yin and Qiu[13] did a direct comparison between VISSIM and SIDRA in delay and queue length on two-lane roundabouts. They concluded that the two simulations predicted similar delays at medium to high traffic flow and at all left turn proportion levels although VISSIM predicted longer queue length than those by SIDRA. Bared and Afshar[14] tested VISSIM, SIDRA, Tanner Wu, and new NVHRP models for multi-lane roundabouts at capacity. Unlike other studies, they concluded that simulation results were compatible with field data collected in the United States by the NCHRP Report 572. Another study conducted by Ambadipudi[15] revealed that VISSIM and SIDRA generated approximately 6 times and 2.5 times longer delay, respectively, on the southern approach and about 10 times and 5 times longer maximum queue length, respectively, on the eastern approach than RODEL. Peterson et al.[16] compared VISSIM and RODEL at capacity on single and dual lane roundabouts finding the capacity from VISSIM were consistently lower than from RODEL. In the early comparison study conducted by Stanek and Milam[7], it was concluded that macroscopic simulations such as FHWA, RODEL and SIDRA can be used for unsaturated conditions whereas microsimulation such as Paramics and VISSIM needs to be used for over-saturated conditions or unusual road geometry features.

Since many microsimulation studies in the last ten years do not include a comparison between SimTraffic and VISSIM in modeling multi-lane roundabouts, the purpose of this study is to compare the two microsimulation packages in terms of average delay for different scenarios including different number of lanes in the roundabout, different proportion of left turning movement, and different proportion of trucks in traffic flow.

Table 1. Past work summary

Author	Package	Calibration	Subject	Measure-ment	Finding
Gallelli and Vaiana[8]	VISSIM	From literature Vaiana and Gallelli[17]	Single-lane roundabouts	Delay	The stop-line delay shows a strong dependence on the value of the assumed time gap; The dependence of the stop-line delay from time gap is even more marked for high traffic flows (of course); The approach speed seems to show no particular influences on stop-line delay for fixed traffic flow; The micro-simulator results are sensitive to geometric variables of each scenario.
Chen and Lee[9]	VISSIM, RODEL, SIDRA	Field data	Multi-lane roundabouts	Queue length and delay	All three software packages overestimated capacities. SIDRA and VISSIM underestimated delays and queue lengths. RODEL overestimated delays and queue lengths at most of the entrances.
Yin and Qiu[13]	VISSIM, SIDRA	From literature[5]; Brilon[18]; Mensah, Eshragh, and Faghri[19]	Two-lane roundabouts	Queue length and delay	There is no significant difference between the delays predicted by VISSIM simulation and SIDRA at medium to high traffic flow rates and at all left turn proportion levels. The 95% queue length predicted by VISSIM is longer than that predicted by SIDRA.
Al-Ghandour and Rasdorf[11]	VISSIM	Default	Single-lane roundabouts	Delay	Average delay and circulating conflict volumes in a roundabout with a slip lane are related exponentially to slip lane volumes up to a saturation point.
Deshpande and Eadavalli[12]	SIDRA, RODEL, VISSIM, SimTraffic, HCM 2010	Field data	Single-lane roundabouts	Queue length and delay	Most models (including HCM 2010 Method) for analyzing roundabout performance are not sensitive to the effects of imbalance in approach volumes. However, the latest versions of SIDRA and VISSIM software seem to account for the effect of one approach volume dominating other approaches.
Bared and Afshar[14]	VISSIM, SIDRA, Tanner Wu, new NCHRP models	Based on field experience and observing the simulation animation	2-3-lane roundabouts	Capacity	Simulation results from this research are compatible with field data in the United States from NCHRP Report 572
Ambadip-udi[15]	VISSIM, RODEL, SIDRA	Observing the simulation animation	Multi-lane roundabouts	Delay, queue length, v/c	RODEL reported lower delays and queue lengths for all the approaches. Delay results from VISSIM and SIDRA were more or less comparable for the three approaches. However, the south approach in VISSIM showed much higher delay than RODEL or SIDRA
Peterson et al.[16]	VISSIM, RODEL	Default for RODEL; NCHRP 572 report, FHWA Roundabout Guide, and AASHTO for VISSIM	Single and dual lane roundabouts	Capacity, delay	The capacity estimates from VISSIM were consistently lower than the estimates from RODEL.
Stanek and Milam[7]	RODEL, SIDRA, VISSIM, Paramics	N/A	Multi-lane roundabouts	Delay, LOS	Macroscopic methods (FHWA, RODEL, and SIDRA) were used to analyze high-capacity roundabouts only for unsaturated conditions or for isolated locations with standard geometry. Microscopic methods (Paramics and VISSIM) should be used when over-saturated conditions are present in the study area, or when unique roadway geometry features are present.

3. MODEL CALIBRATION

3.1. Overview

Calibration is important in micro-traffic simulation because it reproduces the local driving environment that is influenced by many factors such as the relationship between two vehicles, infrastructure, traffic operations, and geometry of the network. The calibration process is carried out by adjusting a combination of coefficient values of parameters in the simulation.

In developing a VISSIM model in terms of roundabouts, three key features need to be carefully considered; coding a proper routing decision and routes, placing priority rules correctly, and defining minimum headway and minimum gap time.

3.1.1. Routing decision and routes

Many drivers often face difficulty in driving in multi-lane roundabouts. The basic rule recommended is that drivers need to consider a roundabout as a normal intersection. In other words, if a driver wants to turn left, he/she needs to approach in the left-most lane and keep the lane on the circular road until he/she exits the roundabout assuming left-hand traffic.

On the left in the Fig. 1 is a normal roundabout modeling in VISSIM that allows vehicles, approaching from any lanes, to make left turns and to change the lane in any given chance. In the other hand, on the right in the picture, vehicles make a decision earlier before approaching the roundabout and proceed driving by linking between an approaching link and a circular link with three separate connectors instead of one connector that has three lanes.

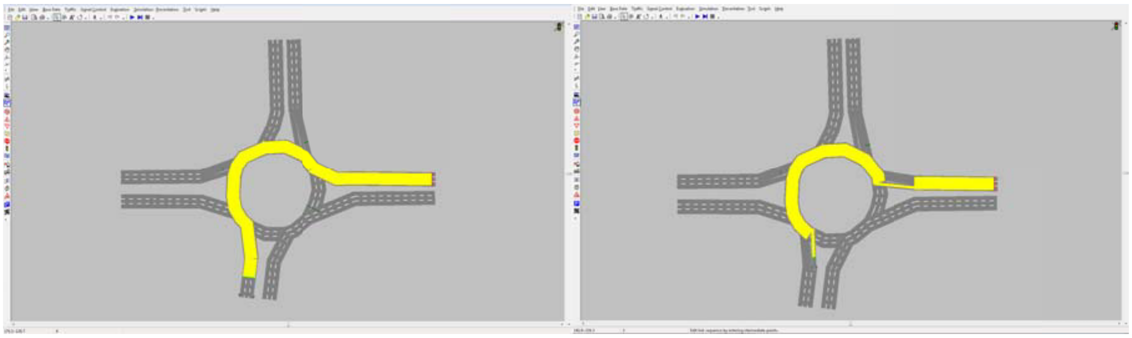

Fig. 1. Default versus enhanced routes

3.1.2. Priority rules with minimum headway and gap time

Priority rules in VISSIM normally are used to model non-signalized intersections. This technique can apply to roundabout conflict modeling as well. Two important factors; minimum headway and gap time are taken into account to decide if vehicles proceed or stop. The minimum headway is defined as the length of the conflict area. Vehicles can proceed unless the current headway is less than the minimum headway that is already set by users. The gap time varies based on the distance between the vehicle in the major flow and the start of the conflict area and the speed of the vehicle. These two conditions need to be satisfied for the vehicle to proceed. The multi-lane roundabout has many conflict points that depend on the number of lanes. Therefore, priority rules are carefully modeled with the minimum headway and gap time.

The SimTraffic parameters such as travel speed, turning speed (left and right), headway factor, and lane change distance (mandatory and positioning) were also calibrated and were found to be within acceptable ranges (for detailed calibration process, refer to Shaaban and Radwan[20]).

3.2. Data collection

Al-Corniche Street located in the downtown area of the city of Doha, Qatar was selected to collect field data for calibration purposes. This corridor has four roundabouts and one signalized intersection with three lanes in each direction at the speed limit of 80 km/h. The selected street consists of 4 segments with a length of 1.5, 0.85, 2, and 0.45 kilometers, respectively. Travel time between the segments and maximum queue length from multiple different approaches at the intersections were selected as measures of performance. Two vehicles equipped with GPS were used in each direction to record locations and times. Based on the relationship between time and space, travel times between the roundabouts and the intersection were compared from one to another. Data collection was performed from 6:00 AM to 9:00 AM, 11:00 AM to 2:00 PM and 5:00 PM to 8:00 PM on a regular weekday in May 2013.

Ten simulation runs with random seed numbers were performed in order to ensure a reliable average travel time due to simulation's stochastic characteristics.

Values for the minimum headway and the gap time were input into VISSIM and the results for travel time were extracted. The default value for the minimum headway (length of the conflict area) and the minimum gap time was 5 meters and 3.0 seconds, respectively. The minimum headway increased incrementally by 1 meter from 4 meters to 6 meters and the gap time in increments of 0.1 seconds from 2.0 seconds to 3.0 seconds. These ranges are supported by other studies (13, 20).

In the case of SimTraffic, three values were chosen for each selected parameter. A combination of the values (3*3*3*3*3*3) was used to match with observed data. Travel speeds were 56, 72, and 88 km/h, left turning speeds were 19, 24, and 29 km/h, right turning speeds were 11, 14, and 18 km/h, the headway factor were 0.9, 1.0, and 1.1, the mandatory lane change distance were 160, 400, and 640 m, and the positioning distances were 240, 600, and 960 m. Once the travel time is close to the data collected, the process is finished. The parameter values obtained from this case study were used to carry out the analysis.

4. Data Analysis

4.1. Experimental design

This study was carried out by loading a wide range of traffic flow rates with different turning proportions on a two-lane and a three-lane roundabout. The traffic flow included five levels of traffic flow rates 1,000, 2,000, 3,000, 4,000, and 5,000 veh/h, four levels of left turn proportion (LT proportion), 10%, 20%, 30%, 40%, and three levels of heavy vehicles proportions in the traffic flow, 0%, 10%, and 20%. Fixed right turn (RT) percentage of 20%, lane width of 3.65 meters, speed limit of 80 km/h, and 21 meters inside radius were used on all approaches. These values resulted in 240 combinations of scenarios (60 scenarios on two types of roundabout for each package).

Due to the stochastic nature of simulation, the output of the simulation will vary from different runs because many parameters used in each simulation run will be generated according to specified distributions. In this study, ten runs with randomly selected seed numbers were performed, and the average values were used in the analysis.

4.2. Results

A direct comparison of results between SimTraffic and VISSIM in terms of traffic flow rate was performed. Five types of traffic flow including 1,000, 2,000, 3,000, 4,000, and 5,000 veh/h and corresponding average delays for both packages are displayed. When traffic flow was less than 4,000 veh/h, average delays remained steady with a small amount of variation. This tendency changed significantly once traffic flow reached 4,000 veh/h. Results from both packages showed that the maximum of average delay was above 150 seconds with a range between 20 seconds and 210 seconds. When traffic flow was above 4,000 veh/h, higher average delays were expected from both but VISSIM provided a smaller range of variation, between 100 seconds and 290 seconds whereas SimTraffic ranged from 40 seconds to 310 seconds.

Since average delays showed a relatively large difference between low traffic volumes (1,000, 2,000 and 3,000 veh/hr) and high traffic volumes (4,000 and 5,000 veh/hr), the comparisons were divided into two groups, namely low traffic and high traffic. Fig. 2 shows a direct comparison of results between SimTraffic and VISSIM in terms of a truck proportion, a proportion of left turns and the number of lanes against average delay at low and high traffic volumes. Firstly, average delays are plotted for 0, 10%, and 20% trucks in the traffic mix. Both packages produced very similar results showing an average of nearly 10 seconds regardless of the proportion of trucks in the traffic flow at low traffic volumes. In the case of high traffic volume, the higher percentage of trucks resulted in an increased average delay. Both packages showed a very similar pattern, but overall average delay was higher in VISSIM than in SimTraffic. Secondly, the graphs showed the average delays against the proportion of left turns. When traffic volume is low, the mean of average delay for both packages shows nearly 10 seconds although variations increase with an increasing proportion of left turns in SimTraffic. In other words, VISSIM produced a consistent variation in different proportions of left turn. With high traffic volumes, both packages showed an increase in average delays with the increase of the proportions of left turns. However, VISSIM produced a mean of nearly 100 seconds more than SimTraffic. Lastly, average delays are displayed against the number of lanes that is two or three, in roundabouts. Since traffic volume is low, the average delay for both packages remains almost the same for both two and three lanes. However, as capacity of roundabouts increases average delays decrease, correspondingly. However, there is a difference in mean of about 50 seconds between the two packages.

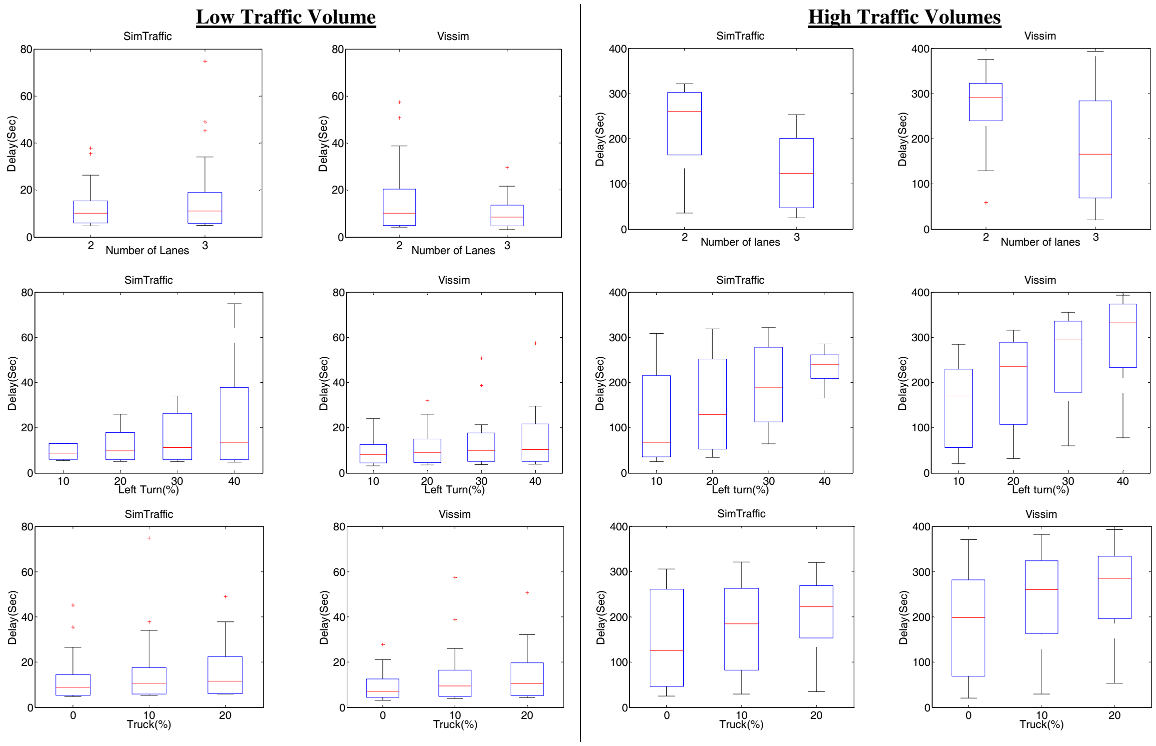

Fig. 2. Average delays from SimTraffic and VISSIM against number of lanes, left turn proportion, and truck proportion at (a) low and (b) high traffic volumes

4.2.1. Test for Equality of Variances between Series

Levene’s test is a test used to assess the equality of variances between two or more groups. If the significance is less than some critical value (e.g. 0.05), then variances are significantly different, and parametric tests cannot be used. Levene's test is often used before a comparison of means. When Levene's test shows significance, ANOVA (Analysis of variance) or t-test can follow to assess the similarity of groups.

In this study, the Levene’s test was used to test whether or not the population (A set of delay) variances are likely to be equal across the two groups (SimTraffic and VISSIM) under a threshold of 0.05 for significance. A p value that is larger than 0.05 fails to reject the null hypothesis, while a p-value that is equal to or smaller than 0.05 rejects the null hypothesis and accepts the alternative hypothesis. It was found that p = .001, which means that the null hypothesis was rejected.

F-test, Siegel-Tukey and Bartlett tests were also used to support the result of Levene's test. The absolute values of the statistical tests (F-test, Siegel-Tukey, Bartlett) are greater than the critical value and p-values (0.015) are less than 5%. Therefore, the null hypothesis was rejected. The results conclude that the two population variances are different at the 0.05 significance level. Finally, the two series have different variability around the mean.

4.2.2. Test for Equality of Means between Series

A measure of central tendency is used to describe a set of data by identifying the central position within that set of data. The mean is widely used as the measure of central tendency, but the median and the mode are also used under some circumstances. The central tendency is the point around which different values in a sample or from a population are grouped, that is, the "center" around which these values "tend" to focus. There are several measures of central tendency also known as position criteria. The best known are the mean, median or mode.

A t-test can be conducted to assess the statistical significance of the difference between the sample means (A set of delay). The null hypothesis states that the population means are equal (H_0: μ1 = μ 2). The associated p-value is .193 (2-tailed test). Since p = .193, the null hypothesis cannot be rejected. This means that the mean delay for SimTraffic and VISSIM is equal, and there is not a significant difference in the mean delay for two packages. Other statistical tests such as Satterthwaite-Welch t-test, ANOVA F test and Welch F-test also supported the null hypothesis with p-values (Probability) of 0.19, which is greater than 0.05, so the null hypothesis is accepted and it is concluded that the two population means are the same at the 0.05 significance level.

4.2.3. Correlation between VISSIM and SimTraffic average delay

The correlation between the values of average delay predicted by SimTraffic and VISSIM is given in Fig. 3. The results showed that a good correlation existed between these values with squared correlation coefficient R^2 nearly 95%. Therefore, the output shows both types of software are strongly correlated each other in terms of delay.

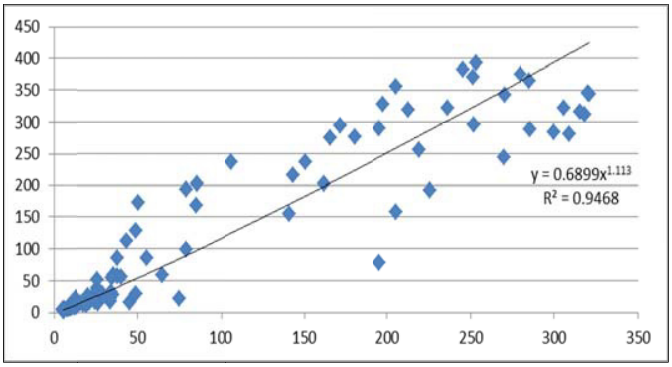

Fig. 3. Correlation between SimTraffic and VISSIM

5. SUMMARY AND CONCLUSIONS

Since inappropriate design of roundabouts in urban areas stimulates a social cost and discourages road users from driving in particular corridors, understanding the capabilities of the traffic simulation tools used in analyzing the performance of roundabouts is important in order to replicate real world traffic situations correctly. The goal of this study was to present the differences and similarities of two widely used traffic simulation packages (SimTraffic and VISSIM) in order to help practitioners, researchers, or traffic planners to choose a traffic simulation package to analyze traffic performance for roundabouts. The two simulation tools did not show statistically significant difference in the mean of the average delay; however, a different range of variances appeared.

It should not be overlooked that each traffic simulation package runs on the basis of an own systematic algorithm behind so that results discriminate among them. Practitioners need to decide wisely on what particular package is in accordance with specific local conditions. Like many studies that have compared simulation tools for certain purposes in the past, this study does not conclude that one is better than another. Rather than that, this study concludes that using only one simulation tool can be risky because the results under different traffic conditions (low traffic volumes versus high traffic volumes in this study) can be different.

Although this study includes comprehensive literature reviews and provides a clear comparison between SimTraffic and VISSIM on multi-lane roundabouts, there is still more to explore regarding using traffic simulation on roundabouts. The scope of this study focuses on the performance of an isolated roundabout; however, multiple roundabouts at the network level should be analyzed in the future in order to understand traffic conditions more comprehensively. Finally, the factors considered in this study are traffic volumes, proportion of left turning movement, and proportion of trucks in the traffic flow. Other factors such as different types of vehicles in the traffic, gender percentages, and the average age of drivers, the size of roundabouts, and weather conditions should also be considered as part of future studies.

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