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Evaluation of VISSIM a Dynamic Simulation Model for an Arterial Network at Mayagüez, Puerto Rico

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Abstract

The rapid evolution in the sophistication of microsimulation models has encouraged their use in transportation engineering and planning. Traffic In Towns SIMulation (VISSIM as its acronyms in Germany) is a microsimulation model used for the design of traffic actuated control systems. The main objective of this research project was to explore the microsimulation commercial software VISSIM, to determine its ability to represent arterial network conditions in Puerto Rico, specifically in a test bed located in Mayagüez.

The test bed is a thirteen (13) kilometers (8.1 miles) corridor located on highway PR-2 between the municipalities of Mayagüez and Añasco. The arterial network was divided in two different segments taking into consideration the geometric characteristics of each segment. Data was collected from both, providing the necessary input to the simulation and compared the results obtained. After performing the simulation, a statistical analysis was completed to study how this microsimulation tool represented the Puerto Rico's traffic conditions. The results obtained using statistical analysis showed that the output obtained in the simulation with VISSIM matches the data obtained from the field studies. Therefore, the program allows for a good representation of current conditions on the arterial corridor studied.

Keywords
Delay studies, Microsimulation, Statistical analysis, VISSIM

1 Introduction

Traffic simulation software has become increasingly more popular as a traffic analysis tool used in transportation analyses. One reason for the use enhancement of simulation is the need to model and analyze the operation of complex transportation systems under congested conditions. Simulation is used when some analytical techniques or conditions, are not represented by using mathematical equations. Simulation models are typically classified according to the level of detail at which they represent the traffic stream.

A microsimulation model is a software tool that is used in a simulation process incorporating in detail the Microscopic model. It employs several submodels, analytical relationships, and logic to model traffic flow. Simulation models include algorithms and logic to:

- Generate vehicles into the system to be simulated.
- Move vehicles into the system.
- Model vehicle interactions.

Some of the microsimulation tools that have been used to model a road networks are AIMSUN, DRACULA, Paramics, SISTM, MITSIM, CORSIM, and VISSIM among others (Dowling R. et. al., 2004).

The area selected in which our study was performed is located in the western coast of Puerto Rico in the municipality of Mayagüez. Mayagüez, called "*La Sultana del Oeste*", has a population of 95,280 (Annual Estimates of the Population 2005 Census Bureau) and an area of 200 km^2. Is the third-largest city in Puerto Rico, and is considered one of the most important cities in the island. Figure 1, presents a map of Mayagüez and its surrounding municipalities. Mayagüez limits to the north (N) with the municipality of Añasco, to the south (S) with San Germán, Hormigueros and Cabo Rojo, to the east (E) with Las Marías and Maricao and to the west (W) with the Atlantic Ocean.

Figure 1 Map of Mayagüez and surrounding municipalities

Demand for highway lanes continues to grow as population increases, particularly in this metropolitan area where congestion has become one of the main transportation problems. Congestion is largely thought of as a big city problem, but delays are becoming increasingly common in small cities and some rural areas as well.

In essence, highway congestion results when traffic demand approaches or exceeds the available capacity of the highway system. Traffic demands vary significantly depending on the season of the year, the day of the week, and even the time of day. On the other hand, the capacity, often mistaken as constant, can change because of weather, work zones, traffic incidents, or other non-recurring events. All of the characteristics mentioned above are conditions that have being seen in the arterial network of the PR-2 at the Mayagüez Metropolitan Area, the mayor system used by the community to travel every day.

Arterial system serves major metropolitan centers, corridors with the highest traffic volume, and those with the longest trip lengths. The selected arterial network has problems with congestion, delays and queue. VISSIM is used to simulate and analyzes the conditions of this arterial system in Puerto Rico.

1.1 Objectives

The main objective of this report is to explore the microsimulation commercial software, "VISSIM", determine its ability to represent arterial network conditions in Puerto Rico, specifically in a test bed located on roadway PR-2 at Mayagüez.

- To enhance knowledge by the literature research.
- To identify and select two different segments on the test bed located on roadway PR-2 at Mayagüez.
- To perform simulations on each of the segments separately, and obtain the output needed.
- To evaluate the output of VISSIM using statistical analysis on the two segments selected.

1.2 Scope of Work

The modeling of individual vehicle movements on a second or sub-second basis for the purpose of assessing the traffic performance of highway and street systems, transit, and pedestrians is called Microsimulation. The rapid evolutions in the sophistication of microsimulation models have expanded their use in transportation engineering and planning practice (Dowling, 2003.). VISSIM (Traffic In Towns: SIMulation) is used for the design of traffic actuated control systems (Fellendorf M., 1994).

A microscopic, behavior-based multi-purpose traffic simulation program, VISSIM, used on many engineering disciplines, has become an indispensable instrument for the analysis of complex technical systems. It is an invaluable cost-reducing tool. It offers a wide variety of urban and highway applications, integrating public and private transportation. Even complex traffic conditions are visualized in great detail providing realistic traffic models. Traffic engineering expertise combined with 3D animations warranties realistic presentation for both technical experts and decision makers (PTV AG, 2004.).

VISSIM is a microsimulation software that has been started to use at different regions to analyzed multi interaction transportation systems. Therefore, in Puerto Rico has not been used and analyzed how well it represents the traffic conditions in our environment. Using VISSIM, we can compare how well this microsimulation tool represents the actual conditions in Puerto Rico.

VISSIM consists of two different programs: the traffic simulator, and the signal state generator. The traffic simulator is a microscopic simulation model comprising of car-following logic and lane changing logic. The signal state generator is a signal control software that polls detector information from the traffic simulator on a discrete time step basis (ATAcenter, 2004.)..

2 Methodology

The process been used to achieve the main objective is to determine how the VISSIM software represents the actual conditions in the specific selected sections. Using statistical inference, compare average conditions obtained as output of VISSIM with the field data measurements.

- Identify at least two segments along the PR-2, starting at the Corazones Avenue and ending with the intersection PR-109 of the Añasco municipality and PR-115 of Rincon municipality.
- Differentiated the sections using some parameters like traffic congestion, traffic volume or street geometry.
- Gather the field data necessary to simulate the traffic conditions of the PR-2, and obtain the data of each of the selected sections including Geometry (lengths, lanes, and curvature), and Control (signal timing and signs)).
- Base model development using VISSIM using aerial photos.
- Verify the input data of the software with the data gathered on the field.
- Compare average conditions obtained as output of VISSIM with the field data measurements.
- According to the results obtained in these comparisons final conclusions will be drawn regarding the suitability of VISSIM to be used in the Puerto Rico environment.

3 Results

The selected Test bed network along the PR-2 arterial street started at the "Corazones" Avenue (PR-114) and ended at the PR-2 intersection with the PR-109 and PR-115 of the Añasco and Rincon municipality respectively. The length of the project was about thirteen (13) kilometers and consisted on twenty (20) principal signalized intersections. This network was divided in two principal segments, taking into consideration the number of lanes in both directions, (Figure 2).

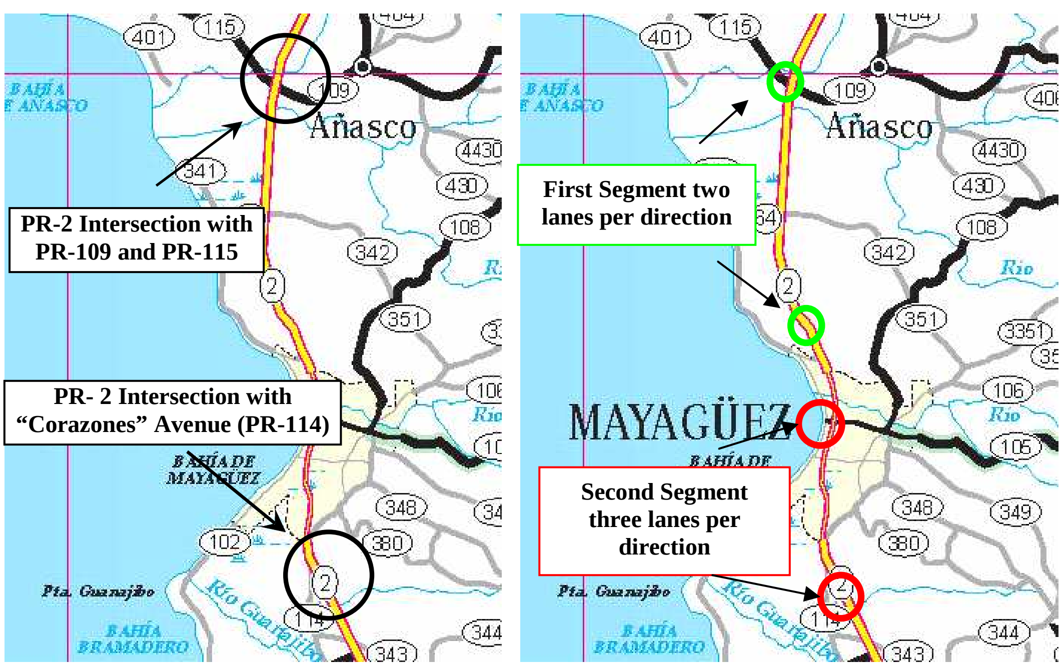

Figure 2: Mayagüez road map area (left) and the two principal segments in which the network was divided (right)

The first segment had two lanes for each direction, and the other section was had three lanes for each direction. In this first segment the intersection used for the analysis was the PR-2 intersection with the “Centro Médico” hospital has three lanes per direction along the PR-2 (north and south direction). The “Centro Médico” west approach has three (3) lanes to exit and 2 entrance lanes (Figure 3). The east approach consisted of 2 entrance lanes and 2 exit lanes with a right turn with a non-stop restriction.

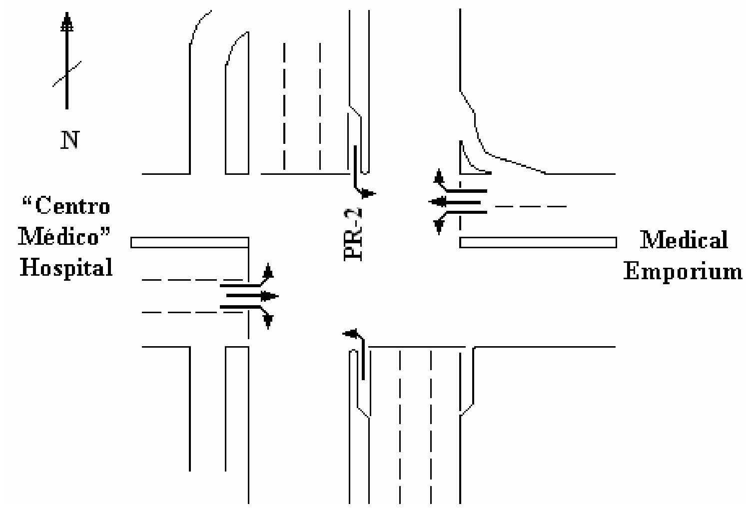

Figure 3 First selected area schematic representation for the maneuvers used in the Delay Study

Table 1 Results for the Delay Study for the morning periods at the PR-2 intersection with the “Centro Médico” Hospital

Period	Maneuvers	Accumulative Queue Vehicles	Vehicles second	Total of exiting vehicle	Average Stopped delay per vehicle (sec)
Morning					
Movements to:	"Centro Médico" Hospital	1,256	18,840	328	57.44
	Medical Emporium	1,333	19,995	252	79.35
Movements out:	"Centro Médico" Hospital	744	11,160	148	75.41
	Medical Emporium	300	4,500	56	80.36

The east approach provided access to commercial buildings (Medical Emporium) where restaurants, fast-food facilities, government offices, medical offices, clinical laboratories, a video rental, a drugstore, and the Veteran’s Hospital are located. On the west approach, we could find the “Centro Médico” Hospital which is the most important trauma and cardiovascular center in the western area of Puerto Rico.

In the second segment, the intersection used for the analysis was the Western Plaza intersection that gives access to a commercial center area with a non-common geometric property (Figure 4). It consists of a frontage road that gives access to a vehicle dealer, fast foods and other commercial buildings. The movie theater, SAM’S, K-mart, Home Depot and other fast foods are located on the other side of the intersection.

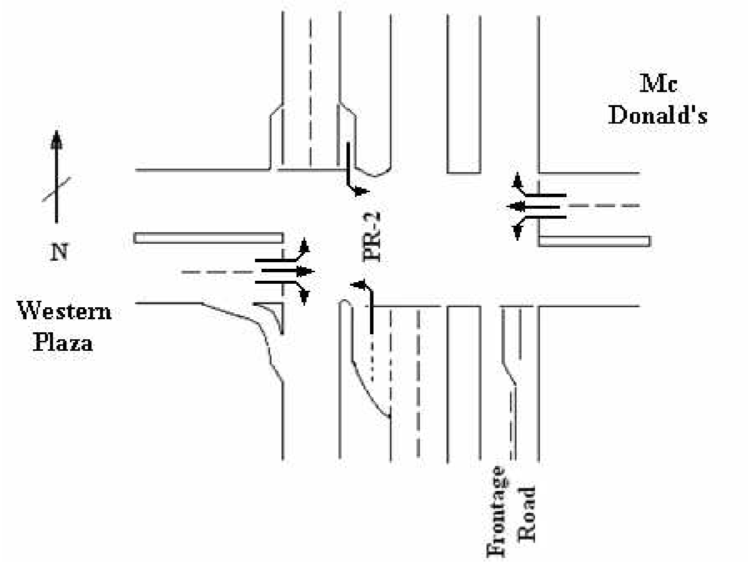

Figure 4 Second selected area schematic representation for the maneuvers used in the Delay Study

Table 2 Results for the Delay Study for the morning and evening periods at the PR-2 intersection with the Western Plaza

Period	Maneuvers	Accumulative Queue Vehicles	Vehicles second	Total of exiting vehicle	Average Stopped delay per vehicle (sec)
Morning					
Movements to:	Mc Donald's	2,262	33,930	203	167.14
	Western Plaza	1,041	15,615	197	79.26
Movements out:	Mc Donald's	1,387	20,805	211	98.60
	Western Plaza	1,131	16,965	277	61.25
Evening					
Movements to:	Mc Donald's	529	7,935	97	81.80
	Western Plaza	4,506	67,590	459	147.25
Movements out:	Mc Donald's	972	14,580	178	81.91
	Western Plaza	2,985	44,775	454	98.62

After performing the VISSIM intersections simulation during the peak period and with the delay study data gathered a ***t***-Test Statistical Analysis was performed. In this section, a comparison between the field measurement and the VISSIM output delay was performed. The Table 3 shows the data used to make the statistical analysis.

Table 3 Average Stopped delay per vehicle in seconds

	Maneuver	Field Data	VISSIM output	Difference
AM	Towards Approach			
	Medical Emporium	79.35	82.10	-2.75
	"Centro Medico" Hospital	57.44	62.60	-5.16
	Departing Approach			
	Medical Emporium	80.36	81.60	-1.24
	"Centro Medico" Hospital	75.41	44.20	31.21
AM	Towards Approach			
	Mc Donald's	167.14	137.40	29.74
	Western Plaza	79.26	78.00	1.26
	Departing Approach			
	Mc Donald's	98.60	99.00	-0.40
	Western Plaza	61.25	71.40	-10.15
PM	Towards Approach			
	Mc Donald's	81.80	94.50	-12.70
	Western Plaza	147.25	151.50	-4.25
	Departing Approach			
	Mc Donald's	81.91	79.30	2.61
	Western Plaza	98.62	89.60	9.02

Table 3 presents the data used for the ***t***-test and the paired ***t***-test: Two-Sample Assuming Unequal Variances analysis. Figure 5 (from MINITAB 14) shows a comparative box plots for the field data and the VISSIM output. These comparative box plots indicated that there is no obvious difference in between the means of the two samples. The ***t***-test: Two-Sample Assuming Unequal Variances analyses gave an exact comparison between these two samples.

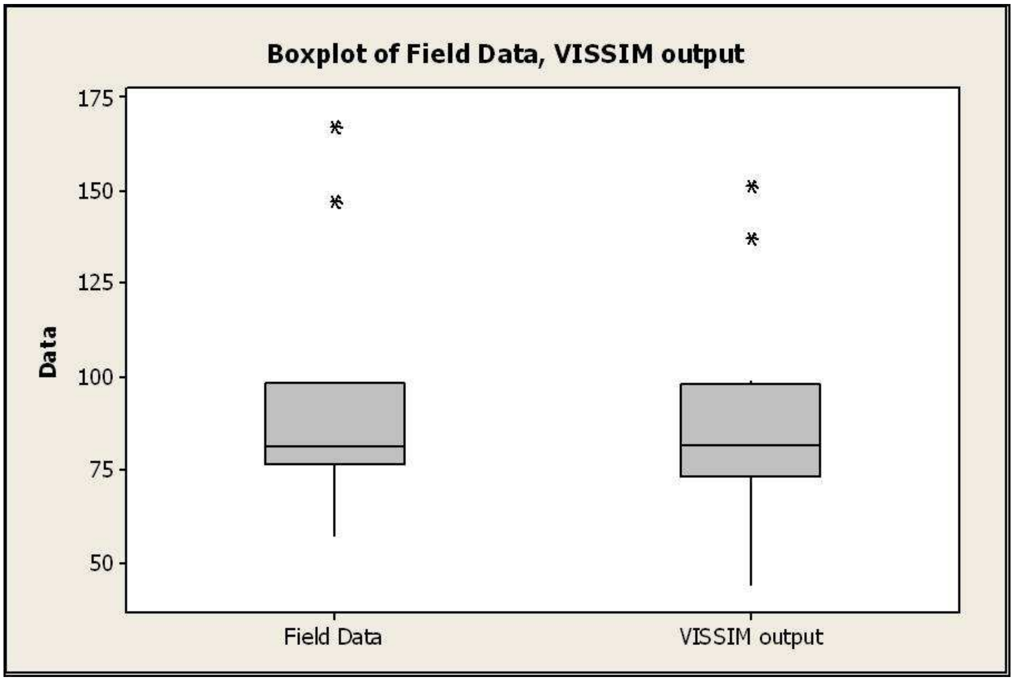

Figure 5 Comparative box plot for the Field data and VISSIM output data

For the two samples analysis, the ***t***-test was used a α=0.05 corresponding for the confidence interval of 95%, The mean difference, $\bar{d}$, was calculated, which is the sum of all the scores divided by the number of scores. The formula in summation notation is:

$$\mu = \bar{x} = \frac{1}{n}\sum_{i=1}^{n}(x_i)$$

where μ / $\bar{x}$ is the mean (population or sample respectively), and n is the number of observations. The mean difference for the Field data was ninety two point thirty seven (92.37), and for VISSIM output was eighty nine point twenty seven (89.27).

The variance was calculated, which is a measure of how a distribution is spread out. It was computed as the average squared deviation of each number from its mean. The formula for the variance is:

$$\sigma^2 = s^2 = \frac{1}{N}\sum_{i=1}^{n}(x_i - \bar{x})^2$$

where σ^2 / s^2 is the variance (population or sample respectively). The variance difference for the Field data was one thousand seventy eight point forty seven (1,078.47), and for VISSIM output was eight hundred eighty two point seventy one (882.71). Then, the standard deviation was calculated. The formula for the standard deviation is the square root of the variance.

$$\sigma = s = \sqrt{\sigma^2} = \sqrt{s^2} = \sqrt{\frac{1}{N}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

The standard deviation difference for the Field data was thirty two point eighty four (32.84), and for VISSIM output was twenty nine point seventy one (29.71). For this analysis, the Degree of Freedom was measured by:

$$df = \frac{\left[\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right]^2}{\frac{\left(s_1^2/n_1\right)^2}{n_1 - 1} + \frac{\left(s_2^2/n_2\right)^2}{n_2 - 1}}$$

The Degree of Freedom resulting from the above equation was 22. Finally, the ***t***-statistic was calculated, which is given by:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

The ***t***-statistic value difference for the Field data and the VISSIM output was 0.24. Detailed statistical results are shown in the Table 4.

Table 4 T-Test: Two-Sample Assuming Unequal Variances results for the comparison between the Field data and VISSIM output

	Field Data	*VISSIM output*
Mean	92.37	89.27
Variance	1078.47	882.71
Observations	12.00	12.00
Hypothesized Mean Difference	0.00	
Df	22.00	
t Stat	0.24	
P(T<=t) one-tail	0.41	
t Critical one-tail	1.72	
P(T<=t) two-tail	0.81	
t Critical two-tail	2.07	

Data gathered from Excel

Since α=0.025, H_0 could be rejected, if $t_0 > t_{0.025,\ 22}$=2.07 or if $t_0 < -t_{0.025,\ 22}$= -2.07. After performing the ***t***-Test statistical analysis, the null hypothesis (H_0: $\mu_1=\mu_2$) was done. Where the result demonstrated that there was no difference between the field data and the VISSIM output (-2.07 < 0.24 < 2.07). This evidence that there is not enough information to demonstrate that exists any difference between the field data and the VISSIM output.

Then, a paired t-test was used to compare the two population's means; in this case, the field data gathered compared the delay study with the VISSIM output. Table 3 presents the column for the difference data used to perform the paired ***t***-test analysis. The null hypothesis procedure to test if the true mean difference is zero, started with the differences calculation between the two observations (d = Field data – VISSIM output).

After the approach differences were calculated, the mean difference, $\bar{d}$, was calculated. The mean difference between the Field data and the VISSIM output was 3.10.

Furthermore, the variance difference between the Field data and the VISSIM output was calculated, this resulted in a value of 195.57. The standard deviation result of 13.98 was found. Finally, the ***t***-statistic difference between the Field data and the VISSIM output was calculated giving a value of 0.77. The statistical results are shown in detail at the Table 5.

Table 5 T-Test: Paired Two Sample for Means

	Field Data	*VISSIM output*
Mean	92.37	89.27
Variance	1078.47	882.71
Observations	12.00	12.00
Pearson Correlation	0.90	
Hypothesized Mean Difference	0.00	
Df	11.00	
t Stat	0.77	
P(T<=t) one-tail	0.23	
t Critical one-tail	1.80	
P(T<=t) two-tail	0.46	
t Critical two-tail	2.20	

Data gathered from Excel

Since α=0.025, H_0 could be rejected if $t_0 > t_{0.025,\ 11}$=2.20 or if $t_0 < -t_{0.025,\ 11}$= -2.20. After performing the statistical analysis for the ***t***-Test, the null hypothesis analysis (H_0: $\mu_1 = \mu_2$) was performed; the result demonstrated that there was no difference between the field data and the VISSIM output (-2.20 < 0.77 < 2.20). This evidenced that there are not enough information to demonstrate difference between the field data and VISSIM output.

4 Conclusion

The research's main objectives were achieved. The commercial microsimulation software, "VISSIM", was explored. It was determined that it has a good ability to represent arterial network conditions in Puerto Rico, specifically in the test bed located on roadway PR-2 at Mayagüez (PR-2 - "Centro Médico" Hospital Intersection and PR-2 - Western Plaza intersection).

Literature knowledge enhancement was achieved, especially on the different simulation programs that are available and the different car following behaviors.

The bed site located on roadway PR-2 at Mayagüez was differentiated in two different segments. In the first segment the PR-2 - "Centro Médico" Hospital intersection was first tested and analyzed with VISSIM. The second segment corresponds to the analysis of the PR-2 - Western Plaza intersection. This intersection, like the first one, was tested and analyzed with VISSIM.

The null hypothesis used for the analysis (H_0: $\mu_1 = \mu_2$) said that there was no difference between the field data and the VISSIM output. The result for the Two-Sample Assuming Unequal Variances Analysis ***t***-test demonstrated that there was no difference between the field data and the VISSIM output (-2.07 < 0.24 < 2.07). Also, the paired ***t***-test result demonstrated that there was no difference between the field data and the VISSIM output (-2.20 < 0.77 < 2.20).

When the t-statistic for the two-sample (0.24) with the t-statistic for the paired ***t***-test (0.77) are compared, the value results for the Two Sample ***t***-test demonstrated that if a difference exist then is practically nothing. This is because the value for the ***t***-statistic is closer to zero (0).

An advantage of the VISSIM program during the simulation process is when a priority sign is located in the intersection; the driver did not make the corresponding priority rule with no other vehicles present. Other advantage of the VISSIM program was its ability of three dimensional representations (3D view) because you can clearly see the intersection surroundings.

5 Recommendations

After the research analysis was performed, we could recommend the use of the VISSIM software. The VISSIM simulation can be performed do to its well represented 3D visual graphics simulation for the actual conditions of any network. Other simulations can be perform, not for an intersection separately; but for the entire arterial network or in the entire segments where the arterial was divided. Future research can be performed, taking into account the potential impact of downstream congestion in both directions of the intersection operation. Furthermore, a comparison can be made using other of the mentioned microsimulation programs versus VISSIM comparing in which one, an easier, real and accurate simulation would be done.

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