

# A Comparison among Manual and Automatic Calibration Methods in VISSIM in an Expressway (Chihuahua, Mexico)

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## Abstract

Traffic microsimulation is an essential tool in urban transportation and road planning. Its calibration is essential to attain representative results validated with real-world conditions. VISSIM (Verkehr in Städten—SIMulationsmodell) operates with the Wiedemann's psycho-physical car-following model for freeway travel that considers safety distances (standstill and movement) during simulation. Calibration in this paper was achieved by using two different approaches: a) manual and b) genetic algorithm (with the GEH statistic formula) calibration techniques. Calibration and validation of this model were performed at the Periferico de la Juventud expressway in Chihuahua City, in northern Mexico. The Periferico de la Juventud (PDJ) has a N-S orientation and a length of ca. 20 km, with its northern section being its most congested portion. Its highest vehicle volume occurs at noon, with 3700 vehicles per hour, with 95% being passenger cars and the other 5% heavy goods vehicles. PDJ's speed limit is 70 km·h<sup>-1</sup>, but the driver's behavior has a tendency towards the aggressive performance. A total of 82 standstill and 82 look-ahead distances were obtained from unmanned aerial vehicles (UAV) images, with values ranging from 0.8 to 4.7 m and from 0.2 to 28 m, respectively. VISSIM calibrated parameter values were calculated for this expressway, being slightly above than the VISSIM default ones; and was validated with travel times and look-ahead distances. Results contribute information for the city's future installment of public transportation systems, and should help decision makers deal with future urban planning.

## Keywords

VISSIM, Genetic Algorithm Calibration, Expressway, Chihuahua

## 1. Introduction

Traffic microsimulation is the main traffic analysis method used to solve transportation issues. Simulation models provide analyzed traffic data under distinct conditions at low cost [1]. VISSIM (Verkehr in Städten—SIMulationsmodell developed by the German company Planung Transport Verkehr, PTV) is one of the most popular traffic flow microsimulation softwares due to its modelling based on the interactions among pedestrians, vehicles, heavy goods vehicles (HGV) and any other type of transportation [2] [3], which also analyses and optimizes traffic flow in detail [4]. VISSIM employs the car following model for freeway travel that accounts the Wiedemann model [5] [6] and consider different aspects such as free driving, approaching, following, and braking [3] [7].

Transportation and its environmental impact, as well as mobility, are two of the most important factors considered in urban economy and quality of life [8]. Hence traffic simulation is crucial for transportation and road planning [4]. Calibration of certain parameters is needed to evaluate traffic and planning operations and applications, being critical for obtaining realistic microsimulation results [9]. Calibration is essential to obtain reliable results, along with the appropriate data collecting technique, which mostly depends on cost and access [1]. Unmanned Aerial Vehicles (UAV or drones) images represent a low cost and accessible method to capture vehicle operations over time [1]. Several techniques have been used to improve calibration in VISSIM. Occasionally, the parameter configuration (such as average standstill distance and additive part of safety distance) should be determined for one location, due to the area's distinct characteristics. Without proper calibration, the simulated traffic outcome does not coincide with real-world settings, and microsimulation models cannot help analysts to solve any traffic issue [1].

Several methods have been developed to calibrate traffic microsimulation parameters, and can be divided in manual and automated [10]. Although the manual technique is broadly used due to its precision without dealing with complicated computer coding [10], it is generally considered as a time-consuming method. Many authors have attempted and successfully developed computerized calibration methods (*e.g.* [11] [12] [13] [14] [15]) using different types of algorithms, such as genetic algorithm (GA), evolutionary algorithm (EA), Nelder-Mead algorithm (NMA), sensitivity analysis method (SA), pareto archived dynamically dimensioned search (PA-DDS), and particle swarm optimization (PSO) [16], but they are still time consuming due to the large number of iterations, and are difficult to use due to their inherent complexity.

This project compares the manual method outcomes with those resulting from the use of a relatively simpler calibration method: an application of the GEH statistics formula within VISSIM's software through a genetic algorithm (GA). It is now possible to link a programming software (*e.g.* Matlab, used in this paper) containing both the GA code and the GEH equation within VISSIM, making it possible to calibrate parameters in a shorter amount of time. Though

the manual method is still widely accepted and employed by traffic analysts, the automatic technique offers its accuracy and it takes less time, once the correct equation is selected and executed.

## 2. Scope and Purpose

This project provides road data (such as flow and vehicular classification, speeds, and flow capacity) of the most important expressway of Chihuahua city: Periferico de la Juventud (PDJ). This data is not currently available and previous records do not exist (as for most of roads in Chihuahua), making it difficult to model it over the years. Manual calibration is the main technique used in previous work performed in the city. This paper uses the genetic algorithm method using the GEH statistic formula within VISSIM, allowing a comparison between both methods. Microscopic simulation of this roadway will allow users (and authorities) to visualize its current behavior, and future scenarios' projection; as well as propose strategies to solve road congestions along its way.

### 2.1. Background

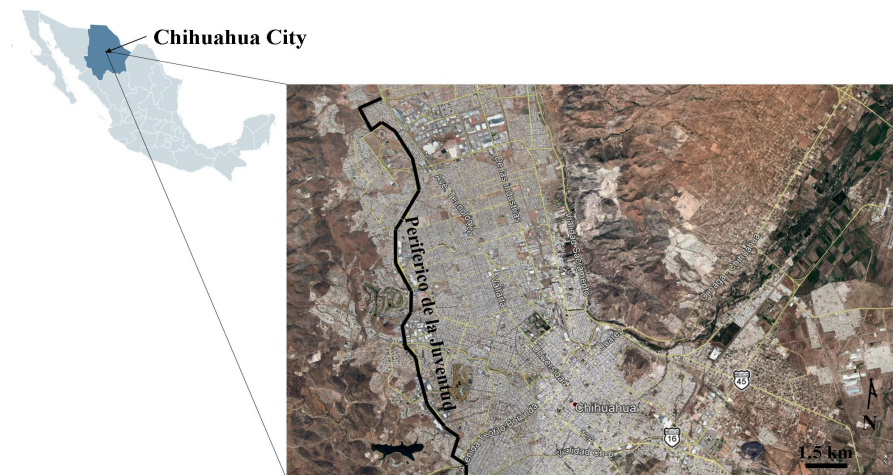
Chihuahua City is the capital of the state of Chihuahua, located in northern Mexico (**Figure 1**). In 2010, its population was 809,232 inhabitants with a ratio of one vehicle for every two inhabitants [17], nowadays, approximately 500,000 vehicles are registered in the city [18]. Chihuahua City is considered a metropolitan zone, and its road infrastructure occupies about the 42% of urban area, and includes a dozen main roads, with traffic jam issues during peak hours [19].

Currently, Chihuahua City faces public transportation problems [20]; the number of automobiles has augmented, requiring a larger circulation space within the city [19]. Therefore, it is vital to simulate traffic scenarios to propose answers integrating displacements of pedestrians, drivers, cyclists, and public transportation users.

Since 1980, Chihuahua city started its growth towards its NW portion, overtaking its outer loop (PDJ), and transforming it in an expressway [19]. PDJ is located west of Chihuahua City; its length is approx. 20 km with a N-S direction (**Figure 1**). According to Chihuahua city's planning department, PDJ was not properly designed, resulting in a series of bottlenecks appearing due to incorrect location of in/out ramps [19]. PDJ does not have traffic lights, and communicates both residential and business zones along its way. Nowadays, PDJ is considered as the most important expressway in the city, while dealing with problems such as traffic jams, flooding, hence becoming the focus of this study.

### 2.2. Drones or Unmanned Aerial Vehicles (UAV)

Traffic counting infrastructure consists mainly of detectors positioned along the roadside, mostly sensors (such as pneumatic tubes, magnetic loops, piezoelectric sensors, etc.) providing reliable data of current traffic conditions [22] [23]. However, their high maintenance cost, difficulties to install and the number of



**Figure 1.** Location map of the case study [21].

needed devices, limit the use of such technique [24]. In contrast, lower cost and flexible techniques controlled by remote observations, such as manual counts, infra-red readers, radar, video image detection, drones (or UAV), etc. are also used [1] [23].

A main issue while collecting traffic data for microsimulation modeling and calibration is its high cost. All the above has motivated researchers to look for more economical tools, such as the use of video and/or photographic images storing single vehicle operations over time, while offering valuable tools and data for calibration and validation of traffic models. UAV technologies were introduced for traffic surveillance and traffic parameters estimation [1] [25]. Drones have been used to perform traffic conditions analyses, because they provide high resolution georeferenced images at low costs and with short data collecting times, but there are also limiting factors, such as weather conditions, physical obstacles, battery life, and permission to fly certain areas, etc. [1] [25].

### 2.3. VISSIM Software

VISSIM is a traffic flow microsimulation software centered on traffic flow behavior and interactions between pedestrians with any type of vehicles [3]; and focuses in analyses and optimization of traffic flow, to model in detailed real conditions [4]. VISSIM works with four different vehicles' behavior models [26]: a) car-following; b) lane changes; c) lateral behavior; and d) reaction to the amber signal light. The car-following model is the one that recreates the better the conditions of an expressway (*i.e.* PDJ), and defines saturation flow. VISSIM operates with a model developed by Wiedemann [5] [6], and has two versions: a) 74, used for urban traffic and merging areas, works with only three parameters (average standstill distance, additive part of safety distance, and multiplicative part of safety distance), and b) 99, used for highways and freeways with no merging areas, which deals with nine parameters (standstill distance, headway time, and seven other parameters related to deceleration), and allows a finer calibration if

enough data is obtained [12] [26]. This research uses model 74, due to its psycho-physical nature, based on safety distance (drivers' deceleration when approaching a slower vehicle [26]); and because the focus of this study is an urban expressway.

### 3. Methodology

Traditional traffic data collecting technology, such as loop detectors, pneumatic tubes, or video cameras, located at fixed locations. They do not provide suitable information about traffic flows over space, routing data nor paths or vehicle trajectories, and along with their high cost and installation difficulties and maintenance [22] make it difficult to use. Alternative techniques such as manual counting, radar speed measurements and UAV images were used in this paper.

PDJ is a congested road, with vehicles usually exceeding speed limits; pneumatic tubes were difficult to install since the expressway is made of concrete in certain sections, thus during operation, several tubes came off the pavement; making data collected unreliable. Traffic flow and vehicle classification were obtained by visual count (both in N-S and S-N directions), while speeds were measured with a radar gun (Bushnell). UAV images were obtained using a drone (eBee sense fly) and were later used to calculate distances between vehicles. Travel times were obtained by driving a car at a 70 km·h<sup>-1</sup> through PDJ's northern section (in both directions).

Calibrated safety distance values and validation with travel times were achieved using two approaches: a) based on an iterative method, where slight changes were made to default values and fed to VISSIM, and results compared to real values, if values were far from fitting real data the changes continued until error was minimal, and b) implementing an optimization function using genetic algorithm (GA) methodology to solve the optimization problem, thus tuning VISSIM parameters automatically.

#### 3.1. VISSIM Data

Microsimulation of traffic flow used the car-following model, because in an expressway, any type of vehicles' speeds should be constant [4] [26]. This model, used in VISSIM, is the one proposed by Wiedemann in 1974, based in drivers' behavior measured in safety distances and speeds. The model Wiedemann 74 is determined by an equation (Equation (1)) presented below [4] [5] [10] [26]:

$$d = ax + ((bx_{addit}) + (bx_{multip}) \cdot (z)) \cdot \sqrt{v} \quad (1)$$

where “*d*” is safety distance between vehicles; “*ax*” is the average standstill distance; “*bx<sub>addit</sub>*” additive part of safety distance; “*bx<sub>multip</sub>*” multiplicative part of safety distance; “*z*” is a range value between 0 and 1, that refers to driver's behavior; and “*v*” is the free flow velocity. The term “*ax*” is given by another equation (Equation (2)):

$$ax = L_{n-1} + ax_{add} + RND1_n * ax_{multip} \quad (2)$$

where “ $L_{n-1}$ ” is the vehicle length; “ $ax_{add}$  and  $ax_{multip}$ ” are calibration parameters and “ $RND1_n$ ” is normal distribution of random vehicles’ number.

A road network was created in VISSIM based on Bing maps satellite images, and PDJ’s lane widths were verified *in situ* (3.5 m), only for its northern section, because it is also its busiest part.

### 3.2. Safety Distance

Safety distance is defined as the drivers’ deceleration when approaching a slower vehicle [26], both stand still and look-ahead distances were measured in UAV images. A total of 164 distances were considered using the drone images in Global Mapper (Figure 2). Images were acquired in peak hours, as well as in normal and traffic jam situations.

### 3.3. Calibration

Traffic simulation is crucial for road planning [8]. Calibration of certain parameters is necessary to evaluate operations and traffic planning, being critical to obtain realistic results during simulation [9]. It is recognized that calibration and corresponding validation of a model, are conclusive steps to generate influence on transport operations, planning and policy [15].

Parameters used in a microsimulation vary depending on the software used, and are responsible for directly affecting the obtained model’s results. In many cases, microscopic simulation is carried out with predetermined parameter values by the software; due to difficulties in obtaining field data or lack of procedures to calibrate and validate the model [15], resulting in unrealistic estimates that will affect the project’s implementation.

Obtaining reliable results is based on the appropriate calibration of parameters used in software and data collection; which depends on costs and accessibility [1]. There are two ways to obtain the calibrated value of the parameters: 1) the generic procedure by iterations which uses sensitivity analysis, as well as trial and error exercises [15] [27] [28] [29] [30], and 2) use of computational algorithms (*e.g.* genetic algorithm), which may be time-consuming due to the high number of calculations linked to traffic simulation [11] [13] [14] [31].

During calibration, two populations (vehicle’s trajectories: N-S and S-N directions) were accounted. First, the default values (standstill distance and look



Figure 2. UAV image took showing peak hour conditions before 10:00 am.

ahead distance) in VISSIM were used, but the results were different from the ones obtained in the field. Slight changes of increments of 0.1 in these default parameters later were fed to VISSIM in an iterative way. Calibrated values were validated using real travel times and look ahead distances, and comparing them to the simulated times.

In the GA, through Matlab, the code was adapted, using the examples of objective functions (GEH statistics) [32] [33] [34]. In the Geoffrey E. Havers GEH function (Equation (3)) [34], data obtained in the field was integrated and the comparison with the simulated data in VISSIM was performed, so that the error could be reduced, and the calibrated parameters could be obtained:

$$GEH = \sqrt{\frac{2*(M - C)^2}{(M + C)}} \quad (3)$$

It is possible to link Matlab with VISSIM through a COM library, which allows the extraction of information from the simulations to be considered in GA iterations. In the same way, as in the iterative analysis, the parameters  $bx_{add}$  and  $bx_{mult}$  were calibrated, so that the particles were optimized within a wide range of data, and the most appropriate selected.

## 4. Results

### 4.1. Vehicle Capacity and Speeds

PDJ is a N-S expressway with long lasting traffic jams at peak hours throughout the day. Its highest traffic flow occurs from the north to south direction. Vehicle count was measured at its northern section, from its north entrance at its intersection with Homero Avenue, all the way to its southern entrance where it joins Cantera Avenue, almost 8.5 km in length. The highest vehicle volume occurs at noon, reaching almost 3700 vehicles per hour (Table 1). The visual count allowed a vehicle type classification, with 95% being passenger cars and the remaining 5%, distributed between heavy goods vehicles (HGV) with different axes number.

PDJ's speed limit is 70 km·h<sup>-1</sup>, but the driver's behavior has a tendency towards the aggressive performance. Radar speeds ranged from 40 to 120 km·h<sup>-1</sup>, and from a total of 2244 measurements, the average speed was 67.75 km·h<sup>-1</sup>.

### 4.2. Safety Distance

A total of 82 standstill and 82 look-ahead distances were obtained from UAV images, with values ranging from 0.8 to 4.7 m and from 0.2 to 28 m, respectively. Travel times were obtained as described in the methodology section.

### 4.3. Calibration and Validation

Manual calibration parameter values were acquired performing several simulations in VISSIM, by changing default standstill distance values (in meters), and both additive and multiplicative part of safety distance (dimensionless).

**Table 1.** Traffic count for PDJ, for both directions N-S and S-N.

Time	Passenger cars		HGV		Total count	
	North entrance	South entrance	North entrance	South entrance	North entrance	South entrance
7:00	3105	1974	98	61	3203	2035
8:00	3082	1659	102	102	3184	1761
9:00	3165	1420	131	122	3296	1542
10:00	3113	1393	121	150	3234	1543
11:00	3170	1504	114	86	3284	1590
12:00	3403	1713	112	148	3515	1861
13:00	3579	2252	97	133	3676	2385
14:00	3249	2467	80	148	3329	2615
15:00	3168	2391	72	152	3240	2543
16:00	2903	2170	62	132	2965	3302
17:00	2870	2290	63	121	2933	2411
18:00	2846	2448	54	93	2900	2541
19:00	2591	2649	33	81	2624	2730

Simulation results were later compared to real look ahead distances and travel times, and then those close to real media values were calibrated. A comparison between VISSIM default and adjusted values are presented in **Table 2**.

To validate calibration, a comparison between real, default and calibrated values of travel times and follow distances was performed (**Figure 3** and **Figure 4**). Data analysis of travel times and follow distances' peaks show a similar behavior, thus validating the simulation. Histograms also reflect how simulated results using adjusted VISSIM parameter values (presented in **Table 2**) match field data. Iterative (manual method) results do not precisely overlap with real and calibrated travel time values (**Figure 3(a)**), however major peaks coincide, again validating calibration; default values cannot be used in PDJ because they do not overlap and are offset (**Figure 3(b)**, **Figure 3(c)**). Manual calibration offers then better results in follow distances (**Figure 3(d)**), with a major coincidence between the major peaks.

A similar histogram analysis was performed for the GA (automatic) method to validate calibration (**Figure 4**). GA calculations provided two decimal places for calibrated parameter values, hence the coincidence between major peaks, thus being more accurate in both travel times and in follow distances (**Figures 4(a)-(c)**), almost reaching the same frequency values. Undoubtedly, default parameter values do not resemble real conditions for PDJ. GA-obtained parameters, are more precise and its model mimics well the field data pattern. Therefore, if flow variables rise, or if changes in vehicle classification occur due to a demographic growth, mobility, or accessibility, they still will allow results to be closer to real data within futuristic projections.



**Table 2.** VISSIM (Wiedemann 74 model) calibration parameter values for Periferico de la Juventud (PDJ) in Chihuahua City, Mexico, using the iterative and GA methods.

Parameters	Unit	Initial (default) values		Adjusted (calibrated) values by iterative method		Adjusted (calibrated) values by GA method	
		max	min	max	min	max	min
Number of observed preceding vehicles	veh	0	4	0	4	0	4
Maximum look ahead distance	m	0	250	0	170	0	170
Average standstill distance	m	2.00		2.30		2.3	
Saturation flow rate	Additive part of safety distance	2.00		2.30		2.35	
	Multiplicative part of safety distance	3.00		3.30		3.35	
Average delay time per vehicle	s	34.98		88.28		13.68	
Delay time range per vehicle	s	0.2 to 339		1.18 to 485		9.38 to 24.01	
Average speed per vehicle	Km-h <sup>-1</sup>	77.29		72.01		81	
Speed range per vehicle	Km-h <sup>-1</sup>	37 to 86		28 to 84		79 to 82	
Average detention delay	s	9.99		25.68		2.3	

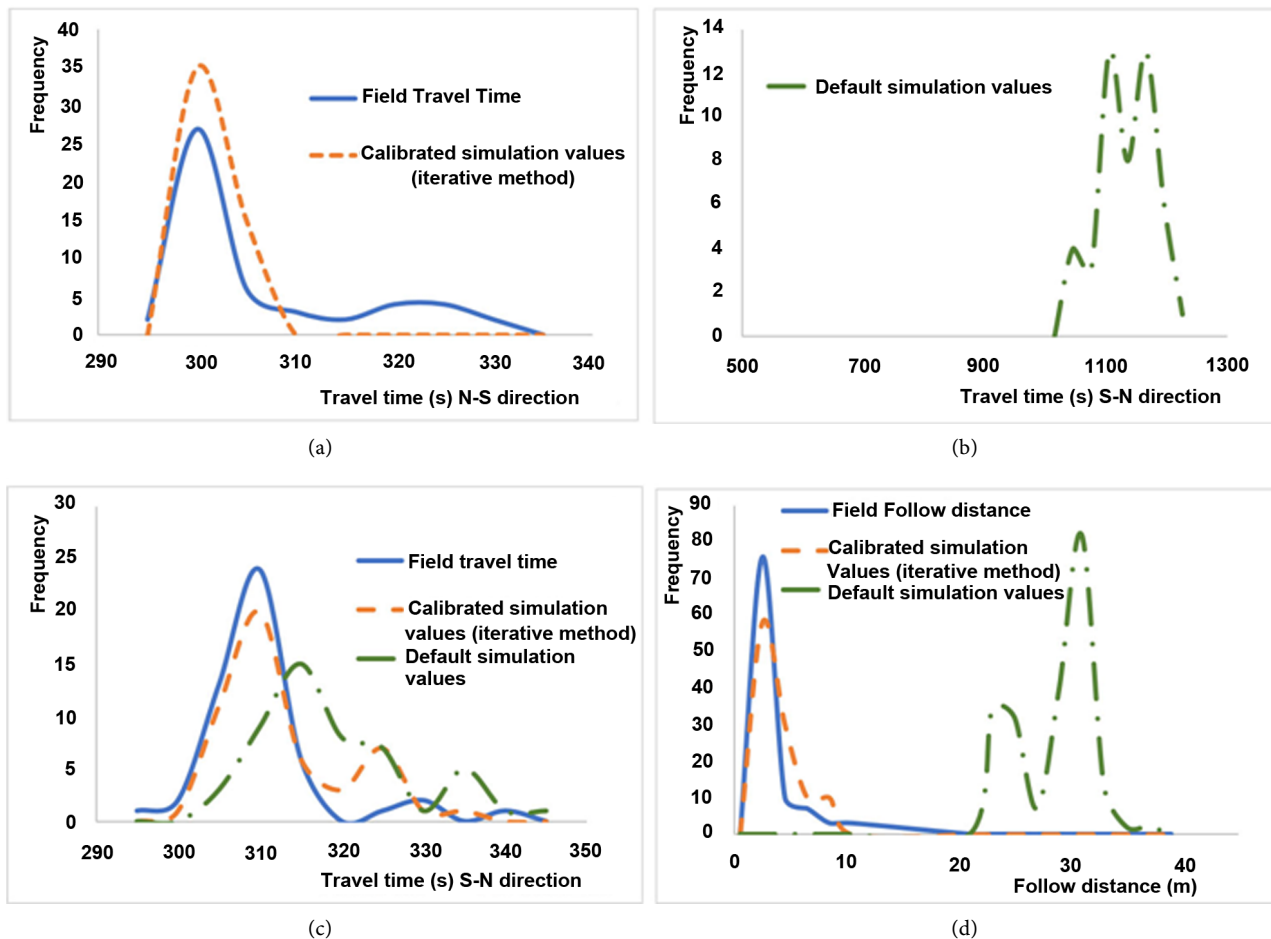
Calibrated values were slightly greater than the default ones, except for the maximum look-ahead distance, which decreases from a range of 0 - 250 (default) to 0 - 170 (adjusted). Average standstill distance and both the additive and multiplicative parts of safety distance increased from 2.0, 2.0 and 3.0 (default) to 2.3, 2.3 and 3.3 (adjusted), respectively.

## 5. Conclusions

Periferico de la Juventud (PDJ), is the most important express way in Chihuahua City, Mexico, and is the only access to commercial and industrial areas. Many vehicles transit PDJ daily, and a new public transportation system will be introduced soon.

Look-ahead distance, average standstill distance and the saturation flow rate (additive and multiplicative parts of safety distance) were calibrated specifically for PDJ being slightly above than the VISSIM default ones; and was validated with travel times and look-ahead distances. The adjustments were needed because PDJ is an expressway with shape changes along its length, occasionally with two lateral shoulders, several steep curves, and very busy junctions, increasing the number of vehicles getting in/out of it at given areas.

Traffic flow microsimulation is essential to represent scenarios of vehicles' behavior and to evaluate traffic problems. PDJ's scheme of entrances/exits, especially in the N-S direction, generates traffic jams at peak hours because it was not

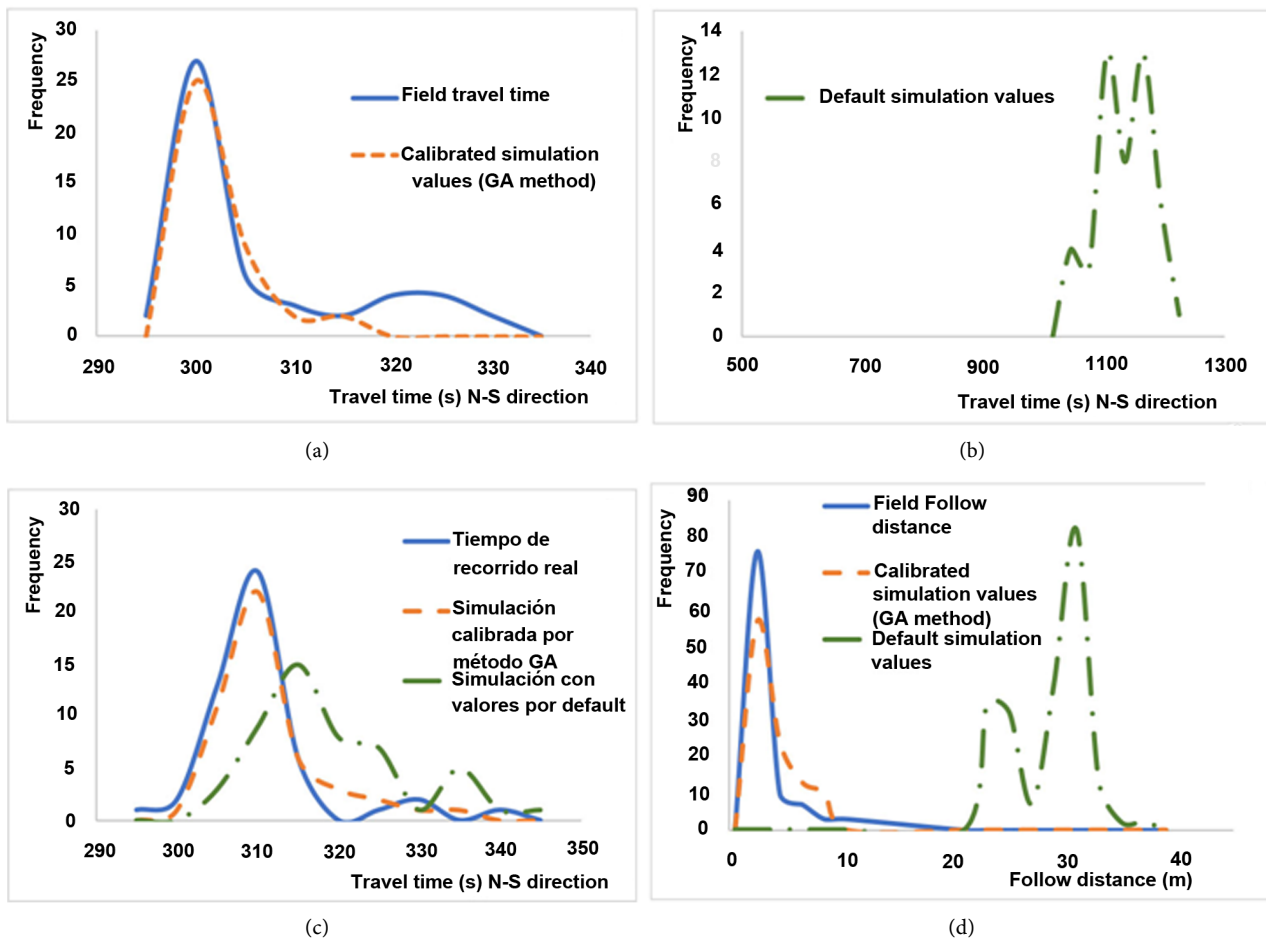


**Figure 3.** Histograms comparing default and calibrated simulation results (iterative method) with real values. (a) Travel times for N-S direction vs. default simulation values; (b) Travel times for N-S direction vs. with real and calibrated simulation values; (c) Travel times for S-N direction; and (d) Look-ahead distances between vehicles.

correctly designed. Revision or redesign of such in/out ramps could prevent traffic issues, and along with the calibrated model, simulated results replicated real conditions.

GA calibration yielded similar results to those obtained by using the iterative process, while using different samples. GA calibration is more accurate, because it uses the entire simulated vehicle sample, since it can be adjusted according to the variables used within the model. It may be possible that once the parameters are calibrated, conditions may suddenly change, but the GA will be ready to adapt to the new conditions, without needing to re-encode. This process helps to easily project flow behaviors, focusing on road characteristics over time-consuming model calibration, which may lead to a more efficient road designs. A limitation found however in calibration, is that it is used for only 3 parameters, so it would be advisable to program all parameters for different roads, so it can work once the simulation starts.

This paper demonstrates how calibration can be eased by using different and relative new techniques, how these techniques are not expensive and can



**Figure 4.** Histograms comparing default and calibrated simulation results (GA method) with real values. (a) Travel times for N-S direction vs. default simulation values; (b) Travel times for N-S direction vs. with real and calibrated simulation values; (c) Travel times for S-N direction; and (d) Look ahead distances between vehicles.

improve precision and be less time consuming than simply following the standard manual technique. It is a worthy option to economically challenged cities or traffic related agencies. However more research needs to be done in this field, not only locally, but also in a broader perspective, so different algorithms can be first selected and later implemented to ease modeling efforts, hence helping decision makers achieve better road designs, monitoring and reducing the number of accidents and traffic issues so typical all around the world.

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