Indicators of pedestrian accessibility and their evaluation using the Social Force Model parameters in urban intersections

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Abstract– ***The growing interest in making pedestrian environments and their road infrastructure suitable for all types of users has contributed to the development of different methods that allow us to assess the accessibility of the public spaces. This with the purpose of integrate the elements of urban design and the management of pedestrian mobility, to achieve an inclusive, accessible, and fair society. In this context, the article seeks to study in depth the different methods established to identify the determining indicators of accessibility and their way of representing them, as well as the surroundings for pedestrian mobility, by using the parameters of the Social Force model in a microsimultaion. To validate and test the correct characterization of the accessibility qualitative indicators and the influence of the parameters on the representation of the reality, an urban intersection, and its mobility ecosystem in the metropolitan area of the district of Lima have been used as a practical case, specifically in the area near the Rebagliati Hospital. The results indicate that the most influential parameters are Tau and Lambda, since in this scenario the time variation is 3.1%, showing its influence on the behavior of pedestrians when transiting at the intersection. Furthermore, the investigation shows that indicators of mobility and comfort such as crossing safety or presence of obstacles can be best represented by parameters like side_preference, ASocIsco, BSocIsoc, Tau y Lambda. However, the simulation of the indicators of accessibility will be complemented by the assignment of vehicular and pedestrian routes, as well as the construction of the model itself, especially those indicators that are physical variables such as the slope, and environmental indicators like the index of trees or availability of crosswalks.***

Keywords—Social Force Model, microsimulation, accessibility, Viswalk

I. Introduction

Accessibility is closely related to access and equity as it proposes the equal use of public spaces and urban infrastructure, thus allowing the integration and participation of all the members of a society [1]. Consequently, it’s imperative to measure the extent of the existing conditions based on different factors that can determine the level of accessibility of pedestrian environments [2].

First, the pedestrian level of service (PLOS) is used to describe the operating conditions that road infrastructures for pedestrians. There are different methods for the determination of PLOS like the one established by the Highway Capacity Manual (HCM), which considers variables such as speed and travel time, assigning a level to the pedestrian environment ranging from A to F [3]. This is a clear example of how most methodologies are based on the measurement of pedestrian flow, speed and walking space, leaving aside other components necessary for the determination of the pedestrian level of service and the accessibility index as the socioeconomic aspects of the area and the presence of obstacles that obstruct pedestrian movement. In other words, despite the existence of different methods, there are still a limited number of methodologies that are properly adapted to the study of pedestrian accessibility and the pedestrian level of service. Most of all, there have been no studies focused on the representation of accessibility indicators through simulation with the help of parameters that allow modeling pedestrian behavior, including the parameters of the Social Force model.

For this reason, the present study proposes to adapt and to look further into the qualitative indicators of accessibility and their representation by the Social Force Model parameters with the aim of evaluating these indicators through the micrsimulation as well as understanding the way that different mobility environments work.

II. Literature review

There are several accessibility measurement methods and modeling techniques that vary in difficulty, criteria, and factors that determine the calculation of the level of accessibility [2]. Although these methods help to identify areas with inadequate services, they are not always complete for what is required. For example, an article from the Universiti Teknologi Malaysia (UTM) proposes a data collection and analysis plan to measure the accessibility of people with disabilities to public transport in Klang Valley, Malaysia [4]. Statistics and a questionnaire were used to collect information on users' perception, ergo it only considers the answers of the survey respondents, based on personal judgment. On the other hand, an example of a semi-quantitative method can be the use of Geographic Information Systems (GIS) and Multiple Criteria Decision Analysis (MCDA) techniques in addition to other analytical processes proposed by Alzouby and company [5]. This study resulted in a map that allows modeling the accessibility to public services of people with disabilities in Irbid, Jordan.

Another example is the Walkability Global Index, a qualitative tool for analyzing pedestrian conditions [6]. This

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index allows us to perform a qualitative analysis of walking conditions and the pedestrian environment and, assess pedestrian infrastructure in four areas: (1) commercial, (2) residential, (3) educational and (4) public transport terminals. It consists of three main components: (1) safety and security; (2) convenience and attractiveness and (3) political support. The first one refers to the safety of the pedestrian environment, considering the physical accessibility and the safety perceived by the pedestrian; while the second one refers to the convenience related to the pedestrian network in terms of distances, presence of obstacles, among other variables [6]. Finally, political support measures the degree to which the municipal government supports improvements in pedestrian infrastructure and services, as well as the institutional organization [6]. As we can see, this study is one of the most detailed; however, not all the criteria proposed in this index can be represented in a microsimulation.

There are also other studies that, in addition to being based on the type of infrastructure in the area, also consider indicators of route walkability and comfort, such as the LUTRAQ method [7] or the one proposed by Brown for the Transportation Research Board (TRB) [8]. These methodologies classify the traffic area according to the urban level but do not represent the pedestrian infrastructure at a micro level.

III. Methodology

The methodology used was divided into phases. The first stage was the literature review. At this point, different tools, and methodologies to evaluate the PLOS and accessibility were analyzed. In second place, essential information was collected from the study area and from pedestrians who pass through said area of interest. Third, the urban intersection was modeled. This stage included the calibration and validation of the model to determine if it fits the reality of the intersection. The last phase was the variation of the parameters in a methodical way to assess the influence of the variation of the Social Force parameters on the characterization of the pedestrian environment, in order to check to what extent, the parameters and the construction of the model allow to represent the indicators of accessibility.

A. Selection of Indicators of Pedestrian Accessibility

As mentioned above, several studies on accessibility evaluation were compared in the literature review. Based on the methodologies proposed in those studies, the different qualitative indicators were regrouped into three major components of accessibility (Table 1).

These indicators were selected due to their importance, because as these factors are satisfied, the pedestrian environment will have a higher level of accessibility [9]. Many of the indicators referred to climatic variables, but for the purpose of the study, only those with a predominant physical character were selected so that they can be represented in the microsimulation and quantify the different physical characteristics of the urban environment.

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TABLE I
INDICATORS OF ACCESSIBILITY

Components	Indicators
Safety	Vehicle - pedestrian conflicts
	Vehicle traffic speed
	Security of crossings
Convenience and attractiveness	Permanent and temporary obstacles on walking paths
	Index of trees
	Route conectivity
	Existence and quality of infrastructure for PD and PRM
	Availability of crossings
Mobility	Siderwalk dimension
	Pedestrian walking speed
	Slope of the road network
	Quality and maintenance of walking path surface

The first conditioning aspect refers to different factors of the social and built environment that strengthen the pedestrian's perception of safety. This aspect is reflected in the urban design through the creation of pedestrian and vehicular areas since the modal conflict of the pedestrian path has an impact on the quality of the specific area [10]. The second aspect is comfort and attractiveness and represents one of the most variable indicators, as it is constituted by a diversity of physical as well as physiological and psychological components [11]. For example, the tree index, which represents the presence of trees in the area, conditions the attractiveness of the road for walkers, as it not only generates shade but also guides the pedestrian flow, defining the road and creating the impression of safety. This category also includes the availability of signalized crosswalks, the connectivity of the routes, which refers to the sinuosity of the pedestrian's path, among other variables that improve walkability. The last and third group is mobility. For this, variables such as the pedestrian section of the sidewalk are essential because it is a key factor to determine the pedestrian flow and the walking speed of users, which means greater freedom of movement [12].

B. Field Data Collection

At this phase, data about the geometric design, road signaglling, presence of obstacles, among other characteristics were collected with the purpose of representing them by the microscopic model using the help of Vissim 9.0.

It is important to mention that prior to data collection, the study area was defined. The intersections analyzed are Jiron Manuel Segura and Arequipa Avenue, as well as Jiron Domingo Cueto and Arenales Avenue. Both intersections are located within the area of influence of the Rebagliati Hospital in the district of Lima, an area of high traffic of people with reduced mobility (PRM) and people in general.

1) Pedestrian Classification: This classification was made based on the predominant characteristics of each pedestrian, grouping them according to qualities in common as observed in the field. Table 2 shows the classification made for this study.

TABLE II
PEDESTRIAN CLASSIFICATION

N°	Type	Characteristics
1	Senior citizen	Person over 65 years of age
2	Person with motor disability	People with physical difficulty to move, with or without a support element such as wheelchairs, crutches and others
3	Person with packages	Person with bags, luggage, babies in arms or other objects that make it impossible to move one or both hands.
4	Person accompanied	Person with an assistant, in family, groups or couples
5	Average person	Person walking alone and with no physical difficulty to move around

2) Walking Speed: Based on the pedestrian classification, we proceeded to record the time users spent walking certain distances.

First, we sampled the walking speeds of 30 people per, i.e., a total of 150 data were taken. This variable was calculated according to the time that pedestrians spent in walking 60 meters with no obstacle that hindered or limited their movement. Table 3 indicates the average values obtained for each class of pedestrian.

TABLE III
AVERAGE SPEED ON A FREE LANE ACCORDING TO PEDESTRIAN CLASSIFICATION

Class	Time (s)	Speed (m/s)	Speed (km/h)
1	49.54	1.24	4.47
2	53.45	1.16	4.18
3	48.19	1.26	4.53
4	52.42	1.17	4.21
5	32.98	1.84	6.61

As well as measuring the speed on the open road, the time pedestrians spent to travel 60 meters with obstacles was also recorded. Table 4 shows the values obtained for the average speeds for each class of pedestrian. These measurements were made with the purpose of analyzing and understanding pedestrian behavior patterns in the studied environment.

TABLE IV
AVERGE SPEED ON ROADWAYS WITH OBSTACLES ACCORDING TO PEDESTRIAN CLASSIFICATION

Class	Time (s)	Speed (m/s)	Speed (km/h)
1	53.51	1.16	4.18
2	59.52	1.06	3.82
3	53.88	1.13	4.07
4	62.52	0.98	3.53
5	37.47	1.61	5.80

3) Occupational Widht and Effective Width: The most appropriate criteria for the design of pedestrian sidewalks considers the sidewalk width as the length of the sidewalk circulation, which ends where the roadway begins. In this sense, the width occupied by a pedestrian is a determining factor for the design of roadways and their different elements.

As observed in the field, the occupational width of Type 1 pedestrians is considerable, as they have right-of-way priority and are usually given space to move. It is estimated that the occupational width of this type is approximately 0.85 meters. Type 2 also occupies a medium area, since they use different support elements to be able to move and just like the elderly, this group has priority of passage, so they occupy more space on the road. The occupational space for this type of pedestrian varies from 0.90 to 1.60 meters, depending on the object of assistance they use. Type 3 occupies a space that is not as large but larger than that of an average pedestrian, especially if it is an individual traveling with children or infants, as they occupy additional space. The space for these pedestrians is estimated at 0.80 meters. Likewise, Type 4 pedestrians occupy considerable space because they travel in groups of two or more, that is, the additional space they occupy should be counted, estimating the space they occupy in the range of 0.80 to 1.50 meters. Finally, Type 5 does not occupy much space because it travels alone and does not use any support element that occupies additional space, approximately the space they take varies from 0.65 to 0.70 meters. Based on this, different manuals recommend a minimum sidewalk width of 1.50 meters for the smooth movement of a wheelchair and a person. While a width of 2.00 meters will allow the transit of two wheelchairs at the same time [13]. The figure below (1) illustrates these design considerations.

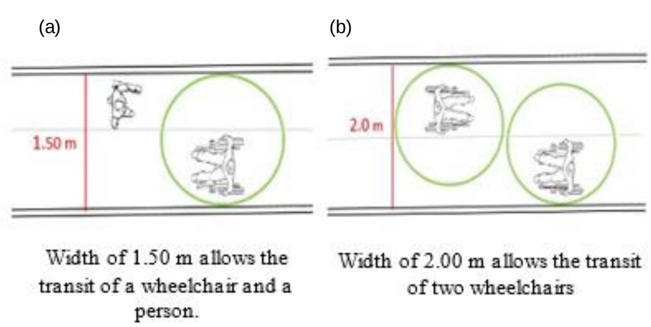


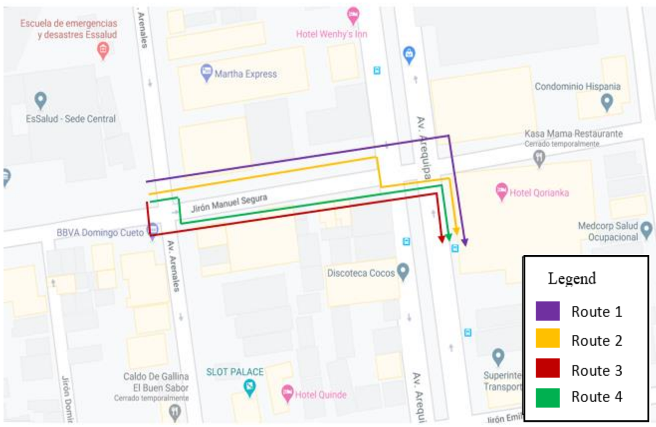
Fig. 1 Minimum circulation width. Capbauno, 2015: (a) Minimum width for the circulation of a wheelchair and a person without wheelchair, (b) Minimum width for the circulation of two wheelchairss

The observation showed that although the sidewalks in the area complied with the minimum sidewalk width, not all of them had the same effective width, since the actual space through which pedestrians circulated when avoiding the obstacles in the area was less than the total width of the sidewalk. Hence the effective width in the study area varied in the range of 1.47 to 2.51 meters.

4) Determination of the Critical Route for Walking Time Measurement: The influence of the Social Force parameters was determined based on the variation of walking times when these parameters are modified.

The time measured was the time it took pedestrians to walk the distance from the corner of Arenales Av. to the Corredor Azul bus stop in the south-north direction, which is located on Arequipa Av. and Ji. Manuel Segura. For this purpose, four possible routes were considered as shown in Figure 2. However, for the comparison of the results, the most critical route is Route 1, as the mapping of trajectories carried out in the field study displayed that it takes the longest time to travel through it and in which most pedestrians move along.

Fig. 2 Routes considered for the comparison of walking times



C. Microsimulation

After organizing the input data such as geometric information, density of users, speed variables and walking time, the current condition of the area is modeled. Figure 3 displays the model that was built based on the collected information.

Fig. 3 Model of the studied urban intersection

1) Social Force Model Parameters: Social Force Model Parameters: The Social Force parameters directly affect the pedestrian times and speeds in the simulation. Although, each one influences in a different way and in different proportions. It should be noted that the parameters of this model were configured by type of pedestrian and it is according to this classification that their different values are established.

Table 5 below briefly explains what each parameter helps us to portray in the microsimulation model, based on the qualitative indicators of accessibility established above and on the pedestrian behavior patterns observed in the field study.

TABLE V
PARAMETERS OF THE SOCIAL FORCE MODEL

Parameters	Description	Default value
Tau	Pedestrian reaction time, it simulates the movement of a pedestrian towards a desired direction at a certain speed	0.40
ASocIsoc	Simulates the yielding action as a function of the distance between pedestrians and the repulsive force between them	1.60
ASocMean		0.40
Lamba	Simulates the influence of nearby people on the pedestrian	0.30
BSocIsoc	Simulates the yielding action according to the distance between pedestrians and the range of repulsive force between them	0.40
BSocMean		2.80
Noise	Represents the randomness of pedestrian movement, which simulates ambulatory movement.	1.20
React_to_n	Regulates the maximum number of people in close proximity to the pedestrian	8.00
side_preference	Considered when a pedestrian wishes to overtake another pedestrian	0.00
queue_order	Order of pedestrian queues	0.70
queue_straightness	Straightness of pedestrian queues	0.60
VD	Relative pedestrian speed, it simulates the action of evading the encounter between opposing flows	3.00

Following the work methodology, Table 6 details the parameter values used for each pedestrian class present at the modeled intersection after the calibration and validation of the model. The parameters that are not mentioned were kept with the default value of the program, since it was observed that the variation of these parameters did not significantly influence the pedestrian speeds or the model in general.

TABLE VI
PARAMETER VALUES FOR MICROSIMULATION ACCORDING TO PEDESTRIAN CLASSIFICATION

Parameters	Pedestrian classification				
	Type 1	Tipo 2	Type 3	Type 4	Type 5
Tau	0.60	0.95	0.45	0.70	0.35
ASocIsoc	2.00	2.00	2.30	2.70	2.72
ASocMean	0.25	0.20	0.35	0.50	0.50
Lamba	0.15	0.15	0.17	0.20	0.20
BSocIsoc	0.20	0.20	0.30	0.35	0.40
BSocMean	2.80	2.80	2.80	2.80	2.80
Noise	0.70	0.50	0.80	1.00	1.40
React_to_n	8.00	8.00	8.00	8.00	8.00

side_preference	0.00	0.00	0.00	0.00	0.00
queue_order	1.00	1.00	1.00	1.00	1.00
queue_straightness	1.00	1.00	1.00	1.00	1.00
VD	3.00	3.00	3.00	3.00	3.00

These parameters will be used for the different scenarios analyzed in the article. For the determination of these values, the movement pattern of each type of pedestrian and the calibration and validation of the model were taken into consideration, varying them to reflect the reality more precisely.

Because the present research seeks to determine how the parameters influence pedestrian displacement, it was necessary to propose scenarios to study the direct relationship of the variation of the parameters with the variation of pedestrian times. This with the purpose of evaluating the different accessibility indicators with the help of Viswalk simulation. The main criterion for proposing the scenarios was the function of each of the parameters studied. The first scenario consists of the variation of the side_preference parameter while the other parameters remain constant according to Table 6, with the values we had determined for each type of pedestrian. The second scenario is based on the use of the values in Table 6 for the parameters Tau, Lambda and Noise, while the remaining parameters kept the software default value. In the third scenario the values of ASocIsoc and BSocIsoc kept the default values and, for the rest of the parameters the values of Table 6. Finally, the last scenario analyzed consists of varying all the parameters according to Table 6, except for the ASocMean parameter, which will keep the software default values.

IV. RESULTS

The results for each of the proposed scenarios are discussed below.

A. *Scenario 1: Side_preference Variable*

The side_preference parameter causes the pedestrian to have the preference to go on the side indicated. In the calibrated model there was no specific direction, so for the first case the right side is the preferential side of traffic, meaning that the value of the parameter will be -1. Table 7 shows how changing this parameter affects walking times.

TABLE VII
VARIATION OF AVERAGE TIMES FOR SIDE_PREFERENCE VARIABLE

Case	Time (min)				
	Type 1	Tipo 2	Type 3	Tipo 4	Type 5
Current	6.85	6.96	6.94	6.47	4.24
Right side	6.56	7.05	6.98	6.26	5.99
Variation %	4%	-1%	-1%	3%	-41%

B. *Scenario 2: Tau, Lamba y Noise Variables*

For this scenario, we kept the calibrated values of Tau, Lambda and Noise for the calibrated intersection and the other parameters are left with the default value. Table 8 displays the variation of these three parameters on pedestrian walking times.

TABLE VIII
VARIATION OF AVERAGE TIMES FOR TAU, LAMBA AND NOISE VARIABLES

Case	Time (min)				
	Type 1	Tipo 2	Type 3	Type 4	Type 5
Current	6.85	6.96	6.94	6.47	4.24
Tau, Lamba, Noise variables	5.98	6.44	6.29	5.88	5.88
Variation %	13%	8%	9%	9%	-39%

C. *Scenario 3: ASocIsoc y BSocIsoc by Default*

In this case, the default values for the ASocIsoc and BSocIsoc parameters were maintained, and the values of the rest of the parameters are the same as those established for the model. The results are shown in Table 9.

TABLE IX
VARIATION OF AVERAGE TIMES FOR ASOCISOC AND BSOCISOC BY DEFAULT

Case	Time (min)				
	Type 1	Tipo 2	Type 3	Type 4	Type 5
Current	6.85	6.96	6.94	6.47	4.24
ASocIsoc y BSocIsoc por defecto	6.25	6.78	6.66	6.22	5.84
Variation %	9%	3%	4%	4%	-27%

D. *Scenario 4: ASocMean by Default*

In this last scenario, the default ASocMean value was kept, and the remaining parameters were modified as established in the calibration and validation according to Table 6. The following Table shows the results for this case.

TABLE X
VARIATION OF AVERAGE TIMES FOR ASOCMEAN BY DEFAULT

Case	Time (min)				
	Type 1	Tipo 2	Type 3	Type 4	Type 5
Current	6.85	6.96	6.94	6.47	4.24
ASocMean por defecto	6.83	6.60	6.76	6.17	6.05
Variation %	0%	5%	3%	5%	-43%

E. *Comparison of All Scenarios*

Table 11 presents the comparison of all the scenarios analyzed, based on the percentage variation of the times with respect to the current condition of the intersection, as well as the difference between their standard deviations and variances.

TABLE XI
COMPARISON OF ALL THE SCENARIOS AND THE CURRENT MODEL

Measure	Time (min)				
	Current	Case 1	Case 2	Case 3	Case 4
Variation %	-	-3.9%	3.1%	-0.9%	-2.9%
Standard deviation	0.611	0.770	0.626	0.897	0.872
Variance	0.373	0.594	0.392	0.805	0.761

As can be seen, the greatest variability occurs in scenario 1, because in this case all the parameters were modified and, in addition, the side_preference parameter, which initially had the default value for model calibration, was also modified. Scenario 2 also presents high variability, which indicates that as the values of these parameters are changed, more significant variations in users' speeds and walking times of the users will arise.

F. Representation of the Indicators in the Microsimulation

Once the simulation of the different scenarios and the analysis of the model have been carried out, we can construct Table 12, which explains how each indicator used for accessibility evaluation is represented in a microscopic model.

TABLE XII
FORMS OF REPRESENTIG THE INDICATORS OF ACCESSIBILITY TRHOUGH THE MICROSIMULATION

Indicators	Characterization
Vehicle - pedestrian conflicts	VD, vehicular and pedestrian speed curves, model construction, pedestrian and vehicular routes
Vehicle traffic speed	Vehicle speed, Wiedemann's parameters
Security of crossings	Model construction, ASocIsoc, BSocIsoc, ASocMean, Tau, Lamba, Noise, side_preferece
Permanent and temporary obstacles on walking paths	Model construction, ASocIsoc, BSocIsoc, side_preference
Index of trees	Model construction
Route conectivity	Model construction
Existence and quality of infrastructure for PD and PRM	Model construction
Availability of crossings	Model construction
Siderwalk dimension	Model construction
Pedestrian walking speed	VD, pedestrian speed, Tau, Lambda, Noise
Slope of the road network	Model construction
Quality and maintenance of walking path surface	Model construction, VD

G. Proposed Urban Intersection Improvement

With the elaboration of Table 12, we have a clearer idea of how to represent the accessibility indicators, and the research also provides us with a better understanding of the parameters of Fuerza Social. This allows the microscopic model to more closely resemble reality, facilitating the design of road infrastructure, since it will be possible to characterize the pedestrian mobility environments and the different types of pedestrians. The latter is extremely important if we take into account that urban design and road management do not always take into consideration the needs of people with reduced mobility (PRM), generating inequality in the conditions of use of infrastructure and public transport.

To make designs more inclusive and accessible, as well as to ensure the operation of the intersection by identifying potential conflicts in the area, a redesign and reorganization of the study area is suggested.

In the field, it was observed that the queue at the bus stops was chaotic, reducing the effective width of the sidewalks and made it difficult for people to walk, especially those in wheelchairs, who are considered the most critical case. For this reason, the four stops of the Blue Corridor were redistributed, and their area was delimited by signs, and the traffic light cycle was reduced from 119 to 105 seconds for intersection 1 on Arequipa Av. and from 115 to 105 seconds for intersection 2 (Arenales Av.). Finally, the sidewalk areas near the bus stop were widened by one meter, ensuring that each bus stop is at least 20 meters from the intersection crossing, thus allowing the smooth flow of traffic and avoiding vehicle congestion. This was verified by reducing travel times by 14.56% for users with reduced mobility and by 6.84% for the average pedestrian. Likewise, the formation of vehicular queues was reduced by approximately 3.30% at all intersections.

Table 13 shows the summary of all the changes included in the improvement proposal, divided into two major work stages.

TABLE XIII
SUMMARY OF THE IMPROVEMENT PROPOSAL PHASES

Phase	Description
Geometry and reorganization of bus stops	Redistribution of bus stops and signaling of the area of each one.
	Change in the width of the sidewalks near the Corredor Azul stops.
Design of the traffic light cycle	Redesign of the traffic light cycle at the intersection of Av. Arequipa with Jr. Manuel Segura (Intersection 1)
	Redesign of the traffic light cycle at the intersection of Av. Arenales with Jr. Domingo Cueto (Intersection 2)

IV. DISCUSSION

Weather is a non-constant variable that cannot be represented by the parameters of the Social Force Model, but it can be modeled by assigning routes pedestrian routes according to the field observation on both favorable and unfavorable weather days. For instance, in a rainy or very hot day we can assign one side of the sidewalk to be taken as a shelter. This scenario could affect the walking speed of pedestrians as well as their interaction with the surroundings. Therefore, the contemplation of the weather in the study would allow us to perform a more complete and accurate analysis.

V. CONCLUSIONS

According to the results, people of Category 5 are more affected in their travel time by the modification of the parameters since they have variations of the calibration data between 27% and 43%. Besides Type 3 presents less variation in the results.

The analysis shows the scenarios with the greatest variability are 1 and 2 with percentage of variation of 3.9% and 3.1% respectively. In this context, it is determined that the most influential parameters are Tau and Lambda since the displacement of people is more influenced by their environment and the people around them (Lambda) and their reaction time or impulse force (Tau). This illustrates the importance of calibration taking into consideration each of the parameters with the aim of modeling the reality more accurately and obtain more precise data. Consequently, we can perform a better evaluation of accessibility, as the different behavior patterns and indicators can be represented more truthfully through these parameters, the construction of the model itself and the assignment of vehicular and pedestrian routes.

The proposed improvement includes the widening of sidewalks and relocation of the bus stops, in addition to a new traffic light cycle, resulting in a 15% reduction in travel times for PRM and 7% for the average person (Category 5), thereby improving the functionality of the intersection.

The parameters side_preference, ASocIsoc, BSocIsoc, Tau y Lambda represent the mobility and comfort indicators at an intersection, given that the circulation spaces between pedestrians, the awareness of obstacles and the consideration of the right-of-way depend on the calibration of these parameters. Nevertheless, it is necessary to complete the simulation of the accessibility indicators by assigning vehicular and pedestrian routes in addition to the construction of the model itself; especially parameters such as slope and tree index, since these represent physical and environmental variables, respectively. It should also be noted that the factors of climate, noise and pedestrian moods have not been considered in the development of the model, which may cause variations in the results because they influence people's behavior.

Finally, it should be noted that each case of the analysis was performed under the same accessibility conditions. This means that in different circumstances there could be greater or lesser variability in the results as pedestrian behavior will be affected by their environment.

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