Microsimulation in the Assessment of Vehicle and Pedestrian traffic in an Urban Network

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***Abstract*— *Metropolitan cities have attracted and accumulated most of the world's population territorially. Concomitant to this, there are impacts generated by urban traffic, which directly affect social life and relationships, namely, educational, personal, commercial, among others. These impacts, by their very nature, involve multiple actors; multiactivities; complex relationships from and between people; different activities and infrastructures. In addition, the effects of rapid urbanization and the modernization and change of urban lifestyles have fostered new behaviors. Because of this, and the wide spectrum of variables, as well as the need to view and analyze scenarios, in this work we used microsimulation, as it offers possibilities to understand behaviors. Being proposed a model that describes the elements that make up the daily movement of vehicles and pedestrians in urban areas. This model is a modification of the traditional four-step approach, considering the behavior of each decision maker and other actors individually involved. The structure of the model consists of five steps: operational analysis; simulation structuring; data collect; measures of efficiency and acceptability. The research unit used was a metropolitan region with a high flow of pedestrians and vehicles, located in the state of Espírito Santo. The results showed that changes in tracing and use of restriction signals are alternatives that lead to the minimization of queues. The contributions of this work are not limited to scientific development, but also serve to compose the framework for decision making in the sector.*

***Keywords*— Urban traffic; Pedestrian and vehicle flow; Integrated simulation platform; Transport policy; Sustainable urban mobility.**

I. INTRODUCTION

Metropolitan cities throughout history have attracted and territorially accumulated most of the world's population. Thus, due to the impacts of the effects of rapid urbanization and the modernization and change of urban lifestyles, these cities start to demand solutions that help the organization of vehicle and pedestrian flows (HASSAN; LEE, 2015; TAN et al., 2016; ZHU et al., 2019).

According to Manaugh et al. (2015), urban transport planning not only aims to organize and balance vehicle and pedestrian flows, but also to promote the use of more efficient transportation systems. Ratifying this thought, Lee et al. (2017) emphasize that this planning must be continually reviewed over time, with the proposition of different mobility alternatives and land use scenarios.

The increasing demands related to the efficiency of urban traffic represent challenges to be solved in metropolitan areas (VERA, 2012). According to Piort et al. (2017), the high migration of people to urban centers has caused significant problems in managing the flow of people and vehicles in cities. With this high migration of people, congestion becomes one of the main factors responsible for urban quality of life, bringing stress, anxiety and tension to drivers and pedestrians (FELEZ et al., 2013).

On the other hand, urban travel flows are increasingly complex to understand (OSORIO; NANDURI, 2015). This view is corroborated by Jeihani et al. (2015), which highlights the high composition of variables from various actors. And, most of the time they need specific studies to understand their incidences and correlations.

The literature indicates that in case of studies of displacement flow involving vehicles and people, good technique suggests the use of microsimulation (COSTA et al., 2017; PASCUCCI et al., 2017; MANLEY; CHENG, 2018). This is explained, according to Lee et al. (2017), because this technique allows investigating transport planning alternatives by modeling a problem situation, with subsequent scenario simulation. And, according to Zhu et al. (2019), their outputs serve two important purposes, namely to present a visualization of traffic flow conditions and to provide quantitative responses to differentiate service levels to be offered according to local conditions.

Thus, considering the reasons given, this work presents a proposal for a microsimulation model, which was used as a tool to contribute to the assessment of vehicle and pedestrian traffic in an urban network. To operate the model, a metropolitan region with a high flow of pedestrians and vehicles, located in the state of Espírito Santo, was used as a research unit.

II. THEORETICAL REFERENCE

Urban mobility takes into account the needs of a wide variety of road users, including various types of motor vehicles, as well as vulnerable users such as pedestrians and cyclists. This mobility decreases rapidly in much of the world. Factors affecting mobility levels and possibilities for improvement vary. Gakenheimer (1999) cites that rapid automobile growth, local demand conditions that far exceed the capacity of facilities, the incompatibility of urban structure with increased motorization, a stronger relationship between transportation and road use in developed cities and the lack of proper maintenance of the roads responsible to address the problem. Costa et al. (2017) adds that as the population of urban centers grows, there is a major challenge: adapting urban development and transport needs, seeking mechanisms to ensure the sustainable growth of local urban mobility. Constant traffic jams in large cities, caused by excessive use of individual transport, hamper urban mobility, resulting in damage to the population and the environment.

According to Pascucci et al. (2017), semaphore synchronization (Figure 1) is essential once idle time losses begin to prove meaningful, so taking drivers as a comparison with those on a traffic-free road takes longer to cross a section of road because of the presence of pedestrian crossings.

Osorio and Nanduri (2015) highlight that the delay time (or idle) is an adequate measure of traffic quality for drivers and pedestrians. These authors further add that energy efficiency is a growing concern of the transportation sector. From this, Osorio and Nanduri (2015) in their work using traffic simulation and vehicle performance assessment tools, concluded that these tools are vitally important in formulating traffic management strategies. Fact corroborated by Lacerda et al. (2012), who highlight a need for strategic management, based on elements that can simulate the ideal conditions of use.

According to Wen and Bai (2017), in the urban environment there are three important policies that must be considered to mitigate traffic volume and also reduce emissions from the urban traffic system. And, as a result, the reduction of energy consumption (renewable and non-renewable fuels), allowing, for example, to increase the average speed of vehicle flow.

Wen and Bai (2017) state that the first policy imposes restrictions on the registration number of vehicles; judged as a short-term policy. As the second policy is about controlling the number of private cars to interfere with traffic congestion, the third was to develop public transport.

Manley and Cheng (2018) suggest that this third policy is long term and has more stable effects. It also concludes that even the simplest models demonstrate how driver cognition significantly influences emerging responses in traffic flow.

Souza (2013) argues that the degree of spatial variation in traffic flow, within the context of fixed models in travel generation and distribution, demonstrates the importance of establishing strong fundamental representations of individual behavior and limited rationality involving the complex systems of travel. development of simulated flows. These simulations, and emerging evidence elsewhere, pose a significant challenge to the status of transport policy development and implementation.

Hu et al. (2015) state that a synchronization experiment showing the road mesh flow algorithm can, in fact, significantly improve the performance of vehicles within traffic under local congestion conditions, but the algorithm may lose efficiency over a traffic flow under traffic conditions. a global shelving.

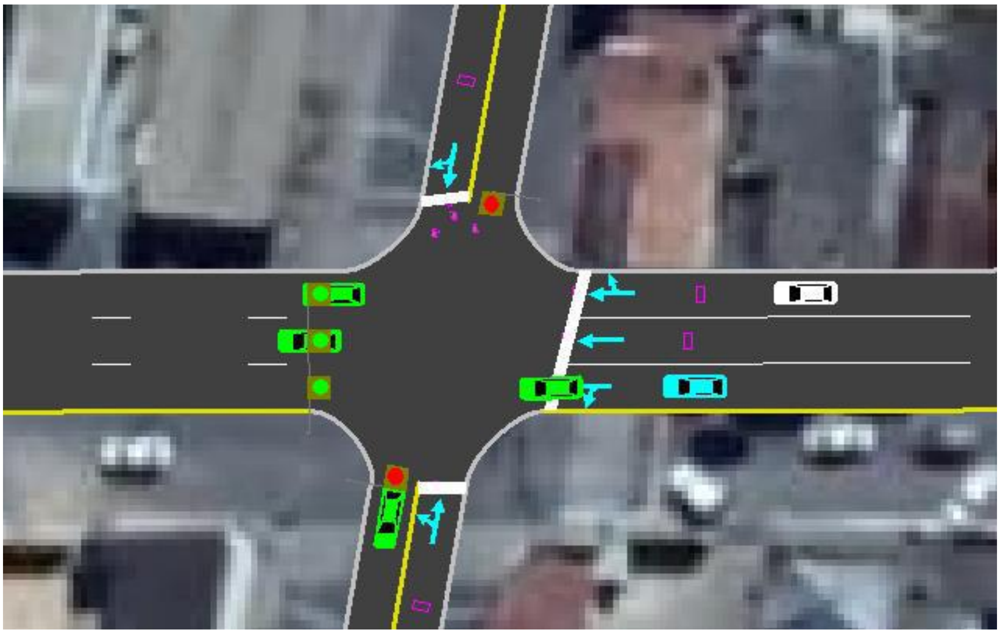

Fig.1: Exemplary semaphore synchronization modeling with stakeholder integration

Piort et al. (2017) demonstrated that it is possible to show that a standard conductor model can be used successfully for simulation purposes, providing reliable results. In addition, it can also indicate ways to develop more specific and useful methods for traffic control, such as signing drivers for appropriate lanes based on their behavioral profile.

Walraven et al. (2016) indicate the use of the simulation tool as a priority in urban flow studies, and is recommended for use by public authorities to gain more insight into how pedestrians and drivers interact with each other in crosswalks. In addition, pedestrian-vehicle encounters can be identified in advance by simulation, which provides information on potential safety issues prior to installation implementation.

From the perspective of Azam et al. (2019), in contrast to models used by other programs, a proposed model that considers each vehicle, including its physical behavior and dynamics, in terms of acceleration or braking maneuvers, and a driver behavior model, which provides braking. , accelerating, changing lanes, etc. maneuvers, depending on the parameters that define the driving style. These authors also point out that over simulations are usually included in a study of flow and urban traffic, to validate the developed model.

III. METHODOLOGICAL APPROACH

The methodological approach adopted in this paper followed the precepts of Walraven et al. (2016), considering that the diagnosis, analysis and planning of actions are used to adjust the elements that compose the traffic of vehicles and pedestrians in urban network. And from this, a use of microsimulation raise several enlightening information. According to Azam et al. (2019), understanding the nature of spatial variation behavior, in terms of time and stakeholder integeration, provides important insights that aid in the planning and management of urban traffic (people and vehicles).

Thus, this approach uses metrics that have the potential to be enlightening because they can be mapped to examine scenarios and alternatives for managing urban and pedestrian traffic flow. Thus, although it is routine in the literature to identify the location of possible traffic bottlenecks, on the other hand, little attention is given to identifying which elements suffer or cause delays. For this reason, the demand of the Origin-Destination (OD) matrix is considered in this paper as a temporal profile, which, according to Zhu et al. (2019) define the demand rate from each source zone to the destination zone within a given time interval.

Considering the postulates of Venkatesh et al. (2016), the data reconciliation in this work employed the concept of data triangulation, and, from that, adjusted procedures and techniques in order to converge results. This conciliation, according to these authors, provides a more intense understanding of the phenomenon studied. The methodological approach employed in this paper is composed of four steps (Figure 2), which are mutually dependent: Operational Analysis; Simulation Structuring; Data Collection and; Efficiency measures.

The first stage began with the identification of parameters considered relevant for the elaboration of the simulation model (Operational Analysis). This identification raised characteristics and particularities of

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traffic that indicate factors, cultural, social, commercial, urban planning, and geometric design, which directly influence the occurrence of congestion and overuse of the existing road network (FELEZ et al., 2013). Such information is that, according to Ragab et al. (2016), reveal to us the number and width of roads, number and location of parking lots.

Thus, considering the data collected in the Operational Analysis, the Simulation Structuring (second step) was performed. This step was started by obtaining a georeferenced map, which was used to characterize the studied roads and intersections. And subsequently selected the most critical points for analysis. These points were selected from the critical consideration of use, as described by Hu et al. (2015). As research unit was used the metropolitan region of downtown São Mateus (Espírito Santo / Brazil), which has a high flow of pedestrians and vehicles, and congestion of stochastic origin. Having from P1 to P7 853.14 m meters and were rounded to 860.00 m (use of integers) meters when using the software. To operate the simulation model, Synchro version 10 - demo software and the assumptions and methodologies established by the Highway Capacity Manual (HCM-2010) were used.

3.1 DATA COLLECT

Tan et al. (2016) highlights as the first step to ensure the success of the simulation and the efficiency of its elaboration are the data collection and analysis steps, including: studies in the area of urban planning and transportation, counts and total traffic volume analysis, pedestrian movement data through filming, interviews with transportation authorities, contour maps, search for the maximum speed established on each lane and their reports. The purpose of the video observation was to obtain useful information on the movement and behavior of road users. Such collection was made in 7 crossings considered with a high traffic flow. Thus we can draw conclusions on the most critical area of the studied region. The video recording technique required certain additional features, such as the location of the cameras, so that the visual fields would allow a full understanding of traffic behavior at the intersection and ensure that they were not affected by any interference.

Traffic data determination, including total volume, accounts for the number of vehicles, pedestrians and cyclists during peak hours. This data collection and analysis will be the basis of all assumptions in the simulation. Using the collected data and mapping of the area in question, we will be able to establish optimal simulation and synchronization of vehicle and pedestrian flow in downtown São Mateus, allowing us to establish the optimal cycle time and color intervals. Green, yellow and red. The number of vehicles and pedestrians could be determined from an interval of one (1) hour between the hours of 07:00 am to 09:30 am, 11:00 am to 13:00 pm and 16:30 pm to 17:40 pm, by manual counting, and through the traffic survey application, which served as an aid for reliable counting and accurate baliser of the shoot.

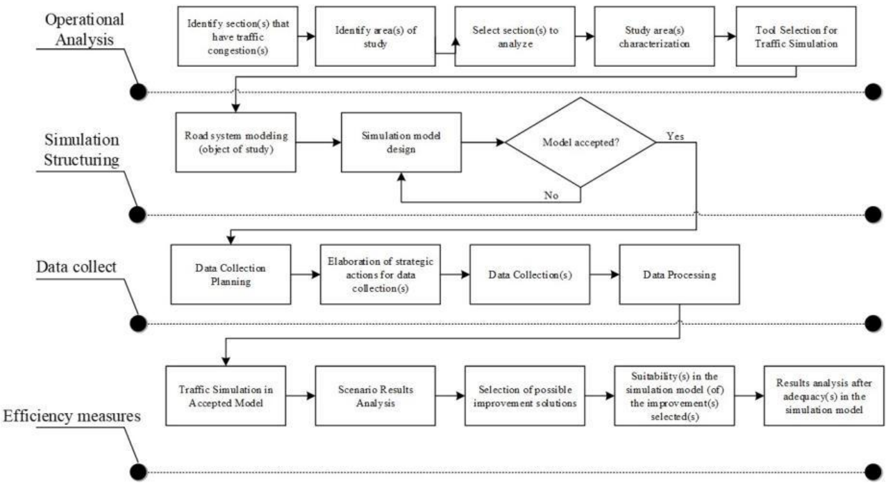

Fig. 2: Síntese da abordagem metodológica

3.2 EFFICIENCY MEASURES

The methodology considers the access to the intersections individually and the set of vehicles and pedestrians that travel through it. Soliman et al. (2016) tells us that Synchro is based on the most critical 15 minutes of the selected simulation time. One of the relevant steps of this research corresponds to data collection; for which, in order to improve the quality of

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records and enable verification where necessary, footage was used. These procedures were described later. The following equation 1 was considered to find the ideal yellow time in the studied crossings:

$$y = t + \frac{v}{2a + 2Gg} + \frac{w + L}{v} \quad (1)$$

Being:

y = the interval time in yellow (sec);

t = driver perception time (1 sec);

v = vehicle approach speed (ft/sec);

a = desaceleração media do motorista 10ft/seg²;

G = degree of approximation (considered 1);

g = acceleration of gravity. 32 ft / sec²;

w = intercession length (ft);

L = vehicle length (15ft on average).

To calculate the total red color time, the following equation (Eq. 2) was used:

$$r = \frac{P + L}{v} \quad (2)$$

Being:

r = total red color time;

L = vehicle length (15ft on average);

P = intersection length (ft). Measured from the nearest to the farthest stop line of the conflicting crosswalk;

v = vehicle speed when passing the intersection.

Thus, after the optimization generated by the software, we were able to generate the ideal timing for each intersection.

IV. RESULTS

It can be noted that at peak times, the traffic of St. Matthew is considerably saturated, making the situation increasingly alarming. In the moments of great tourist arrival, the ideal signage is practically unfeasible, making the region stressful and difficult for both pedestrians, who end up taking risks on out-of-lane crossings and for drivers who often wait for more than one traffic light cycle before they can make their crossings (Figure 3).

With the simulation performed we were able to identify patterns in traffic flow that increase the risk of collision between vehicle and pedestrian, allowing the design of solutions to accommodate these high risk situations. The identified criteria are evaluated to understand their possible direct and / or indirect consequences on saturated congestion. From this, a detailed measurement was performed for each intersection, allowing to regulate the average volume at intersections, considering the types of vehicles, such as possible pedestrians that interfere with the flow (Tables 1 and 2).

Fig 3: Mensuração volumétrica em momentos de pico em São Mateus

Tab 1: Horizontal semaphore synchronization

Critical point	Horizontal Intersection Location	Sync in seconds (sec) Green	Yellow	Red
1	Av. João XXIII e Av. Dr Raimundo Guilherme Sobrinho	22	4	18
2	Av. João XXIII e Rua Manoel Andrade	30	3	18
3	Rua Anchieta e Rua João Bento Silvares	28	4	19
4	Rua Dr. Arlindo Sodré e Av. Jones dos Santos Neves	25	4	22
5	Av. José Tozzi e Dr. Raimundo Guilherme Sobrinho	25	4	22
6	Av José Tozzi e Rua Manoel Andrade	27	3	19
7	Av. José Tozzi e Av. Jones dos Santos Neves	23	4	23

Tab 2: Vertical semaphore synchronization

Critical point	Vertical Intersection Location	Sync in seconds (sec) Green	Yellow	Red
1	Av. João XXIII e Av. Dr Raimundo Guilherme Sobrinho	12	4	28
2	Av. João XXIII e Rua Manoel Andrade	14	3	34
3	Rua Anchieta e Rua João Bento Silvares	18	4	33
4	Rua Dr. Arlindo Sodré e Av. Jones dos Santos Neves	16	4	31
5	Av. José Tozzi e Dr. Raimundo Guilherme Sobrinho	16	4	31
6	Av José Tozzi e Rua Manoel Andrade	14	3	32
7	Av. José Tozzi e Av. Jones dos Santos Neves	17	4	29

Information regarding traffic lights, such as their cycle length, green, yellow and red light time and how long they are running intermittently, was also observed. According to the literature (DESSBESELL et al., 2015), they need monitoring and constant reformulation of simulations. In order to contribute to a better urban mobility for all users.

From the simulation performed, after a careful analysis of the traffic data generated, the data were added to a spreadsheet, point to point and specifying the time of each of the possible colors. Thus, the appropriate timing, according to the software studied, is shown first, point by point, the times related to traffic lights horizontally in Table 1. Then, in Table 2, we show the timing of the points positioned vertically.

We also observed that the maximum speed reached by the drivers was 32.4 km / h (range within the maximum allowed). We can consider the maximum waiting time for pedestrian crossing to be low, being 34 sec. Since in the current scenario the average red time is 35 sec duration. We must take into account that the journey made by the pedestrian is hardly too long (WEI, 2015), so the maximum waiting time at each traffic light is an important factor in the concept of pedestrian transition within the Mateense economic pole.

And an average speed of 21.6 km / h within the studied areas. Analyzing an environment with a very intense flow, it is considered a satisfactory speed in the current context, revealing favorable the work done. This way, drivers will be able to pass these overcrowded places more easily and follow the journey with less stress through less crowded places, thus leading to more safety for pedestrians.

IV. CONCLUSION

This work is relevant not only because it achieves its main objective of making the flow of vehicles and pedestrians more efficient in urban centers by using traffic light simulation to coordinate and improve the performance of traffic management policies. As well as being a contribution in terms of tools to public managers and companies in the sector. In the results presented, it was possible to verify the reduction of travel time and congestion and, consequently, a shorter waiting time among those involved, thus reducing the stress and discomfort of the occasion.

This effect affects the social spheres at the same time, providing a better quality of life for the driver and shorter exposure to traffic stress; economically, by allowing the best time spent to be invested productively or reducing the cost of activities involving vehicle displacement.

One of the main problems encountered during the study was the lack of capacity of downtown São Mateus to withstand the intense and voluminous flow at peak times and seasons, given a city that is watered with tourism and strong variations during certain times of the year. (city and summer party). Thus, our simulation proposed the model not necessarily the ideal model, but rather the model where in both parts, vehicles and pedestrians, would suffer the least loss of time during these moments.

It is noteworthy that other forms of traffic control should be studied, such as alternative routes and stimuli to change peak hours at certain times.

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