Mobility in Smart Cities: Spatiality of the Travel Time Indicator According to Uses and Modes of Transportation

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Abstract. The objective of this document is to present the analysis of the level of vehicular congestion that occurs in the surrounding sectors, the downtown neighborhood, specifically on Alfonso López Avenue, to analyze and propose, what is the best solution, and thus improving the mobility of the road network, and minimizing congestion in the present and the future. The results of the analysis of the measurement of the speeds that were obtained taking the different modes of transportation: private, public: taxis and buses, and plate method, speeds were taken at peak and off-peak hours, in the morning and afternoon days, for 15 continuous days; through cycles that incorporate series of fluid and congested traffic or combined; taking into account the relationship variables between flow, velocity, density, interval, and spacing; Finally, the results were spatialized, to expand the crossovers of variables. The previous analysis seeks to contribute to the discussion about the impact of the different modes of transportation on traffic congestion and how to diagnose and propose solutions to improve mobility.

Keywords: Spatialization · Transport · Travel time · Modes of transport · Villavicencio

1 Introduction

Information and communication technologies ICT are the foundations of modern life in many aspects, and they are determining changes in how cities work. The use of ICT to integrate transport, energy, health, resource management, and other systems in the cities is the concept of smart cities that seek to improve citizens' quality of life, disposing of all services accessible to them [1,2]. The smart

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cities are inspired by the sustainable development goals adopted by world leaders on September 25, 2015, where were planned the masters lines to bring about the world's global development. In this context, the improvement of mobility impacts 13 of the 17 SDGs [3].

Considering that 85% of people will live in cities, it is crucial to rethink mobility within a smart city [4]. The aim is to use the new generation of information technologies to obtain and manage the city's data to mitigate risks, plan, build, and implement a services citizen city [5]. Within smart mobility, strategies have been proposed that range from urban planning, means and modes of transport and intelligent transport systems that, based on the capture of information, allow the generation of adaptable projects for the improvement of mobility and road safety in a city [6,7].

Regarding mobility, one of the biggest challenges in cities, as in LATAM countries, is the transport infrastructure. It has been built a disorderly way and planned for a small population over the years; it is summing to the increasing number of vehicles generating affections such as traffic congestion, longer traveling time for the road users, and even affecting road safety. In the light of all this, it is crucial to begin rigorous research to study the cities context. The way that citizens move, habits, and traffic flow by the hour, the traffic lights conditions, among the others, are essential variables to know the core of the mobility problem and propose viable solutions towards more sustainable mobility and smarter. This article presents a diagnostic study of vehicular mobility, focused on the central area of the city of Villavicencio, based on field work and the uses of ICT to propose solutions that can improve the quality of life of the community.

Villavicencio City, located in the east of Colombia, is focusing on becoming a smart city. In 2020 the city participated in the process led by the Ministry of Information Technologies and Telecommunications Min TIC of self-diagnosis in the measurement of the level of maturity of Smart Cities, within the opportunities for improvement and sub-dimensions with lower indicators are: - Climate Change (score 1) - Environment Dimension. - Digital Government (score 1) - Governance Dimension. - Multilevel Governance (score 1) - Governance Dimension. - Intelligent Mobility (score 1.8) - Habitat Dimension. - Risk Management (score 2.2) - Environment Dimension. In this sense, Villavicencio's city focuses on improving the planning, organization, and direction, formulation and application of policies on mobility, road configuration, signage, and public transport, which consult the community's needs articulate the different modes.

The study of vehicular mobility was developed with graduates of the faculty of civil engineering of the University Corporation of Meta. Firstly, the speed of the vehicles was acquired in Alfonso López Avenue by plate method analyzing two paths: from the GRAMA to the 33rd street with 32rd street and from the 33rd street with the 32nd street to the GRAMA. Secondly, it was made a study of the intersections of Carrera 33 with Carrera 29 and Carrera 33 with Calle 34 based on the methodology of the six steps recommended by CAL Y MAYOR (2007). It consists of establishing the approach to the problem and a logical and adequate solution through: observation of the problem, formulation of hypotheses, data collection, data analysis, and results to propose solutions.

This diagnostic study of vehicular mobility in Villavicencio is directly related to the projections of the city focusing on the general objectives to ensure social development, political, economic, physical, and environmental of the Municipality; the general well-being and the continuous improvement of the quality of life of its population.

2 Methodology

This project is carried out with a quantitative and qualitative approach, experimental, descriptive, explanatory with the simulation model; based on data collection, on the observation of means of transport and speeds; The analysis seeks to establish the vehicular flow, of the means of transport, deliberating in favor of the improvement or increase of the mobility of the existing traffic, and future 15 years, in this area; Alfonso López Avenue was taken as the object of study, from the roundabout of the grass, including the flag park; the length of the sections to be intervened was measured, and travel times and speeds were studied by the plate method; on the other hand, numerical methods referring to counts were used to evaluate the traffic volume, vehicle composition and projection of the results.

2.1 Study Zone

Avenida Alfonso López from the roundabout of the grass, between two paths, path 1 Glorieta de la GRAMA to Carrera 33 with Calle 32, and path 2 return in the opposite direction, from Carrera 33 and Carrera 29, to the roundabout from the grass; These in turn were subdivided into 13 sub-sections (See Fig. 1).

Fig. 1. Left Section 2, Right. Section 1. Google Earth, 2018.

2.2 Experimental Design

In Alfonzo López Avenue, through the plate method, the measurement detail was sought, the total was subdivided, into Sections 1 and 2 north - south, and south - north, and these in turn, into thirteen sub-sections. The three practitioners, "Paola Andrea Velásquez Parrado", "Juan Camilo Cubidez Ordoñez", "Jefferson Clavijo Morales", carried out the data collection; the two graduates Ruby Lorena

Álvarez Vanegas and Camila Andrea Carvajal Pardo, carried out the modeling of the civil engineering program of the Meta University Corporation - UNIMETA. They sought to know the distance, through the odometer measurement, in the total of the thirteen sub-sections, of the two sections and thus totalize, the tabulation of the information, by hand in a format, see image 1, where the last one was written plate letter, with its respective number; With the help of the cell phone timer, the exact time in which the vehicle passed in front of the practitioner was recorded and so on until 40 data were obtained; The measurement was proposed to be carried out at the following times: off-peak hour (8:30 am–11:30 am; 2:30 pm–5:00 pm), and peak hour (7:30 am–8:15 am; 11:45 am–12:30 pm; 5:30 pm–6:45 pm). The travel time method and registration plates annotation were combined, the results of these two methods being obtained, then the data was tabulated. It is to clarify, the concepts to be used, in the field, data on travel time and travel speed are obtained, in this way: Travel time, Time of march or circulation, Movement rate, Travel speed, and Walking speed or circulation.

The plate method, allowed to show in the following table, the travel times, when comparing the data obtained in the sample, the time in seconds that each vehicle took to move from the initial point to the final point was determined, taking into account the waiting time at traffic lights, and at what time of day the shift is made to determine peak and off-peak hours. The analysis of the tables of the plates showed coincidences, in both formats: the travel time from one point to another of each vehicle, the difference in the time it took the vehicle to move from one corner to another, the speed of the section, the mean, the standard deviation, the standard error, the minimum and maximum value of the seconds, the range, the sum of the seconds and the number of tabulated data; then data collection.

It was continued, with this technique each sub-section, of the two sections, object of study was systematized; and the next step, to carry out an analysis compared by days, the speeds of the daytime off-peak, versus the afternoon off-peak time. The distance variable was included, in order to compare and broaden the horizon of the outcome scenarios. The elapsed time was taken, compared to the distance, by bus, private car and taxi in each section.

In the last phase, a step prior to modeling, the behavior of the cycle time of the traffic lights was made known, a physical review of the place was carried out, denoting the different uses and types of soil, governed by the Land Use Plan; as well as its spatial conditions of high densification; Also, an intervention of the municipal administration was found with a view to improving the fluidity of vehicles at intersections, with studies of vehicular traffic, and the management of green light times at traffic lights, which did not work, even though the problem persists. These intersections have a high flow due to the connectivity that it establishes between the city center with the different communes, sidewalks and neighboring municipalities, from Carreras 33, Calle 34 and Carrera 33, they conclude at Carrera 33, see Fig. 3 (Fig. 2).

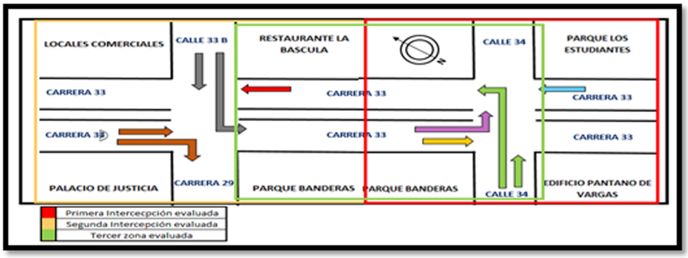

Fig. 2. Scheme of areas to be evaluated. Own source

The data collected were the turns given by the vehicles, in the 3 most representative times, from 9am–10am, 4pm–5pm and 8 pm–8:30pm. They are represented with bars followed by colors: red (time stopped) and green (time in motion), in order to show graphically which are the longest times at each of the two intersections. Now, with the observation of the speed study, we will measure "The speed that vehicles can develop on a road, its inverse and the time it takes to travel a given distance. It is usually measured at a point or short section of a road, to determine the speed with which vehicles pass through there, while the travel time is observed in sections of track of a certain length to know the quality of the overall service they provide or its variations throughout them". It was necessary to use chronometers, explicitly in Carrera 33 in both directions; 60 motorized vehicles were evaluated, from these figures obtained, it was possible to determine the descriptive statistics, and in this way to know the variation data such as the standard deviation, the sample variation, the typical error, the range, among others. relevant data.

It allowed to recognize the distances, and the speeds, that were presented in the results, supported by the norms that are presented in the following section: Data acquisition. Then, it will be visualized in a geographical framework, where it was approached from the approach of human geography, according to [10], a "Cultural turn and spatialization of social science: historical geography, cultural geography and environment" quotes Carl Saúer, who exercises human geography.

Also, he is the one who studies the territory and the human aspects, inherent to the analysis of transport networks and flows, applying spatialization, a technique that seeks to lead to planimetry, data analysis, allowing to cross technical variables, with what are the means of transport: vehicle flow, speed, density, interval and spacing; ending, thus visualizing the deductions of this forecast, taking them to software modeling, [8] the types of intersections and the allowed turns, [11].

In controlled intersections such as intersections, vehicles traveling through different accesses can meet simultaneously; some of them traffic signs, the traffic light [11]. On the other hand, the Intersections without control are those that do not use a type of control, there the rule is the priority for the first vehicle that arrives.

Classification of control devices, are based on the information presented by the Ministry of Transport (2015) a control device is the signals, marks, traffic lights and any other device, which is placed on or adjacent to the streets and highways by a public authority, to prevent, regulate and guide their users. Traffic lights are signaling devices by means of which the movement of motorized vehicles, bicycles and/or pedestrians on the roads is regulated, assigning the right of way or priority of vehicles and pedestrians sequentially, by the indications of red, yellow and yellow lights. Green, operated by an electronic control unit. Vehicle counts are the counts of vehicles that pass through certain network arches. Manual Gauges are generally used to record turnover volumes and classified volumes. The duration of the capacity varies with the purpose of the capacity. Some classified gauges can last up to 24 h.

2.3 Data Acquisition

The data collection was carried out by means of procedures: the method of travel time, and annotation of license plates, tabulation of information; having as a guide the text of Cal y Mayor, R., and Cárdenas, J. Ingeniería de Tránsito. Fundamentals and applications, from 2007. “seeks to establish the approach to the problem and a logical and adequate solution, as follows: 1. Observation of the problem, 2. Formulation of hypotheses of the problem and its solution, 3. Data collection, 4. Data analysis, 5. Specific and detailed proposal, 6. Study of the results obtained”.

To achieve each of these steps, tools such as: Taking of vehicular and pedest-The data collection was carried out by means of procedures: the method of travel time, and annotation of license plates, tabulation of information; having as a guide the text of Cal y Mayor, R., and Cárdenas, J. Ingeniería de Tránsito. Fundamentals and applications, from 2007. “seeks to establish the approach to the problem and a logical and adequate solution, as follows: a. Observation of the problem, b. Formulation of hypotheses of the problem and its solution, c. Data collection, d. Data analysis, e. Specific and detailed proposal, f. Study of the results obtained”. To achieve each of these steps, tools such as: Taking of vehicular and pedestrian counts in the study interceptions. Analysis of the data collected at the traffic gates and the information collected from the traffic congestion through the Google Maps application based on the information and observation collected. Taking traffic light times and study of vehicle flow speeds in the study area Collection and processing of data and information on the road section studied in different software. The travel time methods, in which the travel time between two established points is measured, go hand in hand with the Colombian Traffic Code, in TITLE III “BEHAVIOR RULES”, explicitly in CHAPTER XI “Limits of Speed”-“ARTICLE 106. SPEED LIMITS IN URBAN AREAS PUBLIC. Modified by art. 1, Law 1239 of 2008. Amended by art. 1, National Decree 15 of 2011NOTE: National Decree 15 of 2011 was declared Inexpensive by means of Judgment of the Constitutional Court C-219 of 2011. On urban roads the maximum speeds will be sixty (60) kilometers per hour except when the competent authorities for signs indicate different speeds.”

It is important to bear in mind that the speed of this road should not exceed 60 km, as indicated above. On the other hand, it is important to mention (Cal, Mayor and Cárdenas, 2007, p. 15).

As an element of general knowledge it is important to mention that for Cal y Mayor - Cárdenas (2007). Who in his text relates that the efficiency of the mobility of a road depends on the volume of traffic that circulates on it. It also expresses the concept of vehicle demand is the number of vehicles that require moving through a certain road system or road supply. It is understood that within the vehicular demand are those vehicles that are circulating on the road system, those that are in a queue waiting to circulate. The vehicle counts will be carried out in order to study the traffic volumes which "are carried out with the purpose of obtaining real data related to the movement of vehicles and/or people, on specific points or sections within a road system of roads or streets. These data are expressed in relation to time, and their knowledge makes it possible to develop methodologies that allow a reasonable estimate of the quality of the service that the system provides to users" When it comes to analyzing how the vehicle operation works, which must occur in conditions of stable or saturated flow, then the road supply, which represents the physical space, that is, streets and highways, in terms of their cross section or capacity. In this way, the road supply or capacity represents the maximum number of vehicles that can finally move or circulate in said physical space. (Cal, Mayor and Cárdenas, 2007, p. 15) As an element of general knowledge it is important to mention that for Cal y Mayor - Cárdenas (2007). Vehicle demand and road supply is the capacity of a road system that encompasses quantitative and qualitative characteristics, allowing to determine the sufficiency (quantitative) and quality (qualitative) of the service offered by the system, that is, the supply and users who are the demand.

2.4 Modelling

It is the Synchro software which has begun to be implemented around the world for the modeling of the traffic operation of road corridors, In Saudi Arabia in 2009, by Ratrout and Maen; In Lima, Peru in 2012 by VERA. In Colombia has not been alien to the application in the cities of Medellín and Tunja. In order to carry out the mobility modeling at the intersections of Carrera 33 with Carrera 29 and Carrera 33 with Calle 34, the Synchro 8 software was used, the location of existing traffic lights, travel speeds All this through the use of the results of the analysis of the gauges and physical characterization.

One of the analyzes used is the Webster Method, "it is based on the study of 100 intersections in the city of London whose analysis allowed to conclude on the influences exerted on the traffic or the saturation flow, the distribution of green: by having the cycle time must be distributed for each phase as green time, this distribution is carried out proportionally to the load factor of each of the phases and of the intersection (Highway Capacity Manual, 2010).

$g_i = y_i/Y(C_o - L)(1)$

Where
g_i = Duration of effective green of phase i.
y_i = load factor of phase i.
Y = load factor for the entire intersection.
C_o = Optimal cycle.
L = total lost time of the intersection.

It also analyzes, average delay per vehicle, is given for any access of a traffic light intersection by the following expression:

$d = 9/10(c(1-\lambda)^2/2(1-\lambda x) + x^2/2q(1-x))(2)$
Where:
C = duration of the traffic light cycle (s).
$\lambda = g/c$ = effective green ratio.
g = duration of effective green (s).
q = access flow (veh/h).
s = saturation flow (veh.lig / h.v) = 525w.
x = degree of saturation = $q/\lambda s$.
D = total delay for each access = dq

Traffic Modeling software that offers traffic analysis, optimization and simulation applications. It combines the modeling capabilities of Synchro and the micro-simulation and animation capabilities of Sim Traffic with the 3D authoring viewer. (Methods 2000 and 2010) for signposted intersections and roundabouts. It also implements the intersection capacity utilization method to determine the intersection capacity. Signal optimization routine allows the user to weight specific phases, thus providing users with more options in developing signal frequency plans. In the processes of analysis, evaluation and optimization of road networks, specialized computer programs are currently being used, such as Synchro, which applies the HCM 2010 method. The following advantages will be established:

– Optimization of cycle lengths and distribution of green times per phase, eliminating the need to carry out multiple tests of plans and times in search of the optimal solution.
– Generation of optimal time plans in less time than any other existing program today.
– Interaction, in such a way that when changes are made to the input data, the results are automatically updated, and the operation plans are shown in easy-to-interpret time-space diagrams.
– Application in networks of up to 300 intersections with enough success, being able to disaggregate larger networks and then join them.

The data previously obtained, in the interest of the elaboration of the model to be simulated, such as: the vehicular flows at peak hours for turns, and taking into account the type of vehicle, the taking of gauges carried out on 02/27/2018, 28/02/2018, 01/03/2018 and 04/03/2018. Then, the summary tables of the volumes obtained are presented, with all the vehicles that pass through this intersection, including bicycles in rush hour each day; In addition, its equivalent composition in percentage and its daily FHP are disclosed; obtaining the highest vehicle flows in one hour; with the two intersections, conceiving the results.

3 Results

3.1 Travel Time Estimation

The fieldwork described in Sect. 2 allowed collecting data related to the traffic flow using the license plate method. Data from each segment for both paths of the Alfonzo López avenue gave the mean velocity values for valley and peak times, as shown in the bar graphs presented in Fig. 1. For path 1, the velocities at valley times were similar for all of the segments. In addition, the same behavior was presented for peak times. However, there are differences between the peak and valley moments. The speeds at the valley moment are more significant than peak one, which is expected due to the peak time is related to more traffic congestion. Valley times, there was an exception roundabout of the Grama up to Calle 41 and Calle 32, which showed a higher velocity in respect with the other segments; It could be explained that the buses go down fast because this segment has no stops at this location. On the other hand, path 2 presented similar velocities for all segments except for Palacio de Justicia - Calle 35 and Calle 41 - Grama, which had higher speeds. Likewise, Calle 32 with Calle 33 exhibits an anomaly speed with lower velocities; It can be explained due to traffic jams generated by the cars from Av. 40 (Unicentro). It is crucial to consider that when traffic is slower along the peak hours during the day, people go to their jobs and studies. On the other hand, at night the peak hours is due to the people usually return to their homes. Figure 4 shown the type of vehicle versus velocity at path 1. The data related to the bus, taxi, and private car speeds show that the buses always present lower velocity. Because buses are parking in different areas to wait for passengers, mobility is difficult and obstructs the road. On the other side, the speed obtained on the taxi route on occasions was more significant than the individual. In general, taxi drivers are more impatient and without enough caution to drive. In contrast, the driver is more careful and probably did not hurry to get the destiny sometimes. The behavior of velocities as a function of the mean of transport was similar to path 2, not presented here.

3.2 Traffic Flow Indicators at Intersections

Volume of Vehicles. The evaluation of vehicular traffic at the intersections between Carrera 33 between Carrera 29 and Calle 34 allowed obtaining the total volume of each type of vehicle, including all movements for periods of 15 min, per hour, the hourly and daily variation, the maximum and minimum total volume for all the vehicles per hour, among the others crucial indicators. As discussed later, these indicators were crucial for modeling the traffic flow conditions at both intersections.

Figure 5 shows the number of vehicles at each intersection where the motorcycle is predominant in both intersections under study. The fieldwork data gives

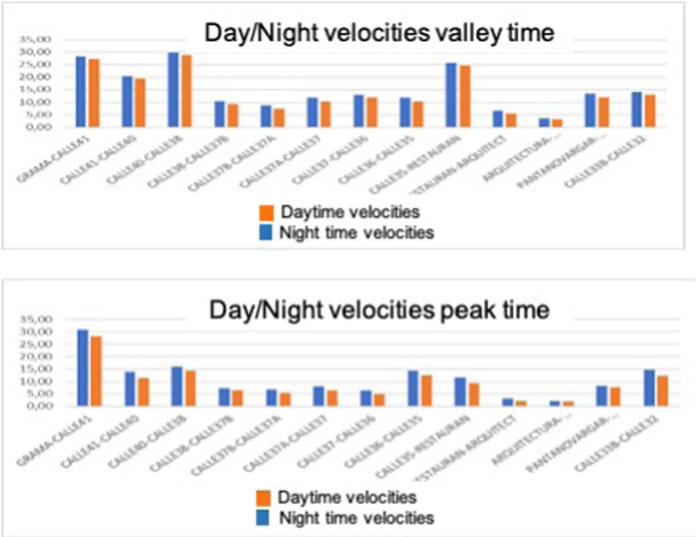

Fig. 3. Day/night velocities for Section 1 of the Avenue under study. The mean velocity is around 15 Km/h.

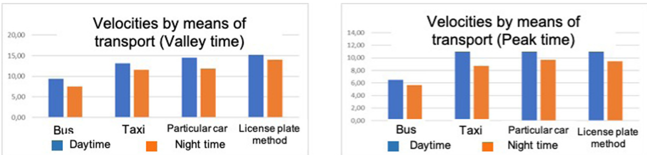

Fig. 4. Velocities according to the type of vehicles (means of transport) at Section 1 of the Avenue under study

to concluded that it is possible to identify the difficulty of mobility between the crossroads of the Carrera 33 when it crosses Carrera 29 (namely, Intersection 1) and Calle 33 with Calle 34 (namely, Intersection 2). Firstly, on the sidewalk with two lanes, which generates an impact on the other advancing movements and causes vehicular bottling. Additionally, movements 1 and 8 (described in Sect. 2) from the intersection between Carrera 33 and Calle 34 show significant congestion on the traffic flow.

Traffic Lights Cycles. To study mobility conditions, a evaluation of the semaphore times was also necessary for each intersection by phases. For example, intersection 1, located on Carrera 33 with Carrera 29, has four stages, called 1,2,3 and 4, as shown in the Fig. 6 Left. In contrast, intersection 2, which is located on Carrera 33 with Calle 34, has three stages, called 5,6 and 7, as presented in Fig. 6 Right.

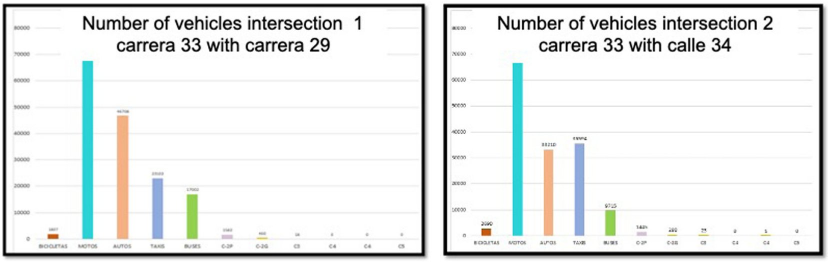

Fig. 5. Number of vehicles per week. Each color is associated with a specific means of transport.

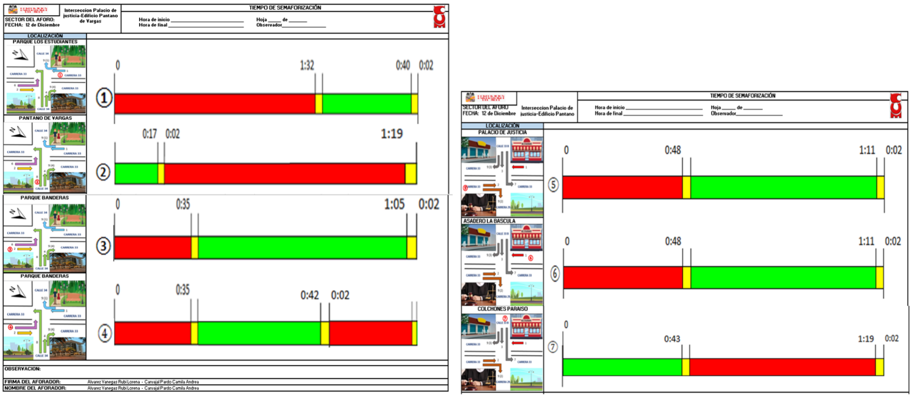

Fig. 6. Traffic lights phases for the intersections. Left, for intersection 1 and Right for intersection 2.

Figure 6, Left, shows the scheme of phases and time belonging to intersection 1. The most prolonged phase was on the third and fourth phases at Carrera 33 with Centro (Downtown) and Barrio Barzal. Likewise, it is possible to see that the second phase, located in front of the Pantano de Vargas building, has a section with less time in green than in red. On the other hand, in the four phases, it is possible to appreciate a similarity of seconds and the average totality of the cycle yellow is 106-second at intersection 1. For intersection 2, phases 5 and 6, as shown in Fig. 6 Left, which are located in Carrera 33 in double direction, are synchronized and more prolonged in 120 s. In the same way, it was possible to observe that the seventh phase, located in Calle 33b corresponds to the section with less time and has a duration in the green of 71 s. Furthermore, in the three phases, it is possible to appreciate a similarity of seconds in yellow light and the average totality of the cycle for the intersection in 120 s.

3.3 Mobility Modelling

Modeling of Current Mobility. From the information collected in the fieldwork, it was possible to have the inputs for the modeling through the Synchro software described in the Sect. 2. It is crucial to establish the essential characteristics of road geometry, such as the length and angle of each lane, vehicle flows per lane and permitted turn for modeling. As presented in Fig. 7, the software calculates the saturation flow with this information, representing the traffic flow and the allowed turns. The vehicular flow refers to the values raised one day corresponding in this study to the data collected at fieldwork for July 1, 2018, a day representing a maximum vehicular volume of 4,018, between the hours of 11:30 am to 12:30 pm.

Figure 8 shown the allowed turns of each lane (lane configurations), the vehicular volumes used (vph), saturation flow (vphpl), lane width, speed (link speed), distance from the lanes (link distance), travel time, peak hour factor for the day July 01/03/2018 and the last indicator corresponds to the utilization factor of the intersection 1. The estimation also was made for all days of fieldwork and intersection 2; not shown here.

The modelings give the estimated saturation flow for all of the lanes of intersection 1. It shows that this has 1900 vehicles per hour, comparing this value with each data entered of the vehicular flow per turn. Therefore, it is possible to determine that the route works with a lower saturation flow calculated as the volume limit of the lanes. Finally, for intersections, the modeling is presented; the results are comparable for both intersections as shown in Fig. 9 left, for intersection 1 and the right one for intersection 2.

Level of Service. To model mobility, it is crucial to consider the service level of a road. This category explains how an intersection works and how much additional capacity is available to handle the traffic fluctuations. This classification is estimated using protocols (Highway Capacity Manual, 2010 [9]) and permits the analysis of the conditions expected at the intersection.

The analysis showed that the intersection Carrera 33 with Carrera 29 (Intersection 1) at "La Bascula-Juzgados Restaurant" presents a general level of service

Fig. 7. Traffic flow and allowed turns simulation for Intersection 1.

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	0	0	0	733	540	43	405	943	0	0	1282	72
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (m)	3.6	4.6	3.6	3.6	3.3	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Link Speed (k/h)		20			20			20			20	
Link Distance (m)		50.2			103.3			114.6			135.0	
Travel Time (s)		9.0			18.6			20.6			24.3	
Peak Hour Factor	0.81	0.81	0.81	0.81	0.81	0.81	0.80	0.81	0.81	0.81	0.81	0.81

Fig. 8. Traffic flow variables and lane configuration abstract estimated by Synchro for Intersection 1.

Fig. 9. Vehicle flows per lane and allowed turns of the current state. Left image, for intersection 1. Right image, for intersection 2.

D. The level of service D represents a circulation of high density, only stable. Speed and freedom from maneuvers are severely restricted, and the driver experiences a low general level of comfort and convenience. Small increments in the flow usually cause problems with functioning. Additionally, the intersection of Carrera 33 with Calle 34 (2) is on a service level "F" (low). It means the intersection is not working optimally, and it represents adverse effects on mobility and, therefore, on user's daily lives.

Mobility Solutions Analysis. Based on the previous results supported by the software Synchro 8, considering the experiences of other projects, three models of a solution have been proposed and analyzed to improve mobility in intersections 1 and 2.

- Solution 1-Optimize the Semaforization Cycles. The modeling shows that this solution improves from "F" to "E" in some lanes in the entire study zone. Therefore, it was determined that optimizing only the signalization cycles is not an efficient solution. This solution is represented in Top Fig. 10.
- Solution 2-Exchange Type of Intersection. This proposal would also negatively impact citizens' daily lives because it will be necessary to close the intersections to construct the roundabouts. In addition to a significant purchase of buildings, which would be a great inconvenience, this route is of great

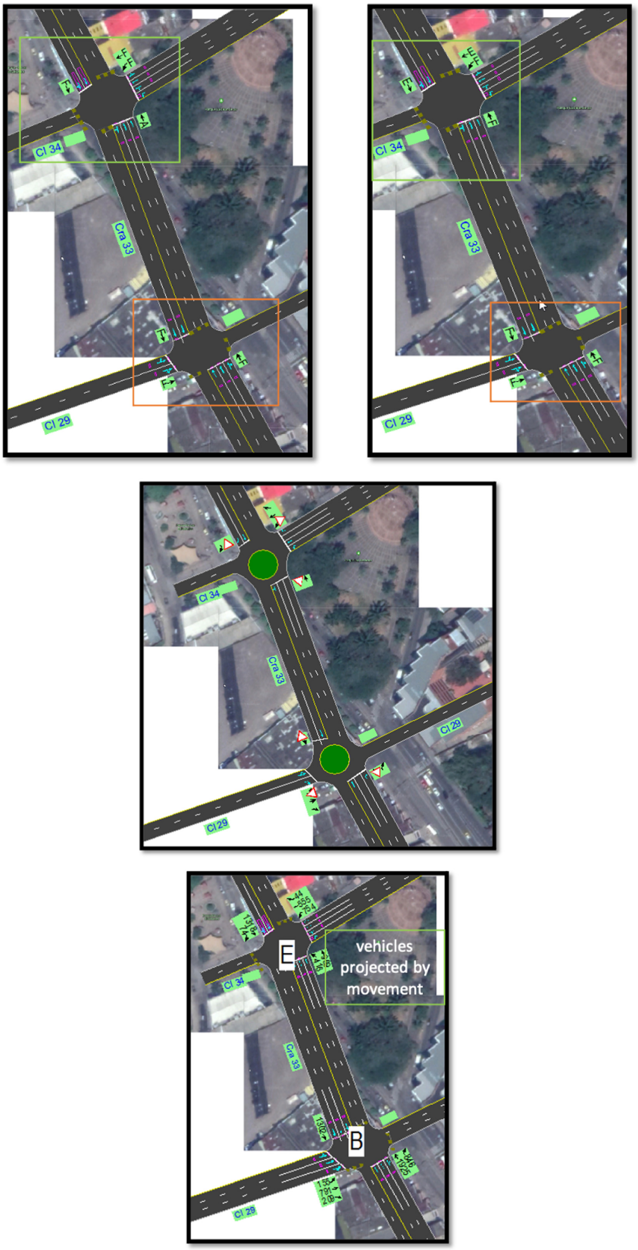

Fig. 10. Models of Solution. Top pictures represents optimizing the semaforization cycles. Middle picture shown the modeling for the exchanging type of intersection. Bottom picture is related to the implementation of new lanes solution

importance for the connectivity that the center represents with a large part of Villavicencio. The proposal simulation is shown in middle Fig. 10.

- Solution 3-Implementation of new lanes. This proposal seeks to increase the road capacity and thus improve the level of service, reducing travel times and improving users' convenience.

  Thanks to the modeling and simulation, it could visualize that the proposed solution is efficient. It improves the level of service from the intersections 1 in E and a service level B to the other intersections 2. Service level B, corresponds to a stable flow range, even though you can take pleasure in observing other vehicles that are part of the circulation. On the other hand, the level of service E corresponds to a level of operation close to the limit of the capacity. Therefore, this is considered a viable alternative. The simulation of solution 3 is represented in Bottom Fig. 10. The results support the planning projects focusing on smart mobility in Villavicencio. The purpose is to continue supporting the local government from the academy in the next step that considers traffic lights infrastructure for smart mobility.

4 Conclusions

- In path 1 in, the sub-section with the lowest speed is in Arquitectura - Pantano de Vargas where most of the time, especially at nighttime rush hour, there is greater damming of cars, either because the buses are parked to wait for the Unimeta students who use this transport, or because of the gauges that are in charge of giving information to public transport drivers on how long it takes a bus to another or through the traffic light at the corner of the Vargas swamp.
- When making the tables with the speeds of the bus, taxi and private car, it can be observed that in all the samples the buses always presented the lowest speed since they have the habit of parking in different areas to wait for passengers, which makes mobility difficult in the sector by obstructing the road.
- The speed obtained in the taxi route was sometimes higher than that of the individual, since in general taxi drivers are more impatient and not very cautious to walk while in the car the driver was more cautious and did not have a desire to get there to his destiny.
- A comparison was also made with the Google Maps application and the route in the private car in the two sections studied, where the application times were always shorter than the real ones, always giving a 2-min difference. It can be inferred that the application is not very accurate because it does not have complete and exact information on the traffic in the area. Even so, it is a very useful tool that allows us to approximate the time it may take to move from one point to another, especially in very long stretches.

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