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Analysis of School Transportation Demand for the Design and Spacing of Bus Stops

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Abstract

This research article studies a very common phenomenon in the field of roads and transport, which includes the absence of school routes. Where you want to propose different solutions to this problem and thus provide both technical and scientific support, acquired during the academic process, the faculty of Civil Engineering to be carried out for the benefit of the student community of scarce resources in the municipality of Abrego-Colombia. This aims to contribute to the socio-economic development of the regions, especially to serve the most vulnerable community which is affected by this phenomenon.

Keywords: School routes, public transport, route optimization, bus stops.

1. INTRODUCTION

Transportation plays an important role in large cities; taking into account that the population is constantly increasing, it is relevant to analyze this issue and make decisions based on the optimization of routes and the improvement of public transportation services. The first level of disaggregation of transport is according to the geographical area in which they provide service: urban, suburban, interurban, rural, and international.

For many years, service quality is a forgotten concept, considering it a difficult attribute to measure, however, it is an issue that always affects the satisfaction of people and it is easy to recognize. The Colombian Technical Standard ISO 9001 [1], in customer satisfaction, states that, to ensure quality in any activity, it is necessary to plan, control and improve quality, which must be accompanied by a flexible and consistent strategy that meets environmental requirements. For this reason, to define and prioritize the main attributes that affect the quality of the service, it is essential to determine the service level scales based on the attributes of safety, comfort, cost and time [2].

Following are some research works that provide a direction to the current research, in this sense it is that at the international level a research was conducted for the optimization of routes in the school transport system at the Autonomous University of Ciudad Juarez (Mexico), whose objective was to conduct research on school transport, its classification, attributes, and its composition, as well as a brief description of the use of technologies and software for the optimization of the service. The methodology used was the search in the database of the University, in conjunction with the EBSCOHOST and ASCE database, in addition to online sources that allowed gathering the necessary knowledge, which were reflected in this research [3].

As a result, the use of tools such as mathematical models, algorithms, GPS and ITS, for the search of efficient solutions for route planning has been to a great extent a very important advance, since in conjunction with different applications have been developed programs (software), which is a great contribution to the research contributing to solve the problems of routing, thus achieving to establish an efficient and durable system.

At the national level in the city of Medellin, a research was carried out at the University of San Buenaventura, whose objective was to perform an analysis for a public transport route in that city using Arcgis [4]. In this context, this article aims to address a quantitative analysis methodology to evaluate urban public transport routes and propose alternatives to improve their performance.

Regarding the results of the optimization and the economy of the initial route compared to the route generated with the solution method, allows to obtain a saving of about 21% in the distance traveled as well as in travel times, also shows an increase in the points of origin destination, about 28% which maximizes the number of users by approximately 40% that would possibly make use of this route.

One of the important contributions is that by using the Network Analyst tool in Arcgis it is possible to plan school transport routes in such a way that it contributes to solving congestion problems and operational costs.

Similarly at the regional level, a research was conducted in the city of Bucaramanga for the design of school routes which was conducted at the Industrial University of Santander [5], whose objective was from the design of a hybrid optimization algorithm and its implementation in a software module using a GIS application and an object-oriented programming language, solves the problem of routing vehicles applied to the design of school routes in the associated transport company Comulclaver Ltda.

The methodology used can be conceived as a model adjusted to a vehicle routing problem with capacity and distance restrictions that is represented as a directed, complete and symmetrical graph, which means that the matrix associated with the distances between the location points of both children and school has similar values in symmetrical and corresponding positions in it. Once the model has been implemented by executing the designed algorithm and considering four types of vehicle capacities (12, 14, 16 and 19 seats), each route generated is shown by column, corresponding to one vehicle each, where the origin and destination node of each one is the same school, and the descending order in each column describes the order in which the route is made. This solution is finally transferred to ArcView, making easily a join on the Excel table and placed on the map of the city to review and compare the results.

In the department of Norte de Santander (Colombia) it is evident the lack of school transportation in most municipalities often due to lack of resources, which was evidenced in 13 municipalities that had been left without the service of school transportation, leading them to walk for more than a month to meet their academic days, In response to this situation, the governor's office signed a contract for 680 million pesos for school transportation agreements in municipalities with difficult access to institutions [6], but for these measures to work, coordination between state institutions is required, as well as improving infrastructure and applying practicality to solve a cultural and logistical problem [7].

Likewise in the municipality of Abrego there is a vile example of the absence of school routes that affects a large percentage of rural areas preventing access to many children and young people of limited resources, and although it seems untrue, it is also evident in the urban area where many students find it difficult to go to their schools as presented in the Mega College Carlos Julio Torrado Peñaranda, where from primary and secondary school children and young people do not have, nor have adequate transportation and in turn with a comprehensive security, which should have minimum and optimal conditions.

One of the contributions to rescue is that for greater ease once digitized and stored the information of the routes of transport in the municipality of Abrego, it proceeds to sectorize or segment the students in order to develop appropriate routes for the Mega College.

2. METHODOLOGY

Four phases are developed: The first ddetermine the economic profile of the students of the institution to measure their social stratum and select potential beneficiaries. The second is to carry out the study of origin and destination of the students of the school to be able to know clearly the behavior of the trips generated and create ideal routes. The third is to identify the main access routes to the Mega School Carlos Julio Torrado Peñaranda to determine the possible routes and the fourth is to classify the students by sectors to establish the respective stops.

In this research, the descriptive method is used because it seeks to identify and express the socio-economic characteristics of a student community and the situation they are going through, measuring various aspects such as school dropout due to the absence of a school route and also because it presents the reason for the absence of transportation that is directly affecting the student community.

The population is composed of 1647 students who are part of the student community of the ***Mega Colegio Carlos Julio Torrado Peñaranda in the municipality of Abrego*** [8]. The statistics provides a study sample of 85 students, which are part of the different grades of primary and secondary school. To determine the sample size, equation (1) is used:

$$n = \frac{\frac{(Z^2{}_{a/2} * p * q)}{B^2}}{1 + \left(\frac{p * q * Z^2{}_{\frac{a}{2}}}{B^2}\right) * (\frac{1}{N})} \qquad (1)$$

Where:

- n= sample size.
- Za/2 = confidence level. (95%)
- p= 0.5
- q= 1- p
- B= permissible error (between 0.05 and 0.2). Value used **0.05**.
- N= study population.

For the collection of information of the present investigation it is done by means of surveys and interviews. The instrument to be used in the investigation consists of a questionnaire that contains closed multiple choice questions. For the structuring of the instrument will be taken into account aspects such as: Social stratum, availability of means of transport and origin - destination of the students.

The following activities were developed in each phase to find the ideal routes:

Conduct surveys

- Create a form with an emphasis on determining the student's economic profile.
- Application of the surveys
- Information processing and student selection.

Conduct origin and destination study

- Information coding and trip generation.

Identify access routes

- Through direct observation identify access routes.

Sectorize the selected students

- Determine demand concentration points.
- Set up bus stops.
- Analyze possible impacts on urban roads.

3. RESULT

3.1 Development of Specific Objective 1

Activity 1. Format for collecting information

To collect information in order to characterize the student demand, as well as to identify some socioeconomic aspects that allow to show the problem found in a preliminary way, since once the demand is characterized, a diagnosis of the existing situation can be made. These surveys also seek to identify the basic characteristics of the trips of the existing demand, such as origin and destination of trips of users [9].

Activity 2. Application of the surveys

On October 29, 2019, the entrance to the Mega Colegio Carlos Julio Torrado Peñaranda de Abrego is made to conduct the respective survey to the student community of the morning session and that same day, but at 2:00 pm this same survey is conducted to the groups of the afternoon session. The institution has 43 groups of students; therefore, two (2) students per classroom were randomly selected to obtain the established sample (Table 1 and Figure 1).

Table 1. Mega College Groups

SECONDARY			**PRIMARY**		
COURSE	Morning Session	Afternoon Session	Course	Morning Session	Afternoon Session
6	3	3	Transition	1	1
7	3	2	1	2	1
8	2	2	2	2	2
9	2	1	3	2	1
10	2	2	4	2	1
11	1	2	5	2	1
SUB-TOTAL	13	12	Sub-Total	11	7
TOTAL	25		Total	18	
TOTAL GROUPS			**43**		

Activity 3. Information processing and student selection

In processing the information obtained in the surveys, the students have been selected taking into account their socioeconomic characteristics, availability of cars at home, level of household income, expenditures on means of transport and that they are located within the urban area. Therefore, the results of the surveys are of great importance in the planning and operation of the system [9].

3.2 Development of Specific Objective 2

Conduct a study of the origin and destination of the school's students in order to clearly understand the behavior of the trips generated and create ideal routes.

Activity 1. Codification of the information and generation of trips.

Coding consists of noting the number corresponding to the origin and destination zones, in accordance with the zoning for the study area and compatible with the purposes of the study of the operation of an urban system. The coding of the origin and destination sites should be compatible with the characterization of the total system network for the stops or sections (Figure 1).

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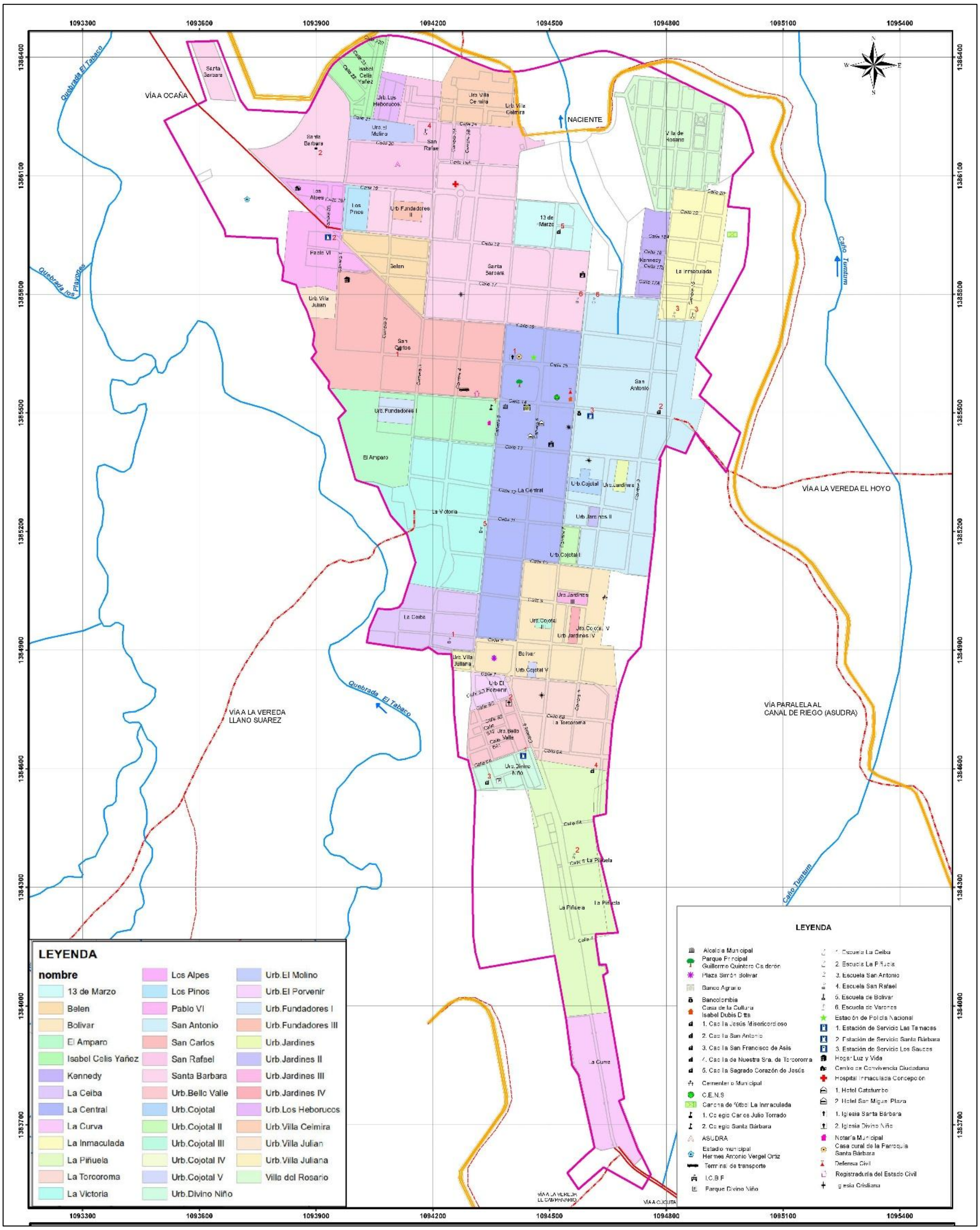

Fig. 1. Map of neighborhoods. Source: Secretary of Municipal Planning

3.3 Development of Specific Objective 3

Identify the main access routes to the Carlos Julio Torrado Peñaranda Mega School to determine the possible routes.

Activity 1. Through direct observation identify access routes.

On November 05, 2019, the field visit to the Mega College Carlos Julio Torrado Peñaranda de Abrego is made to perform the respective information taking with the help of a tape measure; of the access roads, roadway widths, width of berms, width of ditches, vehicular circulation area and parking area of the institution; which are fundamental elements for the operation of an adequate school transportation system. The Mega School has two main entrances, one in the east direction, via Cúcuta and the other in the west direction via Ocaña, for this reason the access corridor to the institution is classified as a primary national road since it gives access to departmental capitals and this makes the circulation in any means of transport more dangerous [10] (Figure 2 and 3).

Fig. 2. Eastbound access road.

Fig. 3. Westbound access road.

Activity 2. Analyse possible impacts on urban roads.

The impacts of the implementation of a transport system correspond to the effects that the transport service generates on its surroundings and within the service area it covers. These impacts can be short-term, such as the reduction of road congestion, the reduction in pollution indexes, noise levels, or the change in visual impact generated by the modification of urban and road furnishings. There are also long-term impacts, such as changes in the value of land or changes in the change of economic or urban activities, as well as the growth of the city. The following is an approximation of the impact generated according to the type of system to be implemented in a city (Table 2) [9].

Means of transport	Pollution	Noise	Visual impact	Security
Buses in mixed traffic	Mala	Regular	Good	Regular
Buses in preferential lanes	Regular	Regular	Good	Regular
Buses in exclusive lanes	Good	Good	Good	Good

Table 2. Impacts produced by the implementation of public transport. Source: [11]

3.4 Development of Specific Objective 4

Classify the students by sectors to establish the respective stops.

Activity 1. Determine demand concentration points.

Once the information has been collected, the student demand is classified by residential areas, and once the demand has been classified, a diagnosis of the existing situation can be made (Figure 4 and 5). (Figure 4 and 5)

Demand concentration points.

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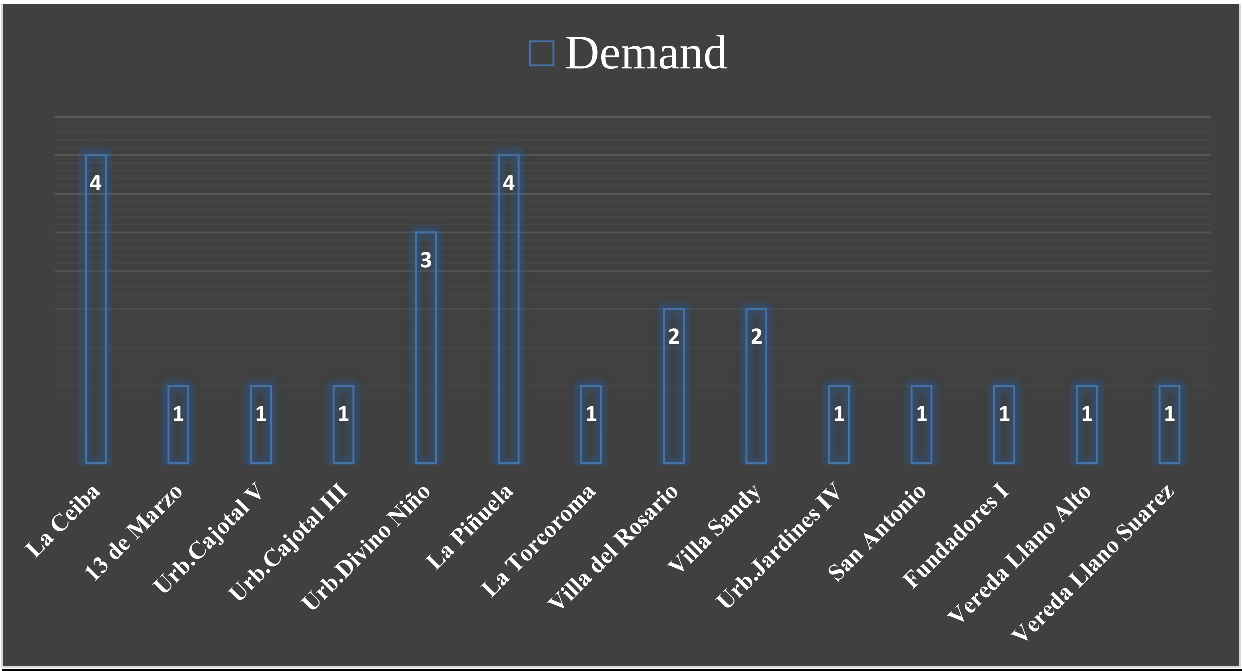

Fig. 4. Concentration of demand - Morning shift.

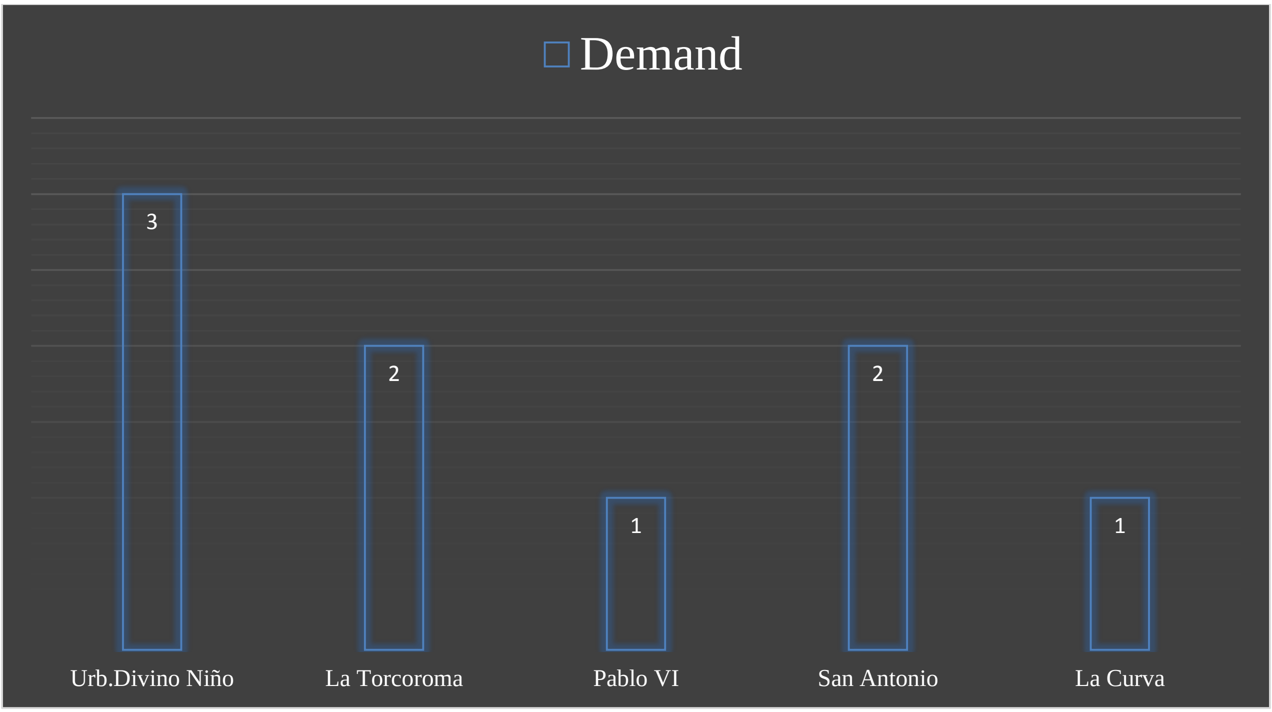

Fig. 51 . Concentration of demand - Afternoon session.

Activity 2. Set up bus stops.

Planning for on-street stops along the bus route involves three aspects: spacing, location and design of stops.

Spacing

The use of spacing that is too short degrades the quality of service provided in terms of speed of operation. In addition, frequent stops make it uneconomical to provide facilities such as shelters, benches, and information boards. On the other hand, too long spacing increases walking distances from the origin to the stop, worsening the accessibility conditions of the transport system. Consequently, a compromise is needed between short access or proximity to stops and high speed of service operation with dispersed stops.

Therefore, the spacing of stops should be related to the number of trips generated/attracted and the volume of passengers circulating through the area analysed. The spacing should be such that on average it is no more than 400m to 500m and no less than 250m to 300m, resulting in operating speeds of 15 to 25 km/h. In exceptional cases, it is possible to consider lower spacings, provided that the stops are divided, as a result of high demands for boarding/ alighting [12].

Location

There are three types of locations for stops along the street or roadway: i) near the intersection before the crossing (AC), ii) far from the intersection after the crossing (LC), and iii) mid-block (MC). The main factors influencing the choice of location are coordination with traffic signals, passenger access including transfer from other bus routes, vehicular and pedestrian traffic conditions at intersections, and turning geometry and stop design.

Passenger access: Bus stops should be located where pedestrian waiting areas are well protected from traffic, with sufficient space for pedestrian circulation, without interfering with pedestrian circulation on the sidewalk [12]. At intersections of two or more bus routes, the location of bus stops should minimise the distance required for transferring between buses, as sketched in Figure 6.

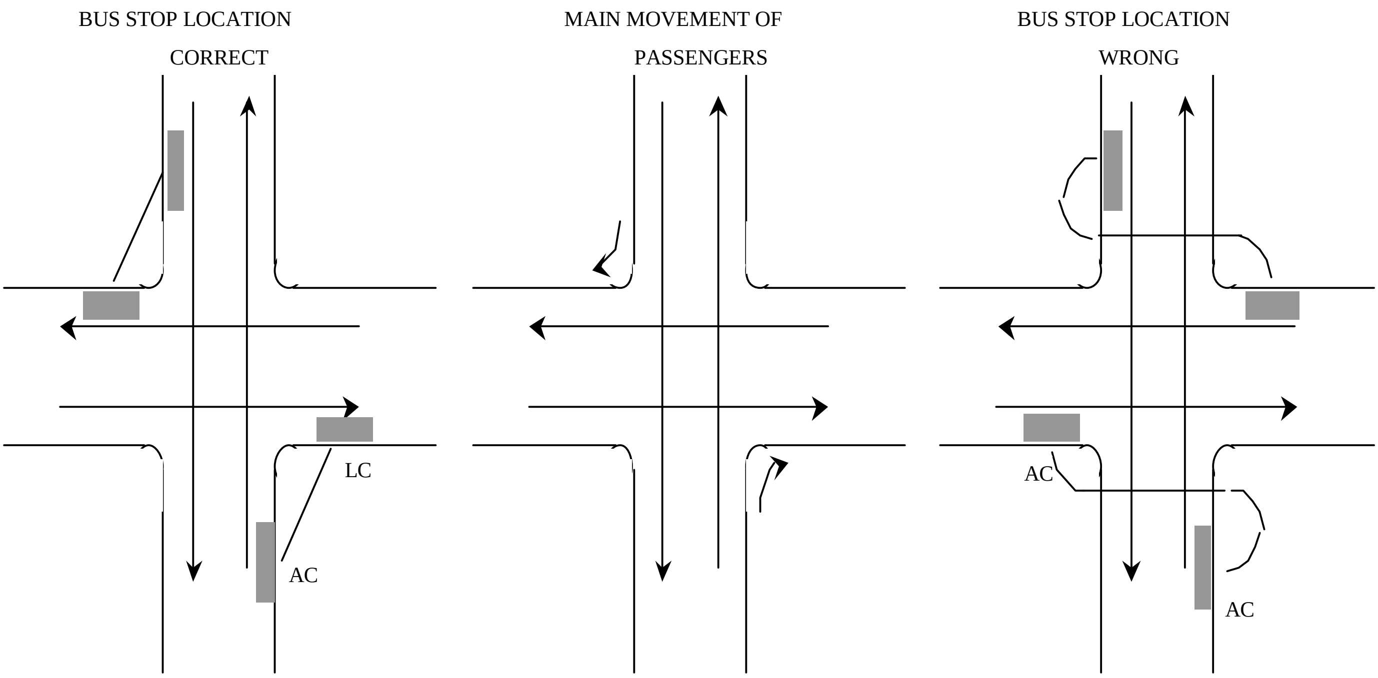

Fig. 6. Impact of stop location on passenger transfer. Source: [12]

Platforms should be attractive to avoid de facto stops. Ideally, over 15 cm from the sidewalk by means of a gentle slope and/or gradient (decreases in height with respect to the bus footing), with pavement of different texture and color. The minimum width should be 3.0 m for longitudinal or transversal stops and their length should be similar to the length of the stop area.

Regarding shelters, their main function is protection against the weather (rain, cold, and heat), citizen protection (luminosity) and comfort (seating). Ideally, they should include a user information system (route maps, cultural information panels). The dimensions of the shelter are calculated assuming a density of 2 to 2.5 pas/m2 at peak climbing hours [12].

Traffic conditions: Traffic conditions should also be considered in the selection of bus stop locations. It is desirable to locate stops to minimize risk and interference with other vehicular and/or pedestrian flows. Interference with turning movements of other vehicles, ability of the bus to merge into traffic, and visibility to pedestrian crossings are the most important issues that should be analyzed for each bus stop location. In general, AC stops cause the least interference when the crossing is one-way (right to left) or when the number of vehicles turning right from the main roadway is small. For the opposite conditions, an LC stop is preferable.

MC stops are optimal in cases where trip generation is in the middle of the block, where the geometric or traffic conditions of the intersection are inconvenient, and when buses turn left and it is not possible to implement LC stops. In conclusion, the use of only one type of stop location is usually not the best solution. The choice of one of the three types of location should be made on a case-by-case basis, based on the factors discussed above [12].

Design

The simplest bus stop design is one where buses stop at the curbside on the roadway. Although such a design is convenient for passengers and requires minimal maneuvering, it blocks other traffic during the stop. This feature makes it necessary to consider this design only when the duration of the stop is minimal or when the traffic flow is low intensity. A better location of the stop is outside the traffic lane, since it provides better safety and less interference to the rest of the traffic. The most common location is on parking lanes and in special bays. Parking lanes are usually located next to the sidewalk, therefore, it is necessary to prohibit parking, via signage and/or pavement texture, where the parking bay is located. This is the best design version as it eliminates illegal parking in the stopping area [12].

Based on the spacing, location and design parameters mentioned above, the location of the stops and a pilot design of the stops for the operation of a school route is carried out (Figure 7 and 8) (Table 3 and 4).

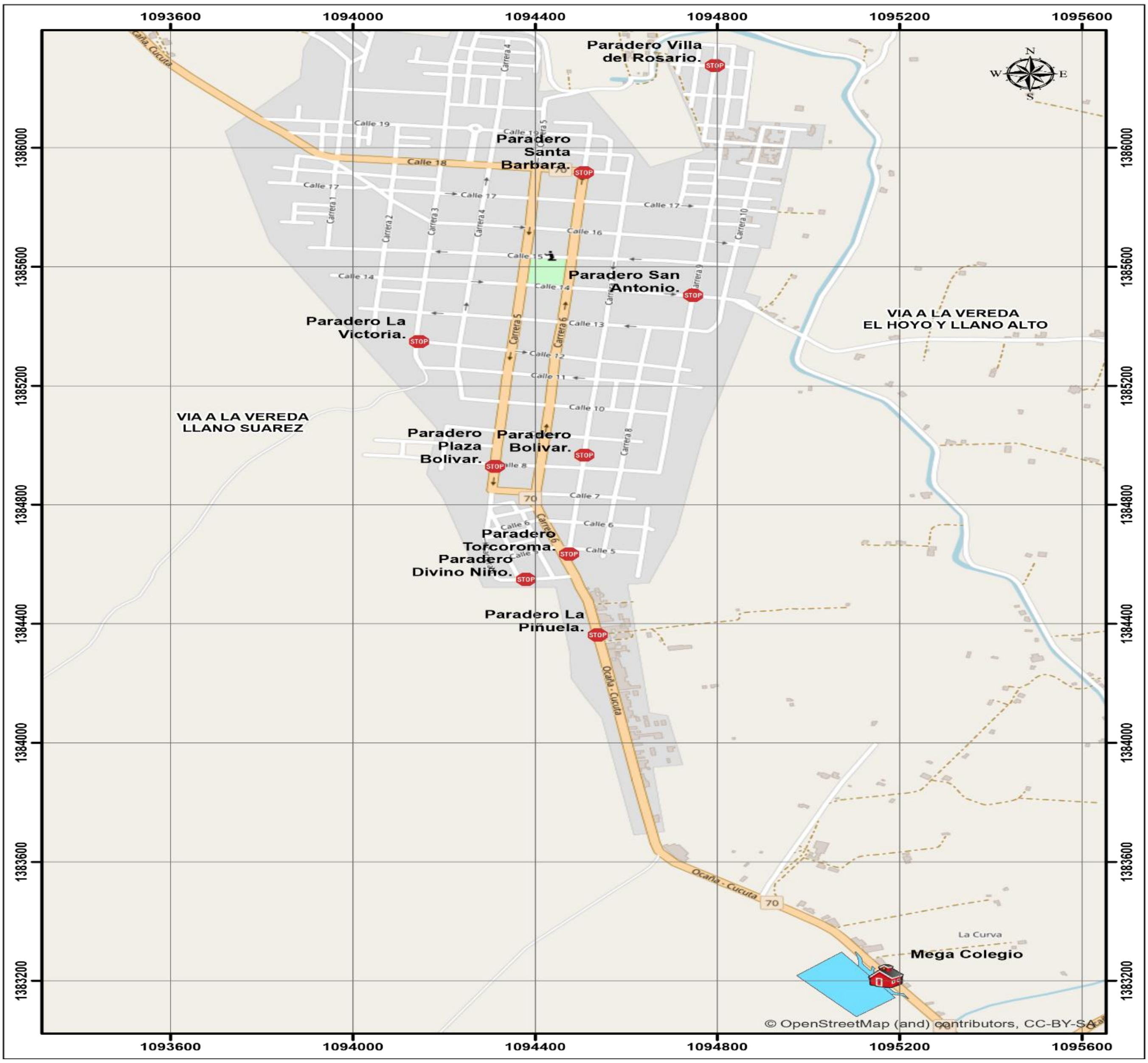

Fig. 72 . Map of bus stop locations - Morning shift.

Table 31. Table of spacing between bus stops - Morning shift.

Spacing			
Code	**From**	**To**	**Meters**
00	Mega College	Torcoroma Square	1681,4
01	Torcoroma Square	Paradero Bolivar	334,3
02	Paradero Bolivar	Paradero San Antonio	735,1
03	Paradero San Antonio	Villa del Rosario bus stop	946,6
04	Villa del Rosario bus stop	Santa Barbara bus stop	1424,5
05	Santa Barbara bus stop	Paradero La Victoria	929
06	Paradero La Victoria	Plaza Bolivar bus stop	594,9
07	Plaza Bolivar bus stop	Divino Niño Park	417,5
08	Divino Niño Park	La Piñuela bus stop	313
09	La Piñuela bus stop	Mega College	1400

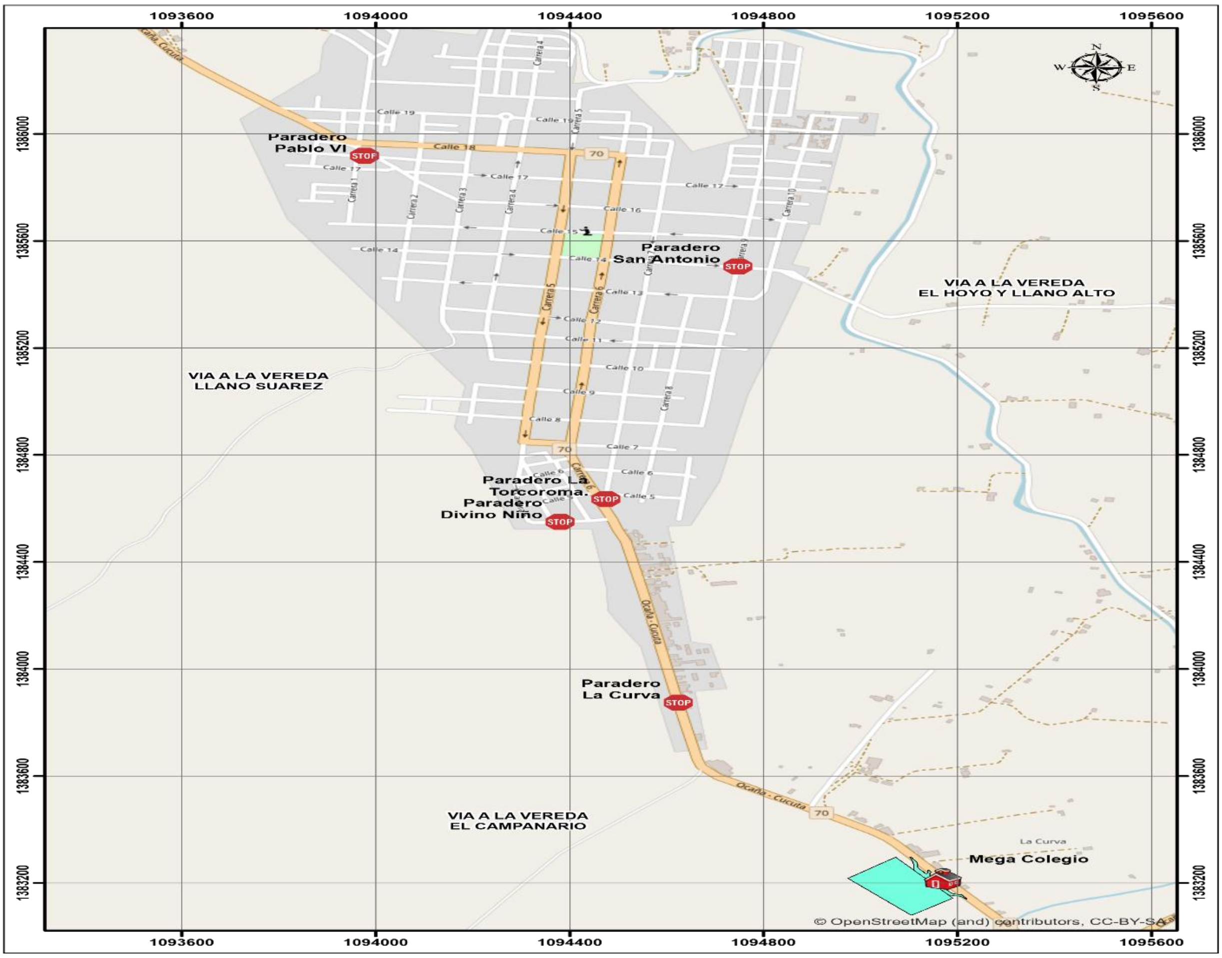

Fig. 8. Map of bus stop locations - Afternoon.

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Table 4.Table of spacing between stops - Afternoon shift

Spacing			
Code	**From**	**To**	**Meters**
00	Mega College	Torcoroma Square	1681.4
01	Torcoroma Square	Paradero San Antonio	1057.9
02	Paradero San Antonio	Whereabouts Pablo VI	1118.3
03	Whereabouts Pablo VI	Divino Niño Park	1901.4
04	Divino Niño Park	Paradero La Curva	809.4
05	Paradero La Curva	Mega College	903.5

Table 52 . Spacing between stops

Spacing			
Code	**From**	**To**	**Meters**
00	Mega College	Torcoroma Square	1681.4
01	Torcoroma Square	Paradero Bolivar	334.3
02	Paradero Bolivar	La Central Bus Stop	255.6
03	La Central Bus Stop	Paradero San Antonio	372.8
04	Paradero San Antonio	Villa del Rosario bus stop	1063
05	Villa del Rosario bus stop	La Inmaculada Bus Stop	606.3
06	La Inmaculada Bus Stop	Santa Barbara bus stop (Car 7)	520.6
07	Santa Barbara bus stop (Car 7)	Santa Barbara bus stop	405.3
08	Santa Barbara bus stop	San Rafael bus stop	400.5
09	San Rafael bus stop	Paradero San Rafael (19th Street)	397.6
10	Paradero San Rafael (19th Street)	Whereabouts Pablo VI	308.2
11	Whereabouts Pablo VI	San Carlos bus stop	346.6
12	San Carlos bus stop	Paradero La Victoria	313.2
13	Paradero La Victoria	Plaza Bolivar bus stop	586.8
14	Plaza Bolivar bus stop	Bello Valle Park	380.7
15	Bello Valle Park	La Piñuela bus stop	508.1
16	La Piñuela bus stop	Paradero La Curva	487.9
17	Paradero La Curva	Mega College	903.5

Next, a merger of the previously mentioned stops is presented in order to provide greater coverage in the provision of school transport services to low-income residential areas of the municipality of Abrego, Norte de Santander; since this initiative guarantees effective and safe access to school transport for the student community (Table 5).

Bus stop design

The stopping place of the vehicle has a width of 2.50 m and a length of 11 m, before the site is considered a sector with signage of no parking. As facilities for waiting students, the bus stop has a shelter with benches and an information board located at the end of the bus stop with themes alluding to education, no drug use and care for the environment, so that students are located in this sector and the bus is forced to park close to the exit (Figure 9, 10 and 11). The entire waiting platform should be located at a higher elevation than the pedestrian sidewalk, ideally about 10 cm above it. To reach the elevation, a ramp with no more than a 12% slope and handrails for handicapped youth is considered [12].

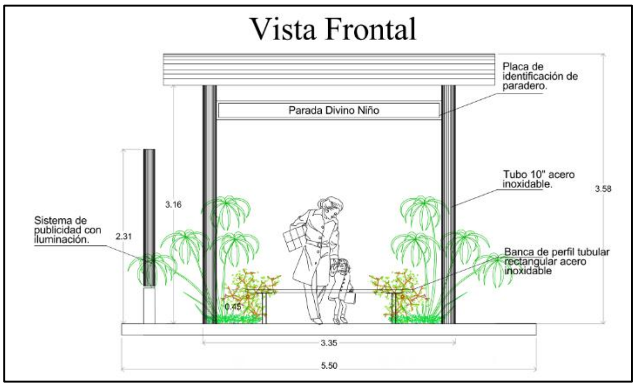

Figure 9. Bus Stop Design - Front View.

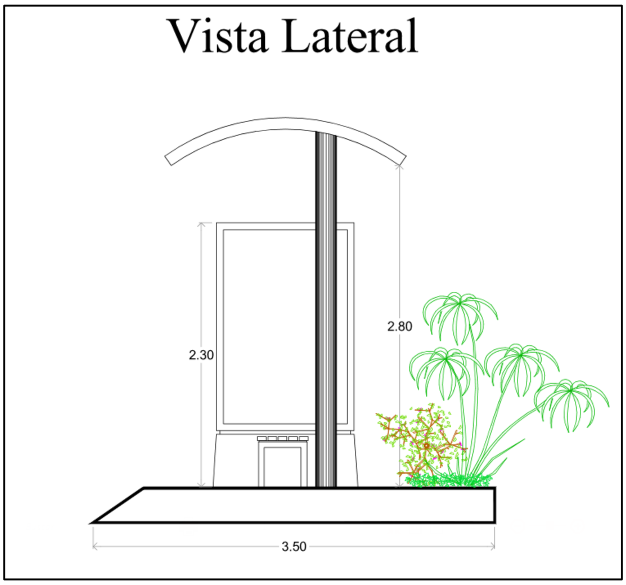

Figure 10. Bus Stop Design - Side View.

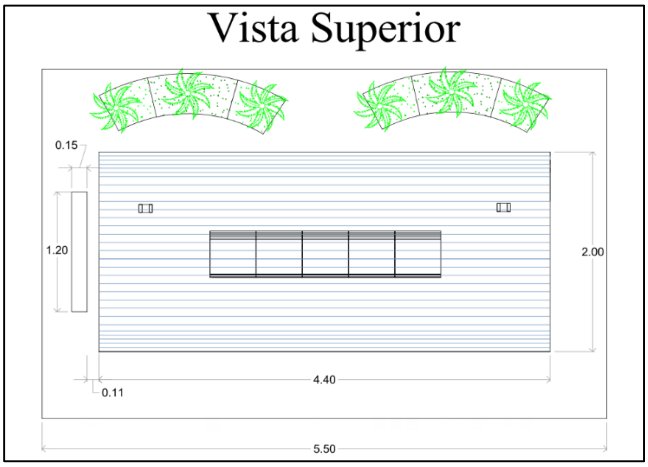

Figure 11. Bus Stop Design - Front View.

4. CONCLUSION

A tour of the streets of the municipality studied showed that not all the locations of the bus stops established along the length and breadth of the road network have sufficient public space for their furnishing.

The distribution of bus stops shown in objective 4 for morning and afternoon students argues that they are insufficient to serve a population that is mostly low-income, so in the proposed hypothesis the bus stops were established in areas with a greater presence of families of stratum 1 and 2.

In order to comply with the time windows between a change of day or start time of the other, possible service times were implemented in the ascent and descent of students, and it became evident that to comply with the schedules stipulated by the Educational Institution had to establish a descent time for the beginning of the day of 2 minutes, 1.5 minutes of ascent and 1.5 minutes of descent for the change of day and 2 minutes of ascent for the end of the day.

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