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Levels of Service determination and pedestrian capacity in critical areas located in the centre of San Juan de Pasto city

Fernando Jove Wilches*[1], Jorge Luis Argoty Burbano[2] and Alexandra Rosas Palomino[3]

[1] Department of Civil Engineering, Universidad de Sucre, Sincelejo, Sucre, Colombia.
[2] Department of Civil Engineering, Universidad de Nariño, San Juan de Pasto, Nariño, Colombia.
[3] Faculty of Civil Engineering, Universidad del Cauca, Popayán, Cauca, Colombia.

**Corresponding author: fernando.jove@unisucre.edu.co*

Abstract

In the present work, Level of Service are established, which are currently provided by the platforms located in the downtown area of the city of San Juan de Pasto, located in southern Colombia. For this purpose, the criteria established in the 2010 version of the Highway Capacity Manual (HCM 2010) are applied, where the Levels of Service and Capacity of the platforms are obtained. The methodology used makes use of the geometric characteristics of the platforms and of the pedestrian flows, for which gauges were carried out at critical points where a large number of pedestrians were determined due to their proximity to important places located along the different sections evaluated. With regard to pedestrian traffic, these were carried out taking into account the most critical expected conditions, according to some dates in particular, as well as identifying the hours of maximum demand. The results of the investigation showed that more than 50% of the evaluated sectors present LOS A and that only a percentage less than 15% are categorized within LOS D, E or F. According to these results, it could be determined that most of the platforms in the downtown area of the city have adequate conditions for pedestrian mobility and that only a small fraction have restricted mobility

Keywords: Levels of Service, Pedestrians, Pedestrian Flow, Pedestrian Capacity, Platforms.

I. INTRODUCTION

As cities grow, it is necessary to implement infrastructure works that allow adequate mobility for both vehicular and pedestrian traffic [1]. However, in many cities throughout the Colombian territory, within their urban perimeter, priority is given to solutions that provide and improve mobility to vehicular traffic, for which the government entities in charge carry out important investments in road infrastructure [2], many times, without adequately taking into account the safety and comfort of pedestrians, thus affecting the safety and quality of life of its inhabitants.

This strategy is not healthy at all, since, within urban areas and especially within the central areas of cities, most of the people travel on foot, which is why they should be given priority for their displacement [3]. Therefore, cities must have platforms, with such specifications, that allow the free flow of people, without any restrictions, implementing a better standard of living in the city and generating fluidity in movement [4] [5].

In the particular case of the city of San Juan de Pasto, over the years, various works have been built that seek to improve vehicular mobility. However, not all interventions have gone hand in hand with the execution of works or alternative solutions that lead to the improvement of the conditions in which the pedestrian passes through the various areas designated for that purpose; This is the case of platforms, which, in many cases, do not present the required specifications to be able to provide users with fluidity, safety and comfort [6], since within urban areas the existence of accesses for people with physical limitations is necessary and some guide devices that allow disabled people to circulate through these elements [7], which is very limited in the city of Pasto.

In the sector adjacent to the centre of the city of Pasto, the problem of the lack of adequate spaces that allows pedestrians an agile and safe movement becomes more evident; Reduced spaces are identified on many platforms, in which pedestrians currently travel at low speeds, caused by the reduced space and in many situations, forcing them to invade the vehicular road, thus generating serious conflicts between pedestrians and vehicles, causing accidents and presenting levels of insecurity for both the pedestrian and the driver.

In accordance with the provisions above, it is necessary to evaluate the platforms located in the study area, to know in what physical condition they are and how the service is being provided to pedestrians. For this purpose, it is necessary to determine the service levels and the pedestrian capacity, through the implementation of gauges along the existing structures, so that a diagnosis of which platforms provide good service and which present deficiencies in their operation, in such a way that in the future, an improvement in their design can be proposed.

II. MATERIALS AND METHODS

The platforms are the elements intended for the permanence and circulation of pedestrians. Its connectivity must be longitudinal and transversely, so that users can move without any problem.

To determine the Capacity and Levels of Service of the pedestrian platforms [8], the following steps must be followed:

- Determination of the dimensions of each of the platforms located within the study area.
- Determination of the most critical areas, taking into account as evaluation parameters, the dimensions of the platforms, the number of pedestrians who come within the sector and the proximity to sites of mass pedestrian congregation.
- Determination of peak hours and days in which pedestrian flow shows a considerable increase over the rest.
- Implementation of an efficient system for the realization of pedestrian gauges along the sectors under study.
- Determination of the service levels and the capacity of each of the platforms in the so-called critical sectors.

II.I Determination of pedestrian capacities

For the realization of pedestrian gauges, the most critical sites in which there are the greatest conflicts on the part of pedestrians must be identified, for their free daily and occasional traffic. To determine these sites, several factors were evaluated, among which we can highlight:

- Platforms that had small dimensions in their cross section, which for practical purposes were established with widths between 1.00 and 2.00 meters.
- Sectors close to the historic centre of the city and places of cultural value.
- Sites in which, in previous gauging carried out, had high levels of pedestrian flow.
- Pedestrian corridors near mass pedestrian arrivals centres, such as shopping centres, religious centres, parks, hotels, offices, banks, recreation and entertainment centres.

II.II Level of Service and pedestrian capacity in pedestrian zones

The determination of these two parameters is fundamental, in order to establish the quality of the service offered to the users of the platforms [8].

Pedestrian Capacity is defined as the space that corresponds to each pedestrian for free movement, expressed in m^2. This parameter must be determined for the period of greatest pedestrian traffic, in a period of 15 minutes and is expressed in terms of the area availability for each pedestrian (m^2/pedestrian).

With regard to service levels on pedestrian streets, these are based on subjective measures, which is why they can be somewhat imprecise. However, it is possible to define certain surface intervals per pedestrian, or traffic intensities and speeds, which can be used in order to be able to evaluate the quality of the service provided.

Table 1 shows the criteria used to determine pedestrian service levels. The most common way to define the level of pedestrian service is through the assignment of a minimum value of available surface for each pedestrian, which would correspond to the inverse of density. Other complementary parameters for determining service levels are average speed and intensity. These criteria are based on the hypothesis that pedestrians are evenly distributed over the useful area of the pedestrian path.

Table 1. Pedestrian Levels of Service boundaries on sidewalk (adapted from the HCM 2010)

Level of Service	Space (m^2/pt)	Speed (m/min)	Flow rate (pt/min/m)	v/c ratio
A	> 5.6	> 78	≤ 16	≤ 0.21
B	> 3.70-5.60	> 76-78	> 16-23	> 0.21-0.31
C	> 2.20-3.70	> 73-76	> 23-33	> 0.31-0.44
D	> 1.40-2.20	> 68-73	> 33-49	> 0.44-0.65
E	> 0.75-1.40	> 45-68	> 49-75	> 0.65-1.00
F	≤ 0.75	≤ 45	Varies	Varies

Source: Highway Capacity Manual - HCM2010

Pedestrian circulation is subject to great variability, and it is convenient to consider the effect of squads or other traffic distributions, modifying the underlying hypotheses for calculating the average intensities of the service levels and consequently making the appropriate adjustments, when it is necessary.

To take into account the effect of the platoons, the magnitude and duration of these fluctuations in demand must be determined, which is carried out by gauging these short-term waves of demand. The value and frequency of pedestrian appearance should be compared with the intensity for the 15-minute period, in order to provide a clearer view of the service level conditions on these stretches of the road.

Within the relevant parameters for determining the Capacity and Service Levels of the platforms, the following are found:

Qp15: corresponds to the highest number of pedestrians registered in the four 15-minute periods corresponding to the hour of maximum pedestrian demand.

Minor width: refers to the smallest cross section on the platform. This measurement is given in meters.

Total area: result of multiplying all the widths that make up the platform by the length where they are developed. The unit for this measurement is given in square meters.

Intensity: it is the ratio that determines the number of pedestrians that circulate per minute on each square meter of the structure.

The main criteria to determine the Service Levels for the street platforms under study are described below, as well as the criteria adopted to establish the Service Level for each section of the platform:

Level of Service according to intensity: according to the value obtained for intensity (Calculated with Equation 1), it is established, according to Table 1, which Service Level it corresponds to:

$$I = \frac{Qp_{15}}{15min\ x\ Am} \qquad \text{(Eq. 1)}$$

Where:

I: Intensity (Pt/min/m)

Qp15: Highest number of pedestrians registered in the four 15-minute periods corresponding to the hour of maximum pedestrian demand.

Am: Minor section width (m)

Level of Service according to Occupation: in this case, the indicator corresponding to the value obtained in the occupation is used, according to the standards established in the HCM 2010.

Occupancy determines the corresponding space for each of the pedestrians that passes the place in a period of 15 minutes (density of pedestrians) and is determined as follows:

$$M = \frac{A_{total}}{Qp_{15}} \qquad \text{(Eq. 2)}$$

Where:

M: It is the pedestrian capacity or the space assigned to the pedestrian (m²/pt)

A_{total}: result of multiplying all the widths that make up the platform by the length where they are developed (m).

Qp15: Highest number of pedestrians registered in the four 15-minute periods corresponding to the time that generated the maximum hourly value.

Level of Service Assigned: it is the level assigned to the platform, choosing the most unfavourable value that has been obtained between the Service Level according to the Intensity and the Service Level according to the Occupancy.

Figure 1 shows the six LOS walkway criteria according the HCM 2010 (LOS A, B, C, D, E and F). These LOS criteria are based on average glow and do not consider platoon flow [8].

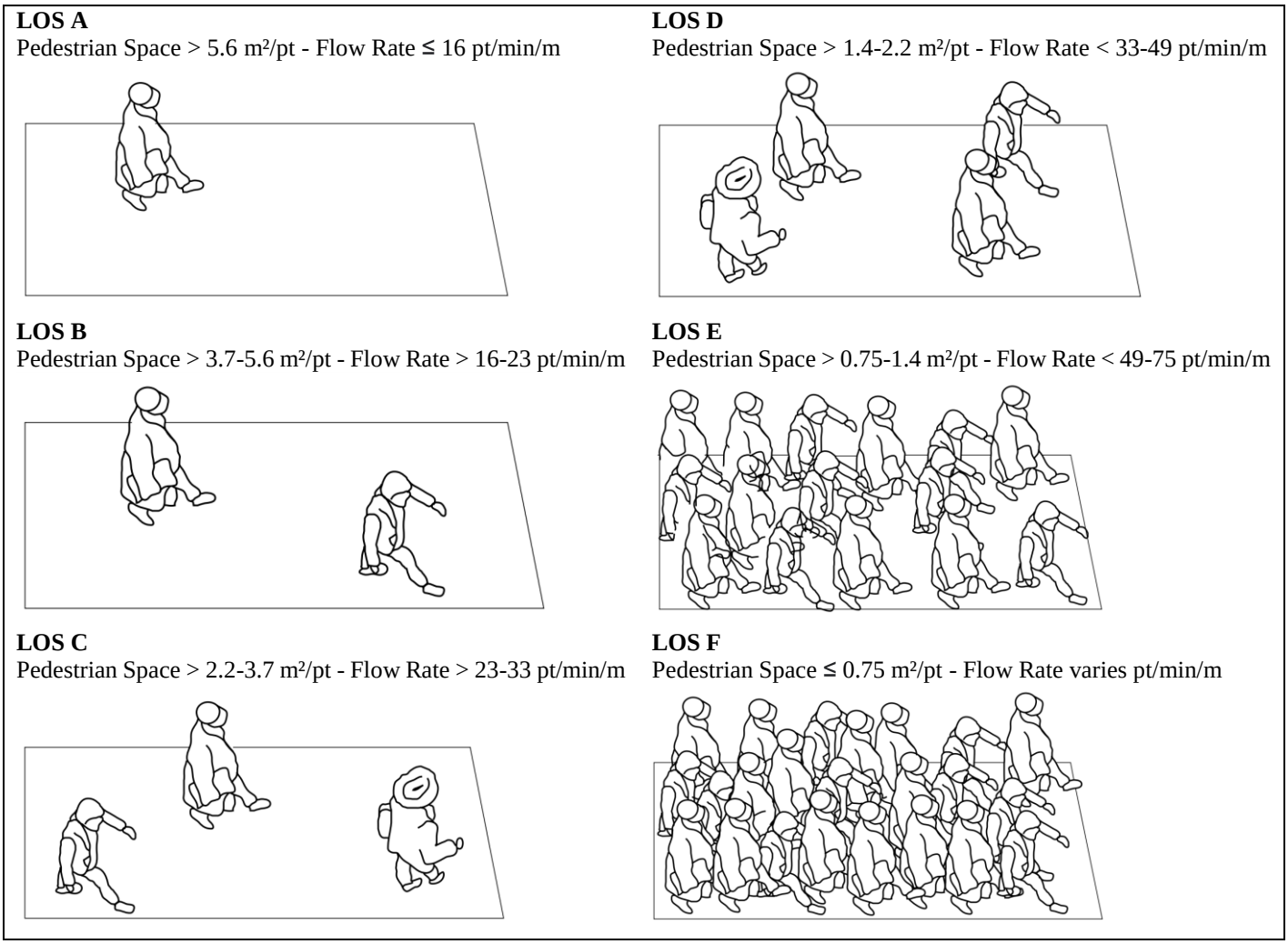

Fig. 1. Pedestrian Walkway LOS – Source HCM 2010

III. RESULTS AND ANALYSIS OF RESULTS

Tables 2 and 3 present a summary of the different parameters obtained to determine the Service Level of each section of platform evaluated. Table 2 refers to the platforms evaluated in the South-North direction and Table 3, to those in the West-East direction. The attributes represented in these tables are: the evaluated site, the platform side, its smaller width, its total area, the value of Qp_{15}, the flow rate, the space and the service levels calculated according to the criteria selected for this investigation.

The field work to determine the Service Levels of the platforms was carried out in 93 different sites, located in urban streets of the city of Pasto. For the corresponding evaluation, perpendicular circulation directions were considered, resulting in two evaluated circulation directions (South-North direction and West-East direction). Furthermore, at each study site, the left and right platforms were evaluated separately, covering a total length of 9069 meters of platforms.

Table 2. Levels of service of the platforms in the direction of pedestrian circulation South – North

Site	Platform side	Minor width (m)	Total area (m^2)	Qp15 (Pt15 min)	Flow rate (pt/min/m)	LOS by Flow rate	Space (m^2/pt)	LOS by Space	LOS assigned
Cll1	Left side	1.25	247.6	241	13	A	15.41	A	**A**
	Right side	0.80	123.9	282	24	C	6.59	A	**C**
Cll2	Left side	0.96	92.3	278	19	B	4.98	B	**B**
	Right side	1.07	103.0	209	13	A	7.39	A	**A**
Cll3	Right side	1.23	198.9	165	9	A	18.08	A	**A**
Cll4	Left side	1.09	214.8	1281	78	F	2.52	C	**F**
	Right side	1.06	176.6	1216	76	F	2.18	D	**F**
Cll5	Left side	1.15	155.4	770	45	D	3.03	C	**D**
	Right side	1.26	147.4	684	36	D	3.23	C	**D**
Cll6	Left side	1.88	248.3	280	10	A	13.30	A	**A**
	Right side	2.29	148.9	598	17	B	3.73	B	**B**
Cll7	Left side	1.40	185.7	824	39	D	3.38	C	**D**
	Right side	1.69	176.0	745	29	C	3.54	C	**C**
Cll8	Left side	1.21	193.3	344	19	B	8.43	A	**B**
	Right side	1.36	129.7	585	29	C	3.33	C	**C**
Cll9	Left side	1.23	173.8	176	10	A	14.81	A	**A**
	Right side	1.39	166.3	380	18	B	6.56	A	**B**
Cll10	Left side	2.83	348.0	933	22	B	5.59	B	**B**
	Right side	2.75	265.1	636	15	A	6.25	A	**A**
Cll11	Left side	4.73	424.5	1180	17	B	5.40	B	**B**
Cll12	Left side	1.24	117.1	739	40	D	2.38	C	**D**
	Right side	1.94	397.1	904	31	C	6.59	A	**C**
Cll13	Left side	1.89	243.4	715	25	C	5.11	B	**C**
	Right side	1.87	234.3	524	19	B	6.71	A	**B**
Cll14	Left side	1.15	112.0	408	24	C	4.12	B	**C**
	Right side	1.88	182.0	427	15	A	6.39	A	**A**
Cll15	Right side	1.15	134.4	570	33	C	3.54	C	**C**
Cll16	Left side	1.41	196.9	535	25	C	5.52	B	**C**
	Right side	1.16	109.3	504	29	C	3.25	C	**C**
Cll17	Left side	1.45	140.5	241	11	A	8.74	A	**A**
	Right side	1.56	150.8	227	10	A	9.96	A	**A**
Cll18	Left side	1.15	119.6	216	13	A	8.31	A	**A**
	Right side	1.34	127.6	253	13	A	7.57	A	**A**
Cll19	Left side	1.36	87.9	102	5	A	12.93	A	**A**
	Right side	1.27	73.8	107	6	A	10.34	A	**A**
Cll20	Left side	2.00	267.2	274	9	A	14.63	A	**A**
	Right side	1.90	241.3	336	12	A	10.77	A	**A**
Cll21	Left side	1.20	114.4	118	7	A	14.54	A	**A**
	Right side	1.22	116.2	160	9	A	10.89	A	**A**
Cll22	Left side	1.34	216.6	177	9	A	18.36	A	**A**
	Right side	2.34	217.0	202	6	A	16.11	A	**A**

Table 3. Levels of service of the platforms in the direction of pedestrian circulation West – East

Site	Platform side	Minor width (m)	Total area (m^2)	Qp15 (Pt15 min)	Flow rate (pt/min/m)	LOS by Flow rate	Space (m^2/pt)	LOS by Space	LOS assigned
Crr1	Right side	2.35	226.0	162	5	A	20.93	A	**A**
	Left side	1.46	140.1	216	10	A	9.73	A	**A**
Crr2	Right side	1.35	131.4	177	9	A	11.14	A	**A**
	Left side	1.45	138.1	254	12	A	8.16	A	**A**
Crr3	Right side	1.53	186.2	387	17	B	7.22	A	**B**
	Left side	1.83	186.8	628	23	B	4.46	B	**B**
Crr4	Right side	1.34	121.1	499	25	C	3.64	C	**C**
	Left side	1.13	219.6	699	41	D	4.71	B	**D**
Crr5	Right side	1.30	156.7	142	7	A	16.55	A	**A**
	Left side	1.25	157.3	115	6	A	20.52	A	**A**
Crr6	Right side	1.31	122.3	427	22	B	4.30	B	**B**
	Left side	1.49	142.2	533	24	C	4.00	B	**C**
Crr7	Right side	2.71	262.2	275	7	A	14.30	A	**A**
	Left side	1.50	206.8	353	16	A	8.79	A	**A**
Crr8	Right side	1.78	170.1	244	9	A	10.46	A	**A**
	Left side	1.56	149.1	223	10	A	10.03	A	**A**
Crr9	Right side	2.02	193.1	706	23	B	4.10	B	**B**
	Left side	1.70	164.5	360	14	A	6.85	A	**A**
Crr10	Right side	1.60	154.1	734	31	C	3.15	C	**C**
Crr11	Left side	1.20	248.7	447	25	C	8.35	A	**C**
	Left side	1.25	119.0	464	25	C	3.85	B	**C**
Crr12	Right side	1.30	123.5	343	18	B	5.40	B	**B**
	Left side	1.19	148.1	454	25	C	4.89	B	**C**
Crr13	Left side	5.72	555.0	570	7	A	14.61	A	**A**
Crr14	Right side	1.27	121.1	367	19	B	4.95	B	**B**
	Left side	1.14	108.9	590	35	D	2.77	C	**D**
Crr15	Right side	1.20	112.8	204	11	A	8.29	A	**A**
	Left side	1.25	151.0	203	11	A	11.16	A	**A**
Crr16	Right side	0.93	167.6	450	32	C	5.59	B	**C**
	Left side	1.24	440.0	984	53	E	6.71	A	**E**
Crr17	Right side	1.17	111.1	952	54	E	1.75	D	**E**
	Left side	2.61	246.6	357	9	A	10.36	A	**A**
Crr18	Right side	1.12	120.4	388	23	B	4.65	B	**B**
	Left side	1.12	117.2	243	14	A	7.23	A	**A**
Crr19	Right side	1.38	132.8	226	11	A	8.81	A	**A**
	Left side	1.41	135.8	405	19	B	5.03	B	**B**
Crr20	Right side	1.60	152.4	220	9	A	10.39	A	**A**
	Left side	1.00	95.4	295	20	B	4.85	B	**B**
Crr21	Right side	2.45	231.6	128	3	A	27.14	A	**A**
	Left side	3.35	174.7	168	3	A	15.60	A	**A**
Crr22	Right side	1.63	156.8	106	4	A	22.19	A	**A**
	Left side	1.57	150.8	130	6	A	17.40	A	**A**
Crr23	Right side	0.75	159.3	150	13	A	15.93	A	**A**
	Left side	1.24	162.0	159	9	A	15.28	A	**A**
Crr24	Right side	3.25	313.2	292	6	A	16.09	A	**A**
	Left side	1.00	95.9	192	13	A	7.49	A	**A**
Crr25	Right side	1.34	125.2	162	8	A	11.59	A	**A**
	Left side	1.60	153.9	210	9	A	10.99	A	**A**
Crr26	Right side	1.58	145.5	192	8	A	11.37	A	**A**
	Left side	1.97	175.0	322	11	A	8.15	A	**A**
Crr27	Right side	1.12	111.5	180	11	A	9.29	A	**A**
	Left side	1.04	95.4	118	8	A	12.12	A	**A**

When evaluating the current state of the infrastructure destined for pedestrian traffic in the city centre, it was determined that 48% of the platforms present a Deficient state, due to the fact that the surfaces are very deteriorated and worn, also presenting absence roughness due to excessive use to which they have been subjected. On the other hand, 43% of the platforms are in a Regular state and only 9% qualify as a Good state.

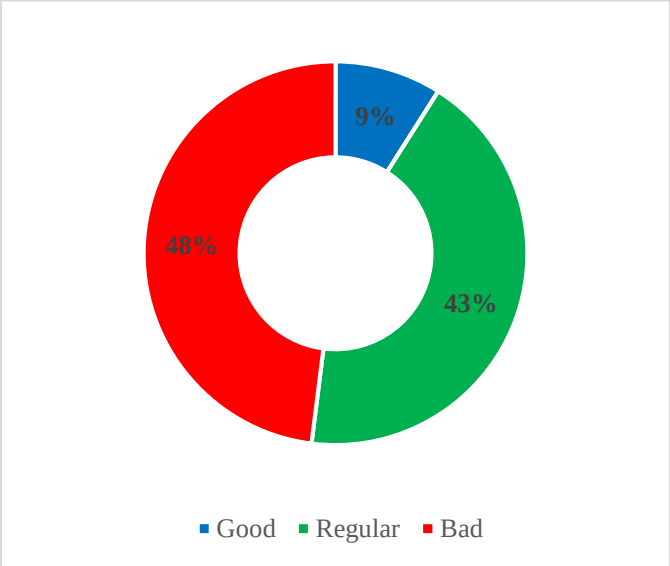

Fig. 2. Current status of the platforms

In the case of the values of service levels themselves, Table 4 has been prepared, where the number of platforms corresponding to each service level can be observed, discriminated for the two directions of circulation (South-North and West-East). Similarly, in this same Table, the length of platforms corresponding to each level of service offered to users is presented.

Table 4. Service levels obtained on the roads

LOS	Platform (S - N)	Platform (W - E)	Platforms (Sites)	Platforms (length)
A	19	32	51	4596.7
B	7	9	16	1421.4
C	9	7	16	1712.6
D	4	2	6	650.3
E	0	2	2	380.4
F	2	0	2	307.5
Total	**41**	**52**	**93**	**9068.9**

On the other hand, in Figures 3 and 4, the number of platforms observed for each level of service is presented in percentage terms, taking into account the two directions of pedestrian circulation.

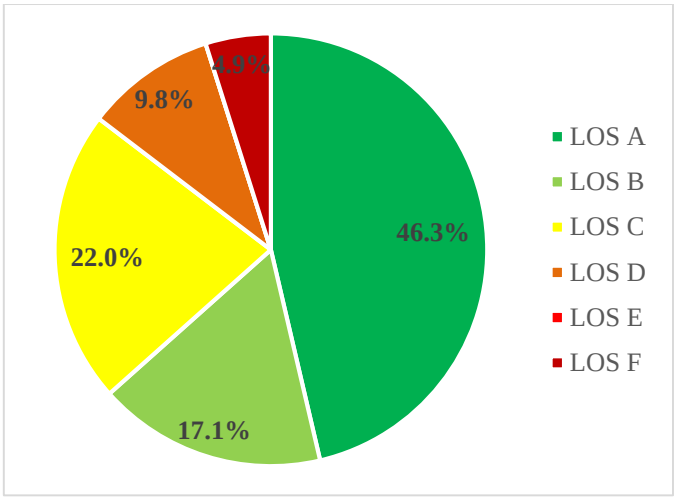

Fig. 3. Levels of Service of platforms located in sites with South-North direction

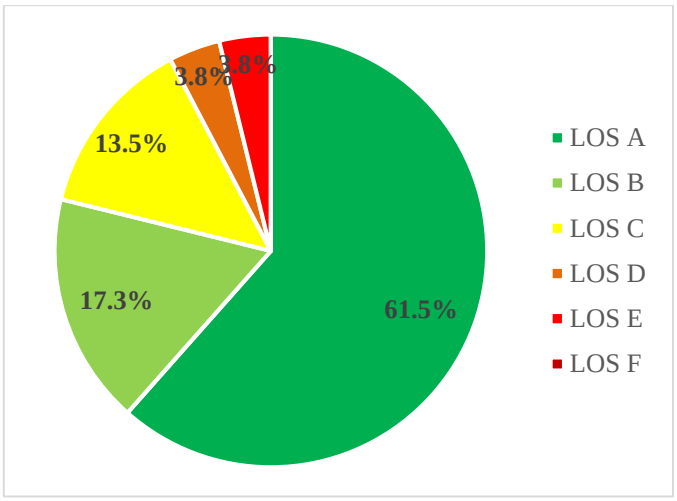

Fig. 4. Levels of Service of platforms located in sites with West-East direction

Figures 3 and 4 present the assigned service levels, based on the HCM 2010 methodology and taking the evaluated sites as a reference: 41 for the platforms in the S-N direction and 52 for those in the W-E direction. As can be seen, for the platforms in the West-East direction (Figure3), it is shown that more than 60% of these have a NS A, while for the platforms in the South-North direction, less than 50% present NS A. For NS B, it is observed that the percentage is practically the same for both directions of circulation, representing approximately 17%. On the other hand, it is observed that the platforms in the SN sense have NS D and F, around 15%, while in the case of the roads in the OE sense, there are D and E values, and their percentage is lower, of approximately 8%, almost half of the value presented above. This shows that the Service Levels, in general, are better on the sidewalks with direction E-E, and therefore, it is expected that the mobility of pedestrians on these streets will be more comfortable.

Figure 5 presents the service levels for the platforms studied, taking into consideration the 93 sites evaluated during the field work. As can be seen, in general, more than 50% of the evaluated sites present LOS A and only approximately 11% present LOS D, E or F.

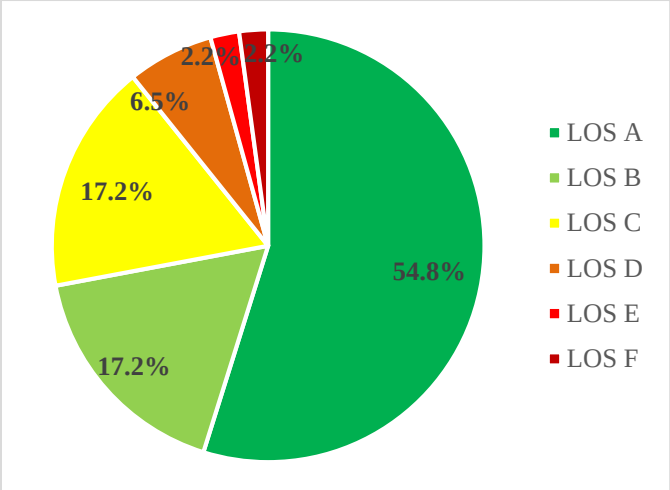

Fig. 5. LOS platform by Sites

On the other hand, this information is corroborated when the platform length analysis is made. For this purpose, in Figure 6 this information is presented and it can be clearly seen that of the 9069 linear meters of platforms evaluated, more than 50% present Level of Service A and approximately 15% of the evaluated length presents LOS D , E or F.

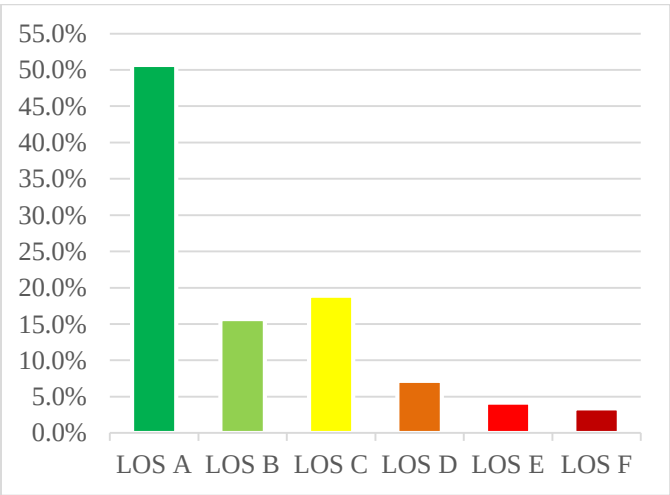

Fig. 6. LOS platform by Length

IV. CONCLUSIONS

The present investigation allowed to know the status of the platforms in the central area of the city of Pasto, based on the Service Levels that they provide for pedestrian mobility. Based on the results obtained, it can be concluded that more than 50% of the existing platforms in the analysed streets have a NS A. On the other hand, it could be observed that the number of platforms where the level of service is considered deficient (D, E, F), is less than 15%, with which it can be concluded that the mobility of pedestrians in the evaluated streets and under the existing conditions, generally presents, under the standards established in the HCM 2010, a mobility pedestrian with few conflicts.

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