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To cite this article: J P Rojas-Suárez *et al* 2019 *J. Phys.: Conf. Ser.* **1388** 012021

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Technical feasibility study for the implementation of pedestrian safety mechanisms

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Abstract. The increase in distractions when driving or walking on a road has proportionally increased the number of accidents that occur each year, with pedestrians being the most affected. For this reason, an attempt is made to study the characteristics of a vehicle road, identifying the critical points and road sections of maximum demand of the inhabitants, who are the ones most in need of pedestrian crossings. For this reason, a statistical and technical study of traffic is proposed by means of vehicular gauges with respect to the most representative days that help to determine quantitatively the vehicular flow that circulates through this road corridor, by means of graphs, tables that help to identify the statistical data without still leaving aside the importance of a study of pedestrian traffic by means of a count in typical days of mobilization with the purpose of determining the pedestrian volume, due to its increase in the indexes of accidents caused by different types of transport, in which the motorcycles stand out.

1. Introduction

Transport is an important criterion for assessing the development of different countries, but it can also be damaging. Pedestrians and cyclists are among the most vulnerable road users [1]. Traffic accidents generally caused by the diversion of the vehicle from the intended direction [2], have been of increasing concern to the public worldwide, underlining the importance of understanding the factors of pedestrian error by having 59% of vehicle to pedestrian accidents [3]; noting that pedestrian safety becomes more questionable at uncontrolled intersections and in half-block sections, making it a high risk due to the lower priority given by vehicle drivers to pedestrian performance [4].

Pedestrians, often referred to as vulnerable road users, are very susceptible to serious injury and death when involved in vehicle accidents [5], with the most serious accidents on rural roads probably due to higher vehicle speeds and less efficient emergency services over long distances [6]. Every year, more than 1.2 million people in the world die in traffic accidents and among these victims, 22% are pedestrians. This proportion of pedestrian fatalities is 14% in Australia [7] while annual pedestrian deaths in the United States increased by more than 30% between 2009 and 2016; approximately 6,000 pedestrians died in 2016, the highest level in nearly three decades [8], with a large proportion of crashes occurring at uncontrolled junctions (without stop or traffic signs) or unmarked junctions (without traffic signs) [5].

Therefore, the needs of these vulnerable street users should be met to make their travels safer. Improving pedestrian safety in low- and middle-income countries (LMIC) is an important public health objective for environmental health, obesity prevention and injury control [9]; consequently, increasing pedestrian safety results in fewer deaths [10], as it can be assessed through the acceptance behavior of pedestrian space and vehicle spaces with the effect of different pedestrian behavior characteristics



(rolling behavior, speed increase, etc.) [11]. However, in industrialized countries, where the mortality rate has generally declined, the cost to society of such accidents remains considerable [6].

This research evaluates an urban design for pedestrian crossings with budgets for pedestrian safety that provides possible solutions to the road corridor of study, which can be used in highly dangerous road sections, determining the feasibility of using pedestrian safety mechanisms in the ring road of the municipality of Ocaña, Norte de Santander, Colombia.

2. Methodology

The development of the research was carried out with a non-probabilistic-intentional sample, being this study population the citizens who transit and make use of the roads of the road corridor "Avenida circunvalar" of the municipality of Ocaña, Norte de Santander, Colombia. In this regard, information was provided by the Minister of Transport and results of vehicle, pedestrian and motorcycle gauges [12], accident report of the National Institute of Roads, to support the analysis of data that were obtained by two quantitative methods, determining traffic volumes, accident rates with respect to the population and vehicle fleet to conclude with a preliminary budget for pedestrian safety mechanism in this area.

3. Results

3.1. Study of vehicular traffic; traffic volumes

The average daily weekly traffic is calculated according to the gauges carried out in the periods of peak hours during the study week [12]. In this case it was comprised of five days from August 25 to 29, calculating three (3) types of average daily weekly transit (ADWT): mixed vehicles (cars, buses and other t), motorcycles and bicycles; the latter being considered as an alternative to vehicles, since they allow people to travel longer, faster, with less effort than walking and with a low environmental impact, which makes them efficient modes of transportation [13].

3.1.1. Weekly average daily transit. To define the average daily traffic volume, Equation (1) was used, as the total number of vehicles passing during a given period (WT), divided by the number of days of the period, which in this case are 5 days.

$$ADWT = WT/5 \quad (1)$$

Table 1 and Figure 1 shows in both directions, the number of motorcycles exceeds the volume of vehicles and bicycles per week, thanks to its low fuel consumption and maintenance, easy parking and high mobility in increasingly congested cities that lack affordable public transport, as a motorcycle with a less powerful engine. Typically costs between 20% - 25% that of a small car [14].

Table 1. ADWT.

Direction	Mixed vehicles	Motorcycles	Bicycles
South-North	1007	2811	4
North-South Direction	1294	3002	3

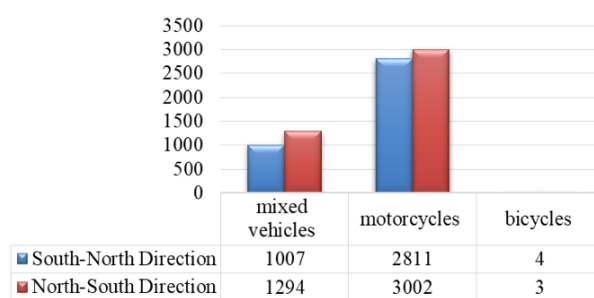


Figure 1. Weekly average daily transit.

3.2. Pedestrian traffic study, pedestrian volume

3.2.1. *Pedestrian volume.* In Equation (2), it is determined in pedestrians per meter per minute (pmm) [12]. Where, V15: Peak pedestrian flow within 15 minutes and We: Effective width of the pedestrian crossing, this being for a pedestrian bridge of at least 2.40 meters.

$$PV = V15 / (15 * (We)) \quad (2)$$

There were 24 pedestrians who moved in these 15 minutes, divided into the effective width of 2.40 meters, resulting in 0.67 (pedestrian/min)/meter, *i.e.* one person per minute per meter walks on a pedestrian bridge and in doing so has a particular experience of moving through an environment where forces converge material, body and elemental. The bridge, as an urban infrastructure, is a conduit for absorbing and exerting movement [15].

3.2.2. *Pedestrian intensity.* Equation (3) represents the number of pedestrians passing through a given stretch of the unit of time [12]. Where, n: Peak number of pedestrians in a period of 15 minutes and t: time unit (15 min).

$$I = n/t \quad (3)$$

There were 24 pedestrians who moved in these 15 minutes, resulting in 1.6 (pedestrian/minute), as pedestrian characteristics, such as walking facilities, travel activities and environmental conditions, have a considerable impact on pedestrian dynamics. These factors are useful for understanding pedestrian flow performance [16].

3.3. Accident rates

The severity of the accident is affected by the type of accident and the surrounding environment; whereas the types of accidents vary under considerations of traffic volumes, number of lanes and curvature of the road [17]. It is important to reduce the traffic accident rate in order to reduce not only human casualties, but also medical expenses, damage to vehicles and road facilities, congestion due to accidents and other economic losses [18].

Table 2 and Figure 2 indicate the variation of the accident records in the vehicle section for year 1 (2012), year 2 (2013) and year 3 (2014), alarming the increase as the accident rate passes and the number of deaths proportional to it. The NHTSA publishes annual reports on traffic safety data, stating that since 1988 there have been more than 5000000 auto accidents in the United States each year and about 30% of them result in deaths and injuries [19].

The accident rates present in the study section were determined according to the concepts contemplated in the book transit engineering of cal and mayor. The determination of these results is made with respect to the population of the municipality of Ocaña, Colombia, for years 1, 2 and 3 projections obtained from the "Departamento Administrativo Nacional de Estadística (DANE)" and the vehicle fleet in the city for the years of study, thus indicating the rates of accident, morbidity and mortality that describe the antecedents occurred in terms of number of accidents, injuries and fatal losses.

Table 2. Mathematical analysis of accident variation for years 1, 2 and 3 [12].

Type of accident	Year 1 and 2	Observation	Year 2 and 3	Observation
Number of accidents	57.69%	Increased	60%	Increased
Number of dead	7.69%	Increased	10%	Increased
Number of Injured	34.62%	Increased	30%	Decreased

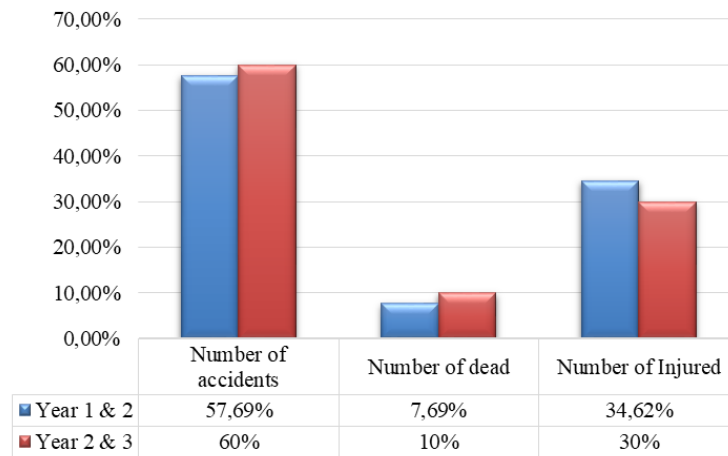


Figure 2. Mathematical analysis of accident variation for years 1, 2 and 3.

3.4. Average of indices with respect to population

3.4.1. Average accident rate. According to Equation (4), where the #Accidents in the year corresponds to the number of traffic accidents occurring in the sector determined in a time interval of one year, divided by the number of inhabitants of the sector, therefore, in these three years, the average accident rate was 6.8, which is a number of 6.8 accidents per 100,000 inhabitants of the municipality of Ocaña in the year with respect to the Avenida Circunvalar from the pass of Alconsure to the roundabout of Francisco Fernandez.

$$I = \frac{A}{P(\text{year})} = \frac{\#Accidents \text{ in the year} * 100000}{\#habitants} \quad (4)$$

3.4.2. Average morbidity index. According to Equation (5), where the number of injured in the year corresponds to the number of road traffic injuries occurring in the study sector over a time interval of one year, divided by the number of inhabitants of the sector, therefore, the average morbidity rate in these three years was 6.72, and having an average of 6.8 accidents, suggests that 6.72 of the accidents of the year per 100.000 inhabitants were injured in the municipality of Ocaña with respect to Circunvalar Avenue from the Alconsure crossing to the Francisco Fernández roundabout.

$$I \frac{Morb}{P(\text{year})} = \frac{\#Injured \text{ in the year} * 100000}{\#Habitants} \quad (5)$$

3.4.3. Average mortality rate. In Equation (6), where the number of injured in the year corresponds to the number of road traffic injuries occurring in the study sector over a time interval of one year, divided by the number of inhabitants of the sector; for our case, in addition to the people who were injured in the course of these three years, the average mortality rate was 6.75, which means a number of 6.75 deaths per year per 100. The number of inhabitants of the municipality of Ocaña with respect to Circunvalar Avenue from the crossing of Alconsure to the roundabout Francisco Fernández.

$$I = \frac{Dead}{P(\text{year})} = \frac{\#dead \text{ in the year} * 100000}{\#Habitants} \quad (6)$$

3.5. Preliminary budget with road safety mechanisms

In Table 3, an estimate was made of the preliminary budget, an approximate amount of 155099.79 is calculated.

Table 3. Construction budget.

Description	Units	Quantity	Unitary value	Total value (u.s. dollars)
Preliminary				\$4400.21
Location and relocation	ml	4350.00	\$0.58	\$2514.95
Camp of 9 m2	Units	1	\$424.83	\$424.83
Spraying and cleaning	m ²	6078.80	\$0.24	\$1460.43
Excavations				\$5195.88
Unclassified manual excavation	m ³	491.94	\$10.56	\$5195.88
Fillers				\$16666.88
Granular base	m ³	983.88	\$13.63	\$13409.14
Compaction with manual vibrocompactor	m ³	491.94	\$6.62	\$3257.73
Removal of excavation material				\$1731.96
Manual removal of excavated material	m ³	491.94	\$3.52	\$1731.96
Roadworks				\$83946.51
Granular gutter base e=0.10	ml	8534.00	\$5.58	\$47638.24
Gutter e=0.10 h=0.30	Ml	256.04	\$141.81	\$36308.27
Pavements				\$18172.88
Concrete pavement e=20	M2	655.92	\$27.71	\$18172.88
Complementary elements				\$16394.72
Horizontal signaling	Ml	17368.00	\$1.38	\$7446.18
Vertical signaling	Units	61.00	\$429.11	\$8114.39
Reflective studs	Units	365.00	\$7.37	\$834.14
Arborization and gardening				\$8590.76
Arborization	Units	89.00	\$13.82	\$381.16
Lawn gardening	M2	3197.61	\$8.28	\$8209.61
Total budgets				\$155099.79

4. Conclusions

Resulting in road safety for roads an important factor in analyzing the dangers that can be caused by the lack of proper implementation of pedestrian crossings, speed reducers and pedestrian paths, being the citizens most likely to suffer its consequences, whether at the entrance to a site, the terminal sector or the entire road in particular. The average daily weekly traffic depends on the transit of different means of transport during important hours of the day (departure of students from institutions or persons from work), being in this case the least used means of transport the bicycle with an average of 4 bicycles used during these hours.

Any mode of transportation, which is not alien to suffer an accident in its mobilization, whether different types of vehicles, bicycles and motorcycles, being the latter with greater acceptance in citizenship to reduce costs and avoid the tram, but equally, increase the indicators of accidents that occur, morbidity and mortality of people, being these occurred on the avenue that show a number of accidents in the period 2012 to 2013 was 57.69% and compared with the period 2013 to 2014 was 60% which reflects a slight increase in the number of accidents.

In order to reduce the rate of accidents, morbidity and mortality, it is necessary to guarantee road safety of sufficient quality and to carry out a technical study at specific times to consider options for improving safety systems.

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