Analysis of Road Accidents in a Small Size Municipality: The case of Ponte de Sor

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Abstract

Compared with countries such as Spain, France and Austria, considered as a reference in the National Strategy for Road Safety, Portugal still has the worst performance when it comes to accidents within the urban areas, registering more than 70% of accidents in these circumstances. It is urgent to develop simple tools to allow an effective evaluation of accident information in an accessible format, so that it is possible to have an effective action in the reduction of urban accidents.

One of the purposes of the present work was the association of the information from two accident databases (provided by two different responsible entities) to a Geographic Information System, in order to map the occurrences directly on the urban road network of Ponte de Sor and then to be able to identify, in a more intuitive way, the exact location of the zones of the urban network with greater register of occurrences, allowing to study in detail the characteristics of these places and to suggest low cost measures of intervention to improve the safety conditions of traffic circulation.

In the analyzed cases, the estimated cost of preventing a single minor injury, evaluated under the conditions of the best approach for the subject, is about 7 times greater than the estimated cost for the interventions developed for the places of high rate of accidents. This demonstrates the need to move in the direction supported by this dissertation.

Keywords: Road accidents, geographic information systems, accident accumulation zones, low-cost measures.

1. INTRODUCTION

Road accidents are generally preventable, but they are also currently responsible for the loss of about 1.25 million lives per year around the world and have devastating consequences on the health and development of any country in the world. In 2020, according to the World Health Organization, road fatalities will be the third leading cause of death in developing countries, surpassing phenomena such as war or AIDS (Santos, 2017), (WHO, 2015).

One of the approaches to improve safety in urban areas, consists of the analysis of accidents occurring in a given time-window. A 3 to 5 year- period is generally considered sufficient, since typically within this period, there is no change in physical conditions, and so it is used to identify the road sections with the highest incidence of accidents. Studies indicate that there is a tendency for road accidents in urban areas to occur in certain locations, particularly at junctions (Carvalheira et al, 2008).

A robust and efficient system of collecting and processing accident data is the basis for an adequate maintenance of the road infrastructure, which has a major influence on improving the safety of roadways and helps to prevent the occurrence of road accidents. The collection and processing of accident information is intended to be the starting point for studies aiming to identify problematic areas and to try to understand what can be done to solve those problems. In order to obtain a statistically significant accident analysis, it is essential to obtain detailed data on each accident, the road segment or intersection and also about the traffic volume in those roads (Carvalheira and Picado-Santos, 2008).

The limitations in the process of collecting that information can affect the reliability of the subsequent statistical analysis in ways that are not easily detectable. The road accident database compiled by the Portuguese Road Safety Authority (ANSR) is based on the information contained in the Road Traffic Accident Reporting Bulletins (BEAV's), completed by the Portuguese Republican National Guard (GNR) or by the Portuguese Public Police (PSP). However, it is important to note that one of the major difficulties in the preparation of studies such as this one, has to do with the maintenance of databases, in the sense that, the information must be continuously updated and the specialized teams that are responsible for their management should be able to adapt the databases to the constant evolution of the processes of collecting information on road accidents (Carvalheira and Picado-Santos, 2015).

For a successful analysis of sites with high accident rates, at a national or local, urban or rural level, it is essential to carry out a systematic survey of the accident information that has taken place in the area under study, using the aid of a Geographic Information System (GIS) tool. This allows, in an expeditious and very figurative way, the evaluation of the disposition of the occurrences of accidents in the road network in digital format (Carvalheira and Picado-Santos, 2015).

The main objective of this study is the treatment, analysis and geo-referencing process of the information collected from the accident data bases of the Municipality of Ponte de Sor, using, for this purpose, a GIS software tool, in order to detect zones with highest accumulation of accidents in urban and peri-urban areas. Another objective that stems from the main one is, for these high-incidence areas, the evaluation of the causes behind of those accidents and to propose the implementation of low cost measures to improve the road circulation safety on those zones.

2. CONCEPTS AND METHODOLOGY

2.1 Introduction

Ponte de Sor is a small-sized Portuguese town, with 16.722 inhabitants (W1, 2018). All available data on road accidents in Ponte de Sor, came from two different entities, which are responsible for road safety in Portugal, and each information, due to its characteristics, had a different purpose. The database provided by ANSR contained information over a five-year period (2012-2016) on the events that resulted in victims, requires the presence of the authorities (GNR) and the filling of the BEAV. This was the base information used to perform an analysis of the road accident Indicators in the

Municipality, due to the fact that its time range was extensive and the information very detailed. On the other hand, the GNR database contained information, not only about the events with registered victims at the scene, but also about the accidents where only material damages were recorded. Despite its shorter time-range, of only three years (2014-2016), the number of accidents listed is much bigger and thus more suitable and as a result, this database was the one used in this study to be associated with a GIS tool in order to locate and characterize problematic zones, and to analyse why, where and how the accidents took place on those specific locations.

2.2 Analysis method

The GIS software is the tool that provides the necessary support for other systems used by GNR, whether in an operational or strategic context. It was in an internal communication document, released by the Directorate of Communications and Information Systems of the Portuguese Air Force in 2014, that became defined the coordinate system to be used, whenever it is necessary to collect positional information. This coordinate system is based on the format provided by Portugal's Integrated System of Emergency and Security Networks (SIRESP) radio devices. The format of the coordinate pair (latitude and longitude) is as follows: two digits are allocated for the degrees, represented by the letter "G", followed by six digits allocated for minutes, which appear in decimal format, being the letter "M" the representation of the integer part of minutes and "D" stands for the decimal fraction of it (Sousa, 2017).

The coordinates field in the GNR database enabled with the help of ArcGis, the direct mapping of the road accidents in the digital road network and to show the exact location of where the events took place.
As stated, since the information was obtained from the accident reports handled by two different entities (ANSR and GNR), it was considered an important starting point to validate the information, in an attempt to understand whether the analogous occurrences in both databases (accidents with victims documented on the spot) were coincident. To do this, the two databases were georeferenced for one of the years in common, being the year 2016, the chosen for this purpose.

As can be seen from Figure 1, it became clear that, after the mapping process, that there was a very large gap between the mapped information from one entity and another, and the information properly projected corresponded to the information in the database provided by GNR and the information that was skewed was the one that came from the database provided by ANSR.

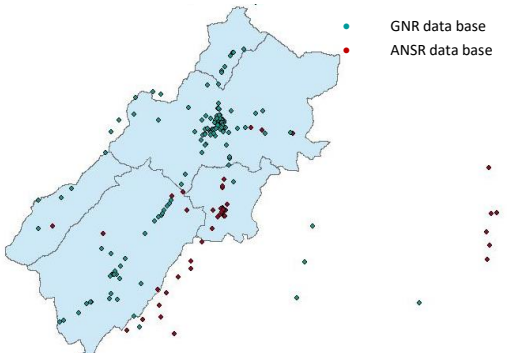

Fig. 1: mismatch between the mapping of the same road accidents coming from two different databases

After extensive research and discussion on the possible sources of discrepancies, it was concluded that the difference in values was due to the fact that the conversion to decimal degree, in the ANSR database was not made correctly. The source of the error came from the fact that, when compiling the coordinate information, the symbol (°) has been omitted and this symbol separates the integer part of the degree and its decimal fraction. Based on the results of the plotting of the accidents from both databases, it was concluded that the information from GNR's database was the one that plotted the accidents correctly (by comparison of the description of the location field and its effective location on the map). Knowing that the location device, the SIRESP radio, returns the coordinates in the format: (GG ° MM, DDDD), it can be concluded that they carefully converted that format to the decimal format (GG, DDDDDD), for all entries of the coordinate field of their database (Sousa, 2017).

Having detected the origin of the error and in order to make the format of the coordinate's field of both databases uniform, the procedure applied was the one as follows: starting from a common accident in both databases, for the selected accident in the

ANSR database, in the field of coordinates, the decimal part of each of the coordinates was isolated, this decimal part was divided by 100 in order to reach the value of the minutes and then, divided again, by 60 so that these minutes became the decimal fraction of the degree. This decimal fraction was added to the integer part of the initial coordinate value and finally reached its value in decimal degree format, and the result format equals the one that the coordinates of the GNR database were found (decimal).

This step was very important because, after applying this correction, for all common accidents in the two databases, it was found that their location was indeed coincident.

Prior to the mapping process of the accidents related to the previous years of 2014 and 2015 from the GNR database, there was also a need to correct the information, by applying the same procedure explained above, in order to homogenize the values of the coordinates and to place them all in decimal format so they all could be loaded into the GIS software.

By mapping each car accident to its exact localization, it was possible to identify the places that have problems of accumulation of occurrences and that need to be treated.

In some cases, the spots that were identified as problematic, showed a certain pattern related to the nature of the events and it was possible to suggest corrective measures.

2.2 Low cost corrective measures

For some of the spots that were identified as problematic, a set of low cost measures were defined to correct existing conflicts, based on the recognized problems and the causes of the accidents. The GIS tool helped to decide which places would be subject to intervention, but it also required a comprehensive deliberation of the main problems regarding road safety in urban and peri-urban areas and learning witch solution will work better on each location.

A cost-benefit study was then made for some of the measures suggested, as described later for one of the intersections in Avenida da Liberdade in Ponte de Sor. The layout of this intersection gives rise to events involving side-to-side or lateral-side collisions due to its bad visibility conditions. In order to change the driver's behavior and induce them to lower their circulation speed in the main road, a set of traffic-calming techniques were used, like the implementation of two zebra crossings.

3. Results for Ponte de Sor

3.1 Analysis of the Road Accident Indicators

As this analysis was focused on the municipality of Ponte de Sor, it was important to understand which one of the urban areas registered higher values of sinistrality. From Figure 2, it can be observed that, considering all accidents in the period under study, the urban area with the highest incidence of accidents was the Parish of Ponte de Sor, Tramaga and Vale de Açor with 163 road accidents recorded.

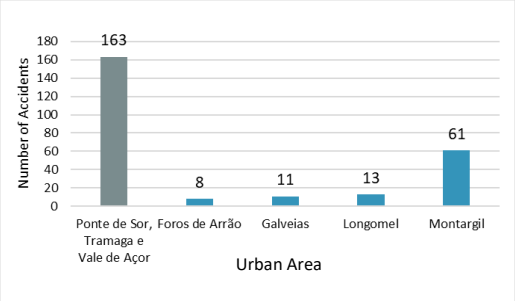

Fig. 2: Number of accidents per urban area between 2012 and 2016

In the municipality of Ponte de Sor, accidents with victims dropped considerably from 2012 to 2013 (around 46%). Between 2013 and 2016, there was a fluctuation on the number of accidents registered, ending in 2016 with a decrease of about 20% when compared with the base year of 2012.

Regarding the number of fatalities, in the first two years its value remained constant and equal to 4, progressively decreasing until 2016 with 3 mortal victims in 2014 and 2 fatalities registered in each of the last two years. With respect to the serious injuries, there was a decrease between 2012 and 2013 of 1 victim, rising again in 2014 to 10 serious injuries and ending in 2016 with 11 serious injuries recorded at the scene of the accident.

Accompanying the trend of the number of accidents with victims, the number accidents who caused slightly injured victims were always close to or higher than the previous ones, and the highest number was 76 slight injuries in 2012, ending in 2016 with 61, which represents a decrease of about 20%, as shown in Figure 3.

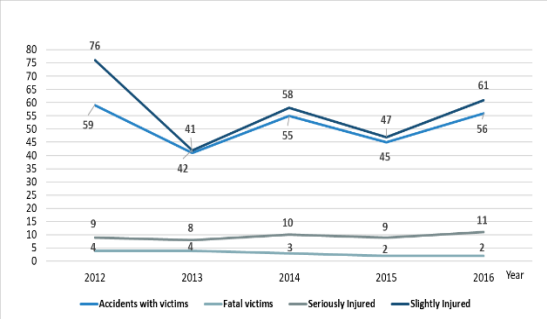

Fig. 3: Evolution of the number of accidents with victims, fatalities, seriously injured and slightly injured victims, between 2012 and 2016

Road accidents can be of three types: Collision, Off-the-Road or Running-Over. According to Figure 4, off-the-road was the most frequent type of accident, with 132 occurrences, or 52% of total records.

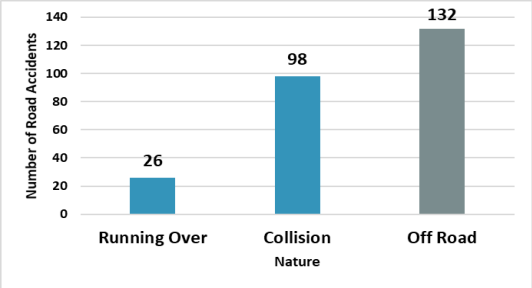

Fig. 4: Number of accidents by nature between 2012 and 2016

The fact that most accidents occurred on national roads may explain the greater incidence of this type of accident because higher speeds are practiced so the probability of losing control of the vehicle is greater.

The collision, with 98 recorded accidents, was responsible for 38% of the occurrences and finally, the running over was the cause of 26 accidents and represents 10% of accidents with victims registered at the scene.

By analyzing the number of accidents with victims according to the type of road in which they occurred, during the period 2012-2016 (Figure 5), it became clear that the National Roads (EN) were the type of road where more than half of the accidents registered took place, about 51%.

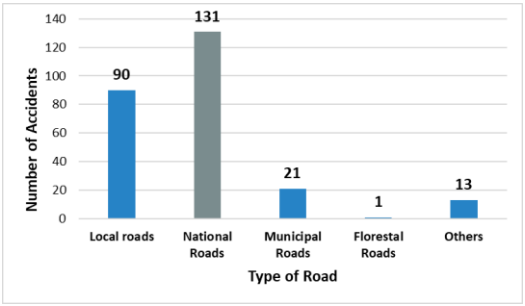

Fig. 5: Number of accidents by type of road between 2012 and 2016

National roads represent the main axis of the road network in the municipality of Ponte de Sor, it is through them that the access between these two urban areas is made, therefore, as the volume of traffic that circulates in them is greater, there will be a greater risk of occurrence of accidents. Of the 131 accidents registered on the national roads, 62 of them took place in the EN2 reason why this one stands out like the most problematic road of the Municipality.

From Figure 6, it can be seen that the peak of road accidents coincides with the summer months, with higher incidence in the month of June and also in the months corresponding to festive seasons such as December, January and February.

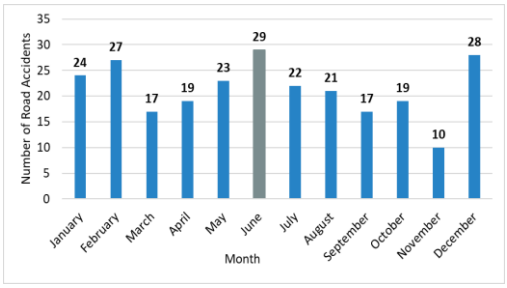

Fig. 6: Number of accidents by the month of the year between 2012 and 2016

On the other hand, November was the month with fewer accidents with victims, only 10. Regarding fatalities, the months of August and January were the ones with higher numbers, with a total of 6 fatalities in five years.

The months of April, May, October and December had no record of any mortal victim. With regard to the victims who suffered injuries, May was the month with the highest number of seriously injured (6), while August and March were the months with

the lowest number of seriously injured (2 seriously injured each month) over the time-period of this study.

3.2 Spatial Distribution of Accidents in the Road Network of Ponte de Sor

As mentioned earlier, a database provided from GNR with accident information regarding a three-year time range, was allied with a geographic route network using ArcGis 10.1. Then, the sites showing an accumulation of accidents were identified.

Figure 7 shows the result of the projection of the accidents in the digital road network of the Municipality of Ponte de Sor for the years of 2014, 2015 and 2016.

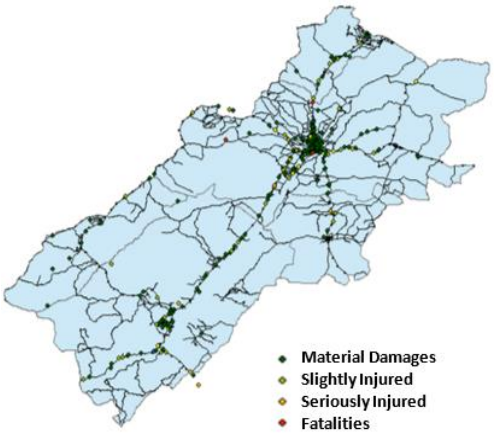

Fig.7: The final result of the road accident mapping procedure over the road network of Ponte de Sor using the ArcGis Software

To make the analysis more feasible and effective, it was decided to do it in detail on urban areas only and more precisely within the Ponte de Sor city limits, as it is the largest urban area in the Municipality, with the highest traffic volume and a relatively high number of occurrences in comparison with the second largest one, Montargil. It was also chosen the section of National Road 2 (EN2), which connects these two urban areas, to try to understand the causes behind the accidents on this road that is in a peri-urban surrounding.
Four zones of greater accident accumulation were selected to be the subject of a more detailed study. The following is an example of the study carried out for zone 1.

Zone1: Intersection between Avenida Liberdade and R. Alexandre Robalo Cardoso

Of the total of 4 accidents occurred in this section, one took place in 2015 with slight injuries only, then another one occurred in 2016 with only damage in the vehicles involved and two accidents happened also in 2016 with a record of only minor injuries.

This spot is characterized as a two-way priority intersection, where the traffic that circulates in the secondary road is subject to a loss of priority, benefiting crossing movements along the priority route which are not subject to any delay.

The traffic of the main road runs on the section of the EN244 that crosses the Municipality, called Avenida da Liberdade and the traffic that crosses it, runs on Rua Alexandre Robalo Cardoso (Figure 8). The geometry and amount of traffic that flows in each road are considerably different.

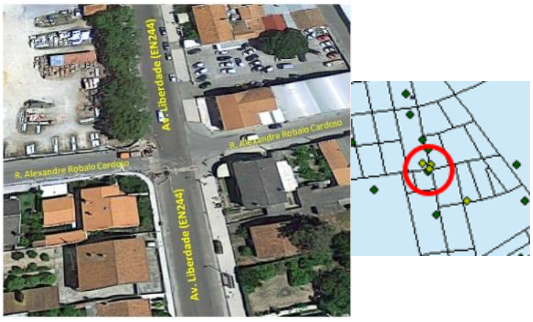

Fig.8: Zone 1 corresponds to the intersection between Avenida da Liberdade and R. Alexandre Robalo Cardoso. Indication of the accidents using ArcGis

The accidents that occurred in this place agree with the expected ones for an intersection of this kind, that is, front-side or lateral-lateral collisions, and the damages caused by crashes like those are strongly related to the angle of convergence and the speed at which the vehicles involved were circulating at the time of the event.

Proposals to intervene in this area should aim to discourage the practice of speeds that are higher than allowed for urban areas, in particular, in the prioritized movements, because the fact that those vehicles are circulating at a much higher speed than permitted by law it results in a reduction of the intersection's capacity, because it makes it more difficult for the non-priority vehicles to converge or cross over in the intersection.

In this sense, speed regulation measures should be implemented, and it was considered as a more

appropriate solution to implement 4 zebra crossings, because these will coerce drivers be more aware and moderate the speed at which they circulate.

Another measure to consider was the demarcation of parking in the lane on both sides on Avenida da Liberdade as shown in Figure 9.

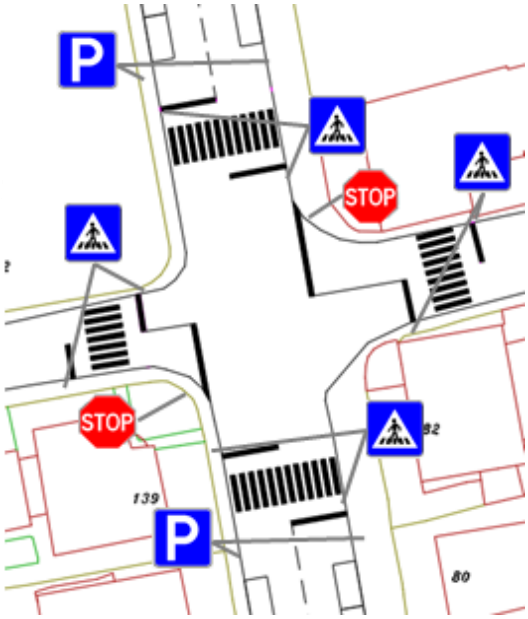

Fig.9: Example of some corrective measures proposed, in this case, for the intersection between Avenida Liberdade and R. Alexandre Robalo Cardoso

3.3 Evaluation of the cost/benefit ratio of the suggested measures

In this case, the evaluation took in consideration only the implementation costs. These were estimated for each solution in two of the selected zones of accumulation of road accidents.

The purpose of this approach is to confront the estimated costs of implementing these measures with the estimated cost arising from deaths or injuries. Socio-economic costs of €23.135 (Simões, 2015) per slightly injured victim were assumed.

Confronting the estimated cost of zone 1, which is around 1 572€, (Figure 10), and the cost of a single slightly injured victim, it can easily be concluded that the investment it takes to prevent one single injurie makes the investment in such measures as the ones proposed, perfectly feasible and sustainable, if the implementation of those procedures does not influence other costs such as the cost of working at night or deviate the traffic flow to alternative roads.

ID	Type	Art.	Description	Un	Qt.	Unitary Cost	Total Cost
0.6.	Chapter	6.	Chap. 6 - HORIZONTAL SIGNALING				
0.6.1	Chapter	6.1	6.1 - Spray Paint				
0.6.1.1	Article	6.1.1	Delivery and marking on the floor with Plastic Spray, according to Inspection indication, including Pre-marking and all necessary work, with different stroke widths: 0,10; 0.12m; 0.20m.	m2	282,00	4,30	1212,60
0.6.2	Chapter	6.2	6.2 - Thermoplastic Paint				
0.6.2.1	Article	6.2.1	Priority loss triangle	un			
0.6.2.2	Article	6.2.2	Simple selection arrows	un			
0.6.2.4	Article	6.2.4	Diversion arrows, type 1	un			
0.6.3	Chapter	6.3	6.3 - Unidirectional Markers				
0.6.3.1	Article	6.3.1	Supply and placement on the floor of unididectional markers of white color, including pre-marking and all necessary work.	un			
0.7.	Chapter	7.	Chap. 7 - VERTICAL SIGNALING				
0.7.4	Article	7.4	Supply and installation of vertical code signaling, with L = 0.70m, including supply, placement, support elements or structures, connecting pieces and foundation masses and any additional work required.	un	8	45,00	360,00
0.7.7	Article	7.7	Supply and placement of BPD, directional bollard for divergence point marking, 1.90x0.80, including supply, placement, support elements or structures, connecting pieces and foundations and any additional work required.	un			
					Total		1 572,60 €

Fig.10: Cost evaluation of adopted measures for Zone 1 (Intersection between Avenida Liberdade and R. Alexandre Robalo Cardoso) according to the formulation of the map of quantities used in the Municipality of Lisbon

4. Conclusion

This study aimed to analyze concrete situations of accidents occurring in urban and peri-urban environments, using as a case study the road network of the Municipality of Ponte de Sor, in order to be able to study the location of the areas with the highest prevalence of accidents, from of the registered occurrence using a GIS tool. For this purpose, information regarding road accidents was obtained from two sources: ANSR and GNR.

The study of road accident victims by type of road and accident was very important to know which ones are more dangerous. Regarding the type of road, the results led to the conclusion that the country roads (EN) are the ones with a greater number of events and that the off-the- road type of accident was the most frequent in the study's time range.

The fact that most accidents occur on national roads may explain the greater incidence of this type of accident because higher speeds are practiced, so the probability of losing control of the vehicle is also greater.

Through the mapping of accidents in the road network, the accident accumulation zones were identified, for which proposals were made to implement low-cost engineering measures to improve traffic safety conditions.

The cost estimate for the implementation of the solution in Zone 1 confirms that investment in these low-cost mitigation measures is perfectly justifiable, since when compared to the cost of a slight injury it was found that investment in road safety is of a much less order.

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