Analysis of car–pedestrian accidents on highways in the Brazilian Federal District

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Abstract

Fatal car–pedestrian collisions are a very common accident type in the Brazilian Federal District, with 121 occurrences registered in 2012. More than 40% of all pedestrian fatalities occurred at highways. It is known that the most common reason for pedestrians to be on the highways is to cross the roads; however, this is not the safest way to do this. In this regard, this paper aims to map all these kinds of events, in order to investigate the causes and propose solutions to ensure the best and safest conditions for pedestrians. For this purpose, all police data and forensic reports were investigated. Statistical results showed, for example, that car–pedestrian accidents occur more frequently at night, with the vehicle being driven by men aged between 24 and 30 years old. In addition, normally the victims are male, wearing dark color clothes, are 30 to 50 years of age and have consumed alcoholic beverages. Besides this, the geographical locations of all 52 accidents revealed that: (*i*) more than 90% of the events occurred less than 100m away from a bus stop; and (*ii*) there was no pedestrian bridge or zebra crossing nearby. Furthermore, no fatal accidents were registered within a radius of 500m from all pedestrian bridges, reinforcing the importance and the efficiency of this apparatus. Thus, from the results of this research, a few suggestions have been proposed to reduce these events. Moreover, it is believed that they can support new public policies related to traffic on highways.
Keywords: intelligence-led policing, forensic intelligence, vehicle–pedestrian accidents, environmental criminology, transportation safety and security.

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1 Introduction

The urban space is characterized by the intensity of human activities and these are often permeated by a series of conflicts of various kinds [1]. Road traffic systems are highly complex and are very hazardous to human health. Making a road traffic system less hazardous requires the understanding of the system as a whole and the interaction between its elements, identifying where there is potential for intervention [2].

Approximately 1.24 million people die every year on the world's roads, and about 20 to 50 million sustain nonfatal injuries as a result of road traffic accidents. Road traffic injuries are estimated to be the eighth leading cause of death globally [2]. In Brazil, the death rate in traffic accidents is 23 per 100,000 inhabitants, leading the country to the fourth position in the world's ranking [3].

Despite the growing burden of road traffic injuries, road safety has received insufficient attention at both the international and national levels [2]. In Brazil, traffic planning has not been considering the demands of different types of users in a balanced way. A fundamental factor in high-income countries is the fact that the modern traffic systems are designed largely from the perspective of a motor vehicle user [4]. Provision for pedestrians and cyclists in low-income countries is rudimentary or even non-existent. In Brazil, outcome measures have systematically privileged motor vehicles causing a high number of pedestrian accidents [5]. Pedestrians account for almost one-third of the deaths from road traffic accidents in Brazil (approximately 10,000 deaths per year) and it is the leading group in casualties (38% of deaths and 11% of mortality rate) [6].

In the late 1990s, an inflection on the evolution of traffic accidents deaths occurred in Brazil, mainly due to the implementation of the Brazilian Traffic Code and the deployment of safety campaigns. More precisely between 1997/1998 and 2000, a decrease in these numbers is noted [7]. Despite the general reduction in mortality rate after the new road traffic code was introduced, this trend was not maintained and since the 2000s a continuous and systematic growth of mortality rates has been being observed [8].

The aim of this paper is to identify the potential factors for fatal vehicle–pedestrian accidents that occurred on the major highways in the Brazilian Federal District in 2012, as well as to determine the most dangerous points and to propose solutions to reduce the accidents.

2 Materials and methods

This study is part of a wider research that applied intelligence-led policing methodology to investigate all traffic accidents resulting in fatality that have occurred within the geographical boundary of the Brazilian Federal District [9, 10] in 2012.

In the Federal District, each traffic accident generates a police report, which is written by the police stations from the Civil Police of the Federal District (PCDF). These reports contain several pieces of important information relating to the accident.

This is a retrospective study from all fatal vehicle–pedestrian accidents that occurred in the main highways of the Brazilian Federal District (BR-020, BR-040, BR-060, BR-070, BR-251, BR-450, DF-001, DF-075, DF-085, DF-128 and DF-130, where the prefixes BR and DF means Federal and State highways, respectively) in 2012. Data regarding the accidents as: date and time of the events; vehicles involved; places of death; age and sex of the drivers and of the victims were obtained from the police report generated by the Civil Police. GPS coordinates, speed limits for the roads and runway surface conditions of the roads were obtained from forensic reports issued by the Criminalistics Institute of the PCDF. Causes of death; types of clothing used by the victims; age and sex of the victims; use or not of illegal drugs and/or alcohol by the victims were obtained from medical forensic examination reports produced by the Institute of Legal Medicine of the PCDF.

All data described above were collected and tabulated in the MS-Excel software and statistical analyzes were performed. In addition, the geographic coordinates from all accidents were plotted using the Maptitude 6.0 software, in order to find out the main hotspots for vehicle–pedestrian accidents in the highways of the Brazilian Federal District.

3 Results: statistical analysis

In 2012, 121 occurrences of fatal vehicle–pedestrian accidents were registered in the Brazilian Federal District, accounting for 31% of all cases of traffic deaths during that same year [9]. Only in the main highways, 52 accidents have occurred, approximately 43% of all pedestrian events. Velloso and Jacques [11] appoint that in a six-month period (between October 2004 and March 2005) 22 fatal pedestrian crashes occurred on the rural highways of the Brazilian Federal District. Comparing with this study, it suggests an increase of pedestrian fatality on highways of the order of 18% in seven years, demonstrating the importance to analyze these occurrences. The data of the fatal vehicle pedestrian accidents on the Federal District highways does not differ significantly from the overall data from all fatal vehicle pedestrian accidents [9], except in terms of frequency, as pointed to above. However, some observations related to environmental criminology are considered below.

The average of vehicle–pedestrian accidents with fatality that was discovered is 4.3 per month. Nevertheless, a certain imbalance in the percentage of these occurrences throughout the year can be observed (Figure 1(a)), with April (2%) and October (4%) showing much fewer accidents then January (13%) and July (13%). A balance in the number of accidents during the days of the week was observed (Figure 1(b)), however it was noted a slight increase of these accidents over the weekend days (32% of total). Future analyzes of these accidents must be done in other years to clarify whether there is a pattern or just a simple random oscillation.

The data showed that a bigger number of events are concentrated at evening (from 4pm to 6pm, 15% of total) and at early night (from 8pm to 10pm, 19% of total). Similar data were described by Alves [12], pointing that these periods

correspond generally to the moments of greater vehicles flow on the streets, of higher number of people who walk on their way home after study/work or even when they are going through a pathway toward their bus stop.

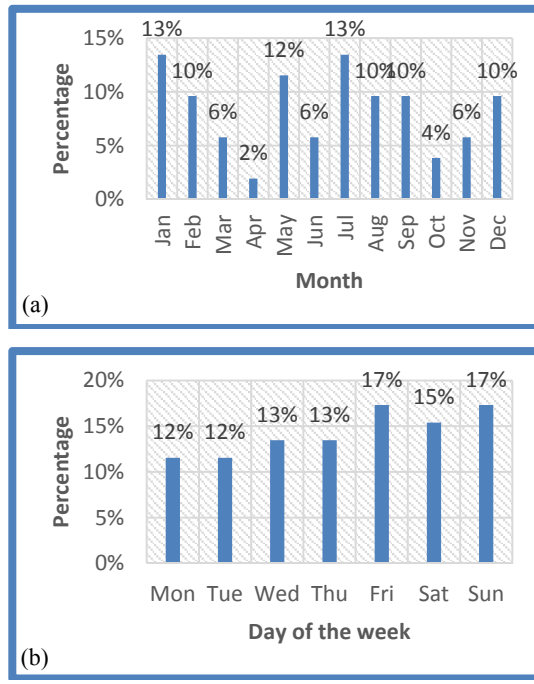

Figure 1: Distribution of pedestrian accidents with fatal victims in 2012 according to (a) the months of the year (b) the days of the week.

Regarding the night period, an important fact to be mentioned is that 72% of the victims were using dark-stained clothes, making it difficult for them to be seen at night. This fact combining with poor or no street lighting can contribute to nighttime crashes, as found by Velloso and Jacques [11]. Educative campaigns could address pedestrians to protect themselves by wearing clothing that increases their visibility, especially in poor daylight and in darkness. Some studies point that the use of light clothing is not effective, the safest way to protect themselves is to use retro-reflective material on clothing or footwear [13].

The data regarding the presence of alcohol in the blood of the pedestrians were also verified. Positive results were observed in 40% of the victims against 21% showing negative results. Not all fatal victims were tested due to some of them being rescued to the hospital and received treatment. Considering just the victims whom were tested, 66% showed a positive blood alcohol content (BAC). This number is superior to those found in international studies that point an average percentage of 20–48% of pedestrians with positive BAC [14–16]. This percentage is disturbing and corroborates the literature, which suggest that consumption of alcohol by the pedestrians increases their propensity of involvement in vehicle–

pedestrian accidents and it is associated with an increased severity and frequency of road kills [17, 18]. A pedestrian who is under the influence of alcohol has reduced their skills, making it more difficult to choose the right moment to cross a road and decreasing the inhibition to take risk.

The data regarding the quantification of BAC showed an average value of 2.3 g/l in the positive victims, featuring alcohol abuse. Lima [19] showed that levels above 0.6 g/l of alcohol causes sufficient brain neurochemical and functional changes to facilitate changes of behavior in risk situations (traffic accidents, domestic violence and homicides). Clayton and Colgan [20] established that for pedestrians there was a significantly higher risk of fatality when BAC levels are above 0.1 g/dl.

Crossing the temporal data of the vehicle–pedestrian accidents and BAC data, it was found out that the accidents involving pedestrian that have consumed alcohol happens, in most cases, between 8pm and 10pm, coincident with the evening hours when people leave work, go to a "happy hour" and return home not too late as they have to work in the day after.

Data regarding victims' gender shows that 76% are male. Over 50% of the global mortality due to road traffic injury occurs among male young adults aged between 15 and 44 years [21]. In 2002, males accounted for 73% of all road traffic deaths, with an overall rate almost three times higher than for females: 27.6 per 100,000 population and 10.4 per 100 000 population, respectively [22]. The male stereotype relief to emphasize the danger, while the female interest is directed to less risky activities [23]. In their studies, Cohen *et al*. [24] noticed that when crossing a road, men tend to accept smaller gaps between vehicles than women do. Salvatore [25] points out that male have much less stringent judgments than women about the speed of the motor.

When considering the use of illicit drugs (marijuana and/or cocaine), the percentage of pedestrians who used it before death is 8% and all users were male. Most drugs, unlike alcohol, do not exhibit a simple relationship between drug blood content and level of impairment [26, 27]. What is known suggests that drug use is a significant factor in some cultures, but inadequate knowledge precludes quantifying the levels of risk at present [2].

The highest number of people, who died due to vehicle–pedestrian accidents in 2012 in the Brazilian Federal District, were people that have ages between 30 and 50 years old (52%), as it can be seen in Figure 2. Much of this contribution, approximately 55% is attributed to the males that made use of alcohol a while prior the accidents. Regarding the female victims, adults between 30 and 40 years old lead the ranking with 36% of the total fatality, followed by elderly women aged from 60 to 70 years old with 27% of the total. These data are in accordance with those found worldwide that stands that over 50% of the global mortality due to road traffic injuries occurs among young adults aged between 15 and 44 years [21]. Road crashes place a heavy burden on national and regional economies, as well as they affect economically productive young adults, and even affect household since it can private the family from its provider [28].

Older pedestrians, in particular, are associated with a very high rate of road injury and death. This is mainly due to the increased physical frailty of the elderly

as well as a progressive loss of mobility and decreased reflexes, key factors for risk perception in traffic. Given the same type of impact, an older person is more likely to be injured or killed than a younger one [29].

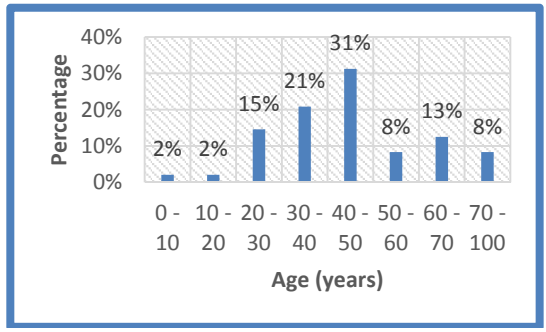

Figure 2: Distribution of pedestrian accidents with fatal victims in 2012, depending on the age of the victims.

With regard to the highways, as might be expected, 85% of the events occurred on roads whose speed limit was 80 km/h (Figure 3) and 12% on highways whose maximum allowable speed were reduced to 60 km/h. This findings corroborate the study conducted by the World Health Organization [2], which indicates that, at a speed of more than 80 km/h, the chance of survival of a victim of trampling is virtually nonexistent, explaining why when analyzing fatalities the numbers are higher in faster roads.

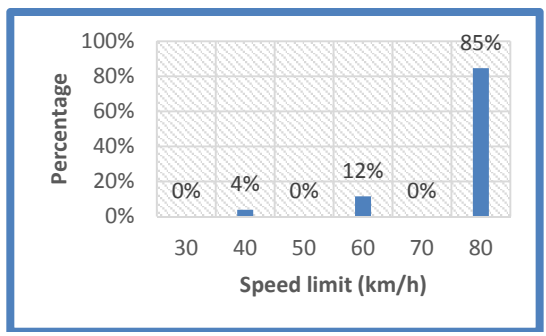

Figure 3: Distribution of vehicles–pedestrian accidents with fatality in 2012, according to the highways speed limits.

A survey conducted in Florianopolis region between 2001 and 2005 [30] showed that 61% of all deaths have occurred on highways (federal and state), evidencing a characteristic of the region that is split by the BR-101 highway and many other state highways without any infrastructure for pedestrians benefit and without any physical barriers which would intimidate any attempting to cross the road. However, in the developed countries, probably because of the difficulties presented to pedestrians to cross the roads and the awareness of the prohibition of

crossing those, the percentage of pedestrian fatality is significantly lower than in incoming countries [14].

4 Results: accidents location study

Using a Geographic Information System software, it was possible to relate all 52 occurrences of pedestrian accidents with fatal victims to their geographical locations. Figure 4 shows the density map and establish four principal hotspots (red arrows).

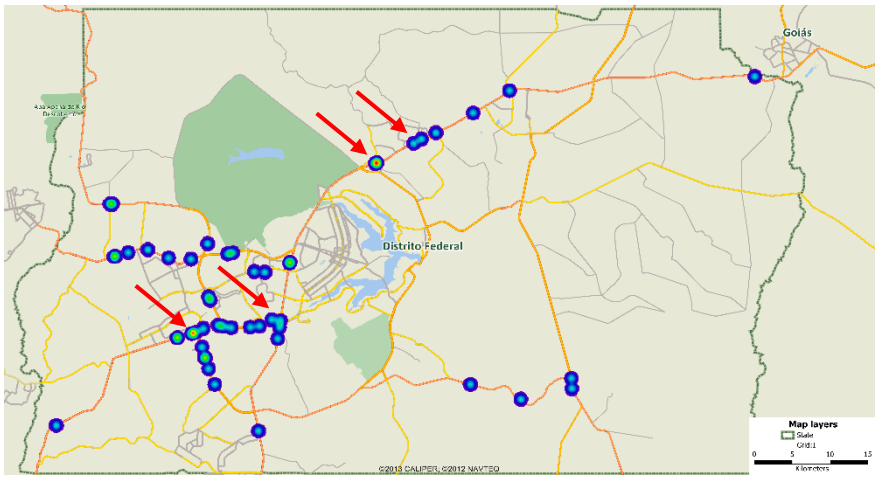

Figure 4: Density map for all fatal vehicle pedestrian accidents in the Brazilian Federal District Highways in 2012.

More than 90% of these events have occurred less than 100m away from a bus stop without pedestrian bridge, this absence forces the pedestrian to cross the road to get to the bus stop or to return to his residence after getting off the bus. In most of the hotspots, there is a path on the ground created by the frequency of pedestrian crossing the highway, indicating the large pedestrian flow (Figure 5). In addition,

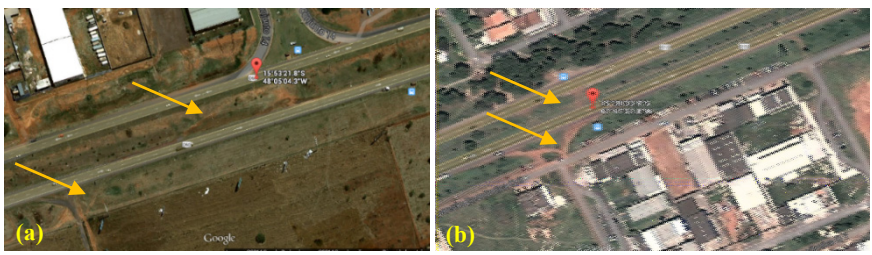

Figure 5: Google Maps images from: (a) BR-060 and (b) BR-020. Arrows indicate the probable path of the pedestrians; red balloons show the location of the accidents; and blue squares illustrate the positions of the bus stop.

it must be considered that in a 500m radius around the footbridges in the Brazilian Federal District highways there were no fatal vehicle–pedestrian accidents in 2012, reinforcing the importance of this alternative.

Clifton and Kreamer-Fults [31] have shown strong correlations between pedestrian-vehicle crashes and pedestrian generators, more specifically, bus stops, corroborating this study. Indeed, unsafe movements, encouraged by the lack of necessary facilities close to bus stops such as pedestrian signals and crosswalks, result in pedestrian-vehicle crashes [32].

5 Discussion

The analyzed data shows three main issues that must be considered for future interventions on the Brazilian Federal District highways, especially in those hotspot sights: lack of adequate infrastructure for pedestrian to cross the highways, roads speed and pedestrians behavior.

In order to reduce the probability of occurrence of these events on the Brazilian Federal District highways, different actions can be taken. However, in this paper it was chosen five solutions, which will be presented and discussed.

5.1 Footbridges

The main risk factor for unprotected road users is the mixing of little protection for people with motor vehicles at high speeds [33, 34]. The survival of unprotected users depends upon ensuring either that they are separated from the high speeds of motor vehicles or that the vehicle speed at the point of collision is low enough to prevent serious injury [2].

At these points of high prevalence (hotspots) of vehicle–pedestrian accidents, the obvious infrastructural needs are footbridges. According to Almeida *et al*. [1], the main problems are that these structures are built in the wrong places, poorly designed, poorly constructed, poorly maintained and they are unsafe.

A Brazilian study showed that many pedestrians who were struck by vehicles had chosen to climb over central traffic-lane barriers, rather than climb the stairs to a footbridge [35]. Therefore, other actions for preventing pedestrian from accessing the highways should be taken as well as educative campaigns to provide instructions for road users, through signs and traffic controls, on what they should do.

A possible solution to the Brazilian Federal District highways, but an expensive one, would be to implement footbridges in the most critical points, where the flow of pedestrians, the lane width and the route speed does not allow inexpensive solutions.

5.2 Highways speed

As established by Lu *et al*. [36], some factors needs to be considered for setting speed limits, like the number of lanes, the visibility, the percentage of heavy vehicles, the pedestrians, the results of an accident, etc.

As shown in Figure 1, 85% of the accidents happened in roads whose maximum permissible speed was 80 km/h. Thus, the speed limit at most of the sites must be review: higher speeds could only be tolerated if the interface between the road infrastructure and the vehicles were to be well-designed and crash-protective/preventive, which is not the case.

5.3 Lightening

It is known that poor lightening conditions are a particular risk factor for users traveling at night [11]. Accordingly, it was observed here that the use of dark clothes was one risk factor to be involved in a pedestrian-car accident. In addition, 52% of the events occurred at nighttime period, between 6pm and 6am.

Therefore, in the accident sites, an especial attention should be given to lightening, in order to minimize the risk of vehicle–pedestrian accidents, as they present intense pedestrian flow and do not offer any secure path for the pedestrians to cross the roads.

5.4 Land-use planning

Risk in road traffic arises out of a need to travel – for going to work, for accessing education or for leisure pursuits. While it may not be possible to eliminate all risk, it is possible to reduce the exposure to risk reducing the volume of motor vehicles traffic by having a better land usage [2].

A proper land-use planning can help minimize pedestrian exposure providing efficient networks where the shortest or quickest routes coincide with the safest routes. Socioeconomic planning, as well, can contribute to road safety, as local shops and local workplaces would decrease the movement of residents from the suburbs to the city center.

5.5 Pedestrians behavior

Human behavior is governed not only by individual knowledge and skills, but also by the environment in which the behavior takes place [37]. Aspects of human behavior in the context of road traffic safety can certainly be altered, either by changing the environment or using educative campaigns.

Additionally, educative campaigns showing the risk of drinking and crossing a highway must be taken, in order to do not reduce pedestrians' skills and to facilitate the choice of the right moment to cross a road.

6 Conclusions

In the first part of this work, it was presented the profile of the fatal victims involved in vehicle–pedestrian accidents at the Brazilian Federal District highways in 2012, as well as the characteristics of the highways and period of accidents occurrence. After that, on one hand, it was showed that the events occurred near a bus stop without pedestrian bridge and, on the other hand, there were no vehicle–pedestrian accidents near a footbridge.

In this way, it was possible to verify that the high incidence of these fatal accidents had relation with pedestrians behavioral and structural factors, such as alcohol usage, lack of safe condition to cross the road and other conditions that cause the increase in traffic mortality.

Public policies that mediate interactions between the various actors in traffic unfortunately show favor to the traffic of motor vehicles, and the pedestrians, even being the weakest link in the whole context, does not receive attention from the authorities. In this context, five possible solutions were discussed.

It is expected that studies like this one help the development of preventive measures to reduce the risk of pedestrian accidents, minimizing the mortality and morbidity from injuries in traffic. Thus, these actions can be based on data that indicate specific factors as catalysts of accidents at Brazilian District Federal highways, being an important method to subsidy new public policies related to traffic on highways.

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