Analysis and Evaluation of Pedestrian Crashes in Urban Highways of Puerto Rico

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Abstract
According to FARS 2001 the maximum percentages of pedestrian fatalities in the United States were in New York and Hawaii against PR who had the maximum value. The issues concerning pedestrian safety in PR and the US are relevant since they affect thousands of people every year. This research arises from the critical situation of the pedestrians in the Island and the lack of local pedestrian research studies. The main objective is to characterize the problem with pedestrian fatalities in the urban settings of the Island.

The steps followed in this research include: (1) search for literature review (2) obtain and analyze crash databases; (3) conduct the preliminary analysis; (4) perform the observational studies; (5) conduct interviews; (6) analyze newspaper articles; (7) analysis of the results; (8) summarize the results; and (9) make recommendations with the potential to reduce pedestrian crashes in PR.

Final results identify the characteristics of the pedestrians injured and killed in the urban highways of Puerto Rico and the characteristics of several pedestrian crashes locations based on observational studies. The elements that characterize pedestrian crashes in PR are the month when the crash occurs and gender of the pedestrian, the classification of the area where the crash takes place, pedestrians actions or behaviors before the crash occurs, the age of pedestrians, the location (intersection or segment) of the crash event, and the geometry of the highway. The results showed that more than 75% of pedestrian crashes occur in urban areas; about 70% in level highways; 87% in clear (no rain) weather; 65% of pedestrians injured and killed are males; 49% of the crashes occur between 6:00 PM and 12:00 MN; 20% on Saturdays; December and August had the highest and lowest frequencies of pedestrian crashes (11% and 6%, respectively); 79% of
Pedestrians were older than 32 years of age; and 32% of fatalities are related to the use of alcohol.

**Keywords**
Pedestrians, safety, crashes, accidents, fatalities

1. **Introduction**
   Pedestrians are one of the most relevant components in the process of highway design. The others are: bicyclists, drivers, vehicles, passengers, road (geometry, pavement, illumination, facilities) and the environment (climate). The existing interrelation between these components is important to understand the possible effects of one component into the other (Garber and Hoel, 2001). Pedestrians represent one of the most serious problems of traffic crash fatalities in the United States and Puerto Rico. According to the Fatal Accident Reporting System (FARS) for the year 2001 the maximum percentages values of pedestrian fatalities in the United States were in the states of New York (22.4%) and Hawaii (21.4%) (FARS, 2001). In comparison, Puerto Rico had 34.7% of pedestrians killed in highways, excluding minor and severe accidents (FARS, 2001). This research arises from the lack of pedestrian research studies in Puerto Rico given the critical situation of these fatalities in the Island.

2. **Objectives**
   The main objective is to characterize pedestrian crashes in the urban highways of Puerto Rico. In order to achieve the objectives of this research, the accidents database involving pedestrians in Puerto Rico and United States will be compared. In addition, visual inspections and statistical analysis will be used to compare and evaluate the results. The specific objective of this research is threefold: (1) identify highway segments or strips with a high pedestrian crash frequency with emphasis on pedestrian fatalities in urban areas; (2) identify which factors are those that can contribute significantly to the pedestrian crash frequency; and (3) provide practical guidelines to reduce/mitigate pedestrian crashes in Puerto Rico.

3. **Scope of Work**
   This research considers all pedestrian crashes occurring along the entire highway system of Puerto Rico. The specific analysis is concentrated in pedestrian crashes occurred in the urban settings of the Island. The time period considered for the specific analysis included years 1997, 1998, and 2002.

4. **Methodology**
   The methodology presented (Figure 1) describes the research approach followed in this study to characterize pedestrian crashes in urban settings in Puerto Rico. The steps followed during the research were combined to form a base of pedestrian researches in the Island. The literature review included previous studies and publications related to pedestrian safety in Puerto Rico, the United States, Europe and Latin America. Then, traffic crashes databases were gathered for the development of the statistical analysis and the main database used was interpreted for the best understanding of its contents. In addition to the information obtained from the crash databases, other information on pedestrian issues was found conducting interviews and field inspections. The analysis of the data was performed using SPSS, Minitab, and Microsoft Excel. The data was analyzed using descriptive statistics, cross-tabs, box plots, and Chi-Square.
5. Findings

The findings of this research are divided in three areas: interviews, observational studies, and statistical analysis. These areas were combined to better understand the issue of pedestrian crashes in Puerto Rico.

Interviews

Four main interviews took place during the process of the research. The officials interviewed were associated with government and federal agencies related to traffic safety specifically the Highway Traffic Safety Commission, NHTSA (FHWA), the Police Department, and the Department of Justice. One particular aspect revealed in some interviews was the importance of the evolution of transportation modes in different countries. One of the interviewed analyzed the reasons why traffic is extremely disordered and compared the traffic with the incidence of pedestrian crashes in Colombia, Puerto Rico, and USA. He said that this issue is related to the “culture of the automobile”, meaning that it is a function of the time the vehicles had been part of the countries and the attitudes of the population about driving behaviors. For example, vehicles arrived first to the USA, then to PR, and then to Colombia, and pedestrian crashes are higher in Colombia, followed by PR, and less in the USA.

Another concern related to pedestrian crashes is the age of pedestrians been killed and the locations. Most of the professionals interviewed agreed that young and elderly pedestrians are the most affected groups in pedestrian crashes, been the group from 50 to 65 one of the highest. Even though, some of the interviewed, also pointed out that a great number of young adults (20-35) are turned to be
unproductive as a result of a fatal or severe pedestrian crash when they were in the age of higher productivity. In addition, experts catalogued urban settings as the zone of higher frequency of pedestrian crashes. In addition, they mentioned highways with a high ADT and highways with no lateral space provided to pedestrians (sidewalks, shoulders).

Other results obtained with the interviews were related to crash causes and crash time. The opinion of the professionals interviewed was that possible causes of pedestrian crashes are multi-factorial. The main factors mentioned were: driving aggressively (speeding, turning lanes); commercial locals along highway corridors; poor illumination; alcohol or drugs influence in drivers and pedestrians; distractions (cellular, children, and publicity signs); pedestrian behavior; pedestrian misperception of vehicle’s distance; and pedestrian cloth. Most of the officials interviewed coincide that night periods are more susceptible to pedestrian crashes than any other time period. In addition, the interviewed agreed that males are commonly more promptly to be injured and killed in a pedestrian traffic crash than females.

Field Inspections

Human factors represent about 95% of the causes of all traffic crashes. The behavior of pedestrians and drivers is critical to analyze the event of a crash. During field inspections in urban highways such as PR-1, PR-2, PR-3, PR-18, and PR-26, many risk actions were observed from pedestrians and drivers. Risk actions are referred as those preventable actions that could cause a traffic accident or crash.

Pedestrians usually make several unsafe movements when walking in Puerto Rico. Some of the risky actions they performed were: crossing not at intersections where pedestrians were not allowed to cross (“Pedestrian Do Not Cross” signal); walking along roadway in the same direction of traffic; crossing in midblock when pedestrian bridges were available; start the mid-block crossing from medians or sidewalks where they can not be seen (landscaping, poles, vehicles, other people); elderly pedestrians stand on medians; and pedestrians walking along shoulders in the direction of traffic. Drivers’ behavior indicated that they are not aware of their responsibilities and behaviors when managing their vehicles through the highways of the Island. Drivers’ actions could not be dangerous or fatal for themselves, but for other road users as passengers, bicyclists, other drivers, and pedestrians. Some examples of dangerous drivers’ actions are: not yielding to pedestrians, speeding, using cell phones while driving, and making right turns and lane changes very fast.

Finally, another issue affecting pedestrian safety is the presence of obstacles. Some of the obstacles observed were: trash cans, mailboxes, electrical poles, water pumps, and cracked sidewalks. Other obstacles were: big tress with surface roots, sidewalks with narrow widths, large groups of pedestrians (low capacity- level of service D or E), signs, construction zones with no access to pedestrians, and walking sellers (hot dog cars, sandwich buses). Another critical obstacle observed was the absence of facilities for people with disabilities in the Island. Some wheelchair users were seen traveling along the border of the highways because they have no adequate ramps to access the sidewalks or the sidewalks were not present. In addition, during the field observations no facilities for blind people were available. Is important to remember that all pedestrian facilities have to comply with American with Disabilities Act (ADA) law and the specifications of the PR HTA based on the 2000 MUTCD.

Statistical Analysis

The first analysis performed was the time series analysis of pedestrian crashes in Puerto Rico and the United States. For this analysis the database used was the FARS 2001. Figure 1 show that during year 2001 PR had 4.3 percent of pedestrian fatalities by 100,000 populations while New Mexico (NM) had 3.9%, representing the first and second in descending ranking when comparing PR to the fifty (50) states of the US Nation. In addition, PR had the highest percentage of pedestrian fatalities as percent of total traffic fatalities in comparison to all the states of the US with 34.7%. The states of New York with 22.4% and Hawaii with 21.4% represented the top states in percentage of pedestrian fatalities as percent of total traffic fatalities. According to the analysis of pedestrian fatalities in PR, using the database from the HTSC, during years 1995 to 2000 the percentage of pedestrian fatalities increased from 31.7% during
1995 to 35.5% in year 1997 and decreased to 31.7 in year 2000. In comparison, USA trends shows that percentages of pedestrian fatalities have been decreasing from 14.5% in year 1996 to 12.7% in year 2000.

Various variables were related and the conditional probabilities were calculated using Equation 1 (Wiley 2004).

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P(A/B) = \frac{\text{Number of A with B characteristics}}{\text{Total Number of A}} \tag{1}
\]

The main findings of this research indicated the following about the variables associated to pedestrian crashes in PR: male pedestrians are three times more at risk than women (Figure 2); young pedestrians are more susceptible than older pedestrians to be involved on a traffic crash, but elders are more at risk of been killed; time periods corresponding to night times are more propitious to pedestrian crashes (Figure 5); highways classified minor arterial non NHS are more represented in pedestrian crashes; pedestrians are unaware of the danger they pursue when walking; more pedestrian crashes occur during clear weather; a high concentration of pedestrian crashes occurs in straight and level highways; most pedestrian crashes occur in urban areas (Figure 3); residential and commercial zones gathered more pedestrian crashes than other zones; almost all pedestrian crashes occurred in highway segments; and most pedestrian crashes occur between October and January (Figure 4). Other findings are focus on the relation between variables.
The calculated probabilities related to pedestrian gender and hour of the fatal collision when considering intervals of one hour indicated the following results. If pedestrian is a male the probability of being killed is higher in the interval from 7:00 PM to 8:00 PM with 13.4 % and if pedestrian is a female the probability of being killed is higher in the interval from 7:00 PM to 8:00 PM with 18.0 %. In addition, given the time period from 9:00 AM to 10:00 AM male and female fatalities has the same probability of 50 % representing the higher for female fatalities and the lower for male fatalities. When analyzing the same variables but in intervals of two hours the results showed other results as follows: if pedestrian is a male the probability of being killed is higher in the interval from 8:00 PM to 10:00 PM with 19.3 %; if pedestrian is a female the probability of being killed is higher in the interval from 6:00 PM to 8:00 PM with 19.7 %; given the time period from 12:00 MD to 2:00 PM male fatalities has the higher probability of occur with 90 %; given the period from 4:00 PM to 6:00 PM females had their higher probability to be killed with 36.4 %. The same analysis in intervals of three hours indicated that if pedestrian is a male the probability of being killed is higher in the interval from 6:00 PM to 9:00 PM with 27.2 %; if pedestrian is a female the probability of being killed is higher in the interval from 9:00 PM to 12:00 MN with 26.2 %; given the time period from 12:00 MD to 3:00 PM male fatalities has the higher probability of occur with 91.7 %; given the period from 3:00 PM to 6:00 PM females had their higher probability to be killed with 38.1 %.

Another group of variables related were month and hour of the crash. Some of the results are summarized as follows: given the month of August the higher probability of a fatal pedestrian crash occur in the period from 7:00 AM to 8:00 AM with a probability of 36.8 %; and given the month of December the higher probability of a fatal pedestrian crash occur in the period from 7:00 PM to 8:00 PM with 36 %. Other variables studied in cross-tables were pedestrian gender and age. The maximum probability of male pedestrian fatalities given their gender was 14% in the age group from “24 to 31” ages. In addition, the higher probability of a fatality given that pedestrian is a woman resulted in 14.6% in the age intervals “32 to 39” and “56 to 63”. Given the age groups the maximum probability of male pedestrian fatalities was in the age groups “24 to 31” and “88 or more”.

The results of the analysis of probabilities performed generated the following results. When considering that pedestrians are males the higher probability of been killed on a traffic crash occur during December. The computed probability was 12.38%. In the other hand, the lowest probability for the same condition resulted 4.95% in September. The females analysis indicated that pedestrian females have more probability of been impacted by a moving vehicle during February with a probability of 21.31%. The evaluation of the minimum probability of a pedestrian female to be killed indicated a probability of 3.28% to occur on July.

The tests of hypothesis indicated the independency between pairs of variables (Wiley 2004). A Chi-Square distribution was used to perform the tests (Figure 7). The test of gender and two hours time intervals had eleven (11) degrees of freedom. In addition, the results indicated a value of Chi-Square ($\chi^2$) of 6.206. The p-value was 0.859. Since the level of confidence ($\alpha$) permitted was 0.01 the results
indicated that there is not enough evidence to prove the alternate hypothesis. For instance, the null hypothesis can not be rejected. The conclusion was that there is no enough prove to establish a relationship between gender and two hours intervals. The test of gender and three hours time intervals contained seven (7) degrees of freedom and the Chi-Square ($\chi^2$) value was 8.398. The resulted p-value was 0.299. Since the p-value was higher than the level of confidence, there was not enough evidence to establish a relationship between the two variables tested and the null hypothesis was not rejected. The test of gender and month of the crash had eleven (11) degrees of freedom. The value of Chi-Square ($\chi^2$) was of 24.63. In this case there was enough evidence to reject the null hypothesis and declare that a relationship between gender and month exists.

![Figure 7: Chi-Square Distribution](image)

6. Conclusions

Based on the results obtained from this research, the following conclusions are made: pedestrian males are more susceptible to be injured and killed than females but they are also more exposed to the danger; special care must take with elderly pedestrians and children because they represented the highest groups of pedestrians involved on pedestrian crashes; pedestrians and drivers do not take the necessary precautions during night hours; the weather affect the frequency of pedestrian crashes since pedestrians reduce their exposure according to weather conditions; education, enforcement, and engineering are not well applied to straight and level highways were pedestrians crossing and speeding vehicles are common; and special attention must be given to urban areas such as tourist centers, residential, and commercial areas.

The recommendations performed were divided in three stages (short term, medium term, and long term) promoting education, enforcement and engineering actions to reduce pedestrian crashes in the Island. Short term recommendations attend faster alternatives for reducing the frequency of pedestrian crashes in urban settings in PR. The implementation of more aggressive educational campaigns, the installation of pedestrian barriers, and the motivation to learn and get conscious of the issues affecting pedestrians in PR were recommended in a short term period. Recommendations for medium terms were focused on improving the technology and the specifications. Two recommendations on medium term are the modernization of police patrols to quicken the process of data entry and reduce errors and to install pedestrian signs on selected corridor strips typically identified with high probability of pedestrian crashes. Finally, long term recommendations included the design and implementations of educational programs on elementary and secondary schools, the amendment of the Vehicles and Traffic Law of PR (Law #22) in relation to some pedestrian concerning issues, the punishment of negligent project developers or owners of pedestrian generators for not advertising pedestrian safety rules or not providing safety facilities for crossing or walking along their corridors, and the use of traffic calming elements to reduce traffic speeds on corridors with high frequencies of pedestrian crashes.
7. References

