



PAPER TITLE (90 Characters Max)	Characterization of Pedestrian Fatalities in Urban Arterial Corridor in Puerto Rico		
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ABSTRACT:

Pedestrian crash related fatalities are a social and governmental concern worldwide. The National Highway Traffic Safety Administration ascribed to the United States Department of Transportation has placed the Commonwealth of Puerto Rico with the highest pedestrian fatality rate in the USA with 2.71 fatalities per 100,000 population, with an average of 31% of all traffic related fatalities in the Island, primarily in urban corridors.

An evaluation of pedestrian fatalities was conducted in an urban arterial corridor located on the Western Region of Puerto Rico. Hazardous segments based upon pedestrian crash data were determined. A database developed using Police crash records showed that urban corridor in Municipality of Mayagüez has the highest frequency of pedestrian fatal crashes of the region with 42%. The highest frequency of pedestrian crashes occurred in July and peak hours of 6:00 PM to 9:00 PM. Cross tabulation showed the highest pedestrian fatalities are between kms. 154-156 on PR-2 eight lane urban arterial where public residential housing, elementary and high schools and government services are located. Observational studies performed on this corridor indicated the lack of pedestrian refuge island and insufficient pedestrian signal phase in the intersections are contributory factors in pedestrian crashes in these locations.

Characterization of Pedestrian Fatalities in an Urban Arterial Corridor in Puerto Rico

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1 INTRODUCTION

Pedestrian fatalities are a major concern to local and federal government officials. Recent statistics published by the National Highway Traffic Safety Administration (NHTSA) ascribed to the United States Department of Transportation has placed our island with the highest pedestrian fatality rates in the United States with a total of 2.71 fatalities per 100,000 population (NHTSA 2012). In Puerto Rico (PR), pedestrian fatalities represent 31% of all traffic fatalities, which is almost 300% as compared to the national figure of 11% in the United States. Based upon this alarming pedestrian fatality statistic, a research study was conducted as part of the Dwight D. Eisenhower Fellowship Program for Hispanic Serving Institutions funded by the Federal Highway Administration with assistance data obtained from the Bureau of Highway Patrol of the PR Police Department and the data of the PR Traffic Safety Commission. This pilot study concentrated on the Western Region, including its surrounding 9 municipalities and focusing on the PR-2 Urban Corridor which is part of the National Highway System.

The goal of this study was to identify hazardous pedestrian locations based upon current geometric and operational characteristics that complement the randomness associated with pedestrians and recommend proper countermeasures to help reduce the pedestrian fatalities in the area. Pedestrian fatalities affects emotionally the family and friends of the victim and creates a comprehensive crash cost of \$4 million USD per fatality crash depending upon the productivity years that the victim cannot produce to society and the mental damages and suffering which affects the future family relations at both home and work (AASHTO 2010).

2 OBJECTIVES

The objective of this study is to characterize pedestrian crash data of the Western Region, which is located on the southwest corner of the island, and to identify potential hazardous sites based on observation and pedestrian crash data. The study period covers the period from 2007 to 2013.

3 METHODOLOGY DESCRIPTION

Figure 1 summarizes the methodology for this research study. Initially, a literature review regarding pedestrians including articles, law, regulations and publications was performed. Data collection regarding crash fatalities was conducted by reviewing crash reports from the Puerto Rico Police Department. The data collected included the 9 municipalities comprising the Western Region of the Commonwealth of Puerto Rico. Other data collected included crash fatality data from the Puerto Rico Traffic Safety Commission (PRTSC 2012) and the Fatality Analysis Reporting System (FARS) and the information regarding pedestrian crashes in the United States published by the National Highway Traffic Safety Administration (NHTSA 2012).

Statistical analysis included tabulations, histograms and cross tabulations. Observational studies were performed to evaluate the pedestrian facilities and pedestrian behavior along the PR-2 Urban Corridor. Countermeasures were recommended using HSM methodology with Crash Modification Factors.

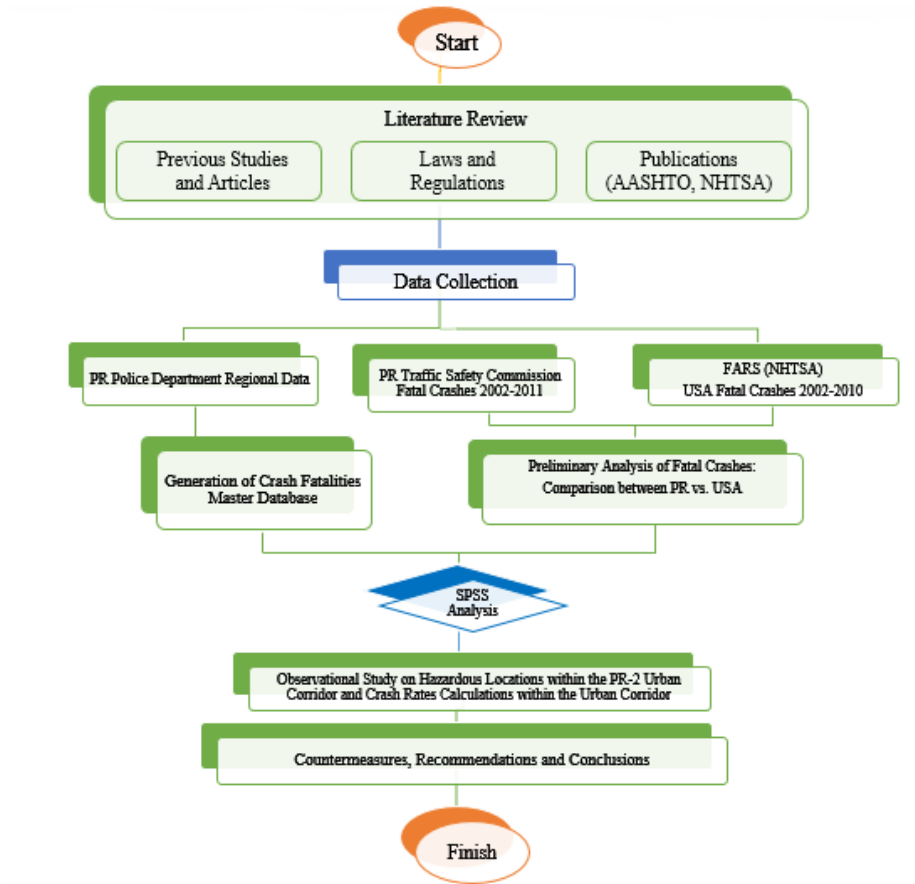


Figure 1. Research Methodology

4 LITERATURE REVIEW

The “Traffic Safety Facts 2010” published by the National Center for Statistics and Analysis of the NHTSA summarized facts involving pedestrian fatalities in the United States (NHTSA 2012). In the United States, a pedestrian is killed an average of every two hours in traffic crashes. The NHTSA reported an increase of 4% of pedestrian fatalities in the year 2010 in comparison with the year 2009, with a total of 4,280 fatalities. In 2010, approximately 67% of the victims were male, almost 30% of the crashes occurred between 8:00 PM to 11:59 PM and approximately 50% of the fatalities occurred during the weekends.

A research study conducted in Puerto Rico characterized pedestrian crashes in urban highways of the Island (Alicea 2004). The Accident Analysis Office of the Department of Transportation and Public Works (DTPW) and FARS provided the databases for this investigation. The investigation concluded that male pedestrian are three times more susceptible than woman, that young pedestrians of 20 years or younger are more susceptible than older pedestrians to be involved on traffic crashes, elderly pedestrians are more likely to be killed than other age groups, and the peak hours of pedestrian crashes are from 6:00 PM to 10:00 PM.

Public perception regarding condition of pedestrian infrastructure in the Island inferred that in many intersections the pedestrians traffic signals are vandalized, the pedestrian marking at the crosswalks are deficient and many sidewalks had poor pavement condition that are hazardous to ordinary pedestrians (Cortés 2013).

5 ANALYSIS

Table 1 summarizes the data collected in the Puerto Rico Traffic Safety Commission (PRTSC) website and the information regarding pedestrian crashes in the United States published by the NHTSA. During the last

decade, pedestrian fatalities represent an average of 31% of all traffic fatalities, which is almost 300% as compared to the national figure of 11% in the United States. This statistic should raise awareness to government agencies in the process of prioritizing pedestrian needs in the planning and design stages.

Table 1. Pedestrian Fatalities in the Commonwealth of Puerto Rico and USA: Study Period 2002-2011

Year	Commonwealth of Puerto Rico (PRTSC 2012)			United States (NHTSA 2012)		
	Total Fatalities	Pedestrian		Total Fatalities	Pedestrian	
		Fatalities	Percent (%)		Fatalities	Percent (%)
2002	519	177	34	43,005	4,851	11
2003	495	150	30	42,884	4,774	11
2004	495	162	33	42,836	4,675	11
2005	457	134	29	43,510	4,892	11
2006	508	140	28	42,708	4,795	11
2007	452	145	32	41,259	4,699	11
2008	406	130	32	37,423	4,414	12
2009	365	109	30	33,883	4,092	12
2010*	340	101	30	32,885	4,280	13
2011	361	111	31	-	-	-
Total	4,398	1,359	31%	360,393	41,472	11%

* In 2010, the reported pedestrian fatality rate for Puerto Rico is 2.71 per 100,000 population (NHTSA 2012)

The NHTSA reported the pedestrian crash fatalities per 100,000 populations for all the territories of the United States using pedestrian crash fatalities for the year 2010. Puerto Rico has the highest index with approximately 2.71, followed by the state of Florida with an index of 2.58, Delaware with an index of 2.45, Arizona with an index of 2.28, the District of Columbia with 2.15 and last were South Carolina and Hawaii with 1.94.

The Traffic Division of the Bureau of Highway Patrol of the Puerto Rico Police Department is the entity in charge of monitoring the principal roads in the different police regions of the island. The Police Academy has trained and a specialized police personnel that goes to the scene of the crash and gathers the information using a standardized police crash report.

Table 2 summarizes the crash fatalities data of the region from the period covering the years of 2007 through February of 2013 and the classification of the fatalities. A total of 170 fatalities were reported in the region during the study period.

Table 2. Classification of Crash Fatalities in the Western Region of Puerto Rico: Study Period 2007-2013

Year	Classification of the Fatalities						Total Fatalities
	Driver	Passenger	Pedestrian	Cyclist	Motorcyclist	Other	
2007	12	6	5	0	3	0	26
2008	8	5	12	2	3	0	30
2009	11	4	11	4	3	1	34
2010	9	3	4	1	3	0	20
2011	12	4	6	0	6	2	30
2012	8	4	10	2	2	0	26
2013*	1	1	2	0	0	0	4
Totals	61	27	50	9	20	3	170

*Only two months were accounted for the year 2013

Table 2 shows the classification of crash fatalities in the Western Region of Puerto Rico for the period of 2007-2013. Based on these data, the highest number of fatal crashes was reported on 2009 with a total of 34 fatalities. The total percentages of the classification of traffic fatalities were 36% of the killed in a crash were drivers, 29% were pedestrians, 16% were passengers, 12% were motorcyclists, 5% were cyclists and 2% were classified as others. The others classification represent a passenger of a motorcycle and two horse riders that were using the road. The 29% percent of the pedestrians killed in this region is consistent with the pattern of the total pedestrians killed in the island, which is approximately 30%.

The Traffic Division of the Bureau of Highway Patrol has reported 50 pedestrian fatalities in the last 6 years. Table 3 has a summary of the municipalities of the region, the population of the municipalities reported by the 2010 census, the total pedestrian crash fatalities for each municipality reported for that period, the pedestrian fatality rate per 10,000 population and the percentage of the total pedestrian fatalities. The Municipality of Mayagüez had the highest percentage of pedestrian fatalities with a total 42%.

Table 3. Pedestrian Crash Fatalities and Fatality Rate According to Municipality:
Western Region of Puerto Rico

Municipality	Population	Total Pedestrian Fatalities	Pedestrian Fatalities per 10,000 Population	Percentage (%)
Añasco	29,261	4	1.37	8
Cabo Rojo	50,197	14	2.79	28
Hormigueros	17,250	3	1.74	6
Lajas	25,753	3	1.16	6
Las Marías	9,881	1	1.01	2
Mayagüez	89,080	21	2.36	42
Sabana Grande	25,265	2	0.79	4
San Germán	35,527	2	0.56	4
Total	282,214	50	N/A	100%

Figure 2 shows the information related to the gender and group age distribution of male pedestrians. In terms of gender, 68% of the victims were male and 32% were female. Almost 48% of the male fatalities were above 56 years of age.

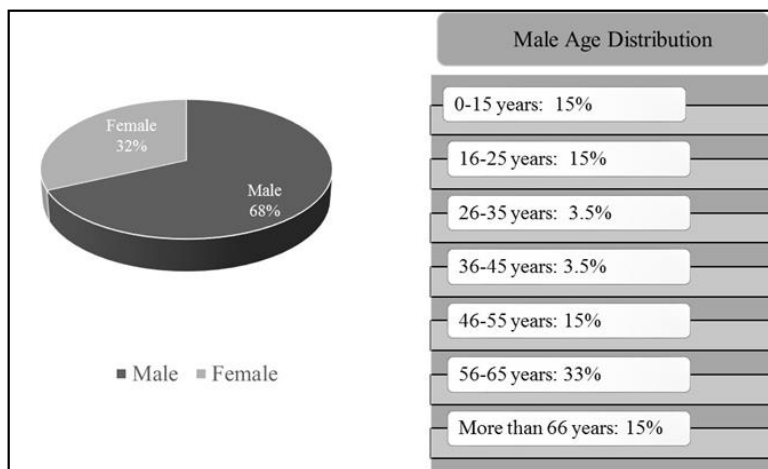


Figure 2. Distribution of Pedestrian Fatal Crashes According to Gender and Age Group

A pertinent aspect regarding pedestrian crash fatalities is the frequency distribution in terms of the month and day of the week of the crash incident. Figure 3 summarizes the information related to month and day of the week of the occurrence of the pedestrian crash. In terms of month, the highest frequency corresponded to the month of July with 16% followed by November with 12%. The southwest corner of the island is a popular tourism destination mainly because of the great beaches and protected wildlife areas. The month of July is the peak of the tourism season in the region and that may be the rational explanation for the incidence increase of pedestrian crash fatalities during that particular month.

In terms of the day of the week, Friday has the highest frequency reported with 30%. Of the pedestrian crashes that were reported on Friday, 60% were after 7 PM or during nighttime and 40% were before 7 PM. During the weekend, which includes Friday night, Saturday and Sunday the frequency was almost 46% of the pedestrian fatal crashes.

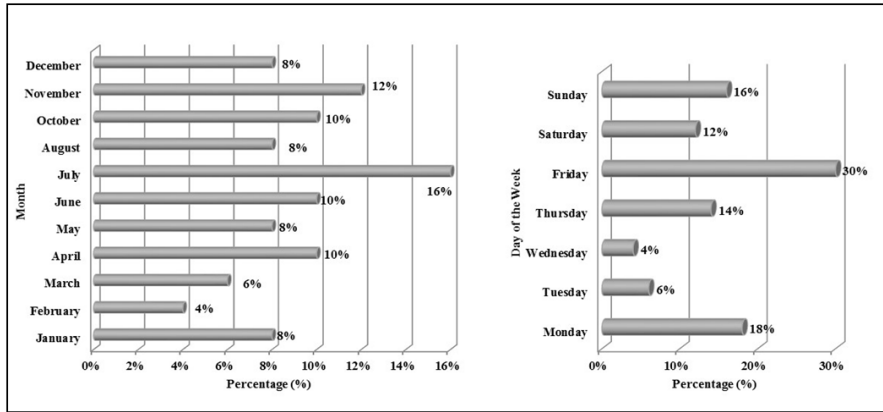


Figure 3. Pedestrian Fatal Crashes According to Month and Day of the Week of Crash Occurrence

Figure 4 shows the distribution of number of pedestrian fatalities per hour of the day. Specifically, it shows that the top frequency observed was from 7:00 to 8:00 PM with 16% of the total pedestrian fatalities. There are two peak hours, one on early morning (12:00 AM to 4:00 AM) with 24% of the total pedestrian fatalities and the other from the periods of 5:00 PM to 9:00 PM with 38% of the total pedestrian fatalities. Importantly, 78% of the fatalities occurred during nighttime.

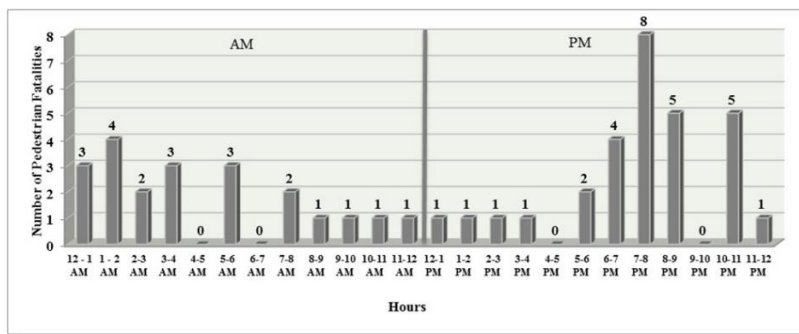


Figure 4. Pedestrian Fatal Crashes by Time of the Day: Study Period 2007-2013

Figure 5 shows the distribution of pedestrian maneuvers prior to motor vehicle - pedestrian crashes for the 6 year period. The highest frequency of pedestrian maneuver is crossing outside an intersection or in a mid-segment with 32%, followed by walking on the roadway against traffic with 24% and walking on the roadway in favor of traffic with 15%. The majority of the rural roads of the western region lack pedestrian facilities such as adequate sidewalks and illumination system which can endanger pedestrians.

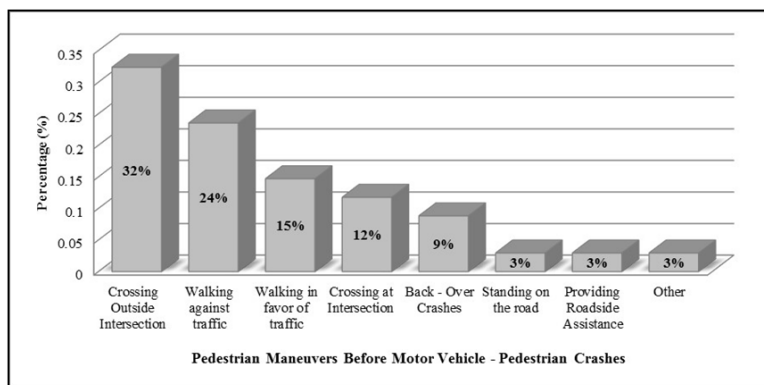


Figure 5. Pedestrian Maneuvers Prior to Motor Vehicle - Pedestrian Crashes

Figure 6 shows the distribution of probable causes of motor vehicle – pedestrian crashes obtained from Police Crash Reports and narratives descriptions prepared by the investigative officer. The highest frequency of probable causes of crashes is the inadequate or absence of illumination on site with 43%.

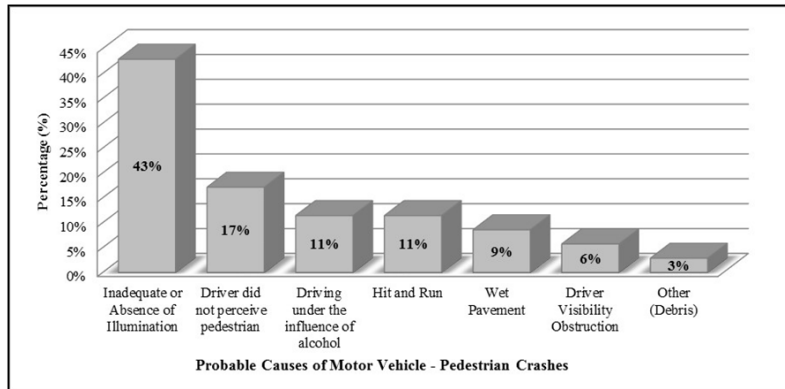


Figure 6. Probable Causes of Motor Vehicle - Pedestrian Crashes

The pedestrian crash analysis showed that the PR-2 Urban Corridor in the city of Mayagüez has the highest incidence of pedestrian fatalities with an approximate 26% of the total fatalities of the Western Region. The PR-2 Urban Corridor is classified as a high speed, urban arterial that crosses the city from north to south. The segment that was evaluated has an AADT with a range between 50,000 to 80,000 vehicles per day. The urban corridor has frontage roads in several segments which provide access to traffic generators such as commercial, industrial, governmental and housing developments. Unfortunately, the frontage roads are not continuous thus, creating gaps in which schools and commercial generators are contiguous to the main highway combined with the lack of continuous sidewalks for pedestrian use.

In order to identify segments in the corridor with high frequency of pedestrian fatalities, cross tabulations and crash rates analysis were performed. The PR-2 Urban Corridor in the Municipality of Mayagüez is ranked among the top ten hazardous highways in terms of motor vehicle-pedestrians crashes in the Island.

The results of the cross tabulation analysis showed that the highest incidence of pedestrian crashes on the PR-2 Urban Corridor was between kilometers 154 to 156, specifically between the Mayagüez bypass to Duscombe Street Intersection, with a frequency of 62% of the total pedestrian crashes of that particular road. This segment has a high density of pedestrians due in part of a large quantity of pedestrian generators such as schools, government agencies, commercial and residential areas.

In order to perform an accurate crash analysis of the PR-2 Urban Corridor it is pertinent to identify the roadway segments and intersections. To calculate the crash rates that take into account the exposure data of the roadway segment in consideration the following formula from the Highway Safety Manual (HSM) is used (AASHTO 2010):

$$R = \frac{C \times 100,000,000}{V \times 365 \times N \times L} \quad (1)$$

Where:

R = Crash rates for road segments expressed as crashes per 100 million vehicle – kilometers travelled

C = Number of pedestrian fatal crashes in the study period

V = Average Annual Daily Traffic (AADT)


N = Number of years within the period of study

L = Length of segment in kilometers

The crash data were obtained from the Traffic Division of the Region of Mayagüez of the PR Police Department. The information related to the AADT was obtained from the PR Department of Transportation and Public Works. The AADT used was from the year 2008. To calculate the segment pedestrian crash rates we divided the PR-2 Urban Corridor based upon the AADT's available between intersections of the corridor.

Table 4 shows the location of the segments and the calculated crash rates for all the road segments of the PR-2 Urban Corridor in the Municipality of Mayagüez.

Table 4. Calculated Crash Rates for Segments on the PR-2 Urban Corridor: Study Period 2007-2013



Segment	Number of Crashes	Length (km)	AADT (veh/day)	Crash Rates
1. Sultana to Carolina Street	1	1.5	66,650	0.46
2. Carolina to Centro Médico Entrance	1	0.5	77,300	1.18
3. Centro Médico to Duscombe Avenue	1	1.1	77,300	0.54
4. Duscombe to Nenadich Street	2	0.8	68,700	1.66
5. Nenadich Street to the Viaduct	3	0.31	59,800	7.39
6. Viaduct to Llorens Torres Avenue	3	1	51,500	2.66
7. Llorens Torres to Chardón Street	1	0.7	54,600	1.19
8. Chardón to PR-3108	1	0.8	51,000	1.12

Table 4 shows the variables and the calculated crash rates for the PR-2 Urban Corridor on the Municipality of Mayagüez. The segment between the Nenadich Street and the entrance to the viaduct has the highest crash rates with 7.39 crashes per 100 million vehicles – kilometers travelled.

Observational studies were performed in the intersections along the PR-2 Urban Corridor. A checklist was developed based upon AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities (AASHTO 2004). The elements evaluated were the sidewalks, crosswalks, pedestrian refuge islands and the pedestrian traffic signals for the urban corridor. A total of 7% of the sidewalks did not comply with the 1.52 meters minimum width requirement. In terms of crosswalks, 14% of them did not comply with the 1.83 meters minimum width requirement. A total of 43% of the intersections did not provide pedestrian refuge island and a total of 7% of the pedestrian traffic signals were not operating properly. Another situation is that the pedestrian signals provided only 12 seconds for crossing the corridor on all the intersections along the corridor. It is pertinent to emphasize that the lack of adequate storage for pedestrians combined with the pedestrian walking interval provided of 12 seconds is not adequate for a 6 lanes plus two turning lanes that has an approximately length of 30.5 meters.

6 DISCUSSION

The Commonwealth of Puerto Rico has the highest pedestrian fatality rate in the USA with 2.71 fatalities per 100,000 population. Furthermore, during the last decade the pedestrian fatalities, on average, correspond to 31% of all traffic related fatalities in the Island, primarily concentrated in urban corridors with traffic generators on both sides and discontinuities in the built infrastructure in terms of frontage roads and sidewalks.

During the study period of 2007-2013, a total of 170 pedestrians has been killed on motor vehicle-pedestrian crashes in the Western Region of Puerto Rico. The 29% of the pedestrians killed in the region are compatible with the pattern of the total pedestrian fatalities for the island (31%). The city of Mayagüez has the highest frequency of pedestrian fatal crashes with a total of 42%.

The characterization of the pedestrian victims of the region involved an analysis of the gender, age distribution, month, day and time of the incident, the maneuvers of the victim before the incident and the probable causes. In terms of the gender of the pedestrian crash victims, 68% of the victims in the region were male which is similar to the statistics of 66% of male victims in the United States. Almost 48% of the male victims were above 56 years old. This statistic reflects that older people have higher risk of been involved in a motor vehicle - pedestrian crash associated with their mobility and reaction time which makes them vulnerable while crossing a street. The month of July had the highest frequency of pedestrian fatalities in the region with a total of 16%. The region is a tourism destination because of the spectacular beaches and



wildlife reserves. The peak of tourism is during the month of July, this rational explanation can be the contributing factor for such statistic. During the weekend that includes Friday night, Saturday and Sunday the frequency was almost 46% of the total pedestrian fatal crashes, which is similar to the statistic reported by NHTSA of the frequency of almost 50% of occurrence of pedestrian fatalities during weekends in the United States. The peak hours for pedestrian fatalities are during nighttime between 6 PM to 9 PM with approximately 34% of the total pedestrian fatalities. The highest frequency of pedestrian maneuver is crossing outside an intersection with 32%, followed by walking against traffic with 24% and walking in favor of traffic with 15%. In terms of probable causes for motor vehicle – pedestrian crashes inadequate illumination had the highest frequency with a total of 43%.

A major achievement was to identify a hazardous segment within the PR-2 Urban Corridor. Cross tabulations and crash rate analysis determined that the segment between Nenadich Street and the viaduct had the highest incidence of pedestrian fatalities in the Corridor. The PR-2 Urban Corridor has a concentration of public residential housing, schools and government services that generates large quantity of pedestrians. In terms of the traffic control devices, the observational studies performed indicated the lack of pedestrian refuge island and only 12 seconds provided to pedestrians to clear the crosswalk. During the night, the illumination provided by light poles were not uniform in the vicinity of the intersections evaluated.

7 CONCLUSIONS AND RECOMMENDATIONS

The PR-2 Urban Corridor in the city of Mayagüez has the highest incidence of pedestrian crashes with approximately 26% of the total pedestrian fatalities of the region. Even though the pedestrian crashes are located in segments, there is an overlap with the intersections contiguous to the segment. Lack of enforcement of pedestrian crossing in crosswalks is a contributory factor in this high pedestrian fatalities rate. Short term improvements for the corridor includes the optimization of the traffic lights along the corridor without increasing the traffic delays. Applying the Crash Modification Factors, using HSM, implementing this countermeasure can reduce the motor vehicle – pedestrian crashes by 50%.

The segment within the PR-2 Urban Corridor between the Nenadich Street and the viaduct had the highest incidence of pedestrian fatalities. Recommended countermeasures for the intersections on this segment are the construction of a pedestrian refuge island, improvement of the illumination system and increasing the pedestrian walking interval phase to better accommodate the necessities of the users.

An inventory of the condition of the pedestrian facilities and potential countermeasures for each intersection on the PR-2 Urban Corridor was performed and was submitted to Puerto Rico Highway and Transportation Authority for evaluation and implementation. This assessment could potentially assist in improving the conditions for pedestrian facilities and reducing pedestrian fatalities in the corridor. Awareness campaigns are also recommended to move toward a safety culture with zero pedestrian fatalities in the Island.

8 ACKNOWLEDGEMENTS

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