

Roadway and Human Factors of Motorcycle Crashes in Puerto Rico

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ABSTRACT

A dramatic increase of 92% in registered motorcycles has been observed in the Commonwealth of Puerto Rico between 2000 to 2005. The frequency and fatality rates of motorcycle-related crashes have also increased significantly during the same period. The increasing use of motorcycles, especially of the motor scooter-type, and the safety-related issues on the island have been mainly attributed to the presence of untrained and young riders on the road due to the lack of motorcycle training requirements and lack of legislative action in Puerto Rico.

This paper presents the results from the initial stages of a comprehensive study of the motorcycle safety problem in Puerto Rico requested by the Puerto Rico Traffic Safety Commission. The methodology consists of analyzing the Puerto Rico Department of Transportation and Public Works crash database complemented with surveys and interviews conducted to police officers, motorcycle riders, and emergency personnel. Main contributory causes of motorcycle crashes, as related to the roadway design and environment and human factors of motorcycle riders are analyzed.

Recommendations are made in five major areas: enforcement, education, training, operations, and administration that have the potential to reduce the motorcycle fatality rate in the island.

Keywords: Motorcycles, highway safety, human factors, roadway design, fatality rates

1. INTRODUCTION

Motorcycle safety has been a significant research topic in recent years. A dramatic increase in registered motorcycles of 92% (from 39,000 to 72,000 motorcycles) has been observed in Puerto Rico between the years of 2000 to 2005. This recent increase in motorcycle use might be attributed to several factors, such as the rising cost of fuel, the traffic congestion throughout the major cities of the island, and the special attraction and appeal of these vehicles. The increase in registered motorcycles has obviously come in hand with an increase in motorcycle crashes and fatalities. Figure 1 shows the registered motorcycles and the motorcycle-related fatalities in Puerto Rico from 1997 to 2005. The data show a positive trend between motorcycle registrations and fatalities. The greatest increase in motorcycle registrations (30%) and fatalities (39%) occurred concurrently in the year 2005.

The fatality rate per 10,000 registered motorcycles has also increased significantly, a 78.5% increase, from 6.65 in 1997 to 11.87 in 2005. NHTSA (2006) indicates the motorcycle fatality rate in Puerto Rico in 2004 was the second largest, after Washington D.C., in the United States.

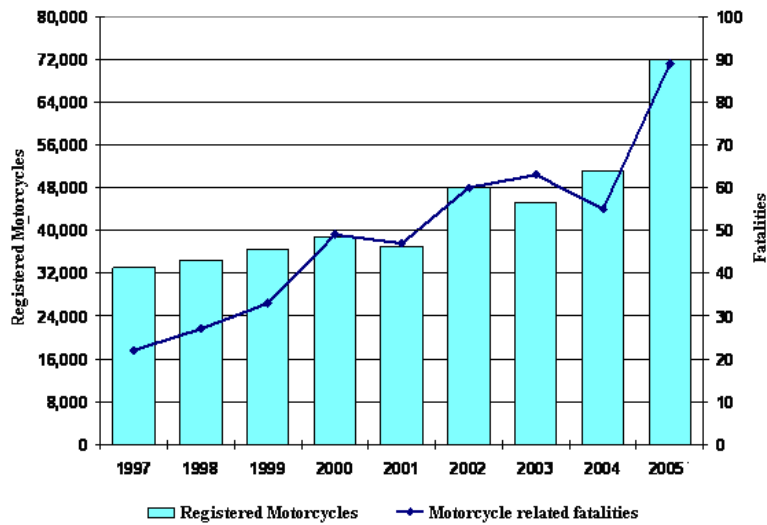


Figure 1: Registered motorcycles and motorcycle-related fatalities in Puerto Rico

The recent increase in motorcycle use is not an exclusive situation of Puerto Rico, similar increasing trends have been also observed in the United States and Europe. Motorcycle registrations in the United States increased 51% between 1997 and 2004, motorcycle-related fatalities have increased since 1997, and injuries have increased since 1998 (NHTSA, 2006). In 2004, motorcycle fatalities amounted to 4,008 in the United States, an increase of more than 89% between 1997 and 2004. Europe has observed a significant increase of 41% in motorcycles between 1998 and 2003, but the safety impact has been diverse for different European countries (FEMA, 2006). Germany, France and the United Kingdom have experienced increasing motorcycle crashes since 1997.

Table 1 presents the total road fatalities and the main related factors of fatal crashes in Puerto Rico between 2001 and 2005. The total road fatalities during this period remain fairly stable, except for a decrease of 42 fatalities in 2005; whereas motorcycle fatalities have considerably increased during this period.

Table 1: Main contributory factors of road fatalities in Puerto Rico

Contributory Factors	Percentage of Contributory Factors in Highway Fatalities by Year				
	2001	2002	2003	2004	2005
Motorcycle riders	9	12	11	13	20
Alcohol-related	52	47	47	51	48
Speeding	48	49	47	48	47
Roadway departure	45	51	50	53	58
Single vehicle	68	68	66	66	66
Pedestrians	34	34	30	33	29
Total Road Fatalities	495	518	495	495	453

The main safety issues observed in Puerto Rico’s highways are related to alcohol, pedestrians, speeding, roadway departure, and single vehicle crashes. Although the current magnitude of motorcycle fatalities does not represent a high percentage of road fatalities in Puerto Rico, the significant increase in the last five years shows the potential for becoming a major safety related issue.

2. STUDY METHODOLOGY

The initial stages of an island-wide comprehensive study of the motorcycle safety problem in Puerto Rico are documented in this paper. The main purpose of this research study is to identify the contributory causes of motorcycle crashes, as related to roadway geometry, characteristics and environment, and human factors. It also addresses engineering, enforcement, and education strategies and will provide safety countermeasures that can potentially improve the safety of motorcycle riders in Puerto Rico. The methodology proposed for this research is presented in Figure 2.

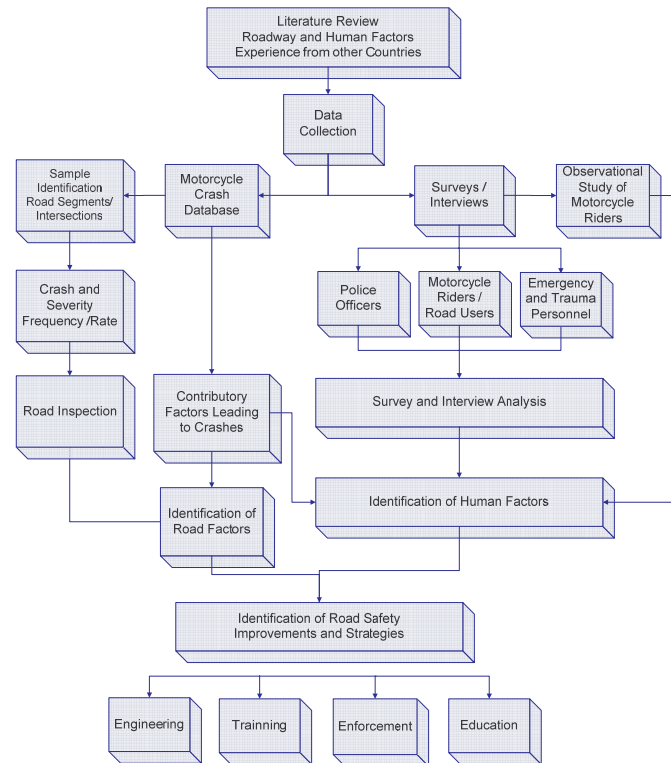


Figure 2: Study methodology

The methodology is divided in three main activities namely, a literature review, the data collection and the identification of safety countermeasures. The literature review focuses on the identification of potentially hazardous roadway features and typical motorcycle rider behavior and demographic trends, and the experience of other countries related to the implementation of motorcycle safety measures.

The data collection process benefits from four activities: surveys and interviews made to several road safety stakeholders, a statistical analysis of motorcycle crashes, an observational study of motorcycle riders' behavior on the road, and a field inspection of road segments and intersections. The surveys and interviews are aimed to collect the opinion on several motorcycle safety issues of four different groups: motorcycle riders, other road users, police officers, and medical emergency personnel. The scope of this paper is to present the analysis that resulted from the surveys made to motorcycle riders and police officers which includes recommendations in the four E's and administrative procedures of safety-related programs.

The Puerto Rico crash database was used to identify the main rider characteristics and the related events of motorcycle crashes from 2002 to 2004. Typically, information related to the road design or condition level and their relationship to the crash is limited on the crash records; therefore, motorcycle crash and severity rates will be calculated for a sample of road segments; which will go through a detailed safety inspection. These segments were classified using a rating index based on their crash frequency, crash rate, severity rate, and other variables. A

sample of road sites crashes were selected for field inspection to evaluate the geometric characteristics and observe the behavior of motorcycle riders on those locations. Based on these inspections, it is expected to identify geometry and road characteristics that could be linked to motorcycle crashes. The identification of human and road factors will provide the basis for a series of safety recommendations and countermeasures, related to engineering, enforcement, and education and training strategies, to mitigate motorcycle fatalities in Puerto Rico.

3. STATICAL ANALYSIS OF MOTORCYCLE CRASHES

The crash database of the Puerto Rico Department of Transportation and Public Works (DTPW) was used as the primary source of data for this analysis. Motorcycle crashes from 2002 to 2004 were the latest years available. A total of 5,614 motorcycle-related crashes occurred during this period, with 54% of these crashes resulting in injuries or fatalities.

Most of the motorcycle crashes, 81% of all crashes, occurred in urban areas (see Figure 3). This distribution was expected due to the fact that 80% of the Puerto Rico’s highway system is located within urban areas and 93% of the vehicle-miles traveled in the system are made on urban roads (FHWA, 2006). The effect of the traffic exposure on urban areas is significantly associated with this trend, showing the importance of providing special emphasis to urban roads to identify potential safety issues of motorcycle crashes.

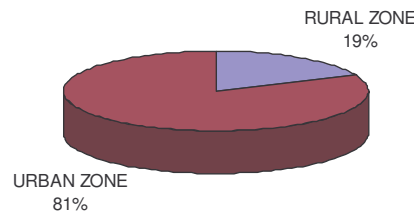


Figure 3: Motorcycle crashes in Puerto Rico by area

The effect of the road horizontal and vertical alignment in motorcycle crashes in Puerto Rico is shown in Figure 4. In summary, 88% of the crashes occurred on straight segments versus 8% on curves. This trend might be attributed to the potential of straight segments for allowing higher operating speeds. It is necessary to analyze the effect of the geometry on the crash severity once more information about the alignment is collected during the road inspections.

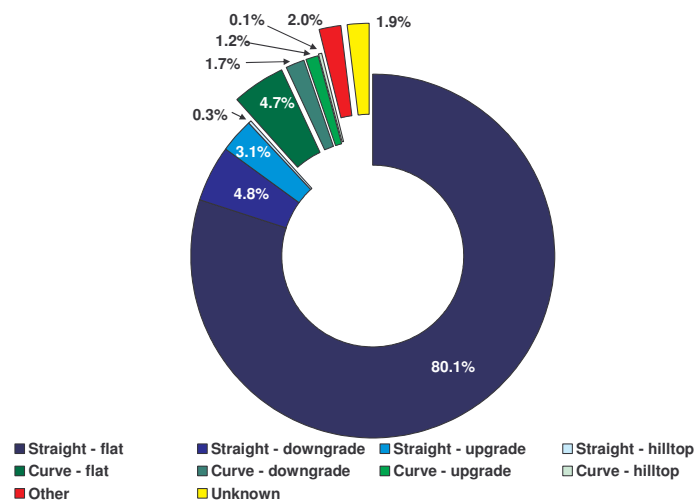


Figure 4: Motorcycle crashes in Puerto Rico by road alignment geometry

In terms of crashes on segments versus intersections, 23% occurred in the vicinity or at an intersection. Figure 5 shows the distribution of the crashes associated with the traffic control type observed. Traffic signals is the main control involved in motorcycle crashes for the period analyzed. The effect on motorcycle safety of the number of lanes, lane movements, and the characteristics of the signalized intersections will be evaluated during the field inspections.

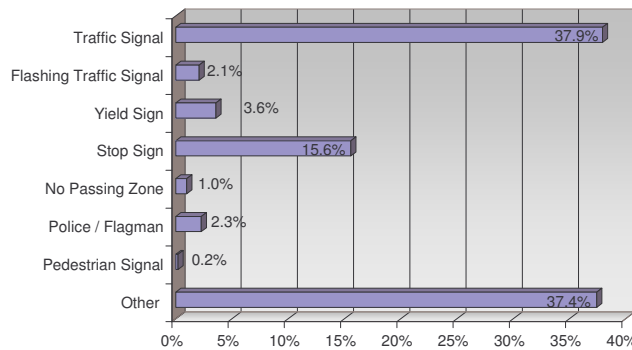


Figure 5: Motorcycle crashes in Puerto Rico by traffic control

Figure 6 shows the circumstances of motorcycle crashes in Puerto Rico. It can be observed that the majority of motorcycle crashes are caused by the driver behavior (52%); whereas 3% are related to roadway elements. This findings are similar to those of the Hurt Report, were 2% of motorcycle crashes were associated with roadway elements.

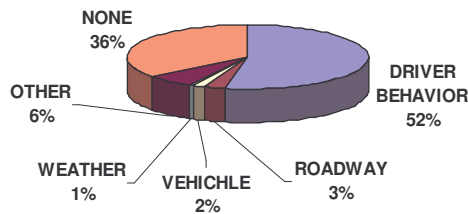


Figure 6: Motorcycle crashes in Puerto Rico by circumstance

The crash database was also used to identify major characteristics of motorcycle riders involved in crashes. Figure 7 shows the gender distribution of motorcycle crashes in Puerto Rico. As other studies in the scientific community in the United States (Hurt, 1981), Germany (Heger et al., 2005), and Taiwan (Chang et al., 2004), male riders are more involved in motorcycle-related crashes (95% of crashes) than female riders. Traditionally, motorcycle use has been associated primarily to male riders so the observed trend directly reflects this fact, although the perception is that this trend is changing in recent years, especially for younger riders.

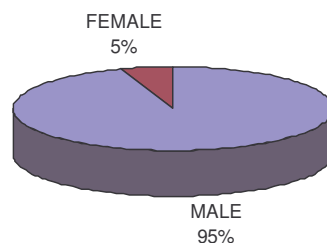


Figure 7: Motorcycle crashes in Puerto Rico by gender

Even though it is accepted that the difference in the numbers of riders by gender is a significant factor in the crash involvement, there is a need to analyze the effect on safety of the risk perception skills of riders. In general, males are believed to show “optimism bias” toward their driving skills and consider they are less likely to be involved in

a crash and more likely to be better drivers than others in their peer group. DeJoy (1992) reported that males perceived lower risk for specific hazardous driving behaviors (e.g., not using seat belts, drinking and driving) than female drivers. Figueroa et al. (2005) reported that female drivers perceived higher risk than their male counterparts when watching the roadway characteristics and road environment of the same four-lane suburban and rural roads.

The rider’s age and the driving experience are also believed to be major factors of motorcycle crash involvement; although it is believed that driving experience has a more significant influence on risk perception than the age of the driver (Figueroa et al., 2005). A typical motorcycle crash allows the motorcycle rider just less than two seconds to complete all the collision-avoidance action (Hurt, 1981). Inexperienced drivers might tend to perceive less risk, or fail to detect or react properly to a road hazard, than experienced drivers on the same road. Renge (1998) showed that as the driving experience increased, the driver perceived more properly the hazardous situations on the road, evaluated the risks higher, and the driving speed selected was lower.

The age distribution of riders in Figure 8 shows that the 26 to 35 years old group is the most involved in motorcycle crashes. Typically, younger drivers are involved in more crashes due to the combination of their lower driving experience and immaturity when assuming risks on the road, so the trend observed is not obvious. Other factors, such as the age when starting riding motorcycles or the accessibility to own a motorcycle, might be associated with this trend. The observational study and the surveys will provide more evidence toward identifying the influence of age and experience on motorcycle safety in Puerto Rico.

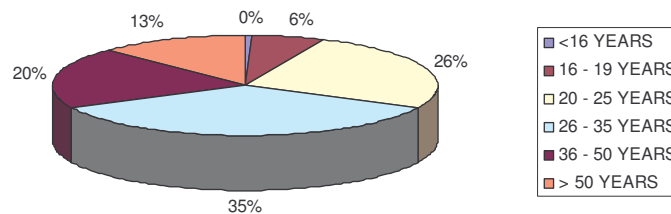


Figure 8: Motorcycle crashes in Puerto Rico by age

The observed trend in Puerto Rico corresponds to the trends in other countries. Heger et al. (2005) observed that the age groups of 18 to 20 and 30 to 39 years old have the highest frequency of motorcycle crashes in Germany. In Taiwan, the age group of 20 to 29 years old has the highest frequency of motorcycle crashes (Chang et al., 2004). Table 2 presents a comparison of particular findings of the Puerto Rico study and the Hurt Report (1981) to establish similarities and differences between the two situations. The Hurt Report was a comprehensive study made in the state of California for the National Highway Traffic Safety Administration and it is considered a significant reference in motorcycle safety research for the evaluation of motorcycle crash issues in other countries. Major similarities in roadway alignment, roadway defects, area type, and gender were observed between the two studies. Major dissimilarities were observed in crash types, crash location, and road classification.

Table 2: Major findings in the Hurt Report and the Puerto Rico Motorcycle Safety Study

Crash-related Elements	Hurt Report	Puerto Rico
Crash type	2.6% property damage only 97.4% injury or fatal	40.1% property damage only 59.9% injury or fatal
Area type	9.4% occurred in a rural area	18.5% occurred in a rural area
Road classification	55.9% occurred on arterial highways	29.7% occurred on arterial highways
Crash location	59.7% occurred in roadway segments	75.2% occurred in roadway segments
Roadway alignment	81.3% on straight and level segment	75.7% on straight and level segment
Maneuver type	29.5% right angle crashes	17.5% side crashes in same direction
Traffic control type	25.5% in signalized intersections	8.9% in signalized intersections
Roadway defects	2.0% were caused by roadway defects	3.0% were caused by roadway defects
Gender of riders	97% of motorcycle riders were men	95% of motorcycle riders were men
Age of riders	62.6% between 17-26 years old	35.6% between 26-35 years old

4. POLICE OFFICERS SURVEYS AND INTERVIEWS

A total of 149 police officers from five different districts on Puerto Rico were surveyed about their experience and perception related to motorcycle crashes. The purpose of the survey was to complement the information of human factors of motorcycle crashes and to obtain information not included in the crash reports. The focus of police crash investigations is toward the identification of the primary contributory causes related to the driver. The driver is typically recognized as one of the contributory factors of road crashes in 95% of the cases (Johnston, 1994). Figure 9 presents the perception of police officers regarding motorcycle crash contributory factors. Although the perception of police officers follows the trend of attributing most of the blame for the crash to the driver error and behavior; the influence on driver behavior of the roadway alignment, the road environment, the traffic volume, among other factors on the road, cannot be neglected and need to be studied methodically by road safety experts and engineers. Figueroa et al. (2005) identified seven roadway characteristics that influenced the risk perception of drivers on four-lane highways.

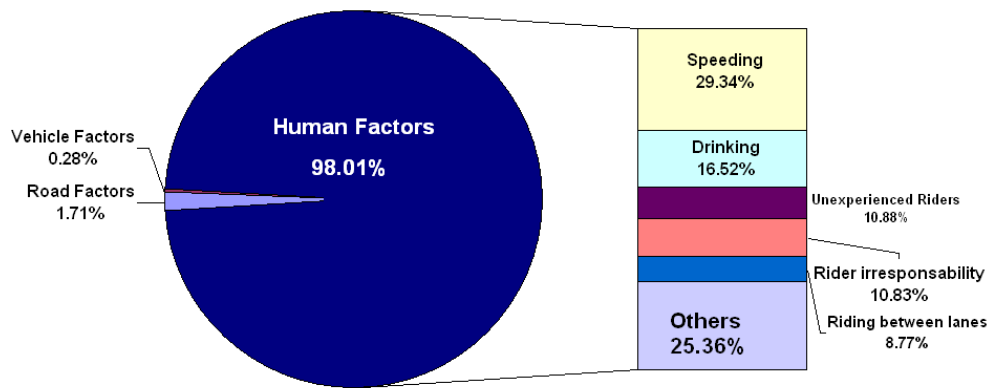


Figure 9: Perceived contributory factors of motorcycle crashes in Puerto Rico

Table 3 presents the percentage of officers that indicated which season is associated with the highest frequency of motorcycle crashes. The winter and summer breaks are associated with the highest frequency of motorcycle crashes in Puerto Rico. These breaks correspond to the vacation period, which corresponds to the stated primary recreational use of the motorcycles on the island (obtained from the motorcycle riders' survey). It should be clarified that these findings are not weather-related since there are not significant climate changes in the tropics, where Puerto Rico is located.

Table 3: Seasons with the highest frequency of motorcycle crashes

Summer	Winter	Other
62%	42%	19%

The most frequent violations were associated with motorcycle riders not wearing helmets or gloves, speeding, and riding between the travel lanes. Riders of motor scooters were associated with a higher frequency of equipment violations. During the interviews, several scooter riders indicated that the safety equipment requirement is unnecessary because their scooters do not generate high speed. The perception of rider of motor scooters contradicts that of the police officers, which believed that, independently of the operating speed, scooters are more involved in crashes in Puerto Rico.

5. MOTORCYCLE RIDERS SURVEYS

A total of 231 motorcycle riders and passengers were surveyed to gather information regarding their riding experience and their motorcycle safety perception. The gender distribution of the riders surveyed is 86.6% males

and 13.4% females. Table 4 shows the type of motorcycle owned/operated by the riders interviewed. The distribution indicates a variability of motorcycle types in the sample that will provide the perspective from different motorcycle users.

Table 4: Type of motorcycle owned/operated by surveyed riders

Scooters	Sport	Cruiser	Standard	Other
24.8%	29.7%	34.3%	5.2%	6.0%

As previously stated, the primary use of motorcycles in the island is the recreational one and during weekends and vacation periods. Ninety-six percent of the police officers interviewed indicated that motorcycle crashes occurred on weekends. Table 5 presents the riders’ preference of days or weekly period for riding their motorcycles and Table 6 presents their primary use. These results confirm that the safety issue in Puerto Rico regarding motorcycles is related to occasional riders.

Table 5: Day or period of the week when motorcycle is mostly used

All days	Weekends	Holidays	Monday to Friday	Weekends and Holidays	Other
30.0%	49.3%	1.9%	5.3%	8.7%	4.8%

Table 6: Principal use of motorcycles

Recreation	Travel to work or school	Working tool	Other
66.1%	25.2%	5.1%	3.6%

The perception of the police officers was compared with the motorcycle crash data between 2002 and 2004. Figure 10 presents the distribution of annual crashes and the rate of injuries and fatalities per 100 crashes by the day of the week. The trends observed confirm the perception of the police officers of a motorcycle safety issue relative to weekends, especially Sundays. The trend of the crash frequency by day of the week for other passenger motor vehicles is reversed with Sunday as the day with the lowest frequency of crashes. In terms of the injuries and fatalities rate, the trend for other motor vehicles is similar to motorcycles, although the magnitude of the rates is substantially less for all days (72 versus 20 for motorcycles and autos, respectively, on Sundays).

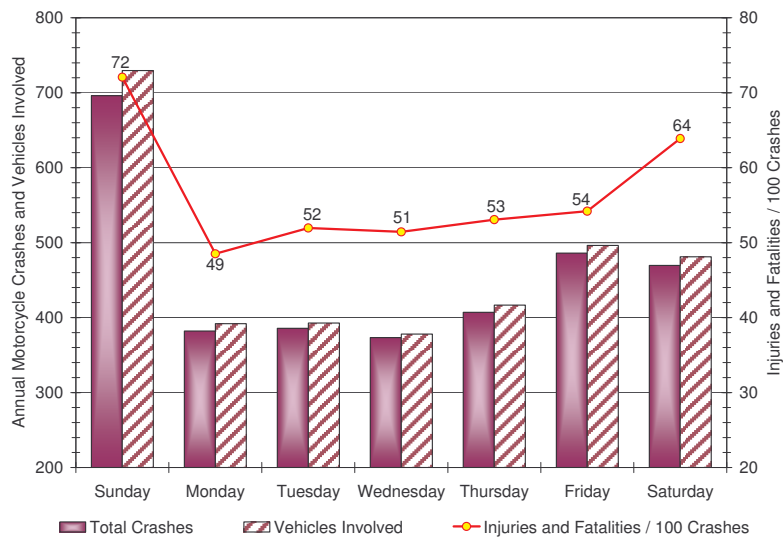


Figure 10: Motorcycle crashes, and injuries and fatalities rates in Puerto Rico by day of the week

Figure 11 presents the riders' perception of the contribution of human factors to motorcycle crashes. The general behavior of drivers of passenger cars is a major factor that contribute in motorcycle crashes. Hurt (1981) indicated that approximately 75% of motorcycle crashes in the United States involved another vehicle. Other relevant findings associated to riders' perception as a contributory factor are shown in this figure.

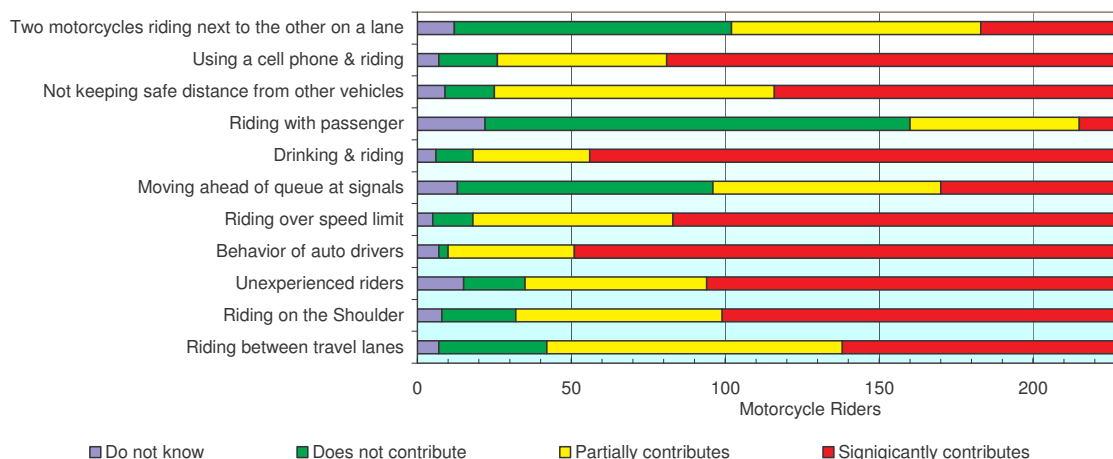


Figure 11: Perception of the contribution of rider/driver behavior to motorcycle crashes

Table 7 presents the ten towns with the major frequency of motorcycle crashes in Puerto Rico. Culebra, a small island on the eastern side of Puerto Rico which has 1,868 habitants, is at the top of the list. Its tropical setting with beaches and scenic trails makes it ideal for tourists to visit the island. Based on these facts, people rent motorcycles as a way to move around the island, including inexperienced and first-time riders. In summary, 60% of these towns are sites with a variety of tourist attractions and the remaining 40% are major metropolitan hubs with a well-developed network of highways with high traffic volumes during peak hours and drastically-reduced volumes at nighttime that offers an attraction for increasing speeds for risk-prone riders.

Table 7: Towns of major frequency of motorcycle crashes per 10,000 inhabitants

Town	Crash frequency	Motorcycle injury and fatal rate per 10,000 inhabitants	Motorcycle Crash rate per 10,000 inhabitants
Culebra	7.67	28.55	41.04
San Juan	701.67	9.57	16.15
Loíza	46.67	9.83	14.34
Dorado	41.33	8.72	12.15
Carolina	215.67	8.38	11.60
Barranquitas	32.33	7.38	11.18
Guaynabo	110.67	6.53	11.06
Bayamón	233.00	6.41	10.40
Cataño	30.67	7.87	10.19
Rincón	14.67	8.13	9.93

6. CONCLUSIONS AND RECOMENDATIONS

This study presented the findings of the initial stages of an island-wide comprehensive study of motorcycle crashes in Puerto Rico. The crash database were analyzed, including age, gender, road alignment, as well as the responses from surveys and interviews, to police officers and motorcycle riders were used as primary elements of

the study. Findings were compared with the Hurt Report and other major studies from the United States, Europe and Taiwan. Based on the integrated analysis of all the data gathered, short, medium, and long-term recommendations are summarized in five major areas, as shown in Table 8.

Table 8: Potential recommendations to mitigate motorcycle fatalities on Puerto Rico highways

Area	Short (S), Medium (M) and Long (L) Term Recommendations
Enforcement	Increase fines of motorcycle traffic-related violations (S)
Education	Education campaign on helmet and safety clothing, increasing risk perception, crash consequences that results in impairment that affects your future quality of life, etc. (M-L)
Training	Implement a motorcycle training and riding test for motorcycle licensing (S-M)
Operations	Provide effective and preventive maintenance to highways (M-L)
Administrative	Legislative action to establish 18-years old as minimum age to obtain a motorcycle license (S) Include specifications for motorcycles in roadway and roadside design manuals and Manual of Uniform Traffic Control Devices (MUTCD)

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