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D.D. Eisenhower Fellowship Program

Final Report

ANALYSIS OF FATALITIES DUE TO MOTORIZED VEHICLES IN HAZARDOUS LOCATIONS OF THE WESTERN & SOUTHERN REGIONS OF PUERTO RICO

by

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LIST OF ACRONYMS

NHTSA	*National Highway Traffic Safety Administration*
FARS	*Fatal Accident Reporting System*
DTPW	*Department of Transportation and Public Works*
TSC	*Traffic Safety Commission*

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ABSTRACT

Puerto Rico is a country with one of the highest vehicle densities in the world, therefore, highway safety is important to improve life quality among all the people that day by day are continuously using our highways and roads. Every time we go to work we are at risk of suffering a car accident due to many factors that could involve the vehicle, the road and ourselves as drivers. A major goal in Transportation Engineering is to provide innovations in *Traffic Safety* to reduce fatalities due to motor vehicle crashes.

There are many types of accidents, but the worst of them are when people get injured or life is lost. That is why *Traffic Safety* deals mostly with the reduction of fatalities on our roads. For investigation purposes the data collection and maintenance is essential to identify hazardous zones, and establish tendencies about possible causes of fatalities due to car accidents.

The *Traffic Safety Commission of Puerto Rico* has information on fatalities due to car accidents. Using the data provided by the commission the major goal in this investigation is to identify hazardous locations in the western region and part of the south region of Puerto Rico with an emphasis on the PR-2 road. This is the arterial with the highest average daily traffic in the western region, and of course, a high risk route. The identification of those hazardous locations is possible using statistical methodologies as frequency and accident rate methodologies. Once we have identified those hazardous regions it is possible to establish trends on fatal accidents in different intersections and segments in order to implement strategies to reduce fatal accidents on the roads.

INTRODUCTION

Puerto is a place with a very particular situation in term of traffic accidents. Our island is 100 miles long and 35 miles wide. We have 3.9 million people using a highway network of 14,781 miles. From those 3.9 millions, 59 percent are drivers and 2.2 million are drivers with license. The most shocking detail is that we have approximately 2.6 millions of vehicles registered in the *DTPW*. Is evident that with high vehicle density the probability of suffering an accident increases.

There are 219,000 reported accidents per year, with 54,000 injuries, and 575 fatalities average per year from 1995 to 2000. From those 575 average fatalities almost 33 percent are pedestrians. This percent is so high that there are almost as many pedestrians being killed than drivers. If we compare the 219,000 accidents reported with 575 fatalities per year, this is a very small percent. However, life is priceless and this is an issue we have to pay attention and work with.

This research tries to offer an overview of how critical fatal accidents are in Puerto Rico, and it is possible to identify hazardous locations. While examining and studying carefully the data files given by *TSC* we focus our attention on the PR-2 road. The analysis performed using the *Frequency Method* and the *Accident-rate Method* tries to give an idea of which are the most dangerous road sections on that particular road, that is by the way the most critical in Puerto Rico. There is no single solution for this issue. It is necessary to understand what is our situation in order to provide counter measures to reduce or prevent fatal accidents in Puerto Rico

OBJECTIVES

The analysis of traffic fatal accident data can be extensive and comprising. The scope of this research is limited to:

- Collect fatal accident data in Puerto Rico during years 1995 to 2000.

The research will be limited to analyze the data provided by the *TSC* during those years.

- Use statistical analysis and traffic safety methods to identify hazardous locations in the western and south regions of Puerto Rico with and emphasis on PR-2 road. The purpose of this analysis is to establish trends on fatal accidents in the study sites.

The PR-2 is the most important route in the western and southern regions. It comes from the Metropolitan Area to Aguadilla, and passing through Aguada, Añasco, Mayagüez, Hormigueros, San Germán, Sabana Grande, Yauco, Guayanilla, Peñuelas, Guánica, and Ponce.

- Provide a useful reference of statistics from 1995 to 2000 for future research on traffic safety.

The appendixes include statistics and charts on fatal accidents based on the data provided by the *TSC* that include all regions of Puerto Rico.

RESEARCH PLAN

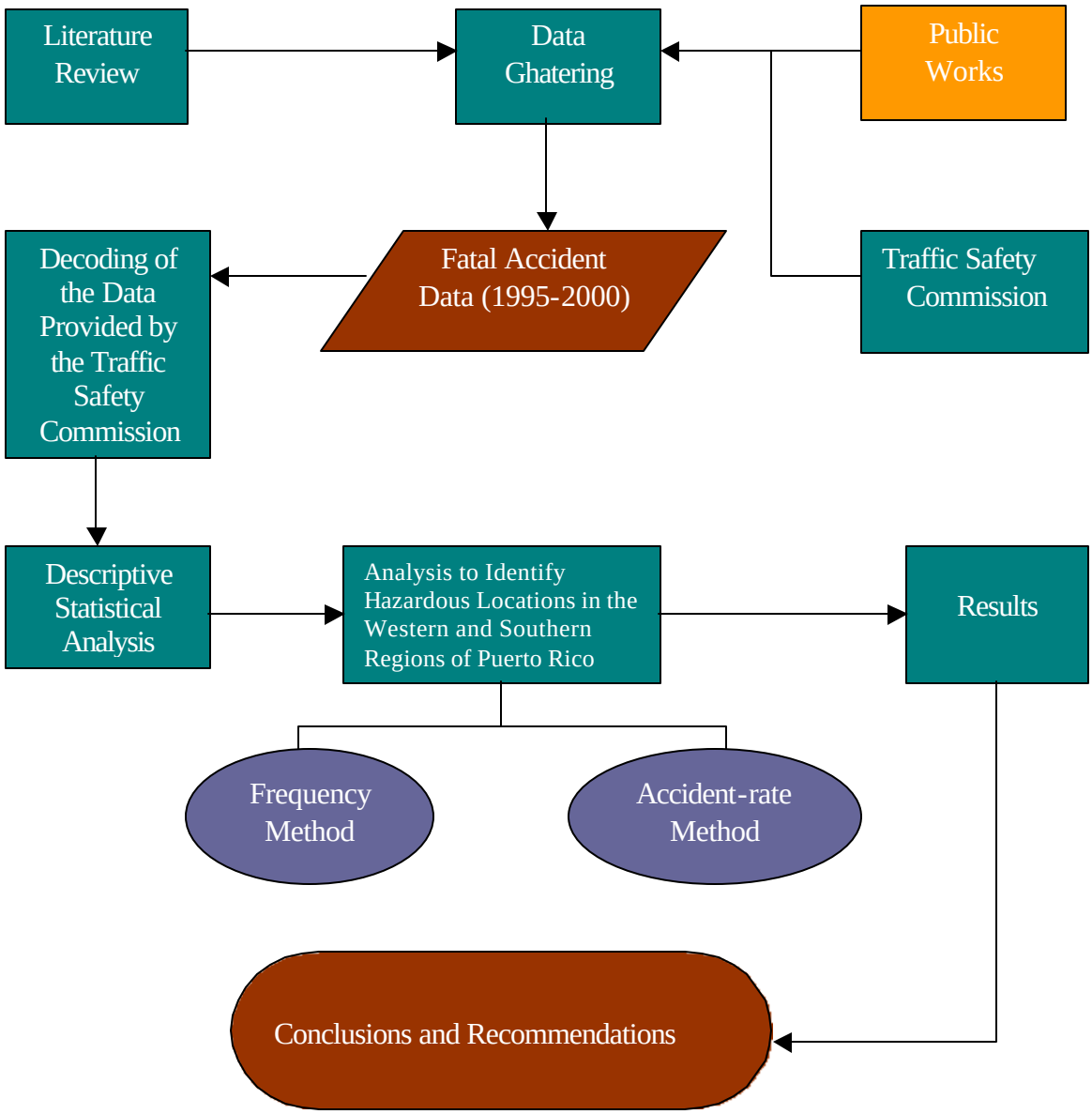


Fig.1 Research Plan Flowchart

LITERATURE REVIEW

Literature review on Traffic Safety has been important to identify the factors that may cause a fatal accident. The growing population in the United States and Puerto Rico increases the exposure to car accidents. Those accidents are described by the *Traffic Safety Toolbox* as complex because of the many factors that may be involved in a single fatal accident. That is why this engineering branch is continuously improving their methodologies and the management systems, because of the complexity of the problem.

There are three major reasons for analyzing traffic data: (1) to identify accident patterns that may exist in a specific region of interest (2) to determine the probable causes of accidents with respect to drivers, highways and roads, vehicles, and (3) to develop countermeasures that will reduce the rate and severity of accidents[1]. The identification of accident trends and patterns can be achieved by having access to the data that is continuously gathered by the different traffic security agencies. In Puerto Rico the *TSC* collects information from the police agencies. This data has mostly fatal accidents in a specific region. The commission organizes and keeps the data in a database that is connected to the *NHTSA* in the United States. Figure 1 and 2 shows an example of the type of data collected in the United States using *FARS*.

[1] ***The Traffic Safety Toolbox,*** Chapter 1, pag. 11-22

	DEATHS	%	CUMULATIVE %
Single Vehicle/Hit Fixed Object	12,331	27.6	27.6
Two Vehicle/Angle	7,489	16.8	44.4
Two Vehicle/Head-On	6,324	14.1	58.5
Single Vehicle/Hit Pedestrian	5,849	13.1	71.6
Single Vehicle/Overturn	4,008	9.2	80.8
Single Vehicle/Other	2,906	6.6	87.4
Multiple Vehicle	2,323	6.3	93.7
Two Vehicle/Rear-End	1,491	3.3	97.0
Two Vehicle/Other	1,378	3.0	100.0

Table 1 Fatal Accident Reporting System Data for the United States, 1990.

SAFETY MANAGEMENT

Figure 2. FARS data for the United States, 1990

National Statistics:

	2000	1999	1998	1997	1996	1995	1994
Motor Vehicle Traffic Crashes							
Fatal Crashes	37,409	37,140	37,107	37,324	37,494	37,241	36,254
Traffic Crash Victims							
Occupants							
Drivers	25,492	25,257	24,743	24,667	24,534	24,390	23,691
Passengers	10,669	10,521	10,530	10,944	11,058	10,782	10,518
Unknown	88	97	109	114	103	119	109
Nonmotorist							
Pedestrians	4,739	4,939	5,228	5,321	5,449	5,584	5,489
Pedalcyclists	690	754	760	814	765	833	802
Other/Unknown	143	149	131	153	154	109	107
Total	41,821	41,717	41,501	42,013	*42,065	41,817	40,716
Other National Statistics							
Vehicle Miles Traveled (Millions)	-	2,691,335	2,631,522	2,561,695	2,485,848	2,422,696	2,357,588
Resident Population (Thousands)	-	272,691	270,248	267,784	265,229	262,803	260,327
Registered Vehicles (Thousands)	-	212,685	208,076	203,568	201,631	197,065	192,497
Licensed Drivers (Thousands)	-	187,170	184,980	182,709	179,539	176,628	175,403
National Rates: Fatalities							
Fatalities per 100 Million Vehicle Miles Traveled	-	1.6	1.6	1.6	1.7	1.7	1.7
Fatalities per 100,000 Population	-	15.30	15.36	15.69	15.86	15.91	15.64
Fatalities per 100,000 Registered Vehicles	-	19.61	19.95	20.64	20.86	21.22	21.15
Fatalities per 100,000 Licensed Drivers	-	22.29	22.44	22.99	23.43	23.68	23.21

* Total fatalities for 1996 include 2 fatalities of unknown person type.

Figure 3. Data collected by the Fatal Accident Reporting System from 1994 to 2000.

The table in figure 1 explains that 80% of highway deaths were produced bye five types of crashes, being the most critical the *single vehicle/hit fixed object accident*. Once the data is revised, accident rates can be used to compare them with accident rates in other locations in a specific period of time.

The analysis can be done using various procedures. The *Frequency Method* uses traffic accident data to rank locations according to the number of accidents during a period of time. The accidents can be divided in different types, including fatal accidents. The second method is the *Accident Rate Method,* which can be divided for intersections and for road sections. The commonly used rate for intersections is the *rate per million of entering vehicles (RMEVs)* which is defined as:

$$RMEV = \frac{A * 1{,}000{,}000}{ADT*365}$$

where:

- *RMEV* is the accident rate per million entering vehicles
- *A* is the total number of accidents or accidents by type (single vehicle/hit fixed object) during 1 year at the location
- *ADT* is the average daily traffic times 365 days.

The rate used for road sections is the *accidents per million vehicle-miles of travel* (R_{se}) which is define as:

$$R_{se} = \frac{A*1{,}000{,}000}{(ADT*365*length\ of\ road)}$$

where:

- *A* is the total number of accidents or accidents by type during 1 year at the road section
- *ADT* is the average daily traffic times 365 times the length of the road.

These two rates can be used for other periods of time like days, or months. The third method is the *Frequency-rate Method*, which combines the *Frequency Method* with accident rates. A procedure is to plot accident frequency on the horizontal axis and accident rate on the vertical axis.[2]

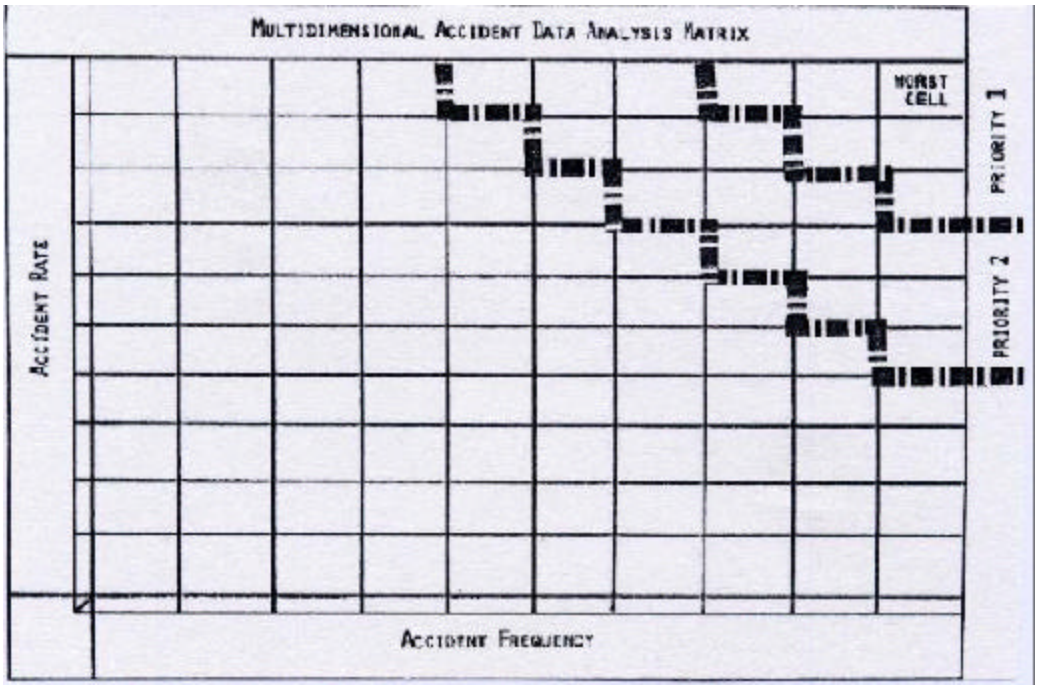


Figure 4. Frequency-rate Matrix.

[2] ***Transportation Engineering:*** *An Introduction, 2nd ed.*, Khisty and Lall, pp. 680, fig. 16-7.

The *Rate Quality Control Method* determines whether the accident rate for a particular location is significantly higher than a predetermined average rate for similar locations, which is define as follows:

$$R_c = R_a + K(R_a/M)^{1/2}$$

where:

- *Rc* is the critical accident rate for a spot or a section
- *Ra* is the average accident rate for all spots or sections with similar characteristics
- *M* is millions of vehicles passing over a spot (intersection) or million of vehicle-miles of travel over a section or road
- *K* is the probability factor determine by the desired level of significance.

A fifth method is the *Accident severity method* which is used to identify and rank hazardous locations where accident severity is classified as follows:

- *(F)* Fatal accident or deaths
- *(A)* Incapacitating accident
- *(B)* Noncapacitating accident
- *(C)* Probable injury
- *(PDO)* is property damage only.

Locations are ranked based on the *EPDO* factor which is define as:

$$EPDO = 9.5(F + A) + 3.5(B + C) + PDO$$

A sixth method is the *Hazard index*, which develops a rating index using a formula for each hazardous location. The seventh method is the *Hazardous roadway features inventory*, which compares highway and road features with safety and design standards previously defined.

All this methods have to be revised in order to identify the most suitable for our cases in Puerto Rico. Once the comparison were made it will be necessary to establish accident patterns. Accident patterns can be identified by a completed summary of accident data or using mathematical and statistical methods. This is necessary to locate hazardous zones such as intersections, basic segments on highways, or a specific line and direction on a road

Motorized vehicle crashes can be grouped into three major categories: (1) driver, occupant, pedestrian (2) highway, and (3) any failure in the vehicle. The most critical category is the one that involves directly the driver. The driver has the major responsibility with the vehicle he is in control. In this category we could find many important factors such as: speed, age, alcohol, drugs, unbelted drivers, reckless and visually or physically impaired. There are important facts that have been identified in the literature review in terms of speed, alcohol, and age. Speed is a major factor causing fatal accidents. The driver cannot control the vehicle efficiently at high speeds, and there is not enough time for proper reaction and action to any situation on the road. The case of bwer

speeds is equally dangerous because the possibility for an accident increases when a vehicle tries to pass another car going at lower speed invading the other line.

Statistics in Puerto Rico for year 2000 reflect that 36% of dead drivers in car accidents were people between 15 and 25 years old, and 15% were drivers between 15 and 20 years old. Between 15 and 25 years old, 41% were drunk, and 15% were using other drugs. Alcohol and drugs affect the senses of any driver. In 1990, according to *FARS*, 60% of the single vehicle/hit fixed objects, 55% of single vehicle/overturn, and 37% of two vehicle/head-on crashes involve alcohol.[3]

The second major category involves the design characteristics of the highway or road. There are also many factors like warning signs, delineation, the distance of warning signs from intersections, the geometry conditions of the highway, and the friction between the wheels and the road surface. Warning signs are very important because they provide information for the security of the driver and pedestrian. They communicate knowledge to the driver about how they have to operate their vehicles, like a "reducing speed" sign or "stop" sign. Deficiencies in sign improvements can cause accidents. Traffic signing is the third most cost-effective highway improvement that can be done for reducing accidents on highways and roads. The distance of one of a warning sign from the intersection is significant because the driver needs a certain amount of time for reaction.

The geometry conditions on the road can be critical. On highways, there must be a transition zone between the straight line and the curve known as spirals to prepare the driver for the change in the curve. Without this transition, the driver could loose control. Also, the geometry has to provide for low changes in velocity, not abruptly changes.

The type of material used on the road influences friction between the road and the wheels of the vehicles. The type of aggregates used on the paviment, or the roughness of the surface, and the wet surface during rainy days could reduce the coefficient of friction, which could cause a fatal accident.

The failures on the vehicle can be unpredictable, and not all vehicles perform the same way in the same situations. The *NHTSA* has data on many vehicles, such as trucks, cars sport utility vehicles, and how they perform in front, side, and angle collisions, including performance under rollover accidents.

All methods of analysis already mentioned will no be used in this research. The *frequency method* and the *accident-rate method* are going to be used as previously specified in the Research Plan Flowchart.

[3] ***The Traffic Safety Toolbox,*** Chapter 1, pag. 11-22

V. DECODING OF THE TSC DATA

Characteristics of the *TSC* Fatal Accident Files from 1995 to 2000

The *TSC* files from 1995 to 2000 on fatal accidents were obtained in ASCII format in Spanish language. The use of a WordPad was necessary to read the files. The data is divided in lines in which every single one is a fatality. This means that there are more than one fatality in accidents in which many people were involved. When the files are opened using a WordPad there are six groups of data.

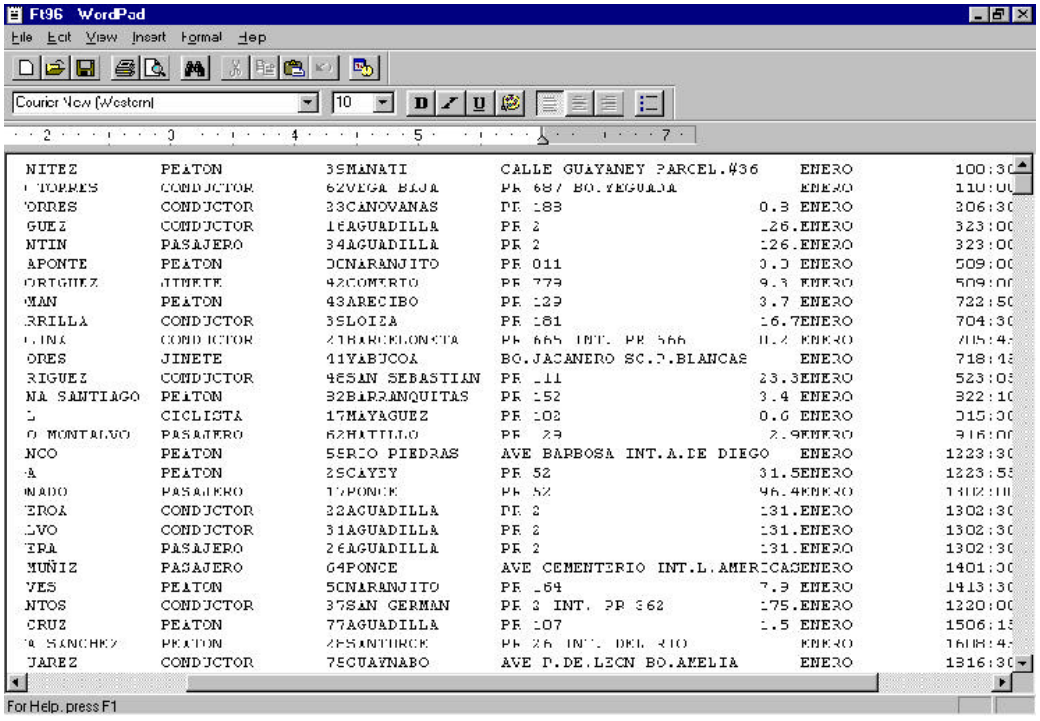


Fig 5. TSC Data sample (1996)

These groups are sub-divided in eighteen categories, which are described below using a legend given by the *TSC*.

- The first two numerical spaces represent the number of the accident reported in the year. When the same number is repeated it means that those fatalities were reported at the same time because they were involved in the same accident. This is the first category.

```
6017                PASAJERO          54NAGUABO
6118                PEATON            60CAROLINA
6219                MOTOCICLISTA      22SANTA ISABEL
6347                PASAJERO          15CAROLINA
6448                CICLISTA          13VEGA BAJA
```

Fig 6. TSC Data. Categories from 1 to 6 (1996)

- The next two numerical spaces are the number of the accident reported per month. This numbers, as the other two on the first category follow an ascending order. In figure 5 the 19, and 47 are not part of the same order but they were reported as the 62 and 63 fatalities in the 1996. The fact is that those fatalities occurred in different months, therefore, the 17, 18, and 19 are from a different month than the 47, and 48, but they were reported as the 60, 61, 62, 63, and 64 fatalities in 1996.

- The third category is the name of the victim from spaces 6 to 35.

- The fourth category is the condition of the victim at the time of the accident (driver, passenger, pedestrian, motorcyclist, cyclist, and horseman).

- The next 2 numerical spaces represent the age of the victim (figure 5), which is the fifth category.

```
PR 31 INT. PR 971          FEBRERO      917:00  0 113 1 5 2 2
PR 3                 8.8   FEBRERO      713:58  0 1 9 2 3 0 2
PR 153               9.0   FEBRERO      412:30  0 1 1 1 7 0 2
AVE.SANCHEZ OSORIO         ENERO       2120:45  0 1 8 2 7 1 2
PR 155              66.2   ENERO        313:25  0 113 1 3 0 2
```

Fig 7. TSC Data. Categories from 7 to 18 (1996)

- The sixth category and the following 15th spaces are the name of the Municipality in which the fatal accident happened (figure 5).

- The next column offers information on the location of the accident by road. Following that column there are 4 spaces identifying the kilometer in which the accident occurred. These are the seventh and eighth categories.

- The next 14 spaces give information on the month.

- The following 9 categories are codified. The first 2 numerical spaces represent the day of the month. The next 6 characters represent time of the day. After the time of the day the next two spaces offer the *Blood Alcohol Content Index*.

- The next number represents the number of fatalities. If there are three victims on the same accident they will be represented by three lines on the file, but the number "3" is assigned to the first victim reported. The other two victims will have a "0" on those spaces.

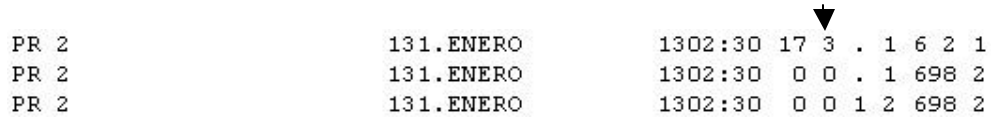


Figure 8. TSC Data. The number of fatalities on the same accident is assigned to the first victim reported

- The next category gives information on the type of infraction that was involved in the accident.

- The next numerical character represents the genre of the victim. These are just two numbers: 1 for male and 2 for female.

- The next category is the day of the week in which the accident occurred. This number goes from 1, which is Monday, to 7, which is Sunday.

- According to the legend provided by the TSC, these 2 spaces represent the number of injured people in the accident.
- The last category deals with the presence of drugs on the victim. This number is independent from the *Blood Alcohol Content Index* as we can see on figure 7.

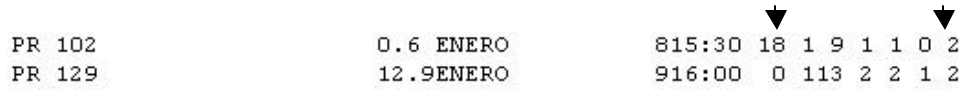
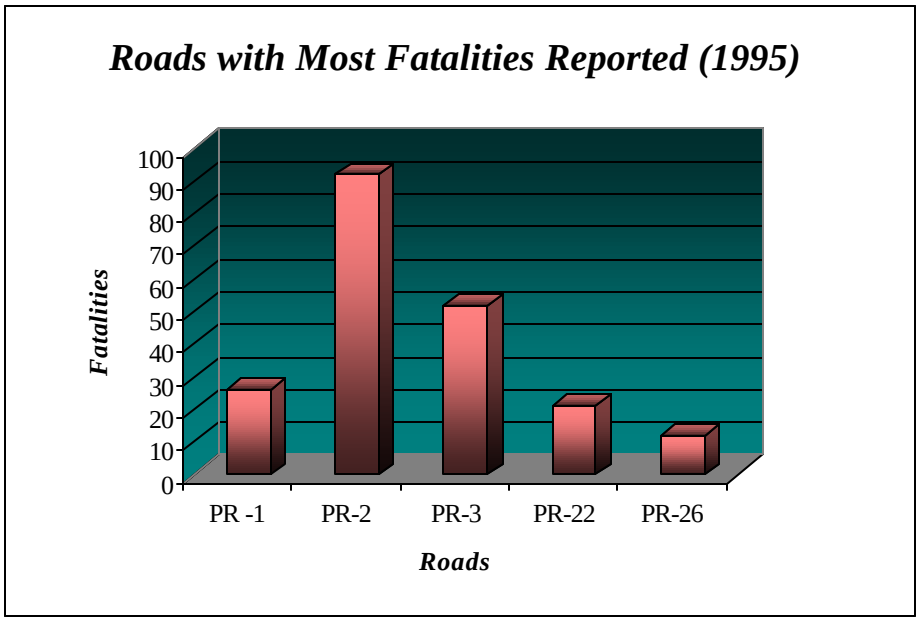


Figure 9. TSC Data. BAC and drug presence

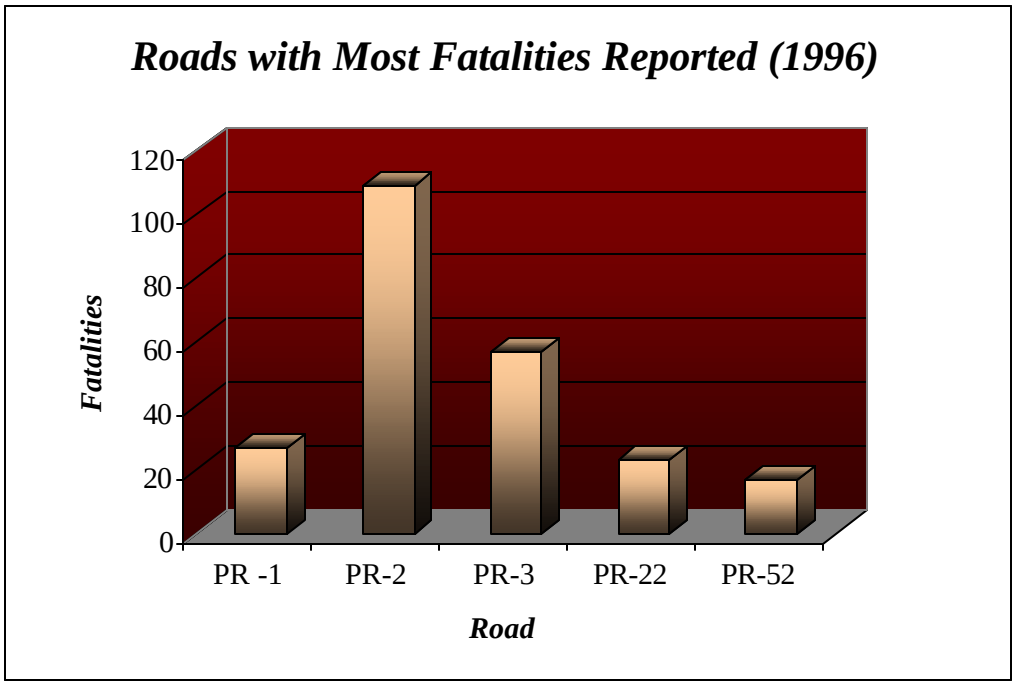
VI. DESCRIPTIVE STATISTICS

In order to identify hazardous locations it is necessary to identify those roads with a high accident frequency. The following charts provide the roads with most fatalities from 1995 to 2000. This analysis covers all region of Puerto Rico.



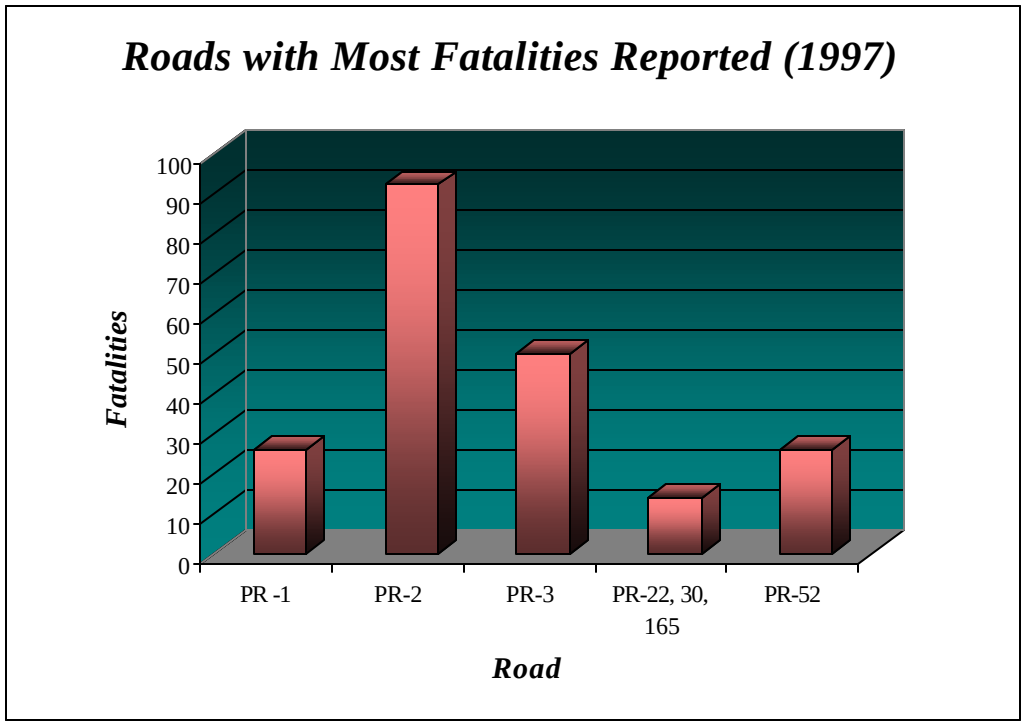
Roads with Most Fatalities Reported (1995)	
Roads	***Fatalities***
PR -1	26
PR-2	92
PR-3	52
PR-22	21
PR-26	12

Figure 10. Roads with most fatalities reported in 1995



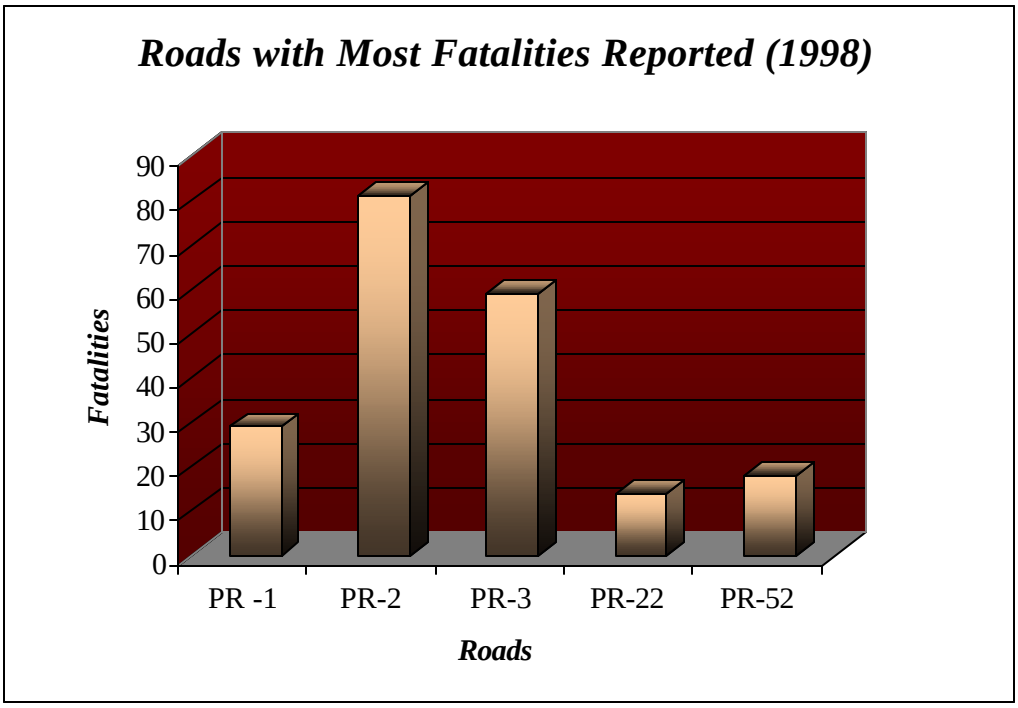
Roads with Most Fatalities Reported (1996)	
Roads	***Fatalities***
PR -1	27
PR-2	109
PR-3	57
PR-22	23
PR-52	17

Figure 11. Roads with most fatalities reported in 1996



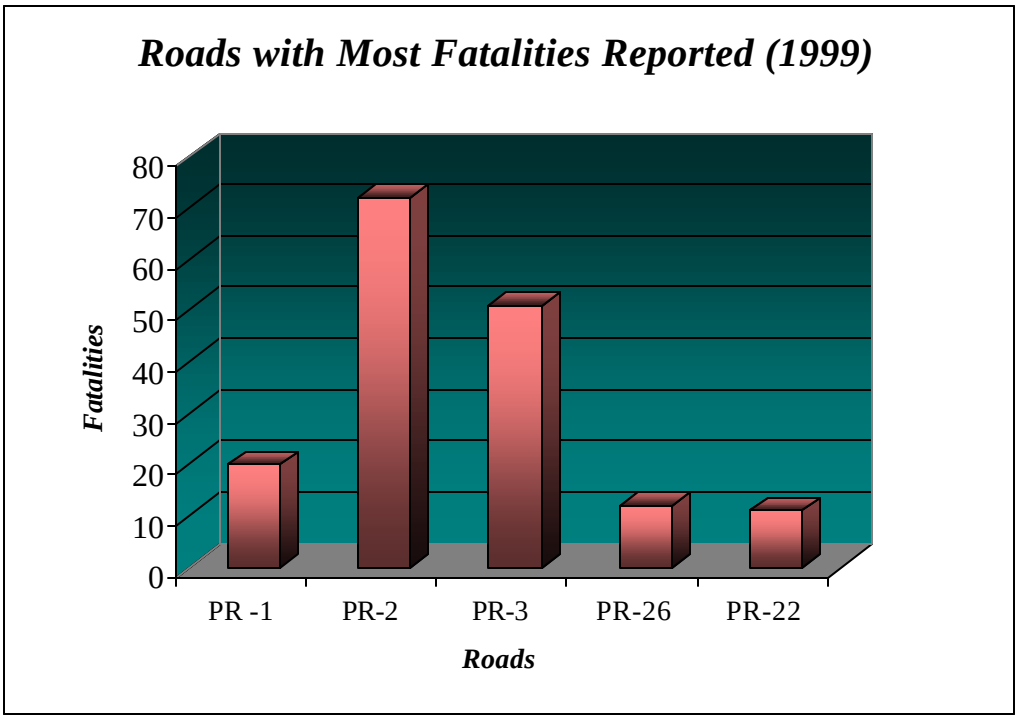
Roads with Most Fatalities Reported (1997)	
Roads	***Fatalities***
PR -1	26
PR-2	92
PR-3	50
PR-22, 30, 165	14
PR-52	26

Figure 12. Roads with most fatalities reported in 1997



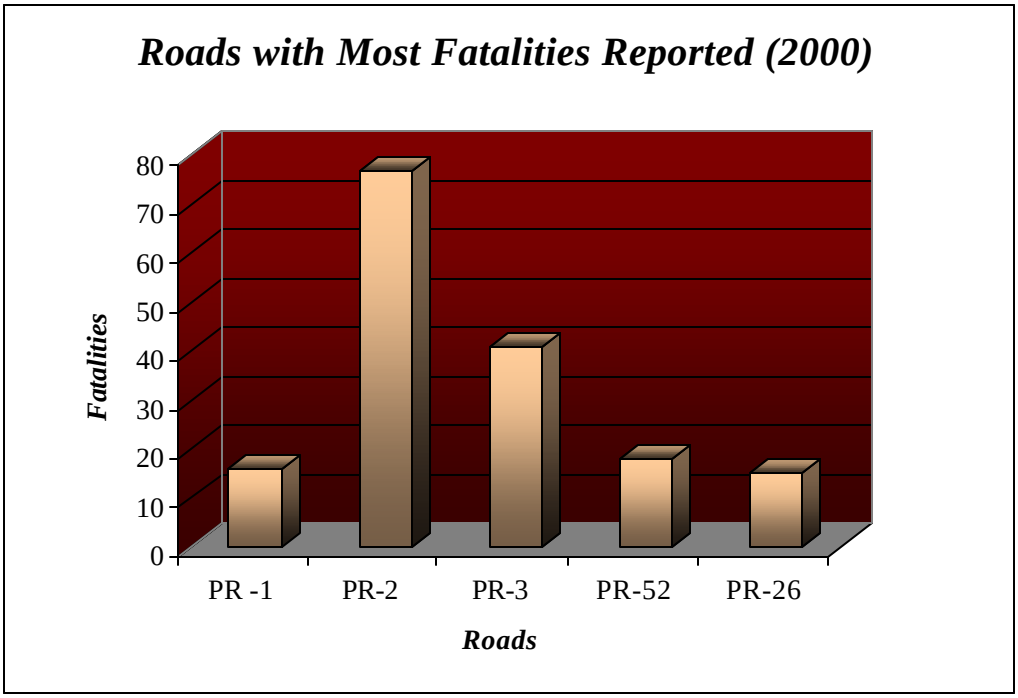
Roads with Most Fatalities Reported (1998)	
Roads	***Fatalities***
PR -1	29
PR-2	81
PR-3	59
PR-22	14
PR-52	18

Figure 13. Roads with Most Fatalities Reported in 1998



Roads with Most Fatalities Reported (1999)	
Roads	***Fatalities***
PR -1	20
PR-2	72
PR-3	51
PR-26	12
PR-22	11

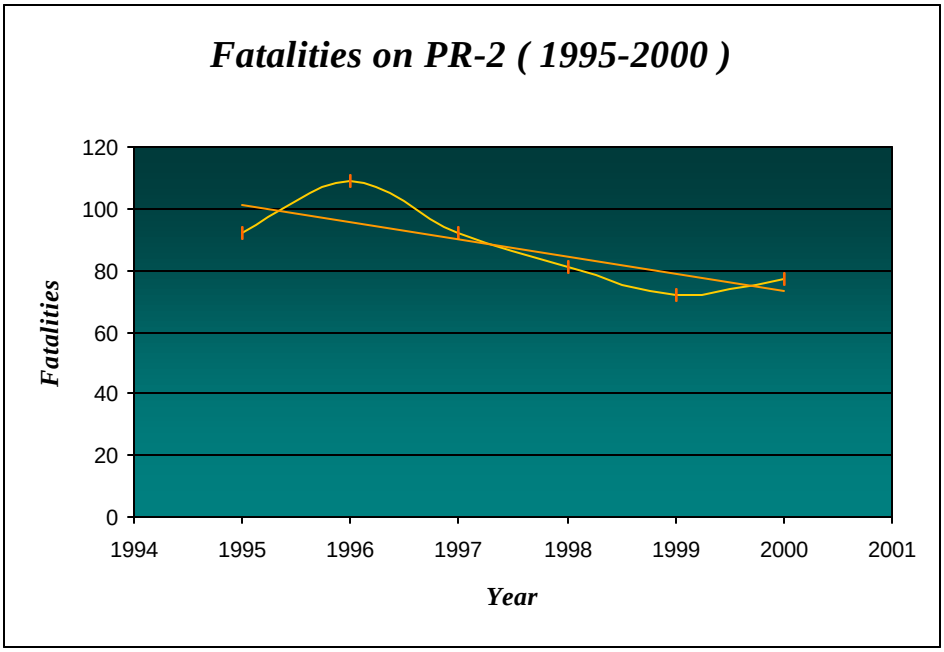
Figure 14. Roads with most fatalities reported in 1999



Roads with Most Fatalities Reported (2000)	
Roads	***Fatalities***
PR -1	16
PR-2	77
PR-3	41
PR-52	18
PR-26	15

Figure 15. Roads with most fatalities reported in 2000

Based on the information on these charts we can identify PR-2 as the road with the highest frequency of fatal accidents in Puerto Rico. This includes all regions from the Metropolitan Area to Ponce.



Fatal Accidents on PR-2 (1995-2000)	
Year	***Fatalities***
1995	92
1996	109
1997	92
1998	81
1999	72
2000	77

Figure 16. Fatalities reported on PR-2 from 1995 to 2000

Figure 14 shows that the number of fatalities reported raises from 1995 to a maximun value of 109 fatalities, and then goes down to a minimun value of 72 fatalities in 1999. The regression line has a negative slope indicating that the number of fatalities on PR-2 had a decreasing trend from 1995 to 2000. The mean for this distribution was 87.16 fatalities and the median was 86.5 indicating that the distribution is fairly uniform. The standard deviation was 13.38. Table 1 summarizes the descriptive statistics from figure 14.

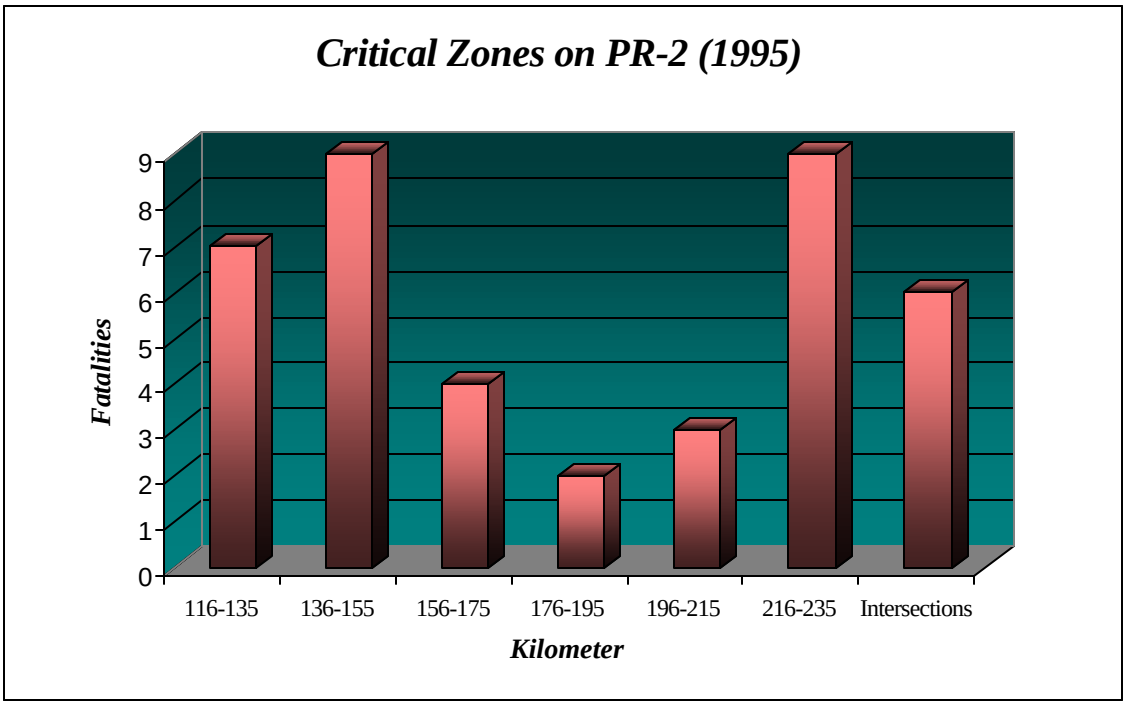
Descriptive Statistical Analysis	
Mean	87.17
Standard Error	5.46
Median	86.50
Mode	92.00
Standard Deviation	13.38
Range	37.00
Minimum	72.00
Maximum	109.00
Largest (1)	109.00
Smallest (1)	72.00

Table 1. Descriptive Statistics summary for Figure 14

VI. ANALYSIS TO IDENTIFY HAZARDOUS LOCATIONS IN THE WESTERN AND SOUTHERN REGION OF PUERTO RICO

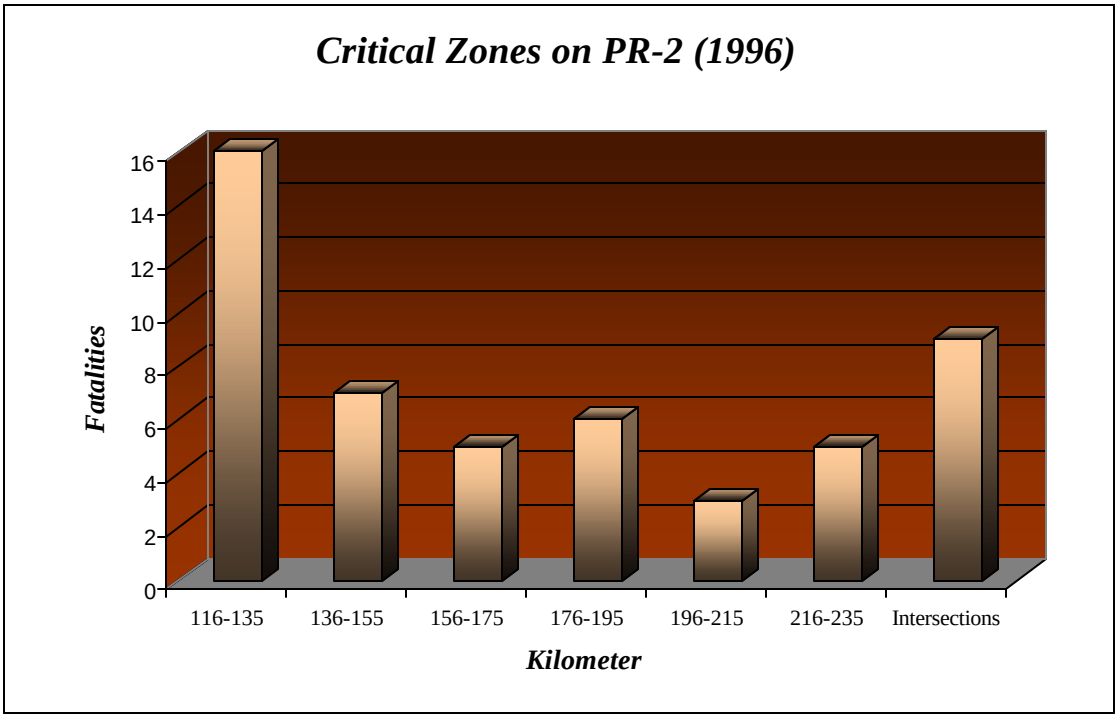
A. Frequency Method

The *Frequency Method* uses traffic accident data to rank locations according to the number of accidents during a period of time. The following analysis covers those fatalities reported from Aguadilla to Ponce. The road has been divided in 6 segments of 19 kilometers covering a distance of 115 kilometers. There is a seventh category for those fatalities that happened at intersections where the kilometer was not specified. The Municipalities shown in the tables are where the accidents actually occurred.



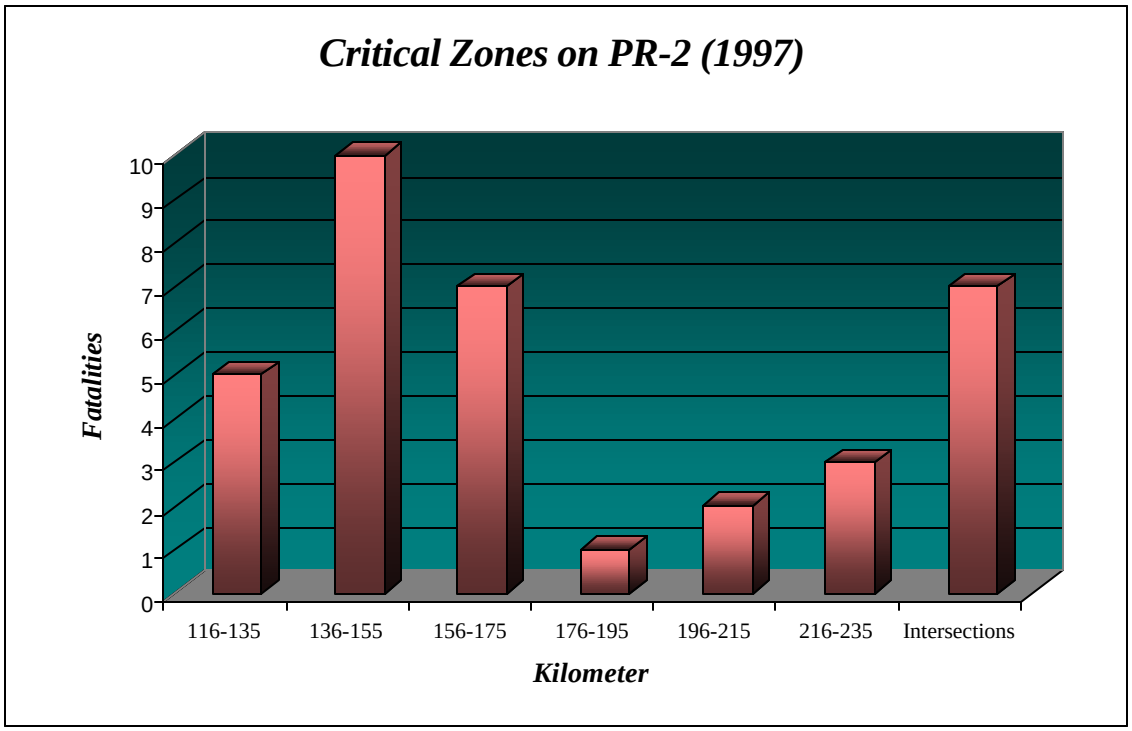
Hazardous Zones in PR-2 (1995)		
Municipality	***Kilometer***	***Fatalities***
Aguadilla, Aguada	116-135	7
Aguada, Añasco, Mayaguez	136-155	9
Mayaguez, Hormigueros	156-175	4
San German, Sabana Grande	176-195	2
Yauco, Peñuelas	196-215	3
Peñuelas, Ponce	216-235	9
Mayaguez, S. Germán,Ponce	Intersections (no km specified)	6

Figure 17. Critical Zones on PR-2 in 1995



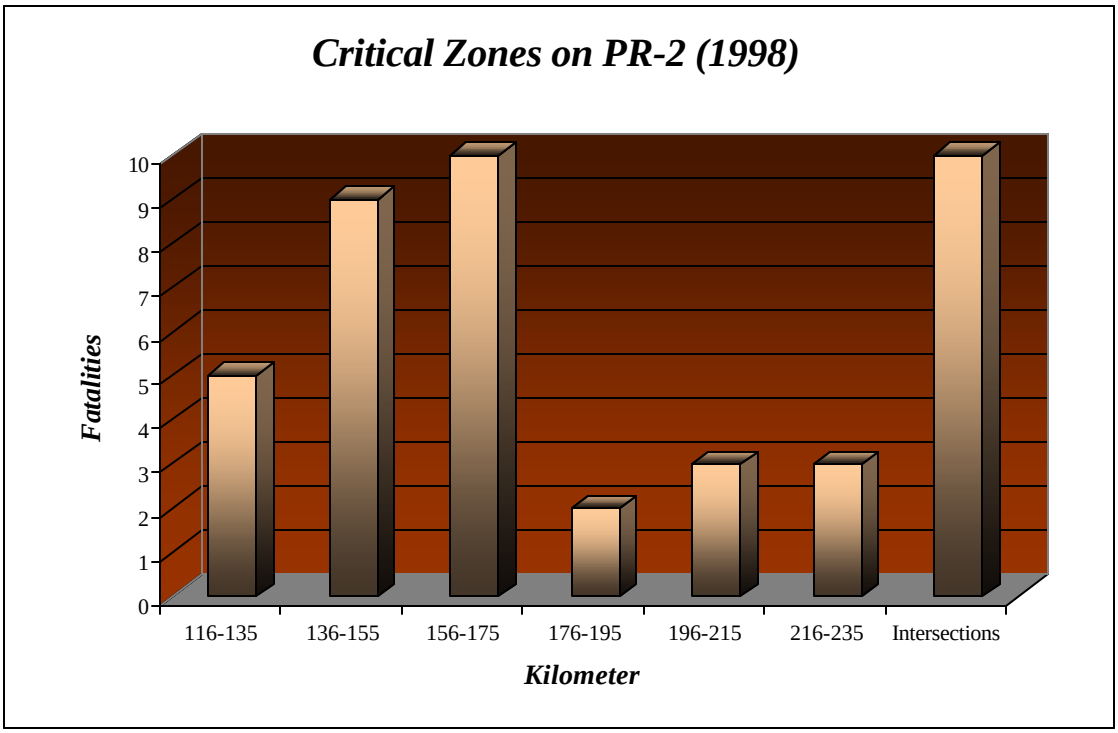
Hazardous Zones in PR-2 (1996)		
Municipality	***Kilometer***	***Fatalities***
Aguadilla, Aguada	116-135	16
Aguada, Mayaguez	136-155	7
Mayaguez, San German	156-175	5
San German, Sabana Grande, Guánica	176-195	6
Yauco, Peñuelas	196-215	3
Peñuelas, Ponce	216-235	5
Mayaguez, Aguada, S. Germán, Hormigueros, Ponce	Intersections (no km specified)	9

Figure 18. Critical Zones on PR-2 in 1996



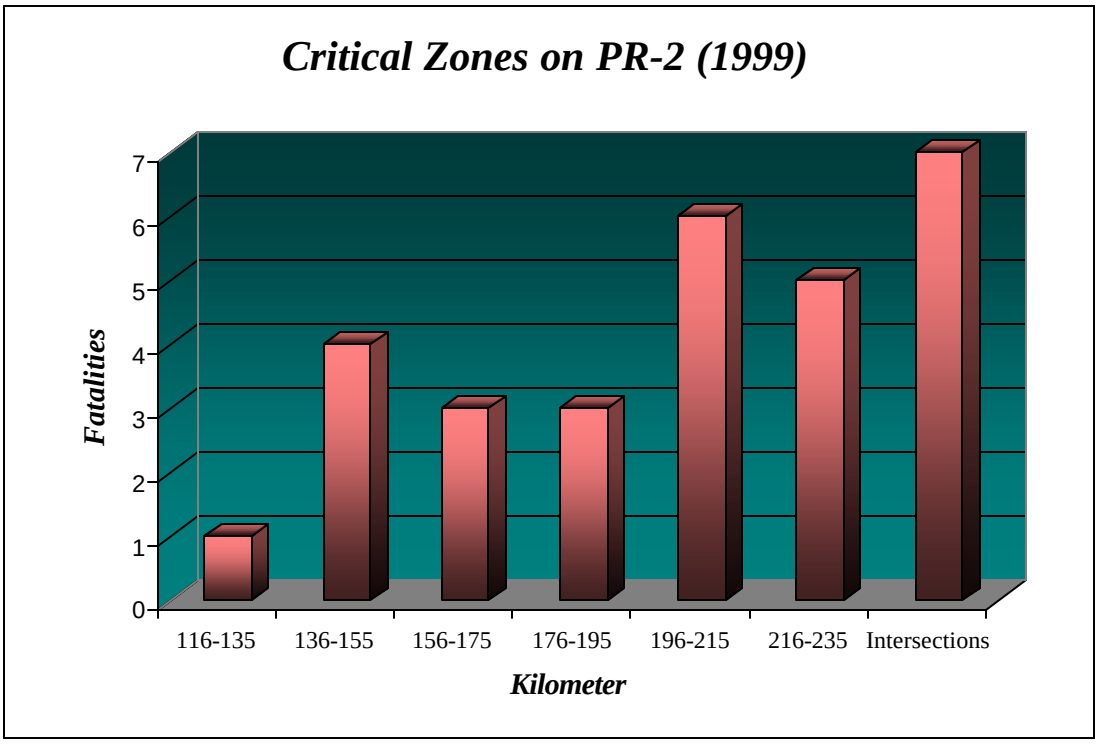
Hazardous Zones in PR-2 (1997)		
Municipality	***Kilometer***	***Fatalities***
Aguadilla	116-135	5
Añasco, Mayaguez	136-155	10
Mayaguez, San German, Hormigueros	156-175	7
Sabana Grande	176-195	1
Yauco, Peñuelas	196-215	2
Ponce	216-235	3
Mayaguez, Hormigueros, Ponce	Intersections (no km specified)	7

Figure 19. Critical Zones on PR-2 in 1997



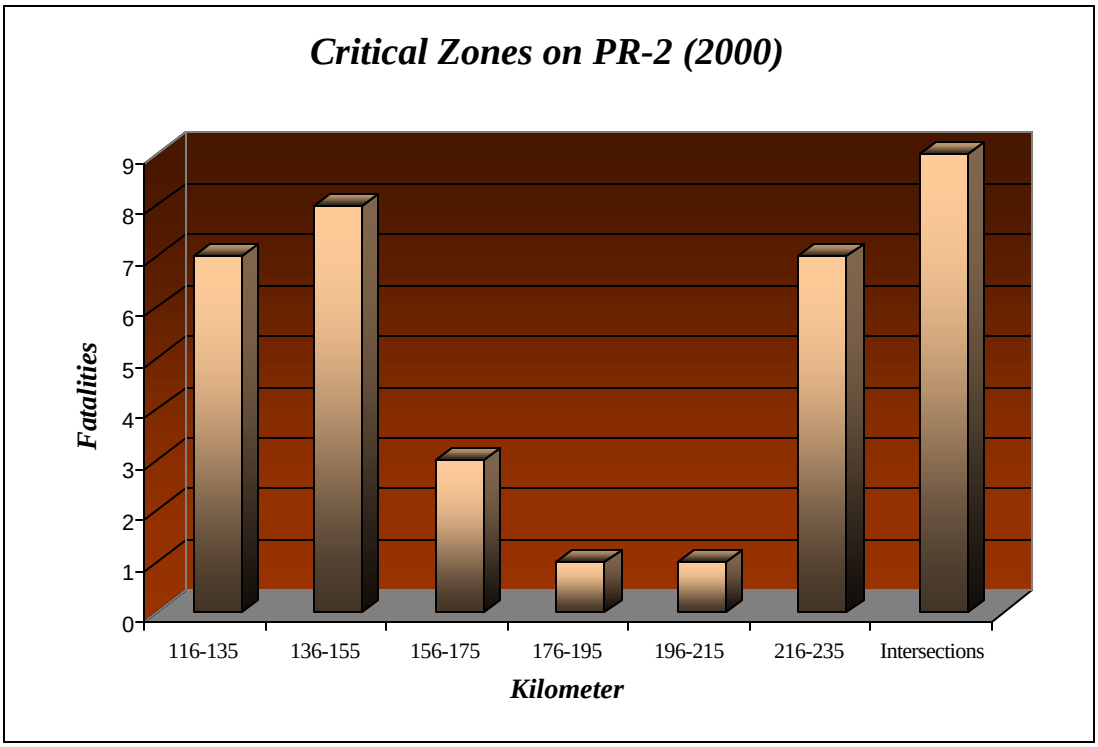
Hazardous Zones in PR-2 (1998)		
Municipality	***Kilometer***	***Fatalities***
Aguadilla	116-135	5
Añasco, Mayaguez, Aguada	136-155	9
Mayaguez, San German, Hormigueros	156-175	10
San Germán, Guánica	176-195	2
Peñuelas, Guayanilla	196-215	3
Ponce	216-235	3
Mayaguez, Hormigueros, Yauco, Ponce	Intersections (no km specified)	10

Figure 20. Critical Zones on PR-2 in 1998



Hazardous Zones in PR-2 (1999)		
Municipality	***Kilometer***	***Fatalities***
Aguadilla	116-135	1
Mayaguez	136-155	4
Mayaguez, Hormigueros	156-175	3
Guanica, Yauco	176-195	3
Guayanilla, Yauco, Ponce	196-215	6
Ponce	216-235	5
Mayaguez, Hormigueros, Ponce	Intersections (no km specified)	7

Figure 21. Critical Zones on PR-2 in 1999



Hazardous Zones in PR-2 (2000)		
Municipality	***Kilometer***	***Fatalities***
Aguadilla, Aguada	116-135	7
Añasco, Mayaguez	136-155	8
Mayaguez, San Germán	156-175	3
Guanica	176-195	1
Guayanilla	196-215	1
Ponce	216-235	7
Mayaguez, Hormigueros, Ponce, Añasco, San Germán	Intersections (no km specified)	9

Figure 22. Critical Zones on PR-2 in 2000

Ranking of Hazardous Locations in 1995		
Kilometer	Municipalities	Fatalities
136-155	Aguada, Añasco, Mayaguez	9
216-235	Peñuelas, Ponce	9
116-135	Aguadilla, Aguada	7
Intersections	Mayaguez, S. Germán,Ponce	6
(no km specified)		
156-175	Mayaguez, Hormigueros	4
196-215	Yauco, Peñuelas	3
176-195	San German, Sabana Grande	2
		total 40

Table 2. Ranking of Hazardous Locations in 1995

Ranking of Hazardous Locations in 1996		
Kilometer	Municipalities	Fatalities
116-135	Aguadilla, Aguada	16
Intersections	Mayaguez, Aguada, S. Germán, Hormigueros, Ponce	9
(no km specified)		
136-155	Aguada, Mayaguez	7
176-195	San German, Sabana Grande, Guánica	6
156-175	Mayaguez, San German	5
216-235	Peñuelas, Ponce	5
196-215	Yauco, Peñuelas	3
		total 51

Table 3. Ranking of Hazardous Locations in 1996

Ranking of Hazardous Locations in 1997		
Kilometer	Municipalities	Fatalities
136-155	Añasco, Mayaguez	10
156-175	Mayaguez, San German, Hormigueros	7
Intersections	Mayaguez, Hormigueros, Ponce	7
(no km specified)		
116-135	Aguadilla	5
216-235	Ponce	3
196-215	Yauco, Peñuelas	2
176-195	Sabana Grande	1
		total 35

Table 4. Ranking of Hazardous Locations in 1997

Ranking of Hazardous Locations in 1998		
Kilometer	Municipalities	Fatalities
156-175	Mayaguez, San German, Hormigueros	10
Intersections	Mayaguez, Hormigueros, Yauco, Ponce	10
(no km specified)		
136-155	Añasco, Mayaguez, Aguada	9
116-135	Aguadilla	5
216-235	Ponce	3
196-215	Peñuelas, Guayanilla	3
176-195	San Germán, Guánica	2
		total 42

Table 5. Ranking of Hazardous Locations in 1998

	Ranking of Hazardous Locations in 1999	
Kilometer	Municipalities	Fatalities
Intersections (no km specified)	Mayaguez, Hormigueros, Ponce	7
196-215	Guayanilla, Yauco, Ponce	6
216-235	Ponce	5
136-155	Mayaguez	4
156-175	Mayaguez, Hormigueros	3
176-195	Guanica, Yauco	3
116-135	Aguadilla	1
		total 29

Table 6. Ranking of Hazardous Locations in 1999

	Ranking of Hazardous Locations in 2000	
Kilometer	Municipalities	Fatalities
Intersections (no km specified)	Mayaguez, Hormigueros, Ponce, Añasco, San Germán	9
136-155	Añasco, Mayaguez	8
116-135	Aguadilla, Aguada	7
216-235	Ponce	7
156-175	Mayaguez, San Germán	3
176-195	Guanica	1
196-215	Guayanilla	1
		total 36

Table 7. Ranking of Hazardous Locations in 2000

In tables 2 to 7 the behavior of fatal accidents in the western and southern regions of Puerto Rico has been changing every year from 1995 to 2000. Intersections or those locations where no kilometer is specified finish with the top ranking in 1999 and 2000. On the other hand, kilometers 136-155 that cover Aguada, Añasco, and Mayagüez were the locations with the highest frequency of fatal accidents in 1995, and 1997. This particular location is very interesting because is the only one that is present in the *top three* in 4 consecutive years from 1995 to 1998, and again in 2000. A closer view to the Municipalities reveals that Mayagüez appears 12 times among the top three places, Ponce appears 8 times, and Aguada appears 7 times. The segment covering kilometers 116-135 is present among the top three places 3 times: in 1995, 1996, and 2000. In 1996 this road section finish first with 16 fatalities. An interesting detail is that the year with least fatal accidents reported was 1999 according to table 6, and this is the only year in which kilometers 136-155 did not appear among the top three places. In fact, this particular year kilometers 116-135 arrived in the last spot of the ranking. Those 2 road sections are continuous from kilometer 116 to 155. This analysis shows that 88 fatalities of 233 were reported in these 2 segments from 1995 to 2000. This represents approximately 38 percent of all fatal accidents reported in those 6 years. According to the frequency method kilometers 116 to 155 covering the municipalities of Aguadilla, Aguada, Añasco, and Mayaguez are critical. This analysis offers an idea of how important it is to provide adequate solutions to reduce the amount of fatal accidents on those locations.

B. Accident-rate Method

The *Accident-rate Method* can be used for intersections and for road sections. The commonly used rate for intersections is the *rate per million of entering vehicles (RMEVs)* which is defined as:

$$RMEV = \frac{A * 1{,}000{,}000}{ADT*365}$$

and he rate used for road sections is the *accidents per million vehicle-miles of travel (R_{se})* which is defined as:

$$R_{se} = \frac{A*1{,}000{,}000}{(ADT*365*\text{length of road})}$$

For this method the *average daily traffic* is needed. The analysis was done using accident-rate for road sections. Different ADT values were obtained for many road sections in 1999 and 2000 and are shown in table 8. For purposes of analysis an average of different ADT for continuous road sections is used as the *ADT* in the formula for road sections.

Kilometer	*Municipality*	*Description*	*Year*	*ADT*
119.75	Aguadilla	Entre PR-110 y PR-462	2000	36,100
121.60	Aguadilla	Entre PR-462 y PR-469	2001	37,600
121.70	Aguadilla	Este De Aguadilla	2000	44,800
125.25	Aguadilla	Entre PR-459 y PR-107	2000	50,800
125.36	Aguadilla	Entre PR-107 y PR-2R	2001	63,200
128.40	Aguadilla	Entre PR-2R y Ave. Juan J. Santos	2000	51,900
129.50	Aguadilla	Entre Ave. Juan J. Santos y PR-111	1999	39,800
130.20	Aguadilla	Entre PR-111 y PR-417	2001	36,100
134.10	Aguada	Entre PR-417 y PR-419	2001	38,300
138.30	Aguada	Sureste De Aguada	2000	39,800
141.50	Añasco	Entre PR-110 y PR-402	2000	40,800
154.70	Mayagüez	Entre Comienza Viaducto y Term.Viaducto	2000	46,700
154.80	Mayagüez	Entre Final Viaducto y Calle Cristy	1999	63,600
154.90	Mayagüez	Entre Calle Cristy y Calle Nenadich	2001	61,400
155.30	Mayagüez	Entre Calle Nenadich y Calle Duscombe	1999	71,400
156.10	Mayagüez	Entre Calle Duscombe y Calle Carolina	1999	69,100
157.65	Mayagüez	Entre Calle Carolina y Calle Post Sur/PR-2R	1999	75,100
202.80	Guayanilla	Limite Municipal Yauco-Guayanilla	2000	37,800
204.35	Guayanilla	Al Sur Sector Guaydia	2001	37,800
206.00	Guayanilla	Sureste Puente Sobre/PR-127	2001	38,000
207.00	Guayanilla	Al este PR-127	1999	32,600
209.00	Guayanilla	Este Guayanilla	2000	34,700
213.40	Peñuelas	Entre PR-385 y PR-127	2000	45,400
221.70	Ponce	Al Oeste PR-52	2001	48,400
224.50	Ponce	Entre Calle Baramaya y PR-2R	2000	44,900

Table 8. ADT values for different road sections of PR-2

1. Analysis of PR-2, Mayaguez (1999)

a. Km. 154.8-Km. 157.65

1) ADT average

69800 veh/day

2) Rate per 100 million vehicle miles (RMVM)

RMVM = A*100,000,000/VMT

RMVM = 5*100,000,000/(69800*365*(157.65-154.8)*0.62137)

11.08221511 fatal/100 million veh/ mi

2. Analysis of PR-2, Mayaguez, Hormigueros, San Germán (1999)

a. Km. 151.60-Km. 173.00

1) ADT average

57223.1veh/day

2) Rate per 100 million vehicle miles (RMVM)

RMVM = A*100,000,000/VMT

RMVM = 11*100,000,000/(57223.08*365*(151.60-173.00)*0.62137)

2.834107852 fatal/100 million veh/ mi

3. Analysis of PR-2, Aguadilla (2000)

a. Km. 121.70-Km. 128.40

1) ADT average

49166.7 veh/day

2) Rate per 100 million vehicle miles (RMVM)

RMVM = A*100,000,000/VMT

RMVM = 4*100,000,000/(49166.67*365*(128.40-121.70)*0.62137)

5.353912598 fatal/100 million veh/ mi

4. Analysis of PR-2, Aguadilla, Aguada, Añasco (2000)

a. Km. 119.75-Km. 141.50

1) ADT average

44033.3veh/day

2) Rate per 100 million vehicle miles (RMVM)

RMVM = A*100,000,000/VMT

RMVM = 8*100,000,000/(44033.33*365*(141.50-119.75)*0.62137)

3.683036449 fatal/100 million veh/ mi

5. Analysis of PR-2, Guayanilla, Peñuelas, Ponce (2000)

a. Km. 202.80-Km. 224.50

1) ADT average

40700 veh/day

2) Rate per 100 million vehicle miles (RMVM)

RMVM = A*100,000,000/VMT

RMVM = 5*100,000,000/(40700*365*(224.50-202.80)*0.62137)

2.4961617 fatal/100 million veh/ mi

In 1999 the municipality of Mayagüez had a rate of 11.08 fatal accidents/100 million/veh/mi from kilometer 154.8 to 157.65. This is consistent with the results of the Frequency Method in which Mayagüez appeared 12 times among the top three locations in the ranking for all 6 years. The municipality of Aguadilla ended with 5.35 fatal accidents/100 million/veh/mi from kilometer 121.70 to kilometer 128.40. If we examine part 2, 4, and 5 each one analyzes three municipalities. In year 2000 the road section covering Aguadilla, Aguada, and Añasco finished with 3.68 fatal accidents/100 million/veh/mi which is higher than 2.50 fatal accidents/100 million/veh/mi in Guayanilla, Peñuelas, and Ponce. In fact this is also consistent with the Frequency Method because fatal accidents from Aguadilla to Mayagüez has been more frequent than fatal accidents from Guayanilla to Ponce. From both methods we see that there is a trend of having more fatal accidents in the city of Mayagüez than a more populated city like

Ponce. Many would think that this is not logical, but according to table 8 if we compare ADT values in PR-2 on both cities, those of Mayagüez are higher.

CONCLUSIONS AND RECOMMENDATIONS

According to the overview of the situation in Puerto Rico that was presented in the introduction of this report, fatal accidents are a very small percent of all accidents that are continuously happening in Puerto Rico. However, almost six hundred deaths per year are significant for those families who suffer the consequences. The purpose of this project was basically identifying hazardous locations in the southern and western regions of Puerto Rico using two methods commonly used in traffic engineering. Using the *Frequency Method* we conclude that the road section going from kilometer 136 to 155 are the most critical. This location is the only one to appear in the top three locations with the highest frequency four consecutive times from 1995 to 1998. Another critical road section goes from kilometer 116 to 135, which is present in the top three critical locations for three years (1995, 1996, and 2000). This means that the PR-2 road section from Aguada to Mayagüez is the most critical in the western and southern regions of Puerto Rico according to the results obtained from the *Frequency Method*. The analysis points Mayagüez as the city with the highest frequency of fatal accidents in the western region.

The *Accident-rate Method* gave us interesting results. The road section going from kilometer 154.8 to 157.7 had 11.08 fatal accidents/100 million/veh/mi in 1999 which is high for a small road section. According with the analysis done with this method, in 2000 the road segment from Aguadilla to Añasco has a higher rate of fatal accidents than the road segment going from Guayanilla to Ponce. If we compare the Aguadilla-Añasco section to the Mayagüez-San Germán section the first one is more critical. We conclude the same with the *Frequency-Method*, that road section of PR-2

going from Mayagüez to Aguadilla is more critical than the road section going from Mayagüez to San Germán and Guayanilla to Ponce.

The reduction of fatal accidents in the western and southern region of Puerto Rico, specifically in the PR-2 depends highly in what kind of counter measures could be implemented from kilometers 116 to 155 from Aguadilla to Mayagüez. The analysis proved that those high numbers on fatal accidents in PR-2 from Aguadilla to Ponce depend enormously of this road section.

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c. National Center for Statistics and Analysis (NCSA)

http://www.nhtsa.dot.gov/people/ncsa.

d. Bureau of Transportation Statistics (BTS)

http://www.bts.gov

e. Fatal Accident Reporting System (FARS)

http://www-fars.nhtsa.dot.gov

APPENDIXES