Analysis of Road Traffic Accident Criticality in CALABARZON Philippines

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Abstract

This study explored the relationship of multiple factors on the criticality of road traffic accidents in CALABARZON Philippines. Five thousand data points from DOH hospital records were used to generate a statistical analysis that can interpret the relevance of each factor on road traffic accident criticality. The significance of each factor was verified through one-way ANOVA. The criticality of road traffic accidents is measured using mean and standard deviation. Results showed that large vehicle size is most likely to cause critical accidents. Driver's age is also a predictor of road accident criticality. It suggests that older drivers are more likely to be involved in critical road accidents than younger drivers. The criticality of road traffic accidents is also dependent on the congestion of the road. The highly congested road tends to limit the driving speed, which reduces the fatality of accidents. From these results, it is highly suggested to impose stricter traffic laws on vehicles that have a larger size. Also, this study recommends the renewal of a driver's license since age has a strong positive correlation with the criticality of traffic accidents. Overall, this study was able to predict the impact of each factor with the criticality of traffic accidents.

Keywords
Traffic Accident Criticality, CALABARZON, ANOVA, Multiple Regression

1. Introduction

Road Traffic Accident occurs when there is a collision of the vehicle with another vehicle, pedestrian, and animals, among others, which at times results in injury, loss of property, and death (Adebola et al., 2015). Approximately 1.30 million people around the world die every year due to road traffic accidents based on the 2018 global status report on road safety released by the World Health Organization (WHO). They predicted that by 2020, road traffic accidents would take the lives of around 1.9 million people annually. Moreover, it will be the second leading cause of disability-adjusted life-years lost in developing countries (Murray and Lopez, 1996). If no immediate and effective action taken by the end of 2030, according to (WHO 2018), road traffic accidents will become the eighth leading cause of death if the current data trend continues. In a review of global road accident fatalities conducted by (Thomas et al., 1999), Injuries and death due to road traffic accidents now acknowledged as a worldwide problem in all countries concerned with the increasing number of people seriously injured and killed on their roads. In recent years, there have been two significant studies of causes of death worldwide which have been published in the 'Global Burden of Disease' (1996, World Health Organization, World Bank and Harvard University) and in the 'World Health Report –Making a Difference' (WHO 1999). The published data related to road traffic accidents caused by death and disabilities were not significant due to various reasons. However, it also forecasted the 2020 number of deaths and disability-adjusted life years.

In the Philippines, motor vehicle traffic is predominant in the major islands (i.e., Luzon, Visayas, and Mindanao) due to the country's archipelagic nature and the fact that major cities and economic activities are located on these major islands (Villoria et al., 2000). According to Oxford (2018), the lack of land area for manufacturing set up and the worst traffic in Metro Manila has led the migration of the metropolis' manufacturing industry into the south. The beneficiary of this migration in investments has been CALABARZON, or Region IV-A, comprising the highly urbanized provinces of Cavite, Laguna, Batangas, Rizal, and Quezon.

CALABARZON has ranked itself as one of the industrial investment sites for the country and is home to the highest concentration of electronics, manufacturing activity with automotive industry assemblers predominantly located in Laguna, semiconductors, high-tech industries, and services in Cavite and Batangas, and garments manufacturers in Rizal. (Oxford, 2018).

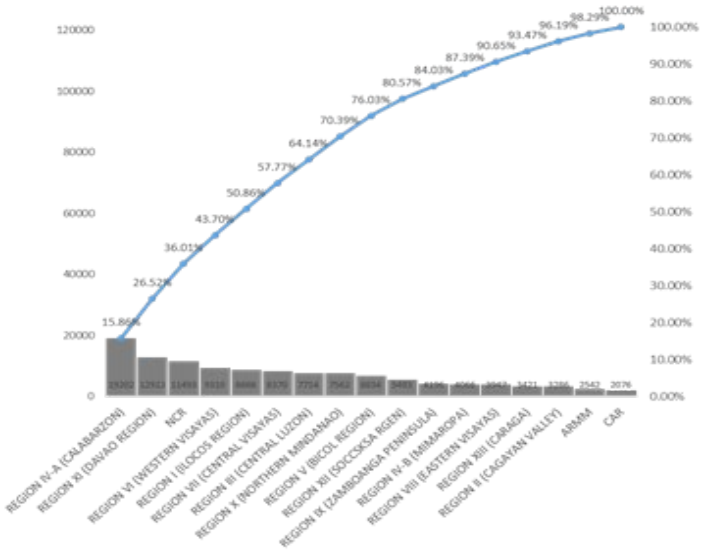

Fig. 1. Pareto Distribution of Accidents in the Philippines (2016 to 2018)

Developing regions such as CALABARZON have higher accident fatality rates, as presented in a Pareto chart in Figure 1. The National Capital Region (i.e., Metro-Manila) has relatively lower reported admission accident rates as compared to CALABARZON (DOH, 2018).

According to Jacobs et al. (1986), the increasing number of motor vehicles and more significant traffic volumes lead to many more opportunities for traffic road-crashes. The growth in motor vehicles that accompanies economic growth usually brings an increase in road traffic accidents (Elizabeth Kopits et al., 2005). In the 2017 study of World Bank on road traffic accidents, between 20 million to 50 million people are seriously injured. Road traffic injury is now one of the primary causes of death for children and young adults aged 5–29 years. It was ranked as the 8th leading cause of death for all age groups. The burden of road traffic injuries and fatalities is disproportionately borne by vulnerable road users, where the growing number of fatalities fuelled by transport that is increasingly motorized (WHO, Global Status Report on Safety 2018).

1.1 Objectives

This study aims to analyze the severity of injuries in motor vehicle accidents victims of the CALABARZON region. Accident severity occurring, according to (William and Roger, 1990), is generally expressed as the number of injuries and deaths. This study will help to give critical analysis from the contributing and determinant factors, the effects, and its threat to the people.

There are no studies yet in the CALABARZON region that focus on analyzing the criticality of the impact of injuries and fatalities caused by road traffic accidents. This paper intends to stimulate the region's awareness and the country's actions to improve road safety through the identification of critical gaps and opportunities. This paper aims to bridge the gap by providing knowledge on factors contributing to road traffic accidents.

2. Methods

2.1. Data Source

In this study, the researcher analyzed 19,202 reported hospital admissions caused by traffic accidents in CALABARZON from 2016 to 2018. However, several entries were incomplete, and only 5384 completed entries were utilized. CALABARZON consists of five provinces, namely; Calamba, Laguna, Batangas, Rizal, and Quezon. Table 1 shows the distribution of accidents per region.

Table 1. Distribution of Accident per Province.

Variable	Alive Conscious	Alive Unconscious	Dead	Grand Total
BATANGAS	1059	27	6	1092
CAVITE	1677	18	11	1706
LAGUNA	634	16	0	650
QUEZON	688	17	1	706
RIZAL	1206	18	6	1230
Grand Total	5264	96	24	5384

The dataset shows that there are enough cases to represent each province in CALABARZON. Cavite has the highest number of accident count among the other regions at 1706 cases of road traffic accidents from 2016 to 2018. Cavite also has the highest population among the different areas in CALABARZON at 3.7M measured last 2015. Laguna is known to have the least count of a road traffic accident at 650 cases. Rizal has the second-highest accident count at 1230 cases from 2016 to 2018. Rizal was known to have severe road conditions because of its location in the mountains. Table 1.1 also shows that 97.7% of accidents were not a deadline, and the victims often ended up alive and conscious. Only 0.45% of accidents result in death. Accident criticality can also be analyzed from the perspective of the victim involved. The dataset includes the gender and age of the victim. Table 2 shows the distribution of accidents per gender and age group.

Table 2. Distribution of Accidents per Gender and Age Group.

Category	Alive - Conscious	Alive - Unconscious	Dead	Grand Total
Female	1470	25	4	1499
AGE >61 yrs.	59	0	0	59
AGE 0~15 yrs.	185	0	0	185
AGE 16~21 yrs.	264	7	2	273
AGE 22~30 yrs.	436	6	0	442
AGE 31~40 yrs.	253	7	0	260
AGE 41~50 yrs.	184	3	2	189
AGE 51~60 yrs.	89	2	0	91
Male	3794	71	20	3885
AGE >61 yrs.	112	5	0	117
AGE 0~15 yrs.	270	5	1	276
AGE 16~21 yrs.	711	17	3	731
AGE 22~30 yrs.	1246	15	7	1268
AGE 31~40 yrs.	782	13	7	802
AGE 41~50 yrs.	426	8	1	435
AGE 51~60 yrs.	247	8	1	256
Grand Total	5264	96	24	5384

Gender and age of the driver can be a significant factor for accident criticality. In this study, there are 3885 (72%) cases of accidents where the driver is male, and 1499 (28%) cases were the victim is female. There are more male driver-related road traffic accidents since male drivers are prevalent. This study used the age bracket scheme suggested by Wu et al. (2016). Drivers age 16 to 21 years old cause most road traffic accidents for both male and female drivers. Overall, each category for gender and age group is well represented based on the number of cases available for each. This study will conduct statistical analysis to root out significant factors to accident criticality based on gender and age. Aside from geographic location and driver's age and gender, this study will also analyze the effect of time and day on the criticality of the accident. Table 3 shows the distribution of the day and time of the accident.

Table 3. Distribution of Accidents per Day and Time

Category	Afternoon	Early Night	Late Night	Morning	Grand Total
Sunday	339	263	221	262	1085
Monday	229	151	192	205	777
Tuesday	196	142	134	189	661
Wednesday	202	166	104	169	641
Thursday	180	157	128	198	663
Friday	226	154	142	185	707
Saturday	279	234	133	204	850
Grand Total	1651	1267	1054	1412	5384

Each category of day and time is well represented with enough cases to represent each category. From Table 3, it can be observed that Sunday has the greatest number of accidents at 1085 cases in CALABARZON from 2016 to 2018. Wednesday has the least amount of accidents at 641 cases. There may be factors each day that affects the concentration of accident in a single day. From the time-based perspective, most accidents happen during the afternoon with 1651 cases, and the safest time to drive is during late-night with only 1054 cases of road traffic accidents. Category of the time was adapted from Wang et al., (2019) in the afternoon at 12:00 to 18:00, early night at 18:00 to 00:00, late-night at 00:00 to 06:00, and morning at 06:00 to 12:00. From the dataset, a conclusion can be derived based on the criticality of accidents concerning date and time. Lastly, this study aims to analyze the road traffic accident for the type of vehicle involved. The type of vehicle that caused the accident is a subject of investigation. Table 4 shows the distribution of accident count per vehicle type.

Table 4. Distribution of Accidents per Day and Time

Row Labels	Bus	Car	Jeepney	Motorcycle	Truck	Van	Grand Total
BATANGAS	1	32	28	1000	2	29	1092
CAVITE	1	97	52	1523	0	26	1706
LAGUNA	3	30	26	573	1	17	650
QUEZON	3	27	17	624	1	34	706
RIZAL	0	64	64	1078	3	21	1230
Grand Total	8	250	187	4798	7	127	5384

Motorcycle accidents have the highest number of counts at a total of 4798 cases. Motorcycle accidents embody 89.12% of all accident records in CALABARZON from 2016 to 2018. The distribution of accident count per vehicle type is expected since there is a large concentration of motorcycle user in the Philippines (MMDA, 2018). However, this does not indicate those motorcycle accidents that are critical in hospital admissions.

2.2. Statistical Analysis

Road traffic accident criticality is scaled from 1 to 5, as suggested by Price and Mueller (1981). Doctors present at the hospital admission rate road traffic accident criticality. Table 5 explains the criticality of road traffic accident levels per each scale.

Table 5. Patient Condition and Road Traffic Accident Criticality Level

Criticality Level	Patient Condition
1	Minor scratches
2	Cut wounds and muscle bruises
3	Piercing injuries, bone fractures and dislocations
4	Serious injury resulting in disability
5	Serious injury resulting in death

This study aims to investigate the factors that affect road traffic accident criticality reported as descriptive indices such as frequency (percentage) and mean ±standard deviation. One-way ANOVA and multiple regression tested the associations between categorical factors in road traffic accidents such as gender and vehicle type. Chi-square statistics proved proportional differences in categorical measures. A P-value of less than 0.05 was considered significant. All statistical calculation is done on Minitab©. From the statistical results, this study draws conclusions that can be compared to related works of literature.

This study constructs a hypothesis based on an already known effect on accident criticality. The hypothesis is stated as follows:

H1: Male drivers have higher road traffic accident criticality than female drivers (Wu et al., 2016).
H2: There is a significant difference between road traffic accident criticality among different age groups (Adanu et al., 2018).
H3: There is a significant difference between road traffic accident criticality among different provinces in CALABARZON (MMDA, 2018).
H4: There is a significant difference between road traffic accident criticality among a different day of the week on which the accident occurs (Heydari et al., 2013).
H5. There is a significant difference between road traffic accident criticality among different times of day on which the accident occurs (Heydari et al., 2013).
H6. There is a significant difference between road traffic accident criticality among different vehicle types involved (Wang et al., 2019).

3. Results

3.1. One Way ANOVA

This study used one-way ANOVA to verify the relationship of accident criticality concerning categorical variables statistically. Table 6 shows a summary of the one-way ANOVA conducted for this study.

One-way ANOVA is showing that there is no statistical difference (p=0.451) between the criticality of a road traffic accident when the driver is either male (M=2.09, SD =1.31) or female (M=2.06, SD =1.38). Thus, we reject hypothesis 1. The stereotype that male drivers are better at driving than female drivers is not valid for this case study. Regardless of gender, age is still the identifier of accident criticality. The difference between which age group of the driver is statistically significant (p=0.001). Thus, we accept hypothesis 2 that states the considerable difference between accident criticality among different age groups. Data seems to follow an increasing accident criticality with increasing age group. The least critical accidents are from minors with ages 15 below (M=1.89, SD=1.28), while the most vital accidents are from senior ages 60 above (M=2.38, SD=1.36).

On the other hand, the province has a significant effect on accident criticality (p=0.005). Thus, we accept hypothesis 3 that states the significant difference between accident criticality among different provinces. Rizal has the least critical accidents (M=2.00, SD=1.26) among the regions of CALABARZON. Rizal has no statistically significant difference between the criticality of accidents in Cavite (M=2.07, SD=1.28), Batangas (M=2.08, SD=1.40), and Quezon (M=2.07, SD=1.32). The criticality of Rizal and Cavite accidents are statistically different between the accidents in Laguna (M=2.25, SD=1.42). Although Rizal and Cavite have the most cases of road traffic accidents, it does not mean that it has the most critical accidents. Laguna has the least amount of traffic accidents record, yet it is the province with the most critical accidents.

Table 6. One-way ANOVA of Road Traffic Accident Criticality

Variable	Category	Sample Size	-Value	Result	Group	Mean	SD
Gender	Female	1499	.451	NS	A	2.06	1.38
	Male	3885			A	2.09	1.31
Age in Years	15 below	461	.001	S	A	1.89	1.28
	16 to 21	1004			A, B, C	1.99	1.34
	22 to 30	1710			A, B, C	2.05	1.29
	31 to 40	1062			B, C, D	2.16	1.33
	41 to 50	624			B, C, D	2.19	1.38

	51 to 60	347			A, B, C, D	2.10	1.32
	60 above	176			C, D	2.38	1.36
Province	Rizal	1230	.005	S	A	2.00	1.26
	Cavite	1706			A	2.07	1.28
	Batangas	1092			A, B	2.08	1.40
	Quezon	706			A, B	2.07	1.32
	Laguna	650			B	2.25	1.42
Day	Wednesday	641	.028	S	A	1.93	1.21
	Thursday	663			A, B	2.04	1.30
	Sunday	1085			A, B	2.08	1.32
	Saturday	850			A, B	2.10	1.36
	Monday	777			A, B	2.11	1.33
	Friday	707			A, B	2.13	1.40
	Tuesday	661			B	2.16	1.33
Time	Morning	1412	.005	S	A	2.00	1.28
	Early Night	1267			A, B	2.06	1.30
	Afternoon	1651			A, B	2.09	1.34
	Late Night	1054			B	2.19	1.39
Vehicle	Motorcycle	4798	.082	NS	A	2.06	1.32
Involved	Van	127			A	2.13	1.30
	Jeepney	187			A	2.17	1.32
	Car	250			A	2.39	1.51
	Bus	8			A	2.41	1.43
	Truck	7			A	2.43	1.51

S = Significant NS = Not Significant

Day and time records of the accident are also statistically significant concerning accident criticality. Thus, we accept hypothesis 4 that states the significant difference between accident criticality among different days. Also, we accept hypothesis 5 that indicates the significant difference between accident criticality among different time groups. Wednesday is the safest day to drive. Wednesday has the least amount of road traffic accident records (N=641) and the lowest value of accident criticality (M=1.93, SD=1.21). The criticality level of accidents on Wednesday is statistically different (p=0.028) with Tuesday (M=2.16, SD=1.33). Weekly events happening during Tuesday and Wednesday should be investigated. This can be the basis to which the government can implement vehicle coding policies for a safer drive. One-way ANOVA result for a time of accident shows that that morning drive has the lowest criticality record (M=2.00, SD=1.28). There is no significant difference between the criticality of accidents in the morning compared to accidents at early night (M=2.06, SD=1.30) and in the afternoon (M=2.09, SD=1.34).

However, the criticality of accidents in the morning is statistically different (p=0.005) compared to the criticality of accidents at late night (M=2.19, SD=1.39). Based on the time-based result, the government can impose time-related traffic laws like truck bans at a specific period.

Lastly, results show that there is no statistical difference (p=0.082) on the criticality of the accident regardless of what road vehicle is involved. Thus, we reject hypothesis 6 that states a significant difference in accident criticality among different vehicle types. However, truck-related accidents are the most critical (M=2.43, SD=1.51). Motorcycle related accidents, on the other hand, are the least critical accidents on the road (M=2.06, SD=1.32). Even if motorcycle-related accidents are prevalent (N=4798), it does not necessarily indicate those motorcycle accidents are critical and fatal. Most motorcycle accidents resulted in minor injuries.

3.2. Correlation Analysis

Table 5 was able to identify variables that have a significant difference with each category. This study further analyses the relationship of each significant variable through Pearson correlation. Table 7 shows the correlation of significant variables with resulting P-Value.

Table 7. Correlation of Significant Variables.

Variables	Pearson Correlation	P-Value
Age	0.076	<0.001
Province	0.047	0.001
Day	0.044	<0.001
Time	0.048	<0.001

The result shows that all significant variables from ANOVA (Table 6) have a significant correlation with accident criticality. Each variable is ranked according to accident cases and compared it to accident criticality. Age has the highest correlation ($r=0.076$, $p<0.001$) among all variables, which implies an increase in accident criticality as the age of the person involved increases. The day of the accident has the lowest correlation ($r=0.044$, $p<0.001$) among all variables. However, the difference between the day of the accident is still significant. Province ($r=0.047$, $p=0.001$) and Time ($r=0.048$, $p<0.001$) closely follows having significant difference in accident criticality as the variable changes.

4. Discussion

This study aims to identify relevant factors that affect the criticality of road traffic accidents. The importance of this study is to be the basis of law enforcement in CALABARZON and other related cases.

4.1. Gender and Age

Male and female drivers do not have a significant difference in traffic accident criticality. Thus, the stereotype that male drivers are better at driving than female drivers is not valid for this case study. However, results show that there is still a slightly lower tendency of female drivers to have a critical accident. The results agree with Wu et al. (2016) that also found out that there is no significant difference in accident severity, but the probability of female drivers being severely injured is lower than male drivers when driving on unpaved surface roads. The result, however, disagrees with Morgan and Mannering (2011) that suggest a statistically significant difference between accident severity among male and female drivers. However, Morgan and Mannering conducted their study on a different cultural reference. Still, the gender difference in CALABARZON is not a relevant factor that determines accident criticality. Age however, has a strong relationship with road traffic accident criticality. The criticality seems to increase as the driver's age increases.

The result of regression shows a statistically significant relationship ($p<0.001$) between accident criticality and the driver's age. However, correlation ($r=0.08$) between the two variables is very low. Still, older drivers tend to have a more critical accident than younger drivers. The result suggests that there should be stricter laws governing drivers as their age increases. Zheng et al. (2020) pointed out that as a driver gains more experience in driving, they tend to be more complacent. Their lax nature causes vulnerability to road traffic accidents (Farradyne, 2000). Require seminars to drivers as their age increase should be able to keep them aware of the impending traffic accidents if they become too complacent. The government should impose earning points from seminars before the renewal of drivers. The Philippine Regulation Committee has used the same concept in the renewal of a professional license. Before you make the renewal of licenses such as an Electrical engineer or Teacher, the individual must earn points first through seminars and training. It ensures to refresh their knowledge to practice the profession.

4.2. Day and Time

The result of this study shows that both day and time are indicators of road traffic accident criticality. Results suggest that driving late at night has higher chances of a critical road traffic accident. According to Yu and Abdel-Aty (2013), there are higher chances of a severe road traffic accident when there is a free-flow condition with turbulence occurring at the downstream inner lanes. Roads late at night tend to be the least congested time of the day. Thus, there is smooth traffic flow. Critical accidents occur at vehicles that are driving at higher speeds (Tanishita and Wee, 2016), and adding the fact that most drivers than to be tired and exhausted late at night justify the criticality of the accident (Wu et al., 2016). Darker roads at night also increase the tendency of a road traffic accident to occur (Tanishita and Wee, 2016). Accidents during mornings are less critical since cars are driving at a slower speed because of traffic congestion. There is heavy traffic during the mornings because of the workers and employee travel time. Most records of traffic accidents during mornings that happened at low speed are often non-fatal (Yu and Abdel-Aty, 2013). The higher level of accident criticality is evident during Wednesdays for the same reason as traffic congestion. Wednesday has the

greatest number of cars on the road (MMDA, 2018), given that it is in the middle of the week. Thus, the vehicle tends to move at a slower speed because of traffic congestion. Since driving speed has a significant effect on the criticality of accidents, local government should impose stricter speed limits during late at night. Better illumination at night, especially at curvature, would also significantly decrease the criticality of accidents. Increasing lane number and median width could alleviate both weekend and weekday crash occurrence (Yu and Abdel-Aty, 2013). Traffic safety-based control strategies needs to be customized during weekends and weekdays. Traffic management should focus on solving queuing issues to decrease congestion. Also, the knowledge of the concentration of traffic accidents per day and time should be the basis on which the government should have better preparation for first aid and medical rescue.

4.3. A Vehicle Type

The most critical road traffic accidents are those that involve trucks while the least critical road traffic accident is with those involving a motorcycle. The results break the prevalent stigma that motorcycles are the most dangerous road vehicle. However, a motorcycle is still the highest contributor to road traffic accidents since it is the most common vehicle on the road. The result agrees from the study of Zheng et al. (2020), where they conclude trucks and bus accidents are 6.07% more intense than those involving only cars. Higher frequencies of severe injury would be more likely to occur for the segments with a higher percentage of heavy vehicles (Wang et al., 2014). Thus, the most devastating effect in such an accident is that the smaller cars may slide underneath the truck and get hit at the most vulnerable part. Traffic accidents involving large vehicles also tend to block more traffic lanes due to its weight and size (Chung and Recker, 2015; Uddin and Huynh, 2017). These types of accidents cause more traffic congestion, which is prone to more traffic accidents. Thus, there should be stricter road traffic laws governing heavy vehicles. To avoid the high criticality of car and truck collision, the government should impose to make under guards on trucks and set higher standards to make it more effective. There should be a whole new level of certification that proves a driver's eligibility to operate such heavy vehicles.

5. Conclusion

This study investigated relevant factors that affect the criticality level of road traffic accidents. Significant factors that affect the criticality of road traffic accidents were identified to be driver age, driving time, driving day, and province. Results showed that there is no significant difference between male and female drivers on the criticality of the accident. This study breaks the current stigma that female drivers are more likely to have a critical accident than male drivers. However, the driver's age proved to have a significant effect on the criticality of the accident. The regression analysis had verified that the criticality of the road traffic accident increased as the driver's age increased. Thus, there should be a stricter law that governs drivers with a higher age group. The government should impose driver license renewal while testing the capability of the driver. Other professions suggest mandatory seminars and pieces of training gain points for a driver's license renewal.

Time and Day are indicators of road traffic accident criticality. Critical accidents tend to occur late at night. Other literature suggests that late-night driving tends to have a smooth flow of traffic. Drivers tend to abuse the continuous flow of traffic and drive at a faster speed. Thus, accidents late at night tend to be more fatal. Traffic congestion also explains why Wednesday is the safest day to operate. The traffic flow is heavily congested during the middle of the week.

Road traffic accidents that involve motorcycles tend to be the least critical. It breaks the prevalent stigma that motorcycles are the most dangerous road vehicle. Moreover, accidents that involve heavy vehicles such as trucks and buses are the most critical traffic accident.

The government should reinforce law-governing traffic to reduce the number and criticality of accidents. Since driving speed was determined to have a significant effect on accident severity, the government should review the enforcement of operating speed, especially late at night, where there is a smooth flow of traffic. The government should treat the result as a warning to create and improve better roads for drivers. Since traffic congestion affects accident count, road widening and addition of lanes are highly encouraged, especially in highly dense cities such as Santa Rosa City in the province of Laguna.

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