Road Safety Management: Assessment of the Accident Severity of Identified Areas and Development of Accident Prediction Model in the City of San Fernando, Pampanga

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Abstract: - The urge to build a good and safe road infrastructure is one of the primary necessities of the government to provide what the community needs. However, according to the Department of Health (DOH), road accidents are still one of the leading causes of mortality in the Philippines. Specifically, the City of San Fernando, Pampanga (CSFP) is one of the places where the number of people killed or injured in car accidents has risen dramatically. The Department of Public Works and Highways (DPWH) states that poor data governance on road accidents is one of the country's biggest problems in addressing road safety. That is why this study determined the accident-prone barangays in the city through an accident severity formula that ranked the barangays from being the most to least severe, as presented by road accident mapping. Along with that is the accident prediction model that shows possible road accidents if the problems in the road transportation system remain unsolved. The study used a mixed-method research design in which a questionnaire was given to 385 respondents and treated by frequency and percentage count. The interview was given to three experts in the road transportation of CSFP, and answers were transcribed and content examined. The study's findings proved that the most accident-prone barangay that had the most severe road accidents in CSFP is Dolores. At the same time, there could be 4,696 road accidents in the city in the year 2032. The most common reason for road accidents is human factors, specifically disobedience to basic traffic rules. The city's conditions of road safety systems also contributed to the problem, as it was revealed that road signages, traffic lights, street lights, line markings, and roadways need to be maintained.

Key Words: — *Road Accident Severity, Accident Prediction Model and Mapping.*

I. INTRODUCTION

It is believed that technological advancement has dominated the history of transportation. The development of technology has enabled people to travel further distances and explore more areas.

However, before humans learned how to domesticate animals like horses and create wheel machinery that would be used for transport, people's only mode of transportation was to walk. It was way safer then since people had only one mode of transport that was not affected by different factors like speed. However, as the world becomes more developed, where human needs and wants often increase beyond what the local community could supply, the means of transporting goods and people from one place to another has become the demand of people, and that leads to what the present transportation system of the world has today. Since then, transportation has been one of the most significant factors that helps humans in daily life and has become the major contributor to the economic growth of people, communities, and the whole country.

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Road transportation is the most commonly used mode by people because of its accessibility to places where people usually go, such as work, school, market, etc. The urge to build a good and safe road infrastructure became one of the primary necessities of the government to provide what the community needs. In the latest update of the Global Economy, Singapore ranked first in Asia and the world for having the best and safest road infrastructure and system. On the 2022 statistics, Singapore's road traffic fatality rate significantly went down to 1.49 per 100,000 people garnering the lowest number of fatalities from road accidents since 1981. However, countries are all different; transportation problems vary from country to country depending on their social, economic, and political situations. In reality, thousands of people die due to road accidents every day, and millions of people spend countless hours in the hospital due to the severe results of these accidents. In India, it is estimated that 120,000 people die yearly, even though the country has only one percent (1%) of the world's motor vehicles. This makes India responsible for six percent (6%) of global traffic deaths (Jatinder Singh et al., 2015). Comparing this to the Philippines, based on the Philippine Statistics Authority (PSA), the country has a total of 107 million population, and there are 11.6 million motor vehicles registered in 2018 by the Land Transportation Office (LTO). Thus, as an area becomes more motorized, road traffic accidents also increase, resulting in a rise in deaths, injuries, and property loss (Abrigo et al., 2021). One of the cities in the province of Pampanga, which is found in the middle of the island of Luzon in the Philippines, the City of San Fernando, Pampanga is one of the places where the number of people killed or injured in car accidents has risen dramatically. Due to its location in the middle of Central Luzon, a great number of cars that are heading to neighboring provinces must travel through this region. When other factors, such as the population of the area, the road and traffic density, etc., are considered, the likelihood of a road accident rises along with the number of vehicles on the road grows. Due to this, extensive study must be done to properly solve the problem. The task of addressing the severe effect of traffic accidents has indeed been brought on by the growth in motor vehicles along with the extension of roads. Road accidents are a global catastrophe with an ever-increasing trend that threatens people's health, and their development has significantly impacted human capital growth in every country. As said by Shivamurthy et al. (2015), convenience is always the priority of people; thus, different types of vehicles were invented to help people to reach their destinations. Nevertheless, these inventions always have negative impacts. With the increase in traffic volume, road accidents occur more often and inevitably. This does affect not only the lives of the people, but also the economy, and an urgent call for a solution is needed to this problem.

There are numerous reasons for road accidents, including the driver's recklessness, unmaintained roads or routes, and a lack of road warnings and signage. Road warnings and signs give critical information that informs drivers about the condition of the approaching road, allowing them to plan ahead of time. According to the study of Bañares et al. (2018), the effectiveness of road warning signs determines road safety in terms of readability. Due to the prevalence of road accidents caused by human error and misunderstanding road warning signs, there is a need to evaluate and improve signals that drivers do not adequately understand. The use of road warning signs as an instrument to control, warn, and inform road users has become standard practice to maintain highway safety in general land transportation. It is planned to encourage road users, notably drivers, to exercise extra caution to reduce the number of accidents caused by human error. It is considered that traffic signs are effective when they demand attention, deliver a clear and concise message, and provide ample time for a correct response. In addition, as stated by the WHO (2022), inadequate law enforcement of traffic laws is also a significant factor in the continuous occurrence of traffic accidents. If traffic laws are not strictly implemented, drivers will not be encouraged to comply with these laws. The anticipated decrease in the number of accidents cannot be expected. Consistent monitoring and updating and available traffic enforcers in national and local places will help to reduce inevitable accidents on the road. Unsafe road design is also a reason for traffic accidents. In designing roads, the safety of all road users shall always be the priority. Sufficient facilities for pedestrians where people can walk, cyclists' lanes, and motorcyclists' lanes shall be distinguished properly to avoid collisions.

Given all the factors and reasons why road traffic accidents are continuously increasing, there is no progress in mitigating the risk and eliminating these accidents. One of the main problems is the need for comprehensive accident studies in the Philippines. According to the Department of Public Works and Highways (DPWH), poor data governance on road accidents is one of the country's biggest problems in addressing road safety. Data may be present and written in each area, but the proper evaluation needs to be done correctly to present clear and

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precise statistics that will show how severe and hazardous the road system is. That is why the use of accident severity analysis and accident prediction models would be a great instrument to show the reality of the road transportation system. According to Social Determinants of Health (2017), a crucial component of effectively managing and regulating road safety is providing precise estimates of the severity of traffic accidents. Automobile collisions are a substantial risk that has historically been associated with considerable monetary and human casualties. According to Eboli et al. (2020), reducing the severity of traffic-related injuries is one of the most effective ways to enhance highway safety. To reduce the number of people killed or injured in traffic accidents, numerous research studies have been conducted to identify the risk factors that can have a significant impact on the injury outcomes of traffic accidents. As reported by Tanprasert et al. (2020), a risky, accident-prone area of the road is referred to as a black spot in the study of road safety. It is an area where there have been at least three major accidents or five injury accidents within 100 meters in the previous three years. In order to reduce accidents, it is essential to pinpoint the area that needs to undergo the first action. Consequently, locating the so-called "accident-prone area" or risky locations must be the first goal. In addition, as reported by Gan et al. (2020), the prediction of traffic accident severity gives critical information to emergency responders for evaluating probable consequences and applying timely accident management techniques. However, interactions among people, vehicles, roads, and the environment play a significant role in the causes of traffic accidents. This study would be a great help to be a basis for mitigating the risk and eliminating road accidents. Along with this parameter is the accident prediction model, where a possible number of accidents will be forecasted to determine how severe the problem is and how it will affect the future. Since they have the capacity to determine both the frequency of occurrence of traffic accidents as well as the contributing elements that may then be addressed by transportation policy, models that anticipate traffic accidents are particularly helpful tools in the field of highway safety.

As stated by Viswanath et al. (2021), the number of accidents occurring on a daily basis is expanding at an alarming rate due to the exponentially increasing number of automobiles on the road. With the enormous number of traffic incidents and fatalities these days, the capacity to anticipate the number of traffic accidents over a given time period is critical for the transportation department to make scientific judgments. In this situation, it will be beneficial to examine the occurrence of accidents so that we can develop strategies to reduce them. Even though unpredictability is a characteristic attribute of the majority of accidents, there is a level of regularity that is observed over time when viewing accidents occurring in a specific location. This regularity can be used to make accurate predictions about accident occurrences in a given area and to construct accident prediction models. According to Yannis et al. (2016), the evaluation of road safety measures appears to be the weakest link in many countries' road safety management systems. Road authorities, road designers, and road safety practitioners require prediction tools, usually known as Accident Prediction Models (APMs), to examine potential safety issues, identify safety improvements, and estimate the potential benefit of these enhancements in terms of collision reduction.

II. METHODOLOGY

This section presents the methodology employed in the study including the design, sampling technique, research instrument, data collection, and data analysis and evaluation.

This study used a mixed-method research design. It was used to allow the researchers to look at various characteristics at once and to determine information about what is happening with the present population in connection with the road system of the City of San Fernando, Pampanga (CSFP). Quantitative research, more particularly a descriptive research methodology, was also implemented in this study to measure and analyze the variables using the numerical data that was acquired during the course of the investigation. According to Cristobal (2017), descriptive research design aims to observe and gather information on certain characteristics within a particular field of study. On the other hand, qualitative research, particularly a phenomenological study, was used to gather information from the people who can provide the richest insight. As stated by Husserlo (2015), phenomenological research methodology was used to capture the lived experiences of the participants and the essence of the phenomenon under investigation. It is a flexible, reflective, and iterative method for exploring lived experiences. The researchers used non-probability sampling; a technique that selects samples based on subjective judgment rather than random selection. Specifically, convenience sampling was utilized to identify the participants of the study for the survey questionnaire. While, purposive sampling was applied to identify the participants for the interview. In the study of Etikan (2016), purposive sampling is typically employed in qualitative

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research to identify and select the most information-dense cases in order to maximize the use of available resources. This entails the identification and selection of individuals or groups who are proficient and knowledgeable about a topic of interest.

The researchers also used Cochran's formula, which can be utilized when the population size is undetermined. As cited by Glen S. (2023), the Cochran formula permits the calculation of an optimal sample size given a desired level of precision, a desired level of confidence, and the estimated proportion of the population that possesses the attribute of interest. It is deemed particularly applicable in situations involving enormous populations and when the population is unknown. The formula of the equation is

$$N = \frac{Z^2 PQ}{e^2} \; ; \; Q = 1 - P$$

Where N is the sample size, Z is the value reliability level or significance level, P is the proportion of the population, and e is the desired level of precision or margin of error. The solution of the sample size is

$$N = \frac{(1.96^2)(0.5)(0.5)}{(0.05)^2}$$

It got a total sample size of 385 respondents who are passing through the City of San Fernando, Pampanga such as the drivers or motorist, commuters or pedestrians, and traffic enforcers. While for the survey interview, the researchers selected one (1) Registered Civil Engineer in the Department of Public Works and Highways Region III (DPWH), one (1) Registered Civil Engineer in the City Public Order and Safety Coordinating Office (CPOSCO), and one (1) police officer assigned in the City of San Fernando Police station who are expert in the field of road transportation of the city.

For the data analysis and evaluation of the study, Accident Severity Formula was used to identify the ranking of the barangays from being the most to least accident-prone. The formula is

AS = F (9) + I (3) + D (1)

Where AS is the accident severity, F is the number of fatal collisions, I is the number of physical injury collisions, and D is the number of property-damage only collisions.

For the Accident Rate Mapping, Quantum Geographic Information System (QGIS) was utilized for encoding the ranking data from the accident severity identification to create accident rate mapping. For Accident Prediction Model, Statistical Package for Social Sciences (SPSS) was used to create the accident prediction model using the time series

method obtained by measuring a single variable over time. The variables were from the number of accidents from the year 2013 to 2019. Forecasting was the chosen technique to produce traditional models. A linear trend was also selected to show the possible road accidents if problems in the road transportation system remain unsolved in the following years. SPSS was also applied to encode the answers from the survey. It was utilized to reveal the frequency count, percentage, valid percentage, and cumulative percentage of the responses of the participants.

III. RESULTS AND DISCUSSIONS

This section presents the results of the study obtained in accident severity equation and prediction that was achieved through the data that came from Pampanga Police Provincial Office City of San Fernando Police Station. It also shows the content examined results from the questionnaire and interview.

3.1 Road Accident Severity Identification and Ranking

Table.1. Accident Severity Ranking in the Barangays of the City of San Fernando, Pampanga

BARANGAY	FATAL COLLISIONS	PHYSICAL INJURY COLLISIONS	PROPERTY DAMAGE COLLISIONS	ACCIDENT SEVERITY (AS)	RANK
Dolores	7	65	479	737	1
San Jose	0	20	219	279	2
Sindalan	3	31	154	274	3
San Agustin	1	11	143	185	4
Telabastagan	0	29	80	167	5
San Isidro	3	14	66	135	6
Maimpis	1	8	86	119	7
San Nicolas	2	19	35	110	8
Del Pilar	1	15	47	101	9
Del Rosario	1	9	56	92	10
Santo Rosario	0	9	57	84	11
Santo Niño	2	12	28	82	12
Calulut	2	4	37	67	13
San Juan	0	7	41	62	14
Saguin	1	8	23	56	15
Dela Paz Norte	1	6	21	48	16
Malpitic	0	9	17	44	17
Baliti	0	6	20	38	18
Quebiauan	0	4	23	35	19
Del Carmen	0	4	14	26	20
Magliman	0	1	15	18	21
Santa Lucia	0	4	6	18	21
San Felipe	1	1	5	17	22
Juliana	0	2	9	15	23
Bulaon	0	1	8	11	24
Lourdes	0	0	7	7	25
Dela Paz Sur	0	1	1	4	26
Alasas	0	1	1	4	26
Lara	0	1	0	3	27
Malino	0	1	0	3	27
Pandaras	0	0	1	1	28
San Pedro	0	0	1	1	28
Santa Teresita	0	0	1	1	28
Panipuan	0	0	0	0	29
Pulung Bulu	0	0	0	0	29
TOTAL	**9**	**106**	**439**	**838**	

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Table 1 presents the result from the accident severity equation. This reveals the status of the different barangays in the City of San Fernando, Pampanga, from having the most severe rate of road accidents to least. In the formula, Barangay Dolores got a total accident severity rate of 737, ranking first for being the most accident-prone barangay in the city. While, Panipuan and Pulung Bulu got zero (0), which makes them the safest barangay in the city. To summarize, the top ten being the most accident-prone barangays are Dolores, San Jose, Sindalan, San Agustin, Telabastagan, San Isidro, Maimpis, San Nicolas, Del Pilar, and Del Rosario.

3.2 Road Accident Mapping
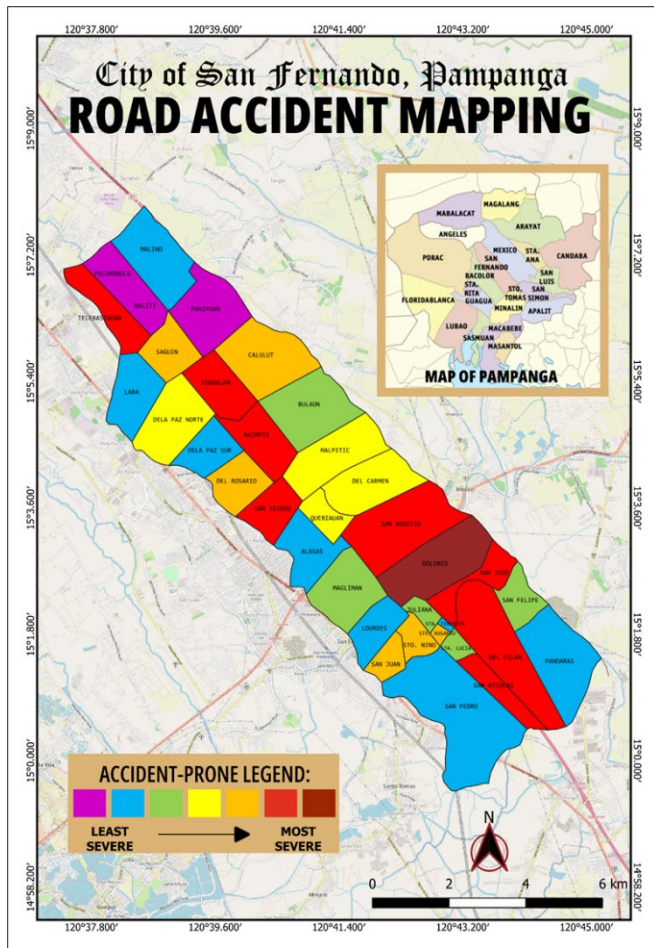
As presented in figure 3, the least severe road accidents in the city are Barangay Panipuan and Pulung Bulu, while the most severe road accidents is in Barangay Dolores.

3.3 Accident Prediction Model

Road accident data from 2013 to 2019 was used to forecast the city's and its top ten (10) most accident-prone barangays' possible traffic accidents for the next ten (10) years.

Table.2. Forecast of 10-Year Possible Road Accidents in the Barangays of CSFP

Top 10 Barangays	2023 Forecast
1.Del Rosario	1,361
2. San Jose	624
3. Sindalan	398
4. San Agustin	423
5. Telabastagan	312
6. San Isidro	171
7. Maimpis	204
8. San Nicolas	97
9. Del Pilar	138
10. Del Rosario	146

Table 2 exhibits the possible road accidents in the barangays of the City of San Fernando, Pampanga, if the problems in its road system remain unsolved. According to the data, road accidents could rise up to 1,361 in Barangay Del Rosario, 624 in Sn Jose, 398 in Sindalan, 423 in San Agustin, 312 in Telabastagan, 171 in San Isidro, 204 in Maimpis, 97 in San Nicolas, 138 in Del Pilar, and 146 in Del Rosario.

3.4 Discussion of Findings

This summarizes the findings of the study from accident severity computation, prediction of accidents, and the answers of the respondents from the questionnaire given to drivers or motorists, commuters or pedestrian, and traffic enforcers, as well as the interview given to selected registered civil engineers and police officer.

- The most accidents-prone barangay in the City of San Fernando, Pampanga that got the highest accident severity rate is Dolores, followed by San Jose, Sindalan, San Agustin, Telabastagan, San Isidro, Maimpis, San Nicholas, Del Pilar, and Del Rosario.
- If the problems in the entire city's road system remain unresolved, the number of road accidents could increase to 4,696 in ten (10) years. While the top ten

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- (10) barangays could see up to 1,316 accidents in Dolores, 624 in San Jose, 398 in Sindalan, 421 in San Agustin, 312 in Telabastagan, 171 in San Isidro, 204 in Maimpis, 97 in San Nicolas, 138 in Del Pilar, and 146 in Del Rosario, respectively.

- The accident rate in the City of San Fernando, Pampanga, is between moderate to high. This suggests that a substantial number of individuals are affected by this issue. Moreover, based on experience and what people perceive in the city, it was discovered that the rate of management is between fair to good.

- Human error accounts for the vast majority of road accidents. These factors include drivers or motorists as well as pedestrians or commuters who significantly contribute to the issue. External factors, such as the road system and the car, are also important and should be looked into. People's lack of attention to simple traffic rules and regulations, like not following road signs and markings, is the main reason for these accidents. In addition, the most common occurrence in the vehicle factor is the vehicle's brakes failing.

- Road signs in the city are in poor shape and are not adequately maintained, which contributes to the high rate of traffic collisions that occur there. According to Burch (2020), severe collisions on roadways can be worsened by a lack of signage and other essential traffic indicators, leading to driver confusion or a failure to warn them of potential hazards.

- Due to a lack of maintenance, some of the city's traffic lights are currently broken, which increase the risk of collisions on the roads. Traffic signals play a vital role in traffic movement every day. It prevents or lessens the possibility of car crashes and collisions on the roads, particularly the intersections. It provides a safe and efficient movement of vehicles on the roads and highways (Sanchez, 2019).

- There are street lights in the city that aren't working correctly and need to be maintained, which may be a contributing factor to the number of car accidents that occur in the area. Jividen Law Offices claimed that street lighting is crucial in helping to prevent car accidents. Without sufficient lighting, it is significantly more difficult for drivers to detect possible hazards on the road, traffic signs, other drivers, pedestrians, and bicyclists. Additionally, poor lighting could make some driving dangers worse.

- The condition of the traffic lines and lane markers in and around the city is not being adequately maintained. Road markings are crucial because they inform motorists where to stop, yield, or turn and the lane boundaries. Faded road markings can confuse drivers because they may not know where to stop or turn. Also, pedestrians won't be able to cross the street safely. These are due to traffic, weather conditions, and a lack of maintenance (Lining, 2014).

- The city's roads are likewise in poor shape because they are not properly maintained. Road maintenance is essential for keeping the road in its original condition, protecting nearby resources, ensuring user safety, and providing efficient and convenient transit. Unfortunately, maintenance is frequently neglected or poorly performed, causing the road to deteriorate quickly and eventually fail due to the impacts of both weather and vehicle use (Fao, n.d.).

- Experts reaffirmed that human factors and external factors are the leading causes of road accidents. In the city, undisciplined road users, such as those who disregard fundamental traffic laws and regulations, are a common occurrence, as are inadequate nighttime lighting and poorly maintained roads. It is believed that the problem stems from officials such as the Land Transportation Office (LTO) who fail to carry out their duties effectively. Officials were advised to rigorously enforce laws to reduce the number of careless drivers contributing to the problem. Investigate also the individuals known as fixers who construct illegal driver's license arrangements for financial gain. In addition, it was suggested that the Department of Public Works and Highways (DPWH) establish an alternate route when road construction is ongoing, as this can also lead to traffic and road accidents. The experts are confident that conducting more seminars and training for the public, particularly the offenders, will educate them on the issue and eventually reduce the number of accidents.

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The barangay that got the most severe road accidents in the City of San Fernando, Pampanga (CSFP) is Barangay Dolores, followed by San Jose, Sindalan, San Agustin,

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Telabastagan, San Isidro, Maimpis, San Nicolas, Del Pilar, and Del Rosario. The researchers discovered that the accident rate in the city is between moderate to high, while the management of road accidents is only fair to good, according to the respondents. The safety of any road transportation is directly correlated to the quality of its transportation system managers. They are the most important part of transportation, and it is their responsibility to ensure that the whole system operates effectively. In addition, most road accidents in the city are caused by human and external factors. Unruly road users, such as those who violate basic traffic rules and regulations, are extremely prevalent in the city. The number of road accidents could rise to 4,696 in ten (10) years if the issue with the CSFP road safety system is not resolved. Ignoring the proper implementation of solutions to the problems in a road transportation system would only exacerbate the problems. It can result in collisions that are much larger and more severe.

Roadways in the city need to be maintained; it was discovered that there are potholes and cracks, as well as uneven roads causing road accidents. Roads are one of the most significant public resources. Poorly maintained roads restrict mobility, drastically raise vehicle operating costs, and increase accident rates and their associated financial implications for humans and property. A well-planned program of maintenance must follow any road improvements. Without regular upkeep, roads may easily deteriorate, making it difficult to achieve the development benefits of improved roadways in the long run. The road safety systems of the city also need to be maintained; the road signages in the city are in poor shape and need to be sufficiently sustained, as well as the traffic lines and lane markings. Some traffic and street lights need to be fixed due to a lack of maintenance. Overall, it was revealed that these causes contribute more to the city's increased number of road accidents. Maintaining road safety systems is very important to prevent the increase in road accidents. These are the most dependable control mechanisms that can be employed to direct the flow of traffic and pedestrians in a safe and orderly manner. Most of these safety systems are regulated and standardized by the Department of Public Works and Highways (DPWH); the policy of the state is put into effect by the DPWH, which is responsible for ensuring that all infrastructure facilities are safe and that all public works and highways are constructed with the best level of efficiency and the highest level of quality that is appropriate. With that being said, officials should take a look at these problems and reassess what is lacking with those parameters that need improvement. Moreover, DPWH must establish an alternative route whenever there is road construction to lessen traffic and road accidents.

4.2 Recommendations

The findings and the overall conclusions of the study have led to the formulation of the following set of suggestions:

- According to the findings, it is suggested that a more structured and stringent approach should be taken in order to establish and enforce the management of the road safety system in the City of San Fernando, Pampanga. Periodically, the officials should go over and adjust the parameters based on the current state of the road system and the difficulties that it has in order to lower the rate of road accidents in the city.

- It is strongly recommended that the road safety system, including the roadways, signages, street lights, traffic signals, and traffic lines or lanes, undergo thorough routine maintenance. Officials should routinely inspect the condition and status of their conditions in order to make an accurate determination regarding whether or not it needs to be replaced or maintained.

- It is recommended that the Land Transportation Office (LTO) should re-evaluate the rules and regulations that are imposed in the City of San Fernando, Pampanga. This is due to the fact that the number of road accidents is still on the rise, despite the fact that traffic laws are already being enforced. In addition, the personnel of the office should be evaluated to verify that they possess sufficient levels of expertise and are capable of carrying out the obligations that have been assigned to them. Fixers who illegally issue driver's licenses without following the proper procedures must be removed from their profession, and the position must then be filled by someone who is capable of doing the job in an ethical manner.

- The Department of Public Works and Highways (DPWH) has to focus greater attention on the current state of its transportation projects. Repairing the areas that have already been damaged by the elements and other drivers is an immediate priority in order to reduce the risk of accidents or collisions. Whenever there is a road construction project that is currently taking place, it is also advised that an alternative route should be created to avoid traffic that might cause road accidents.

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- For future researchers, it is recommended to explore other methods to identify the severity of road accidents that could give better results. Due to the limited time and lack of specific road accident data, the ranking of severity in the city was only done per barangay. That is why it is advised to look more at specific road accident data in every barangay. In addition, future researchers are also encouraged to do the reliability test of the questionnaire to further validate the results.

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