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# Machine learning approach on road accidents analysis in Calabarzon, Philippines: an input to road safety management

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**ABSTRACT**

This research was conducted to help the traffic policy makers and general public in preventing road incidents using the collected traffic accident dataset between the years 2016 and 2019. Data mining using classification algorithm was utilized to develop a predictive model for predicting occurrences of traffic accidents. Classification algorithms such as decision tree, k-nn, naïve bayes and neural network have been compared in identifying better classification capability in classifying stage of felony. Neural network shows a very promising result in classifying road accident with a total accuracy result of 87.63%. Nonetheless, k-nn and naïve bayes both acquired a higher than 80% accuracy which shows that this classification algorithms were also good in predicting road accidents. Moreover, public vehicle is more prone in accident rather than private vehicle in both stage of felony and accident may occur between or on 3:00pm and 6:00pm.



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## 1. INTRODUCTION

Road traffic accidents could happen in any place at any given time. Many studies had noted that these accidents have always been a perennial problem [1]-[4]. This problem has been recognized by the United Nations General Assembly's declaration of the decade of action for road safety 2011-2020 [5]. The road that is supposed to lead, bring, and trigger economic developments, turned out to become everyone's access and gateway to road traffic accidents, resulting in injuries, and worst, death to motorists.

Death is the most significant consequence of injuries [6]. Ghadirzadeh *et al*. [7] cited that as a result of traffic collision, around 1.35 million people die each year, while 20 to 50 million people suffer non-fatal injuries. In terms of disability-adjusted life years (DALYs) lost globally, road traffic accidents were previously ranked ninth leading cause of mortality, morbidity, disease burden in 1990 and were predicted to be the third major killer and the largest leading cause of death and disability by 2020 [8]. Due to the growing demand for cars and automobiles for use, accidents have increased dramatically [9]. This phenomenon causes individuals, their families, and nations as a whole to suffer significant economic losses.

In Calabarzon Region, Philippines, there are a total of 70,178 road traffic accidents recorded by the Philippine National Police from 2016 to 2019. Year 2017 recorded the highest number of fatalities with 18,809 incidents; 2018 with 18,344; 2019 with 16, 987; and 2016 with 16, 038 cases. It is obvious in this data that there is a high accident frequency signifying a problematic and remedy is needed.

Many scholars and researchers have conducted studies and writings of the analysis on the rate of road traffic accidents. These people have used statistical tools such as chi-square analysis, correlation-coefficient analysis, comparative analysis, multiple regression analysis, and time-series analysis to analyze their data. The chi-square analysis of [10] provided evidence for the design and implementation of concrete and urgently needed preventive strategies to control the almost completely preventable fatalities of road accidents. Meanwhile, chi-squared automatic interaction detection (CHAID) decision tree technique was used to identify significant risk factors and explore the effect of various combinations of major risk factors on roadside accidents in accordance to the generated decision rules, and to recommend specific improved countermeasures [11].

Kumar and Toshniwal [12] do analysis of hourly road accident counts using hierarchical clustering, and cophenetic correlation coefficient (CPCC) showed that the proposed method is capable of efficiently group the different districts with similar road accident patterns into single cluster or group which can be used for trend analysis or similar tasks. Vigneshkumar *et al.* [13] do comparative analysis revealed that India has one of the highest fatality rates in road accidents, which are 8.1 deaths per 10,000 motor vehicles on the road in 2013 compared with the rates in other developed countries like Australia, Austria, Hong Kong, New Zealand, USA, Canada, and South Korea. The casualty risk is higher in India as compared to the indices of the mentioned developed countries. While road safety situation is improving in developed societies, most developing countries like India are facing an ever-worsening situation.

On one hand, [14] regression analysis of road traffic accidents and population growth in Ghana showed three key findings: a systematic visible pattern of growth in both road traffic accidents and population over the period; evidence of statistical relationship between road traffic accidents and population growth in Ghana indicated that for the period under study based on the available data, population is able to account for 72.9 percent of the changes in accidents.

Aiming to aid in the reduction of crime incidents in a provincial setting [15] and municipal setting [16], these studies utilized a machine learning to develop a predictive model in investigating crime records. Asor *et al*. [17] analyzed the data from the road accident to reveal new trends that can be used as precautionary measure to at least minimize the yearly accident. Another, the trend analysis of results of [18] call for close monitoring of injuries during high-risk periods in order to manage and reduce the injury rate. Lastly, Parvareh *et al.* [19] ascertained that road traffic accident would be an increase in the number of accidents occurring in the future.

There are also studies that investigated neural network in road traffic analysis. For example, the research of [20], [21] has found out that the neural network enables short-term prediction results which can be used in applications for traffic management. Intelligent transport systems and neural networks were utilized to develop road traffic management model to solve traffic management problems. Furthermore, [22] method provided a solution in making better transportation decisions; and the neural network is a plausible approach to recognize traffic conditions. The modified neural network model of [23] presents a significant opportunity for modeling crash frequency with the structure optimization algorithm and rule extraction method, and therefore can be considered as a good alternative for analysis of road safety.

The information that is acquired from data mining approaches aimed to develop a predictive model for future occurrences of numbers of traffic accidents. According to Srilatha *et al*. [24], accident prediction is one of the most important aspects of road safety, whereby an accident can be anticipated before it actually happens and precautionary measures taken to prevent it. This study aims to develop a model for road accidents using machine learnig algorithms.

## 2. METHODS

### 2.1. Data gathering

A letter of request was submitted to the regional investigation and detective management division (RIDMD) of PNP Calabarzon to obtain the road accident report. The letter assured that the data that will be obtained from the office will be used exclusively in this study. The collected data contains the four (4) year record between 2016 and 2019. As shown in Table 1, the dataset has the attributes police provincial office (PPO), Barangay, Date, Time, Place, Stage of Felony and Vehicle Type. These attributes were tested first to see if they are all responding in the classification algorithms. It will be then selected and extract only those attributes that shows viability on the project.

### 2.2. Data pre-processing/selection

In this part, the dataset is first transformed in lowercase to make sure that it will have the same meaning in the model development. Unnecessary objects in every instance are also removed such as white space and other special character including typographical error. Upon assuring that every instance inside the dataset have the same meaning, some columns are removed for it shows duplication from others.

It is necessary and vital to model development to divide the dataset into two parts which are famous as train set and test set. Shown in the Table 2 that 80% of the dataset will be the train set while the remaining 20% will be the test set. Division of dataset are done through stratified random sampling, which focus in the stage of felony and PPO. This is to assure that bias in classifying and prediction process will be eliminated.

The dataset is trained in three different mostly used machine learning algorithm in document classification and road accidents namely decision tree, k-NN and naïve bayes [16]-[26]. This was done using rapidminer–a famous data mining tool that used by experts in model development [27]. Likewise, the dataset is also trained in neural network.

Table 1. Attributes of road traffic accidents dataset

| Attributes | Description | Data type |
|---|---|---|
| PPO | Police Office in which the accident has been reported and recorded | String |
| Barangay | Barangay where the accident occurs | String |
| Day | Day of the Week when the accident occurs | String |
| Month | Month when the accident occurs | String |
| Year | Year when the accident occurs | Integer |
| Time Committed | Time when the accident occurs | Time |
| Stage of Felony | Period of execution of acts | String |
| Vehicle Type | Type of the vehicle involved in the accident | String |

Table 2. Distribution of stage of felony in train and test dataset

| Stage of Felony | Train Set | Test Set |
|---|---|---|
| Consummated | 4417 | 1104 |
| Reckless Imprudence | 3582 | 896 |
| Total | 7999 | 2000 |

### 2.3. Algorithm evaluation

#### 2.3.1. Confusion matrix

Confusion matrix will be the one to use in visualizing the classification correctness of the machine learning algorithm. It is a well-known table for describing the performance of chosen algorithm or classification model. As illustrated in Figure 1, confusion matrix contains the number of true positive (TP), true negative (TN), false positive (FP) and false negative (FN) in classifying the stage of felony using the dataset. Aside from these, confusion matrix is often used to compute recall, precision, f1-score and specificity.

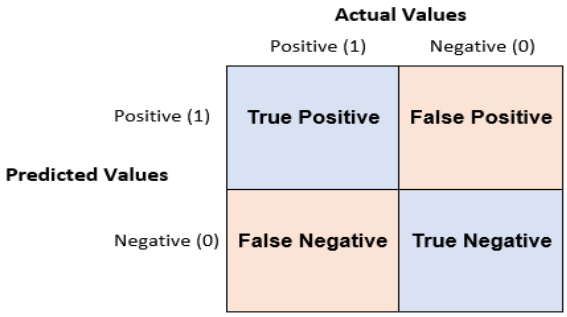


Figure 1. Confusion matrix

#### 2.3.2. Recall/Sensitivity

Recall or sensitivity describes the capability of the machine learning algorithm to point an assigned value as the actual value. In this paper, recall will show the capability of the algorithm to point the correct stage of felony. It is the total number of the true positives or stage of felony (consummated or reckless imprudence) that is identified correctly by the algorithm divided by sum of true positives and false negative or incorrectly labeled stage of felony (a consummated that is labelled as reckless imprudence). Recall's formula is as (1).

$$\text{Recall} = \frac{\text{TP}}{\text{TP+FN}} \quad (1)$$

### 2.3.3. Precision

Precision is used to show the accuracy or correctness of the prediction or classification. It shows the ability of the model to identify relevant data points. Precision is the number of true positive divided by the sum of true positive and false negative or reckless imprudence which is labelled as consummated. The formula for precision is as (2):

$$\text{Precision} = \frac{\text{TP}}{\text{TP+FP}} \quad (2)$$

### 2.3.4. F1-Score

Maximizing either recall or precision to assure that the model will be substantial is an acceptable process. However, it still suggested that both of them blend with each other. F1-score is basically the harmonic mean of recall and precision. It gives an equal weight to both measures; a metric used to create a balance model with optimal balance of recall and precision. The (3) shows the metric formula of F-score:

$$\text{F1-Score} = 2 * \frac{Precision*Recall}{Precision+Recall} \quad (3)$$

### 2.3.5. Specificity

Specificity quantifies the evasion of false positives. It is called True Negative Rate, measuring the proportion of negatives that are correctly identified. It is the number of true negatives divided by true negatives plus false positives. The (4) shows the metric formula of Specificity;

$$\text{Specificity} = \frac{TN}{TN+FP} \quad (4)$$

## 3. RESULTS AND DISCUSSION

It is a very critical decision to choose a classification algorithm. To resolve the existing problem, there is no particular classification algorithm. In other words, any issue is not solved in the best way by the best algorithm. For different datasets or different issues, there are classification algorithms that offer different results. Before going into the deeper investigation, different classification algorithms for the given dataset of stage of felony have been compared in this study.

Table 3 shows that neural network has a better classification capability in predicting stage of felony. It garnered a total accuracy of 87.63% and 0.75 for kappa. From here, neural network will be the focus of evaluation since it shows a very promising result. Neural network has been considered as the best classifiers against several common classifiers in terms of accuracy and computational efficiency.

Confusion matrix in the Table 4 shows that neural network is better in classifying consummated rather than reckless imprudence in terms of number. However, the number of consummated is way higher that reckless imprudence which may cause bias in this part. To take a look closer to the result, it is necessary to evaluate the neural network algorithm based on its ability to classify the stage of felony. 4766 and 755 are the actual number of consummated in the dataset, however, the algorithm classified the 755 as reckless imprudence, this happens when some of the data has the same pattern. Same with 481 and 3997. The F1-score in Table 5 indicates that neural network is better in classifying consummated than the reckless imprudence. This goes to show that consummated as Stage of Felony can provide accurate prediction and reliable statement in predicting the occurrence of road traffic accidents within the region.

Table 3. Algorithm evaluation

| Algorithm | Accuracy | Kappa |
|---|---|---|
| Decision Tree | 74.20 | 0.51 |
| k-NN | 82.01 | 0.63 |
| Naïve Bayes | 86.28 | 0.73 |
| Neural Network | 87.63 | 0.75 |

Table 4. Confusion matrix-neural network

| | true Consummated | true Reckless Imprudence |
|---|---|---|
| Predicted Consummated | 4766 | 481 |
| Predicted Reckless Imprudence | 755 | 3997 |

Table 5. Result of neural network evaluation

| Stage of Felony | Recall | Precision | F1-score | Specificity |
|---|---|---|---|---|
| Consummated | 86.32 | 90.83 | 88.52 | 89.26 |
| Reckless Imprudence | 89.26 | 84.11 | 86.60 | 86.33 |

Shown in Figure 2 is the predicted stage of felony that may occur in each province. It can be observed that there is a higher chance of occurring reckless imprudence in Batangas, Laguna and Quezon while the Cavite has no chance of occurring reckless imprudence however a very high possibility of consummated. Figure 3 reveals that in terms of day of occurrence, consummated has a high possibility of occurring in Sundays while reckless imprudence is Saturdays. It can also be observed that road accident has a high chance in any day of the week. This result could be attributed to the large volume of vehicles every day. People go out every weekday for work or to enjoy their days off from work every weekend. Likewise, Figure 4 reflects that the month of May and December has the highest probability of occurring road accidents, specifically, reckless imprudence in December and consummated in May. This result implied the need for the traffic managers to heighten the traffic policing during this period to reduce the probability of road traffic accidents.

It shows in the Figure 5 that public vehicle is more prone in accident rather than private vehicle in both consummated and reckless imprudence. The most vulnerable road users are passengers on public transport [3] since there happen to be more passengers in one vehicle [28]. Many individuals rely on this mode of transport. Such modes of public transport, with many operating illegally, are poorly regulated and managed [28]. On the other hand, it is also shown in the figure that there is still a possibility that private vehicle must be involved in road accident. Figure 6 presents that both consummated and reckless imprudence may occur between or on 3:00pm and 6:00pm. According to hg.org [29], many fatalities transpire between 6pm and 9 pm, and 3pm to 6 p.m. Most fatal accidents during working days occur between 5pm and 6 pm. It can be also noted that there is a high probability that reckless imprudence may occurred between 9:00am and 12:00pm.

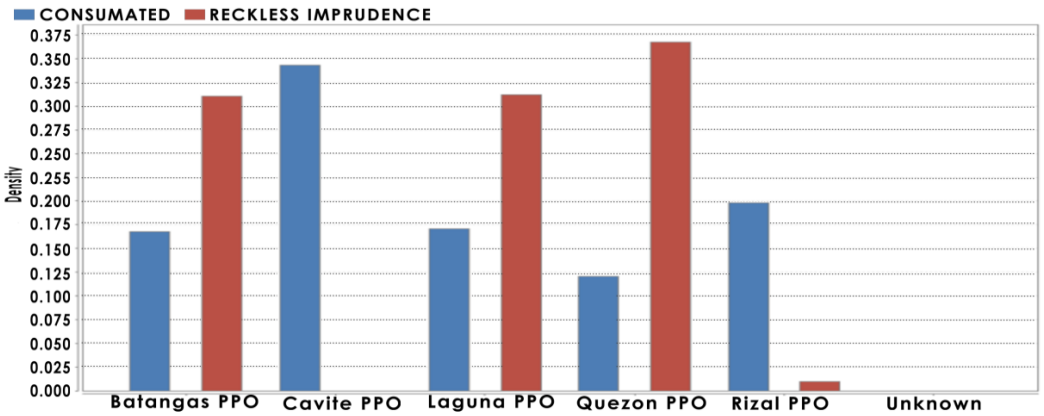


Figure 2. Classified stage of felony in each province

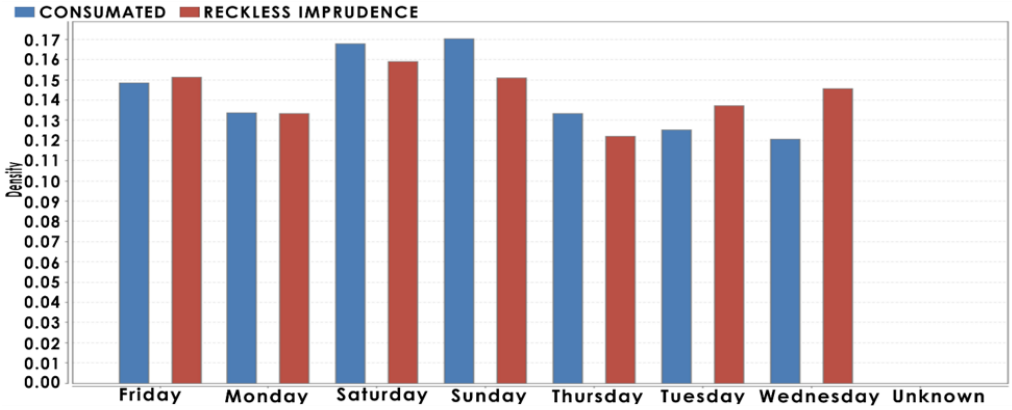


Figure 3. Classified stage of felony based on the day occurrences

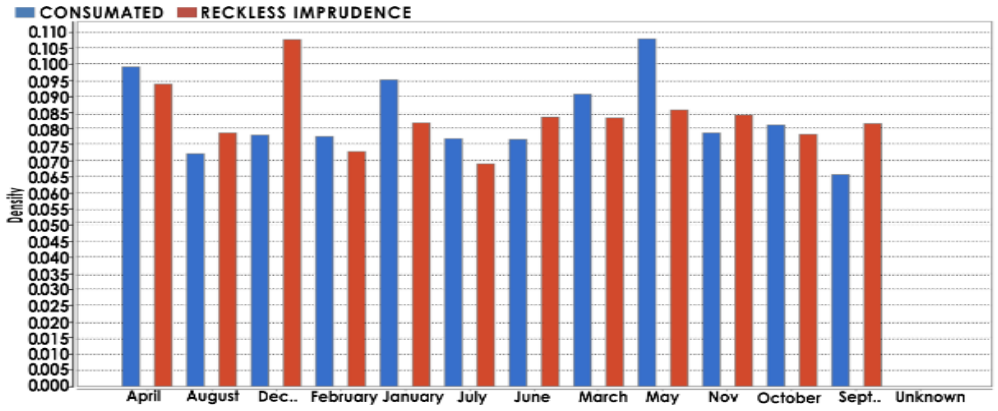


Figure 4. Classified stage of felony based on the month occurrences

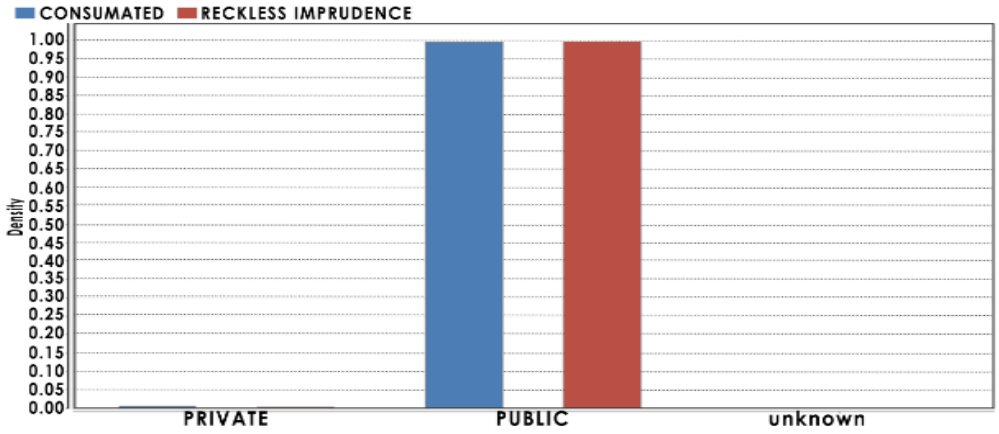


Figure 5. Classified stage of felony based on the type of vehicle

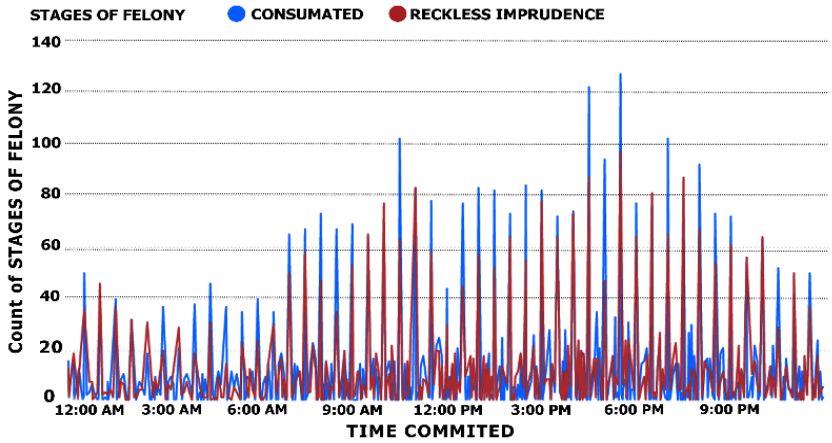


Figure 6. Classified stage of felony based on the time of occurrence

## 4. CONCLUSIONS AND FUTURE WORKS

The given data noted that there is a high accident frequency signifying a problematic and remedy is needed. To help the traffic policy makers and general public in preventing these incidents, data mining using classification algorithm was utilized to develop a predictive model for future occurrences of numbers of traffic accidents. The patterns that were developed using this intelligence are conducive to targeted enhancement of the existing road safety measures and in the future road safety management.

Different classification algorithms such as decision tree, k-NN, naïve bayes and neural network have been compared for the given dataset in identifying better classification capability in classifying stage of felony. The algorithm evaluation showed that the neural network is the best algorithm in classifying the stage of felony. The results of neural network algorithm show that in terms of province, there is a greater likelihood of reckless imprudence in Batangas, Laguna and Quezon while the Cavite shows a very high possibility of occurrence of consummated traffic accidents. In terms of day of occurrence, consummated has a high possibility of occurring in Sundays while reckless imprudence is Saturdays. On the other hand, months of May and December has the highest probability of occurring road traffic accidents; reckless imprudence in December and consummated in May. Public vehicle is more prone in accident rather than private vehicle in both stage of felony. An accident may occur between or on 3:00pm and 6:00pm. It is also notice that most of the accident recorded in the past four years is from the Northern part of Cavite.

Based on the findings and conclusions, there may be a need for the traffic managers, and police and traffic officers to heighten their policing during the given attributes to reduce the probability of road traffic accidents. Traffic managers may consider improving their existing action plans and preventive measures based on the predictive model presented in this research. Traffic managers and policy makers may consider the application of data mining techniques using classification algorithm in formulation of related plans, programs, and measures on road traffic safety. Lastly, the future researchers may conduct similar study using other classification algorithms for further validity of the present findings.

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