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Forecasting the Number of Fire Accidents in the Philippines through Multiple Linear Regression

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Abstract

Objectives: The main objective of this study is to forecast the number of fire for the years 2016 to 2020 that is possible to occur in the Philippines and to find the best fit multiple linear regression models for the said variable. **Methods/Statistical analysis**: The secondary data of Electrical Connections, Electrical Appliances, Spontaneous Combustion, Open Flame due to Unattended Cooking/Stove, Open Flame due to Torch, Open Flame due to Lighted Candle, Liquefied Petroleum Gas (LPG) Explosion due to Direct Flame Contact/Static Electricity, Lighted Cigarette Butt, Lighted Matchstick/Lighter, Under Investigation, and Others that was used in the study were gathered from Philippine bureau of fire protection. The data were analyzed by the use of statistical software such as EViews7 and MATLAB. **Findings:** In this paper, we showed that the independent variables namely, Electrical Connections, Electrical Appliances, Spontaneous Combustion, Open Flame due to Unattended Cooking/Stove, Open Flame due to Torch, Open Flame due to Lighted Candle, LPG Explosion due to Direct Flame Contact/Static Electricity, Lighted Cigarette Butt, Lighted Matchstick/Lighter, Under Investigation, and Others significantly affect the dependent variables which is the number of fire accidents. A normal estimation equation was derived to be the model that is best fit in predicting the number of fire for the year 2016 to 2020 through Multiple Linear Regression. **Application/Improvements:** This paper will be of help in raising the awareness of the citizen and the local government unit that is concerned in this matter to be prepared and allocate more effort in preventing a great damage caused by fire accidents.

Keywords: Fire Accidents, Forecasting, Multiple Linear Regression, Normal Estimation Equation, MATLAB

1. Introduction

Fuel, heat, and air, when these three sustain a chemical reaction, a fire is produce through the process of oxidation. Fire is considered as a need for daily life basis. As long as fire is under human's control, it is significantly useful, but once it gets out of hand, it causes destruction. Fire accident can be a threat to one's life, property, or even to a nation's economy. It usually takes place with enormous economy losses and casualty of personnel. It is considered as an adverse event with tangible costs to property and human life.

According to World Fire Statistics, it is estimated cost due to losses from fire accidents is approximately one percent of global Gross Domestic Product per annum[1]. A total of 883 fires and 824 fire-related casualties were reported from 2010 to 2012 in the Philippines, and the most number of occurrences is recorded in National Capital Region[2].

According to the International Association of Fire and Rescue Services, there are 2.5 to 4.5 million fires that occur every year, and 21 to 62 thousand deaths are recorded as fire casualties[3]. Such number of fire accidents can be lessened if it is systematically planned to prevent casualties and losses.

The goal of this paper is to create a mathematical model that can be used to predict fire accidents. In this study, the causes of fire such as electrical connections, electrical appliances, spontaneous combustion, open flame due to unattended cooking/ stove, open flame due

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to torch, open flame due to unattended lighted candle, Liquefied Petroleum Gas (LPG) explosion due to direct flame contact/static electricity, lighted cigarette butt, lighted matchstick/lighter, under investigation and others are considered as the independent variables and the number of fire accidents as the dependent variable.

2. Method

This chapter focuses on the methods used by the researchers in this study.

Multiple Linear Regression (MLR) Analysis is a statistical approach used to describe the simultaneous associations of several variables with one continuous outcome[4]. It is a generalization of the simple linear regression analysis[5]. To conduct the Multiple Linear Regression analysis, there are assumptions that are needed to be satisfied which includes the following[6]:

1. Linear Relationship between the outcome variable and the independent variables,
2. Normally Distributed Residuals,
3. Absence of multicollinearity, and
4. Homoscedasticity.

If the assumptions of the multiple linear regressions are all satisfied then the regression can be conducted with its model as:

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_k x_{ki} + \mu_i \qquad (1)$$

where y is the dependent variable, x is the independent variables, β is the predicted value of the dependent variable when the independent variables are zero, and μ is the error.

Correlation is the degree to which two or more attributes or measurements on the same group of elements show a tendency to vary together[7]. The formula for correlation coefficients is[8]:

$$r = \frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}} \qquad (2)$$

where r is the Pearson coefficient, N is the total number of observations, x is the independent variable, and y is the dependent variable.

Paired T-test is a test whether the mean difference in the pairs is different from zero[9]. The formula for the paired t-test is as follows:

$$t = \frac{d}{\sqrt{\frac{s^2}{n}}} \qquad (3)$$

where d is the mean difference, s^2 is the sample variance, n is the sample size, and t is the t-quantile with $n-1$ degrees of freedom.

3. Results and Discussions

The graph of the actual number of fire incidents in Figure 1 shows that the number of fire incidents in the Philippines increased from 2005 to 2015. The highest number of fire incidents was actually on March 2015 with 2,863 fires.

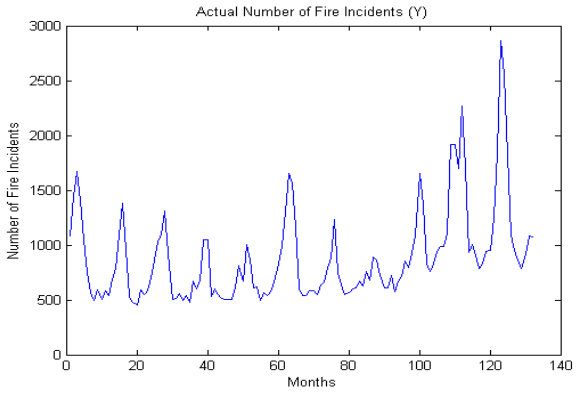

Figure 1. 2005 to 2015 fire incidents in the Philippines.

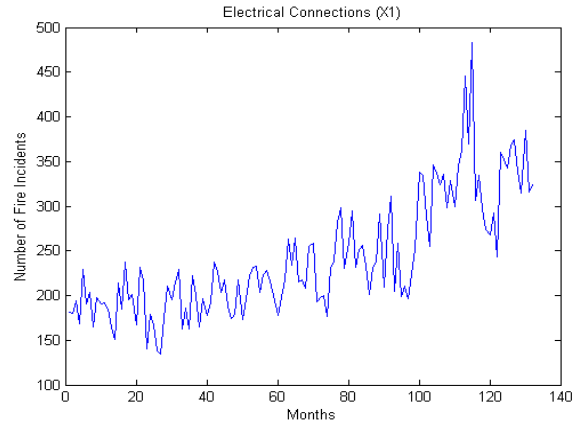

Figure 2. Fire Incidents in the Philippines due to electrical connection.

The number of fire incidents due to electrical connection as shown in Figure 2 rocketed from 2005 to 2015 with the highest peak on May 2014 with 446 incidents and lowest trough on March 2007 with 135 incidents.

The graph of fire incidents due to electrical appliances as shown in Figure 3 states that the highest number of fire incidents dated on March 2007 with 54 incidents. In 2014, the third highest number of fire incidents happened caused by electrical appliances were 2.5% of the total number of fire incidents on the said year with 396 fire incidents.

The graph of fire incidents due to spontaneous combustion as shown in Figure 4 reached the highest level on March 2005 with 138 fire incidents while the lowest level was on December 2011 with only one fire incident nationwide.

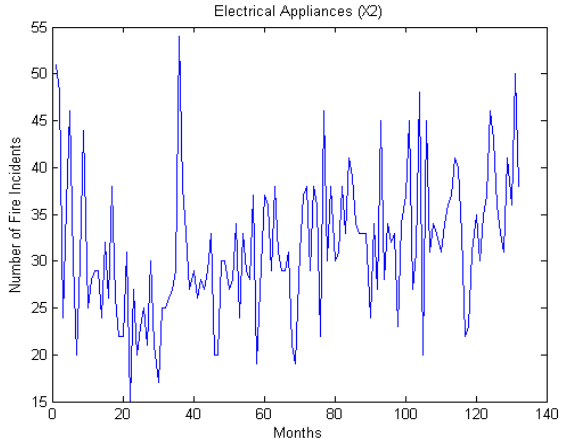

Figure 3. Fire incidents in the Philippines due to electrical appliances.

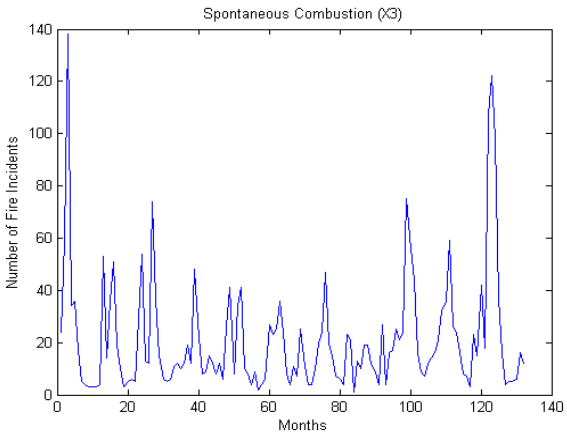

Figure 4. Fire incidents in the Philippines due to spontaneous combustions.

The graph of the fires caused by unattended cooking/stove as shown in Figure 5 reached the highest peak on March 2015 with 133 fire incidents and the lowest trough was on May 2008 with 15 number of fire incidents.

The highest peak of the graph of open flame due to torch as shown in Figure 6 was on April 2014 with 442 fire incidents. This cause of fire was also one of the top causes of fire incidents for the past years.

Figure 7 shows the graph of fire incidents due to lighted candle or gasera. It shows that from the year 2005 to 2010, the number of fire incidents gradually increased. On 2011, the number of fire incidents suddenly went up where the recorded highest number of fire incident dated from the month of March. While the lowest number of fire incidents because of opens flame due to lighted candle was dated on June 2011.

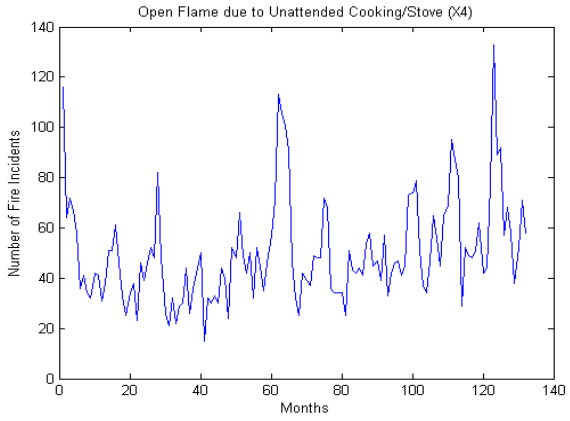

Figure 5. Fire incidents in the Philippines due to unattended cooking/stove.

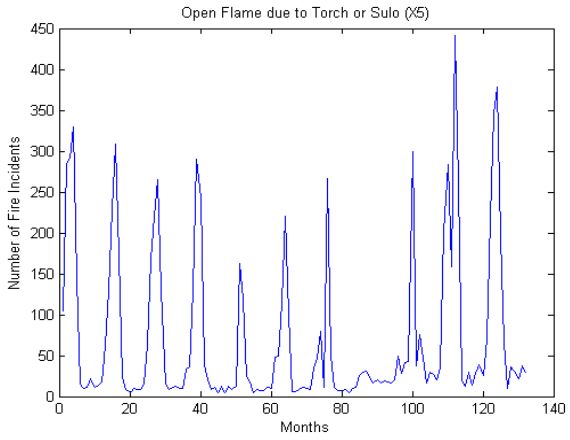

Figure 6. Fire incidents in the Philippines due to torch or sulo

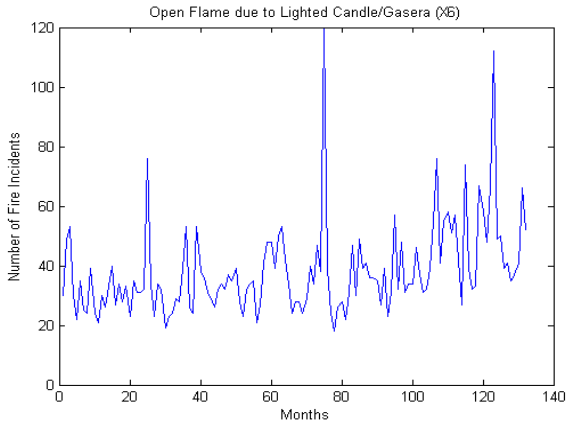

Figure 7. Fire incidents in the Philippines due to lighted candle/gasera

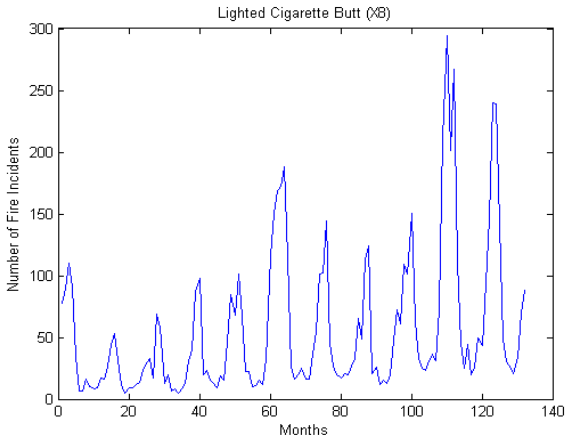

Figure 9. Fire incidents in the Philippines due to lighted cigarette butt.

Figure 8 shows the graph of fire incidents that happens in the Philippines due to LPG explosion. It shows that from 2005 to 2007, the number of fire incidents nationwide never went up to 20 but the graph rocketed up on 2008 specifically on the month of April with 56 number of fire incidents. On the first month of the summer in the Philippines, the number of fire incidents suddenly grew up with 53 fire incidents.

The graph of fire incidents in the Philippines due to lighted cigarette butt exhibits a gradual increase of fire incidents from 2005 to the first quarter of 2010 then it slightly went down from June 2010 until the last month of 2013 as shown in figure 9. But the number of fire incidents rocketed on the year 2014 on its first month with 294 accidents and slightly went down again on 2015. The lowest trough in the said graph was on July 2006 and October 2007 with 5 numbers of incidents.

The graph of fire incidents in the Philippines due to lighted matchstick/lighter shows a gentle increase in number of fire incidents from 2005 to the third month of 2013 as shown in Figure 10. But on April 2013, the number of fire incidents peaked with 103 fire incidents. Then it sharply went down on the next month and never went up again on a three-digit number of fire incidents until 2015.

The graph of fire incidents in the Philippines with unknown cause and still under investigation exhibits the highest peak on the last year of the data gathered as shown

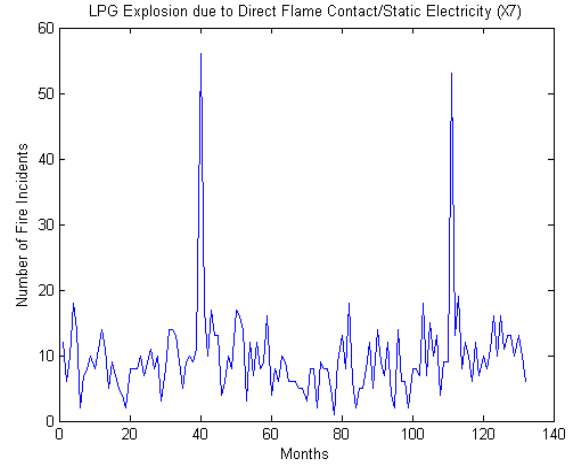

Figure 8. Fire incidents in the Philippines due to LPG explosion.

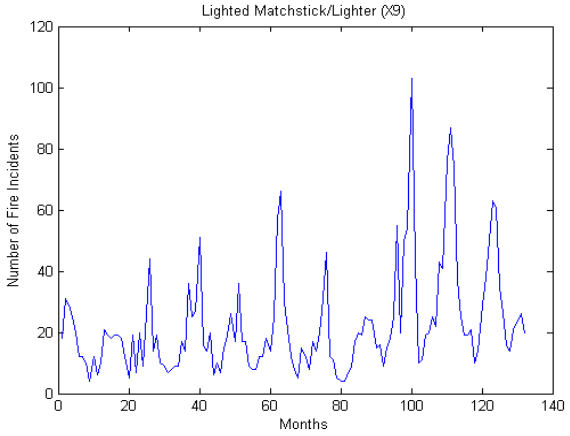

Figure 10. Fire incidents in the Philippines due to lighted matchstick/lighter.

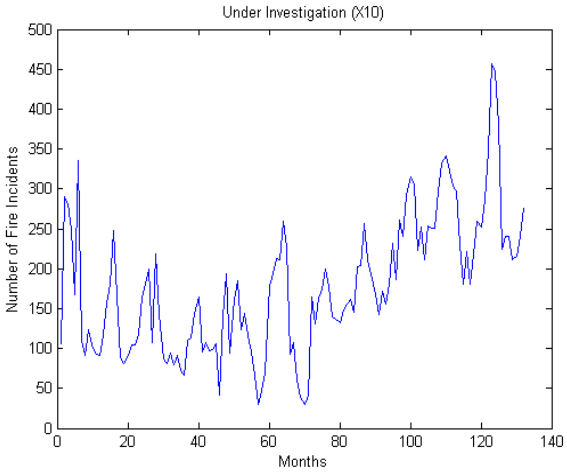

Figure 11. Fire incidents in the Philippines under investigation

in Figure 11, specifically on the month of March with 457 number of fire incidents while the lowest through was on September 2009 and October 2010 with just 30 number of the said incident.

There were other causes of fire incidents that were not specifically designated as the above causes. The graph of the other causes of fire incidents as shown in Figure 12 states that the highest level was on March 2015 with 946 number of fire incidents. It was also the biggest number of fire incidents among all the factors in this paper, while the lowest level was on January 2008 with only 14 number of fire incidents nationwide. It is then concluded that the highest number of fire incidents in terms of the stated causes in this paper from 2005 to 2015 occurred mostly on the summer season, specifically on the month of March and April, in the Philippines.

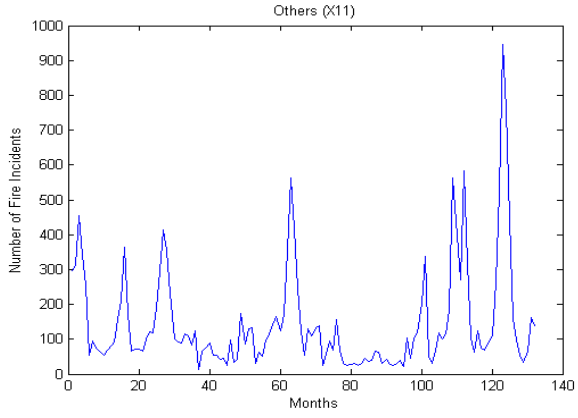

Figure 12. Other causes of fire incidents in the Philippines.

3.1 Significant Relationship of the Independent Variables to the Number of Fire Incidents in the Philippines

The researchers examine whether the independent variables have a significant relationship on the dependent variable. A Pearson's correlation was done to determine the relationship between dependent variable and the independent variables.

According to the Pearson coefficient of correlation as shown in Table 1, the given eleven causes of fire incidents have a positive significant linear relationship with the number of fire incidents that occurred from 2005 to 2015 in the Philippines. The null hypothesis indicates that there is no significant relationship between the two variables.

Table 1. Significant Relationship of the Variables of the Fire Incidents in the Philippines

Variables	R	p-value	Decision	Interpretation
Electrical Connections	0.4562	0.000	Reject Ho	Significant
Electrical Appliances	0.3123	0.000	Reject Ho	Significant
Spontaneous Combustion	0.7190	0.000	Reject Ho	Significant
Unattended Cooking	0.8130	0.000	Reject Ho	Significant
Torch	0.8269	0.000	Reject Ho	Significant
Lighted Candle	0.5332	0.000	Reject Ho	Significant
LPG Explosion	0.2236	0.000	Reject Ho	Significant
Lighted Cigarette Butt	0.8701	0.000	Reject Ho	Significant
Lighted Matchstick or Lighter	0.7667	0.000	Reject Ho	Significant
Under investigation	0.8263	0.000	Reject Ho	Significant
Other causes	0.9007	0.000	Reject Ho	Significant

With a significance level of 0.01, the null hypothesis was rejected because the p-values are all less than 0.01.

3.2 Mathematical Model in Forecasting the Number of Fire Incidents in the Philippines

Using Multiple Linear Regression, the mathematical model for estimating the number of fire incidents was obtained. It is written as:

$$\check{y} = 17.115 + 0.990x_1 + 1.035x_2 + 0.977x_3 + 1.116x_4 + 0.999x_5 + 1.004x_6 + 1.027x_7 + 0.924x_8 + 1.150x_9 + 1.002x_{10} + 1.017x_{11}$$

The obtained model has an R-squared or coefficient of determination of 0.999 indicating that the statistical measure of the data to the regression line is definitely close. To validate the mathematical model that was obtained, the table of Root Mean Square Error (RMSE) and Mean Squared Error (MSE) are as follows.

RMSE in Table 2 tells how concentrated the data around the line of best fit. It is the standard deviation of the residuals or prediction errors. Residuals are defined as a measure of how far data points from the regression line. RMSE is the measure of how residuals are spread out. MSE tells how a regression line is close to a set of points by getting the distance from the points to the regression line, where these distances are the errors, and getting the square of this distance. Squaring the distance removes any negative signs and gives more weight to larger differences.

Table 2. Error of the Model

Root Mean Square Error	Mean Square Error
13.7	171.2236

3.3 Significant Factors

After solving the mathematical model for forecasting the number of fire incidents for 2016-2020, the researchers tested whether the independent variables have an effect on the dependent variable.

According to Table 3, all of the independent variables are significant factors that affect the dependent variable since the p-value is less than the level of significance. It is therefore concluded that the eleven causes of fire accidents have an effect to the number of fire incidents in the Philippines from 2005 to 2015.

Table 3. Significant factors of the fire incidents in the Philippines

Variables	β	p-value
Electrical Connections	17.115	0.000
Electrical Appliances	0.9697	0.000
Spontaneous Combustion	1.0349	0.000
Unattended Cooking	0.9765	0.000
Torch	1.116	0.000
Lighted Candle	0.9987	0.000
LPG Explosion	1.0037	0.000
Lighted Cigarette Butt	1.0273	0.000
Lighted Matchstick or Lighter	0.9236	0.000
Under investigation	1.1498	0.000
Other causes	1.0165	0.000

3.4 Actual and Predicted Values

The researchers plot the graph of the actual values and predicted values of the fire incidents in the Philippines as shown figure 13 to exhibit in graph the differences of the two said values with the aid of MATLAB.

The previous graph in Figure 13 exhibits a close line graph between actual values and predicted values of the number of fire incidents nationwide. The highest peak of the predicted value, with 2,867 fire incidents, is higher than the actual value with 2,863 number of fire incidents. The lowest trough of the actual value with 456 number of fire incidents is lower than the predicted value with 464 fire incidents.

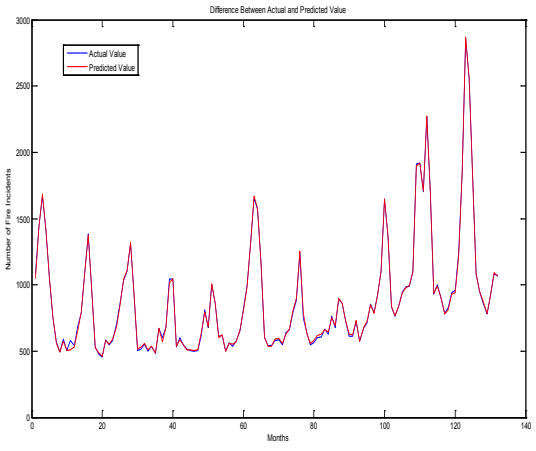

Figure 13. Graph of the actual values and predicted values of the fire incidents in the Philippines.

Table 4 shows that the predicted values of the number of fire incidents have no significant difference from its actual values since the p-value is 1.000, accepting the null hypothesis. The null hypothesis indicates that there is no significant difference between the actual and predicted values of the dependent variable.

Table 4. Paired T-test

p-value	Decision	Interpretation
1.000	Accept Ho	Not Significant

4. Conclusions

The number of fire incidents from 2005 to 2015 is continually increasing. Using the Pearson Correlation Analysis, the researchers concluded that all the causes of fire incidents in this paper are significant to the number of fire incidents in the country. Through Multiple Linear Regression, the researchers formulated a mathematical model for estimating the number of fire incidents in the Philippines. The said model is good enough in predicting the number of fire incidents for 2016 to 2020 with a coefficient of determination of 0.9999. A Paired T-test is executed to show that there is no significant difference between the actual values and the predicted values obtained using the formulated model. Since all the 13 variables were significant factors in the different fire incidents in the Philippines, it is highly recommended that the government, in line with the fire prevention month of the Philippines, should conduct a trainings and seminars that will equip its citizens the necessary skills in preventing fire incidents specially in the poor class community. This is because the model states that among the 13 factors of fire incidents, unattended lighted candles were the most significant factor.

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