Time Series Forecasting using Multiplicative Model: A Predictive Model for Fire Risk in the City of Manila

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***Abstract*— this paper utilized the components in time series such as secular trend, irregular fluctuation, cyclical and seasonal movements to extrapolate prediction using multiplicative model. The main objective of this research is to predict fire risk in short-range period based on the past data. Scrutinizing fire risk based on time series forecasting with multiplicative model, provide possible conclusion on the following questions in analyzing fire risk. Such as, who are the districts that are prone to fire? When is the crucial time that fire will most probably arise? And what is the most possible cause of fire? This study analyzed fire data in the city of Manila from 2011 – 2015 and predicted the possible occurrence of fire and its risk. A tally of 2823 fire incidents were included in this study and as recorded based on the cumulative frequency, Electrical failure is most cause of fire incident with an average of 315 cases per year. Moreover Tondo is the most densely population in Manila and also predicted as the most risk in fire with 153 possible cases a year prediction with 9.96% absolute mean error. The arises of monthly pattern prediction shows that September is the most risk in fire incidents with possible 61 cases a year, meanwhile summer months are also prone in fire occurrence particularly February, March and May with an average of 57 cases a year with 8.09% absolute mean error which is also the warmest month in a year. Daily pattern show much relationship on the fire incident and fire risk prediction, Saturday is the crucial day in terms of fire risk with 109 possible cases will happen on this day and majority of the possible fire accident will arise between 7:00pm to 9:00pm with 120 possible cases a year with 22% mean absolute error. The significance of understanding fire risk using Time series forecasting must be utilize and administer, which can be useful tool to serve as guide and help to mitigate fire incidents. Future researchers recommend to focus on other variables that contribute fire occurrence to predict fire risk with more accuracy rate.**

Keywords—e-government, public service, local government, forecasting, citizen, fire prediction;

I. INTRODUCTION

Fire is one of the most destructive phenomena that a human race deal with that produces major impact in society and economy. In the Philippines fire cases increment significantly, according to Bureau of Fire Protection the number of fire cases last 2015 in most record reached a record high of 17,138 fire incidents in Philippines history with about 16.7% of these cases happened in the month of March which also the warmest month in a year. As we recall a recorded case Ozone Disco fire incidents considered as the worst cases in Philippine history that took 168 lives which was happened way back March 18,1996, the said incident also considered as the 7th World's worst fire incident [1].

Manila is one of the most densely region in the Philippines with 1.7 million residents, fire safety is a critical issue in this city, with the rapid growing of population on this area fire risk is a major concerns. As recorded most fire incident in this city cause by Electrical Failure due to illegitimate power connection [2]. Likewise these results are same with the account of the Manila BFP (Bureau of Fire Protection) Director. In the beginning of March 2015 which is said to the most record fire incident in Philippine history there is an average of 2 cases per day and about 68 million damaged in the said year alone[3]. Fire incident must address seriously by the authorities, fire safety and proper program dissemination should take place.

Environmental and Socioeconomic impact are the major concern of this study, a Time Series Forecasting using Multiplicative Model was utilized in this research to analyzed the past data and predict into the future. This study was initiated to provide authorities and decision makers a better insight of fire risk and its possible cause that help to form fire risk management plan.

Some researches has used predictive modelling in predicting fire risk, "An intelligent system for forest fire risk prediction in Galicia Europe" [4] and "Integrated Spatio-temporal Data Mining for Forest Fire Prediction [5] researches that are similar on this study that dealt with fire risk and the main focus is to identify fire prone area. However this research uses on historical data to predict fire risk in the future which is dissimilar with other studies that uses real time variables such as current temperature and humidity through the usage of Geographic Information System, weather station and satellite imagery [6,7], in predicting fire risk .

In this paper, researchers seek to predict the risk of fire and its possible cause with the use of Time Series Forecasting using Multiplicative Model [8]that allow to study past data to

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extrapolate prediction into the future that will help to identify the threat and risk of fire and to generate significant conclusion which can be used as tool to guide authorities in formulating their risk reduction management plan.

The rest of the paper is organized as follows: Section 2 Methodologies, Results and discussion and presented in Section 3. Section 4 concludes the paper with outline future work.

II. METHODOLOGIES

A. Case Study Implementation

Philippines has 16 urban areas, one of which is Manila and considered as the most densely populated city in the world with 42,857 individuals for each square mile otherwise 111,002 people per square mile. Manila has a population of 1.78 million in 2016, as per census data. Moreover Manila has grown quickly over the last century, separately for a period between 1990 and 2000 when it had negative growth rate of 0.13%. Concerning 2000 and 2010, the people had an average annual growth rate of 0.44%. By 2020, it is foretell that Asia will be the most mega city in the world and Metro Manila will have 20 million populations as projected [9]. Manila is composed of 16 district particularly: Tondo, Binondo, Quiapo, San Nicolas, Sta. Cruz, Sampaloc, San Andres, San Miguel, Ermita, Intramuros, Malate, Pako ,Pandacan, Port Area, Sta. Plateau and Sta. Ana. Tondo was the most populated district with 38% of the total population, followed by Sampaloc with 20.7% and Santa Ana with 10.7% of the total population [10].

B. Data Collections and Procedures

The fire incidents in this study arise during the period of January 1, 2011 to December 31, 2015 which also inspected by the Arson section at the Bureau of Fire and Protection (BFP) Manila Headquarter. Data was collected from the BFP headquarter through reference, data was summarized and encoded by the nature of causes of fire incident, and categorized in different group such as causes ,month, day, time and amount of damages with a total of 2823 fire incidents. The Operation and Arson department in BFP were interviewed by the researchers and to make understand and analyze the data easier the dialogue was recorded in audio format. The data collected also undergone reviews to fill specific gaps. Other reviews were made by the researchers to identify fires individual reports and to create master list of all fire incidents. Raw data were inspected for processing, the yearly report of fire incidents and was made in excel worksheet with monthly record of fire incident per year.

C. Decomposition: Time Series Forecasting using Multiplicative Model

In the multiplicative model an original time series is expressed as a product of three components [11]:

- the trend-cycle component (TCt);
- the seasonal effects (St);
- the irregular fluctuations (It);
- the Observed series (Ot),

Therefore, the multiplicative decomposition is expressed by the following equation (1):

$$\text{Observed series} = \text{Trend} \times \text{Seasonal} \times \text{Irregular}$$
$$Ot = TCt \times St \times I \quad (1)$$

Smoothing: Moving average smoothing

In Moving Average Smoothing [12], each observation is assigned an equal weight, and each observation is forecasted by using the average of the previous observation(s). Using the time series $X_1, X_2, X_3, ..., X_t$, this smoothing technique predicts X_{t+k} (2) as follows :

$$S_t = Average\ (x_{t-k+1}, x_{t-k+2}, ..., x_t),\ t= k, k+1, k+2, ...N \quad (2)$$

where, k is the smoothing parameter.

Absolute mean error [13]
abe = Summation of actual data – Summation of prediction

III. RESULT AND DISCUSSIONS

Based on the result acquire in the combined analysis fire incidences from year 2011 to 2015, a total of 2823 cases were stated in the City of Manila with 16 districts. Table 1. (Fire Incident per District) show the occurrence of fire incident in the different districts, Tondo tallying the most number of cases with 699 incidents, followed by Sampaloc with 586 which is the second of the most number of cases. San Nicolas is the least number of fire incidents. Tondo and Sampaloc are two of the most densely population based on the August 2015 Census of Population and Housing by the National Statistics Office, Tondo accounting 38% of the total population of Manila fallowed by Sampaloc accounting 20.7%. As the Correlation, the more densely district will more possibility of fire arises.

TABLE 1. Fire Incident Tabulation per District

	Year					
District	2011	2012	2013	2014	2015	Total
Tondo	124	102	166	147	160	699
Binondo	25	17	25	29	22	118
Quiapo	12	16	21	36	13	98
San Nicolas	4	1	4	5	1	15
Sta Cruz	64	65	54	60	64	307
Sampaloc	151	120	96	120	81	568
San Miguel	21	6	10	6	8	51
Ermita	31	34	32	44	30	171
Intramuros	10	8	13	3	3	37
Malate	26	22	24	25	26	123
Paco	31	26	41	16	10	124
Pandacan	27	36	25	27	11	126
Port Area	3	5	6	9	6	29
Sta Ana	31	43	45	53	34	206
Sta Mesa	0	12	40	29	28	109
San Andres	6	2	12	12	10	42
Total						2823

Cumulative Frequency Analysis shows relationship and related pattern between Time Series Forecasting as shown in Fig.1 and shows detailed presentation in Table 2. As predicted based on the Multiplicative model it shows that

Tondo is most risk in fire with possible of 153 possible cases in a year, followed by Sampaloc with possible of 124 cases in year and San Nicolas tallying the least fire risk with 4 possible cases in a year, all prediction had 9.96% absolute mean error.

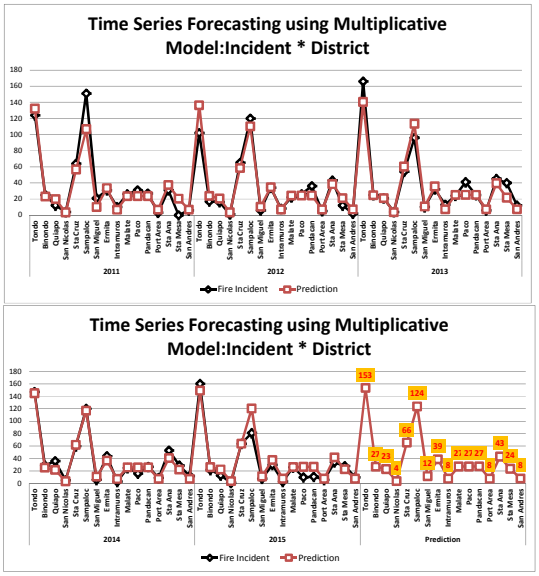

Fig. 1. Fire Prediction by District

TABLE 2. Incident * District

Time Series Forecasting using Multiplicative Model : Incident * District							
		Actual Cases					
No.	District	2011	2012	2013	2014	2015	Prediction
1	Tondo	124	102	166	147	160	153
2	Binondo	25	17	25	29	22	27
3	Quiapo	12	16	21	36	13	23
4	San Nicolas	4	1	4	5	1	4
5	Sta Cruz	64	65	54	60	64	66
6	Sampaloc	151	120	96	120	81	124
7	San Miguel	21	6	10	6	8	12
8	Ermita	31	34	32	44	30	39
9	Intramuros	10	8	13	3	3	8
10	Malate	26	22	24	25	26	27
11	Paco	31	26	41	16	10	27
12	Pandacan	27	36	25	27	11	27
13	Port Area	3	5	6	9	6	8
14	Sta Ana	31	43	45	53	34	43
15	Sta Mesa	0	12	40	29	28	24
16	San Andres	6	2	10	14	10	8
Total		566	515	612	623	507	620

As shown in Table 3. , based on cumulative frequency Electrical Failure is most number of fire incidents across the district tallying 1576 for the period of January 2011 – December 2015. Under Investigation, Unattended Open Flame, Cigarette Butts and LPG related were also enumerated as the other major causes.

TABLE 3. Fire Causes Tabulation per Year

Causes	2011	2012	2013	2014	2015	Total
Electrical Failure	340	288	354	352	242	1576
LPG Related	24	33	52	31	27	167
Cigarette Butt	44	37	51	58	31	221
Unattended Open flame	41	54	36	44	48	223
Neglected appliances/devices	39	31	22	14	19	125
Under Investigation	66	58	90	103	117	434
Intentional	1	2	2	6	14	25
Others	4	6	2	9	6	27
Mechanical Failure	4	5	3	3	3	18
Not Indicated	3	1	0	3	0	7
					Total	2823

Fig. 2, shows the possible month were fire will arise a in a year. Based on Cumulative Frequency fire incident record as presented on table 4, from year 2011 - 2015 the graph does not much shows pattern on Time Series Forecasting model, moreover prediction shows that summer months are the high risk in fire particularly February, March and May with an average of 57 cases a year however September is the most prone month in fire all prediction got an absolute mean error rate of 8.09%.

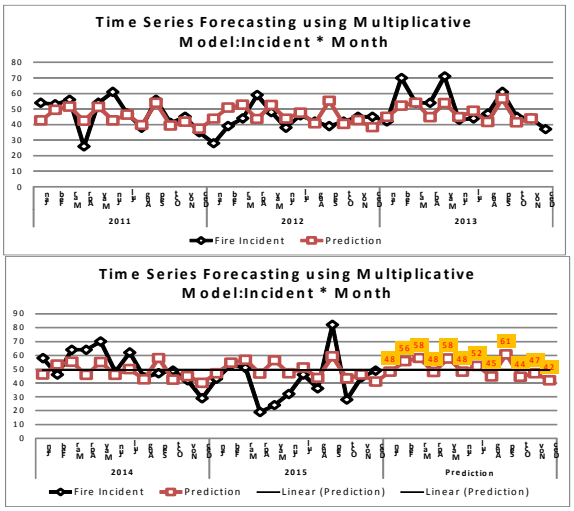

Fig. 2. Incident * Month

TABLE 4. Incident * Month

Time Series Forecasting using Multiplicative Model : Incident * Month							
		Actual Cases					
No.	Month	2011	2012	2013	2014	2015	Prediction
1	Jan	54	28	42	58	43	48
2	Feb	53	39	70	46	53	56
3	Mar	56	44	54	64	51	58
4	Apr	26	59	54	64	19	48
5	May	54	48	71	70	24	58
6	Jun	61	38	43	48	32	48
7	Jul	47	46	44	62	46	52
8	Aug	38	42	47	44	36	45
9	Sep	56	39	61	47	82	61
10	Oct	41	42	45	49	28	44
11	Nov	45	45	44	42	44	47
12	Dec	35	45	37	29	49	42
Total		566	515	612	623	507	607

Fig. 3, shows prediction of the most critical day that fire will arise. Based on the fire incident record, from year 2011 - 2015 the graph shows pattern on Time Series Forecasting using Multiplicative model prediction shows Saturday is high risk in fire with 109 possible fire cases will happen on this day in a year as presented on table 4 with an absolute mean error rate of 13.94%.

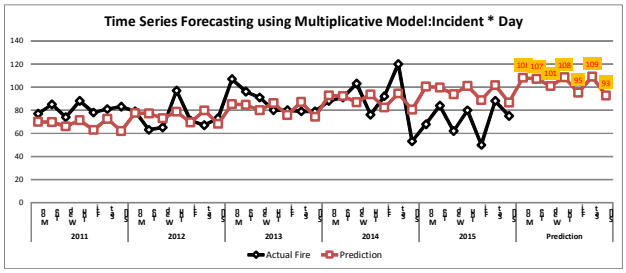

Fig. 3. Incident * Day

Table 5. , shows the detailed presentation of data between actual cases and possible fire occurrence by day, moreover the table shows that Saturday is the most critical day in fire occurrence.

TABLE 5. Incident * Day

Time Series Forecasting using Multiplicative Model : Incident * Day							
		Actual Cases					
No.	Day	2011	2012	2013	2014	2015	Prediction
1	Mon	77	79	107	88	68	108
2	Tue	85	63	96	91	84	107
3	Wed	74	65	91	103	62	101
4	Thu	88	97	80	76	80	108
5	Fri	78	71	80	92	50	95
6	Sat	81	67	79	120	88	109
7	Sun	83	73	79	53	75	93
Total		566	515	612	623	507	721

In fig. 4, the crucial time that fire will possible arise is between 7:00pm to 9:00pm and also this particular time majority of the residents at time moment are using Electrical Appliances, tallying 120 possible fire cases will arise at this specific time in a year prediction with an absolute mean error rate of 22.45%. Moreover the second to most possible fire occurrence in terms of time is between 10:00am to 12:00pm with 109 possible fire cases will arise at this time, also at this moment is the peak of temperature in day.

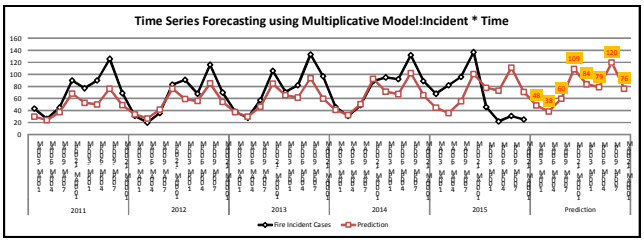

Fig. 4. Incident * Time

Table 6. , shows the detailed presentation of data between actual cases and possible fire occurrence by time and also shows that between 7:00pm to 9:00pm is the most critical time in fire occurrence.

TABLE 6. Incident * Time

		Actual Cases					
No.	Time	2011	2012	2013	2014	2015	Prediction
1	1:00AM -3:00AM	43	31	38	46	68	48
2	4:00AM -6:00AM	26	20	28	31	82	38
3	7:00AM -9:00AM	45	36	57	49	96	60
4	10:00AM -12:00PM	90	83	106	89	137	109
5	1:00PM -3:00PM	77	91	71	95	46	84
6	4:00PM -6:00PM	90	68	82	92	22	79
7	7:00PM -9:00PM	126	116	133	132	31	120
8	10:00AM -12:00AM	69	70	97	89	25	76
Total		566	515	612	623	507	614

IV. CONCLUSIONS AND RECOMMENDATION

Fire is considered as one of the most dangerous incident that repeatedly happen in our daily lives which effect both social and economy. The study seeks to understand the possible risk of fire in the City of Manila using Time Series Forecasting Multiplicative Model, which indicated Tondo is the most prone in fire, Electrical Failure is the common causes of fire, which most happen during these months particularly February, March, May and September, between 7:00pm to 9:00pm and 10:00am to 12:00pm. The data included in the study had a total of 2823 which happened over five year period (2011 - 2015) and presented by Year, Month, Day and Time.

It is found that those fire incidents has a pattern which is similar with the forecasted result, therefore the probability of occurrence fire based on the predicted result can be utilize as a tool to guide decision makers and authorities to have preemptive plan and risk safety management program to mitigate the possible fire incident in the future.

Decision makers, authorities and community as a whole must understand the importance of fire risk to improve fire service, with the use of Time Series Forecasting model it will be a great help and serve as a tool to analyze location that are prone in fire, particular month , day will arise and even crucial time.

With regards to future researcher, there are still numerous variables that affect the occurrence of fire, researchers recommend investigate those variables to make prediction more precisely. Geographic Information System-based Time Series Forecasting model is also must take opportunity that serve a powerful tool to predict fire risk.

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