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Evaluating and predicting losses from thunderbolt and fire events in Nepal: A regression analysis with moving averages approach

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Abstract

Nepal is prone to natural disasters, including thunderbolts and fires,due to its geographical location. However, the lack of awareness and preparedness has exacerbated the impact of these disasters, as evidenced by the current serious pandemic situation. Urgent attention is required in terms of financial, social, and technological development to effectively manage thunderbolt and fire incidents. This study examines the frequency and severity of thunderbolt and fire incidents in Nepal over the past 48 years, revealing a concerning trend of increasing losses and incidents. Despite this alarming situation, the issue remains largely overlooked. It is imperative for relevant agencies to take decisive actions to mitigate the losses caused by these disasters. Implementing awareness programs and ensuring preparedness are crucial steps towards reducing the impact of disasters and safeguarding communities from their devastating consequences.

Keywords
Disaster; Thunderstorm, Fire, Forecasting method.

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1 Introduction

Nepal, encompassing an area of 147,141 square kilometers, comprises diverse regions such as the hilly region, terai region, and Himalayas. The increasing global warming and climate change have resulted in various significant challenges worldwide, including shortened monsoon periods, erratic rainfall, and increased occurrences of natural disasters such as thunderbolts, fires, landslides, floods, and droughts. Among these disasters, thunderbolts and fires stand out as the most destructive in Nepal due to its geographical diversity, making the country a hotspot for natural calamities [1]. Different regions of Nepal face distinct types of disasters on a daily basis, leading to numerous casualties, missing individuals, and widespread devastation. In the terai region, thunderbolts, droughts, and floods are predominant causes of destruction, while landslides and thunderbolts pose significant threats in the hilly region. Additionally, avalanches in the Himalayas region have claimed the lives of many individuals [2].

The prevalent natural disasters in Nepal include thunderbolts, fires, landslides, and floods, with a focus on thunderbolts and fires in this study. Fires have ecological effects on vegetation patterns in ecosystems, with both positive and negative impacts [3]. Forest fires result in economic, social, and ecological damage, necessitating prioritized forest fire management through awareness programs and the utilization of forest firefighting tools to mitigate their widespread socio-economic, environmental, and ecological impacts. Ignoring forest fire management could hinder Nepal's overall development [4].

The majority of fire incidents occur during the pre-monsoon season, with tropical lowland, evergreen forests, and broad-leaved forests being at the highest risk, especially in areas with high tree cover density, lower elevations, and lower slopes [5]. The total burned area has seen a 0.6% increase since 2001 AD [6]. Lightning phenomena involve electrical discharge within a cloud or between a cloud and the earth, while thunderbolts are characterized by a flash of light accompanied by thunder [7]. Most thunderbolt incidents occur in April and May, while fires typically occur in March [8]. Between 2011 and 2021 AD, no lightning incidents were recorded in November, with maximum occurrences observed during the pre-monsoon period. The number of people injured due to lightning is nearly three times the number of fatalities [9, 10]. Investing in disaster preparedness and awareness programs is crucial, as demonstrated by Aryal's findings that investing 1 NPR before a disaster is equivalent to saving 18 NPR after a disaster [11].

Hazard identification can also help to prevent the fire scenarios. Numerous studies have explored the variability and impacts of natural hazards, yet only a limited number have focused on analyzing historical trends and forecasting future scenarios. This research is based on the examination and projection of losses attributed to disasters, recognizing the varying degrees of destructiveness among different types. Within the context of Nepal, our focus lies on thunderbolt and fire, deemed particularly destructive. Through this research, we aim to analyze the overall trend of disaster-related losses and utilize generalized equations to forecast future losses based on these trends. Therefore, prioritizing development work and implementing preparedness and awareness programs are essential in reducing losses due to disasters.

2 Methodology

In conducting this research, the necessary data was sourced from the Disaster Risk Reduction (DRR) portal of the Ministry of Home Affairs (MoHA). Data spanning from 1971 AD to 2022 AD, covering a period of 48 years, was collected. To analyze the data, a moving average of 5 years was calculated, and each period was labeled from 0 to 47. For instance, period zero (0) represents the average from 1971 AD to 1975 AD, period one (1) represents the average from 1972 AD to 1976 AD, and so forth. Graphs were plotted for various variables such as the average number of incidents, total deaths, affected families, and number of injured people over time. Using the time series data, a regression equation in the form of Y = a + bX was determined, where Y represents the dependent variable, X represents the independent variable (time), 'a' represents the intercept, and 'b' represents the slope of the regression line. These graphs were analyzed using MS Excel.

The regression line, which provides insights into the effects on human lives in future years, was fitted based on the trend identified from the plotted data. Error analysis was conducted by comparing observed values (Y) with estimated values (Y') obtained from the regression equation. The deviation between these values was calculated and plotted in tables for further analysis.

The regression equation, expressed as a straight line in the form Y = mX + C, was utilized for this analysis. The normal equations derived from this equation are as follows:

$$\sum Y = m\sum X + nC \tag{1}$$

and

$$\sum XY = m\sum X^2 + C\sum X \tag{2}$$

Solving these equations yields the slope (m) and intercept (C) of the straight line. The formulas used to calculate the slope and intercept are as follows:

$$\text{m} = \frac{n\sum XY - \sum X \ \sum Y}{n\sum X^2 \ - m\sum X} \text{ and, } C = \frac{\Sigma Y - m\sum X}{n}.$$

By utilizing these formulas, the slope and intercept of the straight line are determined, providing valuable insights for the analysis.

In this research, estimated values refer to those derived from the regression equation, while observed values denote secondary data obtained from the specified data source. The estimated values are selected at intervals of five consecutive years rather than encompassing all years, aiming to analyze the data distribution. Subsequently, the disparity between estimated values (Y) and observed values (Y_1) is tabulated for each variable, with this difference termed as the error "e" (defined as the variance between the two data points, estimated and observed). This shows that the estimated values are how closely align with the observed values.

Overall, the data highlights the increasing frequency and severity of both disasters fire and thunderbolt-related incidents over the years, emphasizing the importance of effective disaster management and preparedness measures to mitigate their impact on communities.

3 Results and Discussion

The data collected spans from 1971 AD to 2022 AD, with each period representing a five-year average using the moving average method. In the table provided, each row corresponds to a five-year period, labeled from zero to 46, where zero represents the average from 1971 AD to 1975 AD, 1 represents the average from 1972 AD to 1976 AD, and so forth. The table includes various metrics: 'Ave. NOI' represents the average number of incidents, 'Ave. TD' represents the average total number of deaths, 'Ave. AF' represents the average total number of affected family, 'Ave. INJ' represents the average total number of injured people due to thunderbolt.

A. **Thunderbolt**

From Table 1, it is observed that, the average number of incidents shows a generally increasing trend, particularly after year 34, where there is a rapid increase. The maximum number of deaths is recorded between years 34 and 42, with an average value exceeding 100. The number of affected families exhibits variability, ranging from zero to 1027 in average. This variation could be attributed to a lack of historical information or incomplete recording of disaster-related data in earlier years due to limited communication between societies. The maximum average number of injured individuals is recorded in years 45 and 46, exceeding 300. There is a notable increase in the number of injured people after year 32, indicating a significant rise in incidents resulting in injuries.

The provided graph displays the total number of incidents attributed to thunderbolts, with the original data represented by the blue dotted line. The graph highlights a sharp increase in incidents in recent years. Additionally, a regression line has been fitted to the data, represented by the red dotted line. This regression line serves as a predictive tool, indicating the expected future trend of thunderbolt-related incidents. The regression line equation, expressing the relationship between the average number of incidents (Y) and the independent variable (X), is: Y = -47.32 + 4.70X. In

Table 1: Moving average data of thunderbolt.

Year	Ave. NOI	Ave. TD	Ave. AF	Ave. INJ
0	5.8	5.6	44.6	11.4
1	6.6	5.8	44.6	11.0
2	8.4	7.2	44.6	11.4
3	8.6	10.0	20.6	15.4
4	6.8	8.6	0.0	8.4
5	6.6	8.2	0.0	5.8
6	5.4	7.0	0.0	5.6
7	3.4	5.6	0.0	5.2
8	4.0	3.8	0.0	9.0
9	5.4	5.0	0.0	9.0
10	4.8	4.6	0.0	8.6
11	4.6	4.2	0.0	8.6
12	5.2	4.4	0.0	9.2
13	4.8	3.4	0.8	1.8
14	4.0	4.2	0.8	4.6
15	5.4	6.6	3.0	9.8
16	9.4	12.0	3.0	14.8
17	11.4	15.2	3.0	16.0
18	20.0	24.2	2.2	25.0
19	31.0	32.6	33.8	36.8
20	32.2	32.8	31.6	33.0
21	34.4	34.0	109.0	37.4
22	45.2	45.0	789.2	59.2
23	39.4	38.2	789.2	54.6
24	32.0	32.8	757.6	49.4
25	35.8	34.2	757.6	56.8
26	39.4	40.4	680.2	63.4
27	31.4	32.2	0.0	48.0
28	38.6	42.2	324.0	64.2
29	41.4	41.2	324.2	69.8
30	40.2	44.0	324.2	73.4
31	39.8	39.4	324.2	85.2
32	46.4	42.4	325.0	109.4
33	51.2	41.6	21.4	119.8
34	64.0	53.2	153.0	141.6
35	75.8	61.2	172.6	163.4
36	94.2	73.8	528.4	195.8
37	112.6	86.6	738.4	224.4
38	121.6	100.2	1027.2	252.2
39	137.0	103.6	896.0	206.8
40	149.0	109.2	888.8	209.8
41	162.0	111.8	584.8	197.6
42	169.2	106.8	425.6	186.8
43	192.6	95.6	188.4	241.0
44	233.8	95.0	293.2	285.8
45	265.2	90.8	403.0	310.4
46	265.6	78.2	412.4	301.0
47	280.8	78.6	439.0	295.4

this equation, Y represents the dependent variable, which is the average number of incidents of thunderbolts and X represents the independent variable, which could be time or another relevant factor. This regression equation allows for forecasting future trends in the number of thunderbolt-related incidents based on the provided data and the identified regression line.

Table 2: Estimated and observed data of number of incidents due to thunderbolt

Year (X)	**Estimated Y = -47.32 + 4.70X**	**Observed Y1**	**Error e = Y - Y1**	e^2
0	-47.32	5.8	-53.12	2821.734
5	-23.82	6.6	-30.42	925.3764
10	-0.32	4.8	-5.12	26.2144
15	23.18	5.4	17.78	316.1284
20	46.68	32.2	14.48	209.6704
25	70.18	35.8	34.38	1181.984
30	93.68	40.2	53.48	2860.11
35	117.18	75.8	41.38	1712.304
40	140.68	149.0	-8.32	69.2224
45	164.18	265.2	-101.02	10205.04

The figure 2 is the graph of total death of the thunderbolt. Here straight line is the predicted line of average total death. From figure 2 it is clear that the total death due to thunderbolt is increasing sharply. The peak number of total deaths are seen in the year 35 to 45 and the lowest number of deaths are in the years 0 to 15. This is the regression line of average total death, Y= -13.21+2.30 X.

Table 3: Estimated and observed data of number of total deaths due to thunderbolt

Year (X)	**Estimated Y = -13.21 + 2.30X**	**Observed Y1**	**Error e = Y - Y1**	e^2
0	-13.21	5.6	-18.81	353.8161
5	-1.71	8.2	-9.91	98.2081
10	9.79	4.6	5.19	26.9361
15	21.29	6.6	14.69	215.7961
20	32.79	32.8	-0.01	0.0001
25	44.29	34.2	10.09	101.8081
30	55.79	44.0	11.79	139.0041
35	67.29	61.2	6.09	37.0881
40	78.79	109.2	-30.41	924.7681
45	90.29	90.8	-0.51	0.2601

The figure 3 is the graph of affected family. Here the straight line represents the predicted graph of affected family. There is the irregularity in the data structure. In some years the number of affected family is zero and in some years the number of affected family is high around thousand. The maximum number of affected family is seen in the years 20 to 25 and 35 to 40. The number of affected family is zero in the years 5 to 20 is zero. This could happen because in the past years there is no sufficient data available and there could be missing the data. This is the regression line of average injured people, Y= 11.74 + 0.13 X.

The figure 4 is the graph of injured people the straight-line is the predicted line for the thunderbolt. The graph of injured people is also in increasing order in which the graph is not that much increasing till the year 30. Then after the graph is increasing sharply after the year 30 and the peak number of injured peoples due to thunderbolt is in year 45. This is the regression equation for injured people by thunderbolt, Y= -57.58 + 6.32 X.

Table 4: Estimated and observed data of number of affected families due to thunderbolt

Year	Estimated Y = -57.55 + 13.89X	Observed Y1	Error e = Y - Y1	e^2
0	-57.55	44.6	-102.15	10434.62
5	11.9	0.0	11.9	141.61
10	81.35	0.0	81.35	6617.823
15	150.8	3.0	147.8	21844.84
20	220.25	31.6	188.65	35588.82
25	289.7	757.6	-467.9	218930.4
30	359.15	324.2	34.95	1221.503
35	428.6	172.6	256.0	65536.0
40	498.05	888.8	-390.75	152685.6
45	567.5	403.0	164.5	27060.25

Table 5: Estimated and observed data of number of injured people due to thunderbolt

Year	Estimated Y = -57.55 + 6.32X	Observed Y1	Error e = Y - Y1	e^2
0	-57.55	11.4	-68.95	4754.103
5	-25.95	5.8	-31.75	1008.063
10	5.65	8.6	-2.95	8.7025
15	37.25	9.8	27.45	753.5025
20	68.85	33.0	35.85	1285.223
25	100.45	56.8	43.65	1905.323
30	132.05	73.4	58.65	3439.823
35	163.65	163.4	0.25	0.0625
40	195.25	209.8	-14.55	211.7025
45	226.85	310.4	-83.55	6980.602

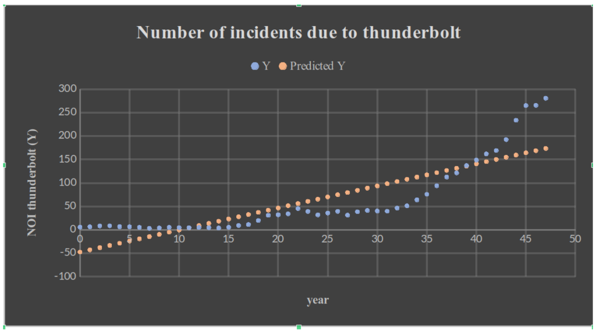

Figure 1: Graph of average number of incidents due to thunderbolt.

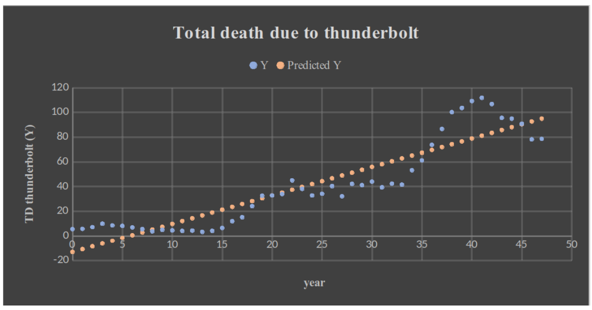

Figure 2: Graph of average number of total death due to thunderbolt.

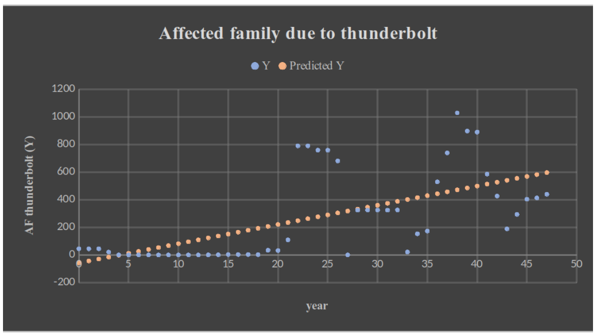

Figure 3: Number of affected family due to thunderbolt.

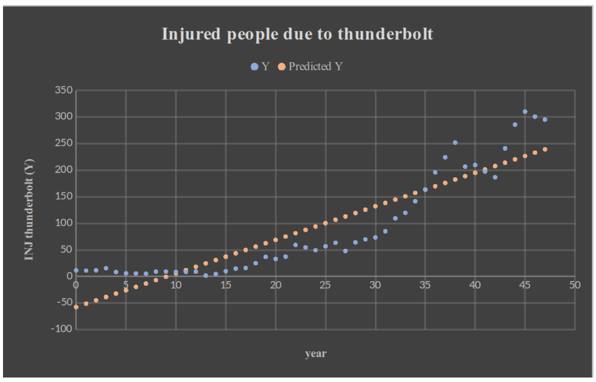

Figure 4: Number of injured people due to thunderbolt.

B. Fire

Table 6 presents data on fire incidents, including moving averages for the number of incidents, total deaths, affected families, and injured people across 47 different years. In this table, the periods are labeled from 0 to 46, where 0 represents the moving average from 1971 AD to 1975 AD, and subsequent periods represent consecutive five-year averages. 'Ave. NOI' represents the average number of incidents, 'Ave. TD' represents the average number of total deaths, 'Ave. AF' represents the average number of affected families, 'Ave. INJ' represents the average number of injured people. From the Table 2, it is observed that the number of incidents shows an increasing trend as the number of year approaches 47, with the maximum recorded at year 47, averaging 2542.8 incidents. Year 47 corresponds to the average from 2018 AD to 2022 AD and the total number of deaths also exhibits an increasing trend, reaching its peak at year 47 with an average of 84.8 deaths. The number of affected families follows a similar pattern, increasing steadily until year 25, then reaching a peak value exceeding 10,000, before decreasing thereafter. Similarly, the number of injured people shows a consistent increase over the years, with the maximum average of 345 injuries recorded at year 47.

Overall, the data indicates a concerning trend of increasing fire incidents, resulting in higher numbers of deaths, affected families, and injured individuals, especially in recent years. These observations underscore the importance of effective fire prevention and management strategies to mitigate the impact of fires on communities.

Fig. 5 is the graph of average number of incidents of fire from 1971 to 2022 AD. And the straight line is the predicted line which helps to predicts possible number of incidents in future. The number of incidents due to the fire is sharply increasing after the year 40. Till the year 40 the graph is flat. This is the regression equation for number of incidents. By the help of this equation the future forecasting is possible by this the future events can be predicted. The regression line equation is Y= - 315.77 + 29.48 X.

Fig. 6 is the graph of average number of total deaths. And the straight line is the predicted line for future events. From the figure 6 the graph is increasing sharply and there is certain increase in the year 20 to 25. And then it increasing from year 35. Here the straight line which gives the prediction that how many peoples would die in the latest years due to fire. The regression equation for fire which helps to predict the average total deaths in future is Y = 9.76 + 1.25 X.

Table 6: Moving average data of fire

Year	ave. NOI	ave. TD	ave. AF	ave. INJ
0	54.2	10.0	6859.8	5.4
1	78.4	17.0	8475.4	12.8
2	87.4	17.8	8607.0	22.8
3	87.2	16.8	8740.4	23.4
4	91.4	24.6	8972.6	22.8
5	91.8	25.0	3771.0	32.4
6	77.2	19.4	2407.4	34.8
7	71.0	19.6	2458.8	25.4
8	66.2	18.8	2893.0	27.4
9	66.4	13.0	3395.6	27.2
10	66.4	13.2	3230.4	19.2
11	61.8	14.4	3665.2	9.6
12	63.2	13.6	5214.4	9.6
13	62.8	14.2	4834.0	6.0
14	76.8	14.8	4661.8	7.8
15	78.8	13.8	4176.6	7.8
16	89.0	15.0	3803.4	10.6
17	123.6	22.6	3544.0	10.4
18	142.0	25.6	4886.0	15.0
19	136.4	30.8	6001.0	18.8
20	153.8	49.0	10089.6	26.0
21	160.4	67.8	17355.6	37.8
22	154.4	74.4	19457.4	46.8
23	134.6	73.4	17928.2	45.0
24	133.0	70.8	16486.2	41.0
25	132.8	58.8	12753.6	34.8
26	157.8	45.8	5462.0	28.6
27	134.8	33.0	2258.2	20.0
28	155.2	36.4	3995.4	20.4
29	155.6	32.6	3009.0	22.0
30	148.2	27.6	2780.2	21.6
31	122.6	25.2	2492.2	22.2
32	129.2	26.4	2091.4	25.8
33	160.6	32.8	3129.8	51.0
34	211.4	41.6	5595.8	73.4
35	259.6	50.6	6791.6	82.2
36	299.8	49.4	9192.8	93.6
37	361.0	58.0	15127.8	119.8
38	362.6	53.8	14049.8	108.4
39	474.8	54.0	11594.4	101.4
40	526.6	56.8	10164.4	103.0
41	766.2	62.6	8455.2	131.2
42	978.6	62.6	2968.6	142.4
43	1407.8	70.0	1991.0	192.2
44	1788.2	72.6	2707.6	241.6
45	2086.6	69.0	3181.6	290.8
46	2321.0	76.2	3174.4	314.4
47	2542.8	84.8	3300.4	345.0

The figure 7 is the graph of average number of total affected family by fire from 1971 to 2022 AD. And the straight line is the predicted line which helps to predicts future events. The peak number of affected peoples is seen in year 20 to 25.

And the overall graph is seen constant and has an average value of around 6500. The regression equation for average number of affected family is, Y=6502.22+5.39 X.

Fig. 8 is the graph of total number of injured people and the straight line is the predicted line which helps to predict future events. The graph 8 shows that the number of injured peoples due to fire is also increasing and has a peak value at year 47. The graph is sharply increased after the year 30. There is no significant increase in the trend till the year 30. The regression equation for injured people by fire is, Y = -37.53 + 4.37 X.

While the literature is rich in studies on hazard management, there is a notable absence of research focusing specifically on the trend analysis and prediction of losses over time. This manuscript uniquely emphasizes the examination of past loss trends to forecast future losses. Our observation indicates a significant upward trajectory in losses compared to previous years, especially in recent times. Overall, our study aims to analyze the escalating trend in losses, particularly notable in recent years. However, it's important to acknowledge that the prediction of future losses may encounter challenges due to potential variations in the data obtained from the sources, which could introduce additional errors into the forecasting process.

Table 7: Estimated and observed data of number of incidents due to fire

Year	**Estimated Y = -315.77 + 29.48X**	**Observed Y1**	**Error e = Y-Y1**	e^2
0	-315.77	54.2	-369.97	136877.8
5	-168.37	91.8	-260.17	67688.43
10	-20.97	66.4	-87.37	7633.517
15	126.43	78.8	47.63	2268.617
20	273.83	153.8	120.03	14407.2
25	421.23	132.8	288.43	83191.86
30	568.63	148.2	420.43	176761.4
35	716.03	259.6	456.43	208328.3
40	863.43	526.6	336.83	113454.4
45	1010.83	2086.6	-1075.77	1157281

Table 8: Estimated and observed data of number of total deaths due to fire

Year	**Estimated Y = 9.76 + 1.2X**	**Observed Y1**	**Error e = Y - Y1**	e^2
0	9.76	10	-0.24	0.0576
5	15.76	25	-9.24	85.3776
10	21.76	13.2	8.56	73.2736
15	27.76	13.8	13.96	194.8816
20	33.76	49	-15.24	232.2576
25	39.76	58.8	-19.04	362.5216
30	45.76	27.6	18.16	329.7856
35	51.76	50.6	1.16	1.3456
40	57.76	56.8	0.96	0.9216
45	63.76	69	-5.24	27.4576

Table 9: Estimated and observed data of number of affected families due to fire

Year	**Estimated Y = 6502.22 + 5.38X**	**Observed Y1**	**Error e = Y - Y1**	e^2
0	6502.22	6859.8	-357.58	127863.5
5	6529.12	3771	2758.12	7607226
10	6556.02	3230.4	3325.62	11059748
15	6582.92	4176.6	2406.32	5790376
20	6609.82	10089.6	-3479.78	12108869
25	6636.72	12753.6	-6116.88	37416221
30	6663.62	2780.2	3883.42	15080951
35	6690.52	6791.6	-101.08	10217.17
40	6717.42	10164.4	-3446.98	11881671
45	6744.32	3181.6	3562.72	12692974

Table 10: Estimated and observed data of number of injured people due to fire

Year	**Estimated Y = -37.53 + 4.37X**	**Observed Y1**	**Error e = Y - Y1**	e^2
0	-37.53	5.4	-42.93	1842.985
5	-15.68	32.4	-48.08	2311.686
10	6.17	19.2	-13.03	169.7809
15	28.02	7.8	20.22	408.8484
20	49.87	26	23.87	569.7769
25	71.72	34.8	36.92	1363.086
30	93.57	21.6	71.97	5179.681
35	115.42	82.2	33.22	1103.568
40	137.27	103	34.27	1174.433
45	159.12	290.8	-131.68	17339.62

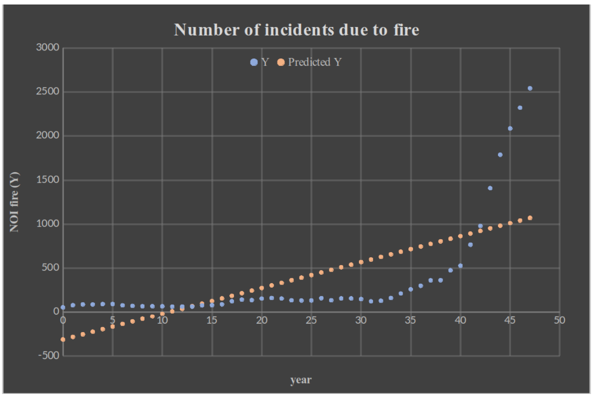

Figure 5: Graph of number of incidents due to fire.

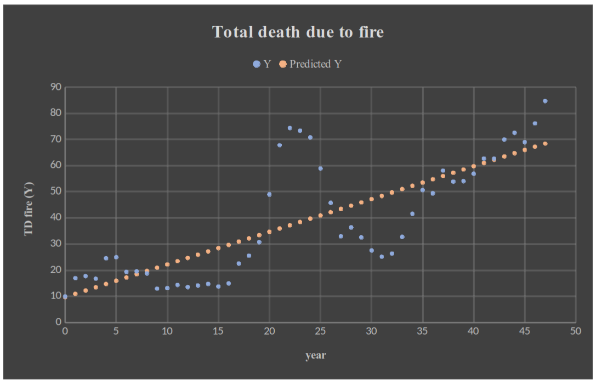

Figure 6: Graph of number of total death due to fire.

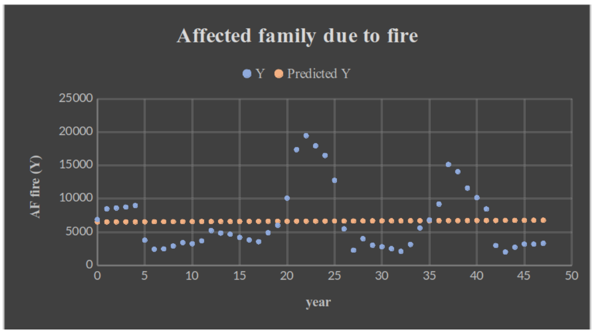

Figure 7: Graph of number of affected family due to fire.

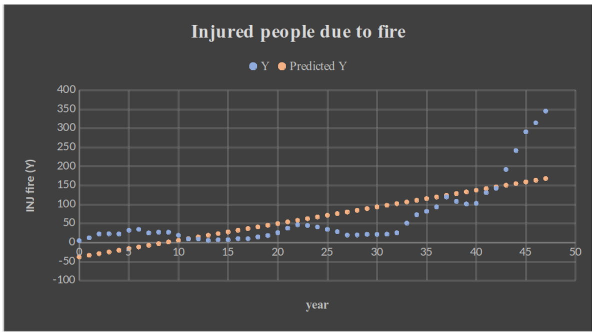

Figure 8: Graph of number of injured people due to fire.

4 Conclusion

The data clearly indicates a significant increase in losses and incidents, particularly in fire and thunderbolt incidents. The period from 2018 AD to 2022 AD stands out as having peak averages of 2542.8 fire incidents and 280.8 thunderbolt incidents. Graphs depicting these parameters show a sharp upward trend, highlighting the pressing need for intervention. Given the continuous rise in incidents and losses, it's evident that without major actions, there is no sign of reduction in these disasters. Therefore, it is imperative for the relevant agencies and the government to devise a clear plan to mitigate the losses caused by these disasters. Effective disaster management strategies, including well-preparedness measures and awareness programs, are crucial in reducing both human and material losses significantly. By enhancing preparedness and raising awareness about these disasters, communities can better protect themselves and their assets, ultimately reducing the overall impact of these calamities.

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