Available on: http://gjetr.ep-journals.org/ E-ISSN: 3051-3782, P-ISSN: 3051-3774

Global Journal of Engineering and Technology Review

Volume: 02 Issue: 04 April 2026

Forecasting Fire Incidents and Direct Property Losses in Vietnam: A Comparative Time-Series Study

Nguyen Thi Lan Anh

Faculty of Firefighting and Rescue, University of Fire Prevention and Fighting, Vietnam

Published Date: April 25, 2026 **Article DOI : 10.65150/EP-gjetr/V2E4/2026-02**

ABSTRACT: This article compares several short-term time-series models for forecasting fire incidents and direct property losses caused by fire in Vietnam. The study uses annual data for the 2020–2025 period compiled from official releases and published materials of the Fire Prevention, Firefighting and Rescue Police Department. Five forecasting methods are employed: the average absolute increase method, the average growth rate method, linear trend regression, simple exponential smoothing, and the three-year moving average. The results show that the three-year moving average model is the most suitable for both indicators. According to this model, Vietnam may record approximately 3,568 fire incidents and VND 774.08 billion in direct property losses in 2026. The article also indicates that although the share of direct fire-related property losses in GDP remains small, the actual economic impact of fire on firms, households, and supply chains is substantial. The study therefore underscores the role of fire forecasting in fire prevention, firefighting, rescue operations, and economic risk governance.

KEYWORDS: fire incidents, direct property losses, time-series models, short-term forecasting, fire prevention, firefighting and rescue, Vietnam.

1. INTRODUCTION

In the context of rapid socio-economic development and urbanization, fire prevention, firefighting, and rescue operations are playing an increasingly important role in ensuring public safety, maintaining production stability, protecting life and property, and sustaining the investment environment. From the perspective of modern governance, forecasting is not only intended to identify future trends but also to support resource allocation, preventive organization, and better managerial decision-making. According to Dang Tri Dung (2021) [1], forecasting must be built on past and present data and must ensure scientific rigor, objectivity, and methodological accountability.

In the field of fire prevention, firefighting, and rescue, the need for forecasting becomes more pressing as the number of fires, the accumulation of assets, and the scale of economic activity increase alongside urbanization and industrialization. In practice, the number of fire incidents and the scale of losses do not move in complete synchrony. In some years, the number of fires rises while direct property losses do not increase proportionally; in other years, only a few major fires at high-value facilities may sharply raise the total level of losses. Therefore, analyzing only the number of fires is insufficient to fully reflect risk in this field.

Based on this requirement, the present study adopts a two-indicator approach: the number of fire incidents and direct property losses caused by fire. Using annual data for 2020–2025, the article addresses three research questions: (i) under conditions of a short data series, which time-series models are suitable for short-term forecasting; (ii) which model produces lower forecasting errors for fire incidents and direct property losses; and (iii) what does direct fire-related property loss mean when considered in relation to Vietnam's economic growth and GDP scale.

2. THEORETICAL BACKGROUND AND ANALYTICAL ORIENTATION

Modern forecasting theory emphasizes that no single model is optimal for every data series; the appropriate model must be selected according to data characteristics, research objectives, and forecast error performance. Armstrong and Collopy (1992), Makridakis (1993), and Hyndman and Koehler (2006) [2]-[4] all argue that forecast evaluation should employ multiple error measures and should test model performance on empirical data. Gardner (1985, 2006) and Makridakis, Spiliotis, and Assimakopoulos (2018) [5]-[7] also point out that when data series are short, simple, transparent, and interpretable models often perform better than more complex models.

For fire prevention, firefighting, and rescue, monitoring only the number of fires is not sufficient. Studies by Bringula and Balahadia (2019), Chhetri et al. (2018), and KC and Corcoran (2017) [8]-[10] show that fire risk should be approached simultaneously from the perspectives of frequency, spatio-temporal distribution, and consequences. Regarding consequences, Rahman et al. (2023) [15] emphasize that fire losses extend beyond direct property damage to include lost productivity, interrupted income, and many other social costs.

Accordingly, this study selects five commonly used short-term time-series models: the average absolute increase method, the average growth rate method, linear trend regression, simple exponential smoothing, and the three-year moving average. These models have the advantage of clear structure, ease of computation, ease of interpretation, and suitability for short annual series, which is consistent with prior forecasting research [5]-[7].

3. DATA AND RESEARCH METHODS

3.1. Data Sources

The data used in this study were compiled by the author from official releases, statistical reports, and published materials of the Fire Prevention, Firefighting and Rescue Police Department on the situation of fires, explosions, and losses in Vietnam during 2020–2025 [16]. The use of official statistical data from this agency ensures both authoritativeness and relevance to research requirements in this field.

Macroeconomic data used for comparison were drawn from reports of the General Statistics Office, including GDP growth, GDP at current prices, and GDP per capita in Vietnam during 2020–2025 [17].

3.2. Study Indicators

The article uses two core indicators: (i) the number of fire incidents, reflecting the frequency of fire risk at the national level; and (ii) direct property losses caused by fire, reflecting the value of property directly damaged by fire, measured in VND billion.

Table 1. Fire Incidents and Direct Property Losses in Vietnam, 2020-2025

Year	Fire incidents (cases)	Direct property losses (VND billion)
2020	2.764	932,023
2021	2.245	374,420
2022	3.234	634,000
2023	3.440	878,000
2024	4.112	657,450
2025	3.151	786,780

Source: Compiled by the author from data published by the Fire Prevention, Firefighting and Rescue Police Department.

Descriptive statistics indicate that the average number of fire incidents during 2020–2025 was 3,157.67 cases per year, while average direct property losses amounted to VND 710.45 billion per year. Average direct property loss per fire incident fluctuated considerably, indicating that the magnitude of loss does not move in step with the number of fires. This is why the study adopts a two-indicator approach rather than analyzing fire frequency alone, in line with the broader literature on multidimensional fire-risk assessment [8]-[10].

3.3. Forecasting Methods

The study compares five short-term forecasting methods, as follows:

(1) Average absolute increase method. The average absolute increase method assumes that the phenomenon increases or decreases each year by a nearly stable absolute amount.

$\bar{\Delta} = (y_n - y_1)/(n - 1)$

$\hat{y}_{(n+1)} = y_n + \bar{\Delta}$

Applied to fire incidents, the forecast for 2026 is 3,228.40 cases; applied to direct property losses, the forecast is VND 757.73 billion.

(2) Average growth rate method. The average growth rate method assumes that the series changes proportionally.

$\bar{T} = (y_n / y_1)^{(1/(n-1))}$

$\hat{y}_{(n+1)} = y_n \times \bar{T}$

The corresponding forecasts for 2026 are 3,234.67 fire incidents and VND 760.57 billion in direct property losses.

(3) Linear trend regression. Linear trend regression describes the movement of the series as a linear function, where t is the time variable.

$\hat{y}_t = a + bt$

For the fire-incident series, the estimated forecast for 2026 is 3,931.87 cases; for direct property losses, the forecast is VND 747.13 billion.

(4) Simple exponential smoothing. Simple exponential smoothing assigns greater weight to observations closer to the present.

$F_{(t+1)} = \alpha y_t + (1 - \alpha)F_t$

In this study, the most suitable smoothing coefficient is approximately 0.50 for fire incidents and approximately 0.31 for direct property losses. The corresponding forecasts for 2026 are 3,392.16 cases and VND 750.76 billion.

(5) Three-year moving average. The three-year moving average forecasts the next year by taking the arithmetic mean of the three most recent years.

$\hat{y}_{(t+1)} = (y_t + y_{t-1} + y_{t-2})/3$

The forecast for 2026 is 3,567.67 fire incidents and VND 774.08 billion in direct property losses.

Corresponding Author: Nguyen Thi Lan Anh

3.4. Error Evaluation Criteria

The study uses two evaluation criteria: MAE (Mean Absolute Error) and MAPE (Mean Absolute Percentage Error). Using multiple measures rather than a single indicator allows for a more comprehensive assessment of forecasting performance, because each measure captures a different aspect of error [2],[4].

4. RESULTS

Table 2. Forecast Results for Fire Incidents and Direct Property Losses in 2026

Method	Fire incidents (cases)	Direct property losses (VND billion)
Average absolute increase	3.228,40	757,73
Average growth rate	3.234,67	760,57
Linear trend regression	3.931,87	747,13
Simple exponential smoothing	3.392,16	750,76
Three-year moving average	3.567,67	774,08

Source: Author's calculations.

The results show that the models generate quite different forecasts for the number of fire incidents, ranging from approximately 3.23 thousand to 3.93 thousand cases. This reflects the fact that Vietnam's fire data series is not yet stable, with some years showing a sharp decline and others a strong increase. For direct property losses, the forecast range is narrower, mainly from VND 747 billion to VND 774 billion, but this does not imply low risk; in practice, the series of direct property losses is still strongly affected by atypically large fires.

Table 3. Forecast Errors of the Models

Method	MAE - Fire incidents	MAPE - Fire incidents (%)	MAE - Direct property losses	MAPE - Direct property losses (%)
Average absolute increase	820,42	24,88	402,68	57,41
Average growth rate	817,69	24,86	306,55	42,76
Linear trend regression	835,66	25,25	380,80	53,36
Simple exponential smoothing	849,68	23,93	177,63	24,75
Three-year moving average	758,56	20,64	107,82	12,93

Source: Author's calculations.

The results indicate that the three-year moving average model yields the lowest error for both indicators. This suggests that under conditions of a short annual data series and strong fluctuation, a simple model capable of smoothing short-term variation is more appropriate than models that impose a more rigid trend structure. On this basis, the three-year moving average can be selected as the reference model for short-term forecasting for 2026; this finding is consistent with the methodological literature emphasizing the robustness of simple forecasting models for short and volatile series [5]-[7].

5. ANALYSIS OF THE ECONOMIC IMPACT OF FIRE LOSSES

5.1. Distinguishing Direct Property Losses from the Economic Impact of Fire

In this article, the forecasted indicator is direct property loss caused by fire. This indicator captures the portion of asset value that is burned, destroyed, or directly damaged and recorded in official statistics. However, the actual economic impact of fire is much broader. In addition to direct property damage, fires may cause production disruption, revenue loss, job loss, reduced household income, medical expenses, environmental remediation costs, and many other social costs. Rahman et al. (2023) [15] show that indirect losses caused by fire can substantially exceed direct property losses.

5.2. Fire Affects the Economy through Multiple Channels

First, fires destroy physical and productive capital. When a fire occurs in factories, warehouses, stores, markets, mixed-use residential-business premises, or production-related vehicles, the destroyed assets are not merely existing property but also accumulated capital invested in economic activity. For small firms, household businesses, and households, this is often core capital; its loss may disrupt cash flow, weaken solvency, and shrink operational scale.

Second, fires disrupt production, business operations, and supply chains. A fire-damaged establishment loses not only its existing assets but may also require weeks or months to restore electricity, water, premises, equipment, labor, and supplies. During that period, the business loses revenue, contracts, and customers, while linked entities may also be affected through chain effects. Consequently, the actual economic damage caused by fire is often substantially greater than the direct property loss recorded in statistics.

Third, fires affect labor and household income. A major fire in a factory, workshop, market, or shopping center may cause workers to lose their jobs temporarily or for a prolonged period. Household income falls, purchasing power declines, and the effects can spread to local markets.

Fourth, fires increase public and social costs through expenditures on firefighting, rescue operations, medical treatment, cause investigation, environmental remediation, victim support, and infrastructure recovery.

Table 4. Comparison of Direct Property Losses Caused by Fire with Selected Economic Indicators in Vietnam, 2020-2025

Year	Direct property losses (VND billion)	GDP at current prices (VND trillion)	GDP growth (%)	GDP per capita (USD)	Loss/GDP (%)
2020	932,023	8.044,4	2,91	3.552	0,01159
2021	374,420	8.479,7	2,58	3.717	0,00442
2022	634,000	9.548,7	8,02	4.124	0,00664
2023	878,000	10.221,8	5,05	4.284,5	0,00859
2024	657,450	11.511,9	7,09	4.700	0,00571
2025	786,780	12.847,6	8,02	5.026	0,00612

Source: Compiled by the author from data published by the Fire Prevention, Firefighting and Rescue Police Department; GDP data from the General Statistics Office.

5.3. Comparison with Vietnam's Economic Growth

During 2020–2025, Vietnam maintained positive economic growth, with GDP growth rates of 2.91%, 2.58%, 8.02%, 5.05%, 7.09%, and 8.02%, respectively. GDP per capita rose from USD 3,552 in 2020 to approximately USD 5,026 in 2025. GDP at current prices increased from VND 8,044.4 trillion in 2020 to VND 12,847.6 trillion in 2025 [17]. When direct property losses caused by fire are compared with GDP, the share at the national level appears small, ranging from 0.00442% to 0.01159% of GDP.

However, the fact that the share is small relative to GDP does not mean that fire has only a minor impact on the economy. The national GDP denominator is very large, while the compared numerator includes only directly damaged property. At the level of firms, households, business establishments, and supply chains, a single fire can still produce very serious economic consequences.

More importantly, direct property losses caused by fire do not move in synchrony with GDP growth. GDP increased rather steadily over the years, whereas direct property losses fluctuated much more sharply. This indicates that economic growth does not automatically lead to an increase or decrease in fire losses at a fixed proportion. Nevertheless, a structural relationship still exists: when the economy develops rapidly, the accumulation of assets, building density, and intensity of production and business activity all rise; if fire prevention, firefighting, and rescue capacity is not strengthened correspondingly, both fire risk and loss per incident may increase.

5.4. Economic Implications of the Forecast Results

When the forecast for 2026 reaches approximately 3,568 fire incidents and VND 774.08 billion in direct property losses, the study provides not only a technical figure but also guidance for more effective resource allocation. If the number of fires remains high, policy should focus primarily on reducing fire frequency through targeted inspections, stricter electrical safety management, tighter control of mixed-use residential-business premises, improved community skills, and better fire-access conditions. If direct property losses tend to rise, policy should shift more strongly toward reducing loss severity per incident through early detection, initial fire suppression, containment of fire spread, asset protection, and effective rescue operations.

6. DISCUSSION

The findings show that the number of fire incidents and direct property losses reflect two different dimensions of fire risk. The number of fire incidents measures the frequency of occurrence, whereas direct property losses reflect the severity of loss in each incident. Therefore, these two indicators cannot substitute for one another in policy analysis. A strategy focused only on reducing the number of fires does not necessarily lead to a corresponding reduction in property losses. Conversely, even if the number of fires does not decline markedly, better control of fire spread, improved early detection, and more effective initial suppression can still substantially reduce actual losses.

Another important finding is that the three-year moving average performs best among the models considered. This suggests that under conditions of short and highly volatile data series, simple models capable of smoothing short-term fluctuations are often more suitable than models that rely heavily on an assumption of stable trend. Methodologically, this underscores that empirical fit to real data is more important than technical complexity [5]-[7]. For the field of fire prevention, firefighting, and rescue in Vietnam, this has practical value because it shows that relatively simple forecasting tools can still effectively support analysis and decision-making when data remain limited.

The study also shows that the assessment of the economic impact of fire should not stop at direct property losses recorded in official statistics. This indicator reflects only the tangible losses that can be quantified immediately after an incident. In reality, the economic impact of fire also includes production disruption, income loss, employment decline, supply-chain interruption, and increased public expenditure. Therefore, the small share of direct property losses in GDP does not mean that the economic effect of fire is small. At the level of firms, households, and localities, the ripple effects of fire may be considerably larger than the losses directly captured in statistical reports [15].

However, the findings must be interpreted within the limits of the available data. The series is short and remains annual and national in scope, so it does not yet allow deep identification of seasonality, regional variation, facility type, or specific fire causes. This limits the possibility of extending the results toward more detailed forecasting. In the future, if databases can be developed by month, locality, facility type, and fire cause, subsequent studies will be able to construct forecasting models with higher accuracy and greater practical value.

7. CONCLUSION AND RECOMMENDATIONS

This study compared five short-term time-series models to forecast two important indicators in fire prevention, firefighting, and rescue in Vietnam: the number of fire incidents and direct property losses caused by fire during 2020–2025. The results show that the three-year moving average is the most suitable method among the models considered. According to this model, Vietnam may record approximately 3,568 fire incidents and VND 774.08 billion in direct property losses in 2026.

The study makes two main contributions. First, it provides an empirical comparison of short-term forecasting models under conditions of limited fire data in Vietnam. Second, it confirms the need to distinguish between forecasting the number of fire incidents and forecasting direct property losses, because these two indicators reflect two different dimensions of fire risk [8]-[10],[15]. On this basis, the article shows that fire should be understood not only as a safety incident but also as a form of economic risk.

Based on these findings, the study proposes three main directions. First, the fire-statistics system should continue to be standardized and expanded with greater detail by time, space, facility type, and fire cause. Second, in fire prevention, firefighting, and rescue practice, the objective of reducing the number of fires should be distinguished from the objective of reducing direct property losses. Third, forecast results should be integrated into development-risk governance, especially in rapidly urbanizing localities, industrial zones, commercial areas, and mixed-use residential areas.

More broadly, the study shows that forecasting in fire prevention, firefighting, and rescue has value not only in operational terms but also in development governance. When built on sufficiently good data and used appropriately, forecasting can become an important tool for shifting from a reactive approach to a preventive one, and from post-incident response to loss reduction before risks materialize [1],[5]-[7].

REFERENCES

1) Dang, T. D. (Ed.). (2021). Forecasting and the Science of Forecasting. National Political Truth Publishing House, Hanoi. [in Vietnamese]
2) Armstrong, J. S., & Collopy, F. (1992). Error measures for generalizing about forecasting methods: Empirical comparisons. International Journal of Forecasting, 8(1), 69-80. https://doi.org/10.1016/0169-2070(92)90008-W
3) Makridakis, S. (1993). Accuracy measures: Theoretical and practical concerns. International Journal of Forecasting, 9(4), 527-529. https://doi.org/10.1016/0169-2070(93)90079-3
4) Hyndman, R. J., & Koehler, A. B. (2006). Another look at measures of forecast accuracy. International Journal of Forecasting, 22(4), 679-688. https://doi.org/10.1016/j.ijforecast.2006.03.001
5) Gardner, E. S., Jr. (1985). Exponential smoothing: The state of the art. Journal of Forecasting, 4(1), 1-28. https://doi.org/10.1002/for.3980040103
6) Gardner, E. S., Jr. (2006). Exponential smoothing: The state of the art-Part II. International Journal of Forecasting, 22(4), 637-666. https://doi.org/10.1016/j.ijforecast.2006.03.005
7) Makridakis, S., Spiliotis, E., & Assimakopoulos, V. (2018). The M4 Competition: Results, findings, conclusion and way forward. International Journal of Forecasting, 34(4), 802-808. https://doi.org/10.1016/j.ijforecast.2018.06.001
8) Bringula, R., & Balahadia, F. (2019). A spatiotemporal analysis of fire incidents in Manila from 2011-2016: Implications for fire prevention. Disaster Prevention and Management, 28(2), 201-215. https://doi.org/10.1108/DPM-05-2018-0147
9) Chhetri, P., Corcoran, J., Ahmad, S., & KC, K. (2018). Examining spatio-temporal patterns, drivers and trends of residential fires in South East Queensland, Australia. Disaster Prevention and Management, 27(5), 586-603. https://doi.org/10.1108/DPM-09-2017-0213
10) KC, K., & Corcoran, J. (2017). Modelling residential fire incident response times: A spatial analytic approach. Applied Geography, 84, 64-74. https://doi.org/10.1016/j.apgeog.2017.03.004
11) Madaio, M., Chen, S.-T., Haimson, O. L., Zhang, W., Cheng, X., Hinds-Aldrich, M., Chau, D. H., & Dilkina, B. (2016). Firebird: Predicting fire risk and prioritizing fire inspections in Atlanta. Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, 185-194. https://doi.org/10.1145/2939672.2939682
12) Wang, Q., Zhang, J., Guo, B., Hao, Z., Zhou, Y., Sun, J., Yu, Z., & Zheng, Y. (2019). CityGuard: Citywide fire risk forecasting using a machine learning approach. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 3(4), Article 156, 1-21. https://doi.org/10.1145/3369814
13) Wang, K., Yuan, Y., Chen, M., & Wang, D. (2021). A POIs based method for determining spatial distribution of urban fire risk. Process Safety and Environmental Protection, 154, 447-457. https://doi.org/10.1016/j.psep.2021.08.039

Corresponding Author: Nguyen Thi Lan Anh

14) Zhang, X., Yao, J., & Sila-Nowicka, K. (2018). Exploring spatiotemporal dynamics of urban fires: A case of Nanjing, China. ISPRS International Journal of Geo-Information, 7(1), 7. https://doi.org/10.3390/ijgi7010007
15) Rahman, F. S., Tannous, W. K., Avsar, G., Agho, K. E., Ghassempour, N., & Harvey, L. A. (2023). Economic costs of residential fires: A systematic review. Fire, 6(10), 399. https://doi.org/10.3390/fire6100399
16) Fire Prevention, Firefighting and Rescue Police Department. (2020-2025). Official releases, statistical reports, and published materials on fires, explosions, and rescue operations during 2020-2025.
17) General Statistics Office. (2020-2026). Fourth-quarter and annual socio-economic reports, statistical yearbooks, and official publications on GDP, GDP growth, and GDP per capita.

Corresponding Author: Nguyen Thi Lan Anh