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Predicting Firefighting Response Time in Urban Settings Using Machine Learning: Key Factors for Enhanced Emergency Management

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A B S T R A C T

Introduction: This study addresses the challenge of accurately predicting firefighting operation times in urban areas using machine learning techniques.

Materials & Methods: Data from 1,399 firefighting incidents in Ilam City during 2022 were analyzed after preprocessing, focusing on 19 key variables out of an initial 31. Among the evaluated models, the Generalized Linear Model (GLM) showed the best performance with the lowest RMSE (14.21 ± 1.65) and estimated an average operation time of 26.96 minutes (95% CI: 12.75–41.17).

Results: Important factors influencing operation duration included the number of personnel, rescue equipment, fire engines, and manual extinguishers. The results demonstrate the potential of ML models to optimize resource allocation and response strategies, contributing to more efficient urban fire management and reduced losses.

Conclusion: Further work is needed to enhance data quality and model accuracy for improved operational planning.

Keywords: Firefighting, Urban Emergencies, Response Time, Machine Learning

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Statement of the problem and the necessity of implementation

Fires inflict enormous financial and human losses, destroy urban facilities, reduce air quality, destroy forest ecosystems, and ultimately, contribute to global warming(1). The use of quick reaction standards and appropriate response time can minimize human and financial losses. Over time and during firefighting operations, the fire may propagate, and a subsequent rise in temperature will restrict visual acuity, rendering the controlling of fire more difficult(2). It is important to correctly identify, prioritize, and manage the factors affecting the firefighting operation time during emergency responses. In surveys conducted in Iran, examples of the factors affecting the firefighting operation time have been reported as the location of the fire truck, wearing and adjusting the breathing apparatus (BA), and crowding at the scene of the event(3). A study in Sweden showed that 38% of emergency situations include building fires, road traffic accidents, and drowning accidents, where only a 5-10-minute delay in the rescue operation increases casualties up to 97% (4). In another study, a 1-minute shortening of the delay in starting firefighting operations was reported to increase saving lives by 2-3% on average (5).

Machine learning (ML) models have been noted to be useful in predicting the arrival time and firefighting operation length. In a study by Lian et al., machine learning models, including linear regression (LR), decision tree (DT), and random forest (RF), were used to predict the emergency response time of the fire department and the factors affecting this parameter in San Francisco, reporting the location of the station, the location of the fire, and the time receiving the emergency call as the most important determinants(6) . In another study, an algorithm was utilized to find the best pathway to predict the shortest response time, identifying the most important influential factors as the number of ambulances, the frequency of receiving calls, and the number of regional vehicles, and the duration of the call (7).

In recent years, studies on ML models have focused on improving the fast response time during emergency situations (police missions, medical emergencies, firefighting operations), offering strategies from the use of the GPS system to find the best and shortest route to the accident area to other technological advances helping in the appropriate apportion of firefighting equipment(8). Therefore, the use of ML models can help save time during data analysis and deliver the results of predictive measures within a shorter time.

In this study, all firefighting operations conducted in Ilam City during one year (2022) were investigated. A total of 1402 firefighting operations were analyzed to predict the firefighting operation time based on the variables recorded before and during the operation in urban areas.

According to the results of the present study, the most important predictors of a shorter total firefighting operation time were the number of personnel, rescue equipment, automobile fire engines, and manual fire extinguishers.

Some factors causing or affecting the problem include:

- Failure to comply with operational response standards and time criteria
- Lack of rapid response for industrial firefighting operations
- Complex and unplanned conditions at the scene of the accident
- Non-use of manual fire extinguishers by ordinary people.

Table 1. A number of stakeholders of this study are briefly mentioned in the table below

Beneficiaries	Role	Level of penetration	Readiness to participate
Ordinary people	Direct beneficiary	High	Medium
All service centers	Direct beneficiary	High	A lot
Fire Department	Policymaker	Very high	A lot
Municipality	Policymaker	Very high	A lot
Provincial Office	Policymaker	Very high	A lot
Governor's Office	Policymaker	Very high	A lot
District Office	Policymaker	Very high	A lot

The consequences resulting from the failure to investigate the problem and the continuation of the issue include the following:

- Increase in human casualties
- Increase in financial damages
- Reduction and weakness in the performance of the fire department during fire incidents

Evaluation of Past Policy Performance

Before conducting the present study, most previous research focused on predicting response times in firefighting operations in forests and areas outside urban boundaries. This study is one of the few that addresses the prediction of firefighting operation times in urban areas. Additionally, the results of machine learning studies can reduce the cost and time required to identify the causes of firefighting operation durations, a method that has not been used in previous studies.

Summary of findings

The present study recognized a number of factors substantially contributing to the reduction of the firefighting operation time in urban areas. According to the results of the GLM model, as the finally selected model, the most important predictors of shortened firefighting operations included the number of firefighters, rescue equipment, fire engines, and manual fire extinguishers at the scene. By expanding data infrastructure and studies on the applications of ML models, it is amenable to obtain more accurate information on the factors determining the firefighting operation time, and therefore, to reduce human and financial losses as much as possible.

The proposed policy options:

1. Reducing operation time which ultimately leads to a decrease in casualties and related damages:

-increasing skilled personnel and firefighting equipment.

2. Determining an appropriate location for the fire truck (neither too close nor too far from the incident site).

3. Increasing fire safety:

-developing and distributing educational packages including booklets, videos, and simple visual tools for both literate and illiterate groups.

- How to use a fire extinguisher and the correct way to escape from the fire site to the general public.

Requirements and barriers for implementing the policy options

Requirements

- Financial support from the municipality for the fire department to purchase equipment and hire more personnel.

- Securing funds needed to print simple and understandable educational packages for both literate and illiterate groups.
- Training capable and well-educated personnel to provide related training at executive centers.

Barriers

- Budget shortages for purchasing equipment.
- Lack of sufficient human resources.
- Insufficient budget for printing educational packages on this matter.

Solutions

- Implementing a pilot project in 2-3 centers in Ilam city before expanding provincially.
- Actively involving trained individuals as facilitators to address existing challenges.
- Increasing the number of fire stations throughout the city.
- Increasing the number of handheld fire extinguishers in public places and organizations.
- General public and staff training on how to use handheld fire extinguishers.

Brevity and Clarity

This policy brief is prepared in a clear, simple, scientific, and understandable structure within 6 A4 pages (approximately 1300–1400 words), designed for policymakers and usable as a basis for decision-making in organizations such as the Fire Department, Municipality, Governor's Office, District Office, and Provincial Office.

Research Project Audiences

· Fire Department

· Municipality

· Governor's Office

· District Office

· Provincial Office

Conflict of interest

The authors declare no conflict of interest

References

1. Feng Y, Cui S. A review of emergency response in disasters: present and future perspectives. Natural hazards. 2021;105(1):1109-38.
2. Xin J, Huang C. Fire risk analysis of residential buildings based on scenario clusters and its application in fire risk management. Fire safety journal. 2013;62:72-8.
3. Aleisa E, Savsar M, editors. Response time analysis of firefighting operations using discrete event simulation. 2014 UKSim-AMSS 16th International Conference on Computer Modelling and Simulation; 2014: IEEE.
4. Mattsson B, Juås B. The importance of the time factor in fire and rescue service operations in Sweden. Accident Analysis & Prevention. 1997;29(6):849-57.
5. Jaldell H. How important is the time factor? Saving lives using fire and rescue services. Fire technology. 2017;53(2):695-708.
6. Lian X, Melancon S, Presta J-R, Reevesman A, Spiering B, Woodbridge D, editors. Scalable real-time prediction and analysis of san francisco fire department response times. 2019 IEEE SmartWorld, Ubiquitous Intelligence & Computing, Advanced & Trusted Computing, Scalable Computing & Communications, Cloud & Big Data Computing, Internet of People and Smart City Innovation (SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI); 2019: IEEE.
7. Nordin NAM, Zaharudin ZA, Maasar MA, Nordin NA, editors. Finding shortest path of the ambulance routing: Interface of A∗ algorithm using C# programming. 2012 ieee symposium on humanities, science and engineering research; 2012: IEEE.
8. Kupschick S, Pendzich M, Gardas D, Jürgensohn T, Wischniewski S, Adolph L. Predicting firefighters' exertion based on machine learning techniques. Federal Institute for Occupational Safety and Health: Dortmund, Germany. 2016.