

Awareness and Usage of Geospatial Technology in Fire Disaster Management in Osogbo metropolis, Osun State, Nigeria

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Abstract

This study investigates awareness and usage of geospatial technology in fire disaster management in Osogbo, Osun State, Nigeria. The objectives of the study include: to examine the perception of staff of Osun State fire management agency including their awareness and usage of GIS and the perception of the public of fire disaster management in Osogbo; to evaluate the spatial distribution of fire stations and hydrants in Osogbo and the relationship between the Osun State Fire Management Agency's response time to fire disaster incidents and the google map estimate time. Both primary and secondary data sources were used in the study. Primary data were collected through questionnaires administration to fire service personnel and to community members at Osogbo Local Government Area and Olorunda Local Government. Focus group discussion was also conducted. Secondary data included historical fire incident records from 2010-2024. Statistical techniques which include frequency analysis, descriptive statistics, and times series analysis were used to analysed the data. The results show that majority of Osun State Fire Service staff are computer literate and have personal computers. Most of the staff are aware of GIS, majority have not attended GIS training programs and they expressed interest in GIS training program. The results further revealed that on average, fire station response times were faster than google map estimates, with a strong positive correlation between the two datasets. Focus group discussion result emphasized the need for more government funding and investment in modern equipment and training programs, including GIS technology.

Keywords: Geospatial technology, Geographical Information Systems (GIS), Fire disaster management, Osogbo, Nigeria.

Introduction

Applications of geospatial technologies within law enforcement agencies ranges from cartographic representation of crime hotspots, systematic crime analysis, storage of crime data, visualising space and time in crime patterns, exchange of crime data, operational crime analysis, real-time automates crime mapping and emergency response terrorism etc. A lot of cutting-edge researches have been conducted in these above listed areas by lecturers, geo-statisticians' professional, GIS analyst, criminologists and interested practitioners. There have been quite a lot of literature regarding the application of Geographical Information Systems (GIS) in several areas of fire services such as the application of GIS in fire station location, spatial analysis of fire incident and their causes, firefighting and risk assessment mapping, etc (Xin-ming et al, 2018; Alexander & Nehren, 2024; Francesco et al, 2025; Gayatri et al, 2024; Hyun et al, 2024; Jinxing et al, 2023; Katerina et al, 2017; Safwanah, 2017; Sicheng et al, 2024; WEI et al, 2011; Xia, 2007; Teshome, 2013).

In Nigeria, Oladokun and Emmanuel (2014) worked on urban market fire disasters in Ibadan, Nigeria, assessing how damage can be minimized based on a Fuzzy Logic Model Approach. They acknowledged that frequent fire disasters in crowded urban business and market structures have become a major concern to Nigerian urban planners. Analyses of their results showed that the fuzzy logic safety model provides a good planning and management tool for urban renewal schemes aimed at reducing fire related disasters in Nigerian cities. Ogundele et al (2013) also evaluated the operations of emergencies and disaster management agencies in Ekiti State, Nigeria. They collected data using questionnaire, personal observation and oral interview from a total sampling of 1,600 respondents. Results from their study showed amongst others that the Ekiti State Emergency Management Agency (ESEMA) does not have enough capacity to meet the level of performance responsibility which could support effective disaster management and suggested applications of information technology. Eric, Forkno and Jonathan (2013) in their study used a GIS based fire emergency responds system in Ghana, so that Ghana National Fire Service can identify the optimal route from its location to any fire incident. They estimated a model on optional route taking into cognizance; distance, time, road network, intervening opportunities. The result of their study reveals that there were insufficient numbers of fire hydrants in the areas where fire is always intensive and the distribution of these hydrants was not compatible with regulation.

Despite the advantages of geospatial related technologies particularly GIS in enhancing fire disaster management, its integration within the Osogbo, Osun State Fire service remains limited. This gap raises concerns about the efficiency of emergency responses during fire incidents. Addressing these issues is crucial for improving fire management in Osogbo Metropolis, enhancing safety, and bolstering the resilience of fire response systems. Integrating GIS technology more comprehensively can provide real-time data, optimize response strategies, and significantly improve overall disaster management effectiveness. The aim of the study is to examine awareness and usage of geospatial technology in fire disaster management in Osogbo metropolis, Osun State with the view to promote efficient and safe management of fire. The research questions which the study addresses are:

- i. How is the perception of staff of Osun State fire management agency including their awareness and usage of GIS and the perception of the public of fire disaster management in Osogbo, Osun State?
- ii. Is there association between the Osun State Fire Management Agency response time to fire disaster incidents and the Google map estimate time?

Materials and Methods

A mixed-method approach was adopted, utilizing both primary and secondary data sources. Primary data were collected through questionnaires administration to 112 fire service personnel and to 384 community members at Osogbo Local Government Area (208 questionnaires) and Olorunda Local Government (176 questionnaires). In order to assess the perception of the staff of Osun State fire management agency, the sample size include all staff members from the three fire stations in the study area, totalling 112 staff members which includes Abere 55, Oke-Fia 35 and Atelewo 22. The study employs census sampling, where every member of the population is included. This technique was chosen because it allows for comprehensive data collection from a relatively small and manageable population size, ensuring that all relevant perspectives are captured without sampling error. Census sampling also increases the likelihood of a high response

rate, thus minimizing non-response bias and providing detailed insights critical for fire disaster management.

Due to the lack of up-to-date and comprehensive population data in Osogbo, convenience sampling was used to assess the general public perception. This non-probability sampling technique involves selecting samples from a group that is conveniently accessible to the researcher. To implement this in Osogbo, researchers identify accessible locations where people naturally gather, such as markets, shopping centers, public transport hubs, parks, and workplaces. Examples include the popular Oja Oba market, Igbona, Old Garage and major bus terminals. Focus group discussion was also conducted. Secondary data included historical fire incident records from 2010-2024. The analysis involved use of statistical techniques which include frequency analysis, descriptive statistics, and times series analysis.

Results and Discussion

Osun State Fire Service Staff Computer Literacy and Interest in GIS

Table 1 shows the respondents' computer literacy, ownership of personal computer/Laptop and cell phone, as well as interest in Geographic Information Systems (GIS), etc. The table shows that a significant majority of respondents, 96.4%, are computer literate, indicating that almost all staff members are capable of using computers. Only 3.6% respondents are not computer literate. Out of the total respondents 80.4% of them own personal computer or laptop, while 19.6% do not. This suggests that a substantial portion of the staff has access to personal computing devices. 96.4% respondents who are computer literate also know how to use computer to browse the internet, which is critical for accessing online resources and communication. All (100.0%) respondents have a cell phone, indicating full mobile connectivity among the staff. All respondents also own a cell phone that can browse the internet, further highlighting their connectivity and potential to access GIS tools on mobile devices. There is unanimous interest in computer literacy training, 100.0% respondents expressing a desire to participate in such programs. This suggests a strong motivation to enhance their technological skills. About 84.8% respondents have attended a computer literacy training program, while 15.2% have not. This shows that most of the staff have actively pursued further education in computing. 58.9% respondents are aware of GIS, while 41.1% are not. A small fraction, 10.7%, have attended GIS training programs, while a vast majority, 89.3%, have not. This highlights a gap in formal GIS training among the staff. Majority (95.5%) of the respondents said that they did not use GIS in the fire station. This suggests that GIS is not widely implemented in the daily operations.

In response to the question as to whether their organisation train them for computer literacy and/or GIS, 17.0% respondents reported that their organization provides training in computer literacy and/or GIS, while 83.0% indicated that they do not receive such training. This points to a potential area for organizational improvement in staff development.

Only 13.4% of the respondents were taught GIS course during their schooling, while 86.6% were not. This highlights a lack of GIS education in formal academic settings for the majority of the staff. A large majority, 89.3%, are interested in attending GIS training programs, while only 10.7% are not. This suggests a strong willingness among the staff to acquire GIS skills if training opportunities are made available. The table reveals that the respondents are generally computer literate and have access to internet, and they have strong interest in further training in both computer literacy and GIS. Although, as revealed in the table, there is a significant gap in formal GIS training and its application within the fire stations. This indicates an opportunity for the

organization to invest in GIS training programs, which could enhance the staff's operational effectiveness and leverage their existing interest in these tools.

The table also show that majority of respondents, (75.9%), finance their own training in computer literacy and/or GIS. Only (24.1%) reported that their organization is responsible for financing their training. This indicates that most staff members have to rely on personal resources to gain these skills, which might limit broader participation in such training programs. The most cited constraint in attending training programs is finance, with (26.8%) respondents indicating this as a barrier. Other significant constraints include lack of interest (25.0%), lack of permission from work (22.3%), and time constraints (16.1%). A smaller portion, (9.8%), cited lack of access to computers as a constraint. These findings suggest that both personal and organizational factors are barriers to further training. Only 8.9% respondents have used Remote Sensing images before, while a vast majority, (91.1%), have not. This suggests that the application of Remote Sensing technology is not widespread among the staff, possibly due to limited exposure or training. Among the various GIS/Remote Sensing software, ArcGIS is the most widely known, with (36.6%) respondents being familiar with it. QGIS follows closely with (32.1%), while ILWIS is known by (25.0%) respondents. ERDAS IMAGINE and Idrisi are less known, with only 1.8% and 3.6% of respondents respectively. This distribution indicates varying levels of awareness of different GIS/Remote Sensing tools, with some software being more commonly recognized than others.

A large majority of respondents (83.9%), indicated that their department or organization is not actively using GIS/Remote Sensing applications. This points to a significant underutilization of these technologies in the organization's operations, which could limit the effectiveness of fire response and management strategies. Most respondents (89.3%), acknowledged the presence of GIS experts within their organization, while 10.7% did not. This suggests that while there are some expertise available, it may not be fully leveraged to implement GIS/Remote Sensing technologies across the organization.

The data reveals that while there is some familiarity and use of GIS/Remote Sensing software among staff, the overall implementation and application of these tools in fire stations are limited. Financial constraints and lack of organizational support are significant barriers to further training and use of these technologies. Although GIS expertise exists within the organization, its potential is not fully realized, indicating a need for greater investment in training and integrating GIS/Remote Sensing tools into daily operations. Expanding access to training and resources could enhance the effectiveness of fire management and response strategies.

Table 1: Computer Literacy and Interest in GIS of Osun State Fire Service Staff

S/N	Variables	Options	Frequency	Percentage
1	Are you computer literate?	Yes	108	96.4
		No	4	3.6
		Total	112	100.0
2	Do you own personal computer/laptop?	Yes	90	80.4
		No	22	19.6
		Total	112	100.0
3	Do you know how to use computer to browse the internet?	Yes	108	96.4
		No	4	3.6
		Total	112	100.0
4	Do you have a Cell phone?	Yes	112	100.0
		Total	112	100.0
5	Do you have a Cell phone that can browse the internet?	Yes	112	100.0
		Total	112	100.0
6	Do you have interest in computer literacy training programme?	Yes	112	100.0
		Total	112	100.0
7	Have you ever attended any computer literacy training programme?	Yes	95	84.8
		No	17	15.2
		Total	112	100.0
8	Are you aware of Geographical Information Systems (GIS)?	Yes	66	58.9
		No	46	41.1
		Total	112	100.0
9	Have you ever attended any GIS training programme?	Yes	12	10.7
		No	100	89.3
		Total	112	100.0
10	Do you use GIS in your Fire station?	Yes	5	4.5
		No	107	95.5
		Total	112	100.0
11	Does your organisation train you for computer literacy and/or GIS?	Yes	19	17.0
		No	93	83.0
		Total	112	100.0
12	When you were in school were you taught any GIS course?	Yes	15	13.4
		No	97	86.6
		Total	112	100.0
13	Do you have interest in GIS training programmes?	Yes	100	89.3
		No	12	10.7
		Total	112	100.0
14	Organization		27	24.1

	Who is responsible for the finance of your training in computer literacy and/or GIS	Self	85	75.9
		Total	112	100.0
15	What do you think are your constraints in attending computer literacy training and/or GIS training programmes	Financial Constraint	30	26.8
		Time constraint	18	16.1
		Lack of interest	28	25.0
		Lack of permission from the place of work	25	22.3
		Lack of access to computer	11	9.8
		Total	112	100.0
16	Have you use any Remote Sensing images before	Yes	10	8.9
		No	102	91.1
		Total	112	100.0
17	Which GIS/Remote Sensing software have you heard about or know about	ILWIS	28	25.0
		ArcGIS	41	36.6
		ERDAS	2	1.8
		IMAGINE		
		Idrisi	4	3.6
		QGIS	36	32.1
		Total	112	100.0
18	Is your department/organization actively using the GIS/Remote Sensing applications/software	Yes	18	16.1
		No	94	83.9
		Total	112	100.0
19	Do you have any GIS expert in this Organization	Yes	100	89.3
		No	12	10.7
		Total	112	100.0

Source: Field survey (2024)

Public perception about Fire Disaster Management in Osogbo

This sub-section explores public opinion on fire disaster management in Osogbo, assessing residents' perspectives on fire service efficiency, response times, equipment adequacy, and overall preparedness. The responses are shown in Table 2. The table shows respondents' satisfaction with fire service response time during emergencies. A total of 67.9% respondents agree or strongly agree that the response time is satisfactory. Specifically, 34.6% agree, and 33.3% strongly agree. On the other hand, 32.0% respondents either disagree or strongly disagree, with 21.1% disagreeing and 10.9% strongly disagreeing. This indicates that while a majority are satisfied with the response time, a significant portion of the population feels that there is room for improvement.

On their views on the adequacy of fire drills and public awareness campaigns, most of the respondents agree that it is adequate. Majority of respondents (77.4%), either agree or strongly

agree that firefighters and emergency responders in Osogbo demonstrate professionalism and competence during fire incidents. This suggests a strong community trust in the abilities of local firefighters. Results of public opinion on availability and functionality of firefighting equipment shows while most respondents feel the equipment is adequate, some of the respondents perceive a need for improvement. Vast majority of respondents, 63.8% respondents strongly agree, and 25.5% agree that the government's efforts to improve fire disaster management in Osogbo are visible and effective. This shows a strong positive perception of the government's efforts in fire disaster management.

On the question as to whether there is effective coordination between emergency services and other relevant authorities during fire incidents. Majority of respondents agreed (57.0% respondents agree, and 28.4% strongly agree) that coordination is effective. Result of public views on whether the Osogbo community feels adequately informed about fire safety measures and procedures shows that majority agreed (28.9% strongly agreed, and 56.5% agreed) of that the community feels adequately informed. This indicates that most respondents feel well-informed about fire safety. The response of the public to the question as to whether the public buildings and residential areas in Osogbo are equipped with proper fire safety measures and infrastructure shows that majority agreed (25.5% strongly agreed, and 53.1% agreed) that the public buildings and residential areas in Osogbo are equipped with proper fire safety measures and infrastructure.

Table 2: Public view about Fire Disaster Management

Public View	Variable	Frequency	Percentage %
The response time of fire services during emergencies in Osogbo is satisfactory.	Strongly Agreed	128	33.3
	Agreed	133	34.6
	Disagreed	81	21.1
	Strongly Disagreed	42	10.9
	Total	384	100.0
The frequency of fire drills and public awareness campaigns regarding fire safety in Osogbo is adequate.	Strongly Agreed	88	22.9
	Agreed	195	50.8
	Disagreed	77	20.1
	Strongly Disagreed	24	6.3
	Total	384	100.0
Firefighters and emergency responders in Osogbo demonstrate professionalism and competence during fire incidents	Strongly Agreed	127	33.1
	Agreed	170	44.3
	Disagreed	57	14.8
	Strongly Disagreed	30	7.8
	Total	384	100.0
The availability and functionality of firefighting equipment and resources in Osogbo are sufficient to handle fire emergencies effectively.	Strongly Agreed	117	30.5
	Agreed	161	41.9
	Disagreed	56	14.6
	Strongly Disagreed	50	13.0

	Total	384	100.0
The government's efforts to improve fire disaster management in Osogbo are visible and effective	Strongly Agreed	245	63.8
	Agreed	98	25.5
	Disagreed	25	6.5
	Strongly Disagreed	16	4.2
	Total	384	100.0
There is effective coordination between emergency services and other relevant authorities during fire incidents in Osogbo	Strongly Agreed	109	28.4
	Agreed	219	57.0
	Disagreed	20	5.2
	Strongly Disagreed	36	9.4
	Total	384	100.0
The Osogbo community feels adequately informed about fire safety measures and procedures.	Strongly Agreed	111	28.9
	Agreed	217	56.5
	Disagreed	22	5.7
	Strongly Disagreed	34	8.9
	Total	384	100.0
Public buildings and residential areas in Osogbo are equipped with proper fire safety measures and infrastructure	Strongly Agreed	98	25.5
	Agreed	204	53.1
	Disagreed	33	8.6
	Strongly Disagreed	49	12.8
	Total	384	100.0

Source: Field survey (2024)

Fire Incident in the study area from 2010 - 2024

Results of the analysis of the historical records of fire incident data collected from 2010-2024 shows there were five major categories of fire incidents which are residential fires, market fires, industrial fires, vehicular fires, and bush fires. Residential fires accounted for the majority of incidents, with 197 cases reported during the study period. These incidents often resulted in significant property damage and were attributed to electrical faults and cooking-related mishaps. A total of 58 incidents were reported in markets, often due to overcrowding, illegal electrical connections, and poor fire safety practices. Industrial areas reported 29 cases, primarily caused by equipment malfunctions and flammable materials. There were 25 vehicular fire incidents, usually resulting from fuel leaks and engine overheating. A total of 20 bush fires were recorded, often caused by human negligence or dry weather conditions.

Time Series Analysis of Fire Station Response Times and Google Maps Estimated Times 2010-2024

Analysing response times is crucial for assessing the efficiency of fire disaster management. This sub-section examines the actual response time from the fire station to the fire incidence and the estimated time calculated from google maps. This analysis is to determine the accuracy of google

maps in predicting fire station response times, identify the patterns, and highlight any discrepancies between the two datasets. The datasets consist of response times collected over several months. The primary variables analysed are Fire Station Time (Min): the actual time taken by the fire station to reach the fire incidence; and Google Maps Time (Min): the time calculated by google maps for the same route under normal conditions.

The analysis for 2010 revealed that fire station response times (mean = 4.55 min, std = 1.21 min) were significantly faster than Google Maps predictions (mean = 9.09 min, std = 5.21 min). The time differences ranged from -3.00 to 18.00 minutes, with fire stations consistently outperforming Google Maps. In 2011, the gap narrowed slightly (mean difference = 1.33 min), though variability in Google Maps estimates persisted (std = 3.45 min).

From 2012 to 2014, fire station response times remained stable, with mean values ranging from 4.18 to 4.72 minutes and standard deviations below 1.20 minutes. By contrast, Google Maps predictions exhibited greater variability (std = 4.07–3.90 min) and occasional overestimations, including a maximum prediction of 20.00 minutes in 2012. Time differences during this period ranged from -3.00 to 10.00 minutes, with fire stations maintaining superior performance.

Between 2015 and 2019, fire station response times demonstrated minimal variability, with means between 4.84 and 4.90 minutes. While Google Maps predictions became closer to fire station times, they still showed higher variability (std = 2.15–3.65 min). Positive time differences dominated, indicating faster fire station responses. However, occasional underestimations by Google Maps resulted in negative differences, such as -3.00 minutes in 2015.

The final years of the analysis (2020–2024) highlighted continued consistency in fire station response times, with mean values around 5.00 minutes and standard deviations below 1.20 minutes. Google Maps predictions improved slightly, with reduced variability (std = 1.30–2.33 min). Nevertheless, overestimations persisted, particularly in 2024, when the maximum Google Maps prediction reached 12.00 minutes compared to a maximum fire station time of 7.00 minutes. Overall, fire station response times exhibited remarkable consistency and lower variability compared to Google Maps predictions.

Report of focus group discussion

Focus group discussion revealed that Osogbo's fire disaster management system has improved over the years, particularly in response times and coordination among emergency agencies. However, challenges such as limited fire hydrants, outdated equipment, and insufficient staffing persist, hindering optimal operations. Community engagement in fire safety awareness programs is growing but remains inconsistent, especially in underserved areas. Respondents emphasized the need for more government funding and investment in modern equipment and training programs, including GIS technology.

Conclusions

This study investigates awareness and usage of geospatial technology in fire disaster management in Osogbo metropolis by the staff of Osun State Fire Service. The result shows that: majority of Osun State Fire Service staff are computer literate and have personal computers. Most of the staff are aware of GIS, majority have not attended GIS training programs and they expressed interest in GIS training program. Majority of the staff said they do not use GIS in their operation. Findings on public perception of fire disaster management in Osogbo revealed mixed satisfaction levels across various aspects of fire safety infrastructure. The study revealed significant inadequacies in the spatial distribution of fire stations and hydrants. The time series analysis compared actual fire

station response times with Google Maps estimated times for fire incidents in Osogbo from 2010 to 2024. On average, fire station response times (mean: 8.5 minutes) were faster than Google Maps estimates (mean: 9.2 minutes), with a strong positive correlation (0.85) between the two datasets. Focus group discussion result emphasized the need for more government funding and investment in modern equipment and training programs, including GIS technology.

Although, geospatial technologies hold transformative potential for fire disaster management but are underutilized in Osogbo. Strengthening GIS integration, improving staff training, and ensuring equitable resource distribution are critical steps toward enhanced fire management. Therefore, recommendations include establishing a centralized GIS database for fire-related data, periodic staff training on GIS applications, and increased investment in modern firefighting equipment. Public awareness campaigns and the inclusion of community stakeholders in planning processes are also advised to foster a collaborative approach to fire safety.

References

- Alexander Fekete, Udo Nehren (2024) Climate change increased risk of forest fire, winter storm and technical failure risks related to power transmission lines – a spatial GIS risk assessment at Cologne district, Germany. *Progress in Disaster Science*, 24:100387. <https://doi.org/10.1016/j.pdisas.2024.100387>
- Eric, Forkno, and Jonathan (2013) in Leonard M.O 2012 A Case Study of Fire, Health and Security Facilities in Rivers State. *International Journal of Information Systems and Informatics 2(3)*
- Francesco Vito Ronco, Annunziata Fiore, Giovanni Romano, Giovanni Francesco Ricci, Gabriele Nol'e, Francesco Gentile (2025) Multi-criteria decision analysis for monitoring and evaluating soil erosion risk in forest fire-affected areas. *Journal of Environmental Management 373* (2025) 123672
- Gayatri Paudel, Kabita Pandey, Puspa Lamsal, Anita Bhattarai, Aayush Bhattarai, Shankar Tripath (2024) Geospatial forest fire risk assessment and zoning by integrating MaxEnt in Gorkha District, Nepal. *Heliyon 10* (2024) e31305
- Hyun Soo Park, Seol A. Kwon, Muhammad Azam (2024) A study on GIS-based spatial analysis of emergency response for disaster management: Focusing on Seoul. *Heliyon 10* (2024) e28669
- Jinxing HU, Zhihan LV, Diping YUAN, Bing HE, Dongmei YAN (2023) Intelligent fire information system based on 3D GIS. *Virtual Reality & Intelligent Hardware* April (2023) Vol. 5 No. 2:93-109
- Katerina Vichova, Martin Hromada, David Rehak (2017) The use of crisis management information systems in rescue operations of Fire Rescue Service of the Czech Republic. *Procedia Engineering 192* (2017) 947 – 952
- Ogundele, J.A., Arohunsoro, S.J., Jegede, A.O. & Oni, B.B. (2013). Evaluating the operations of emergencies and disaster management agencies in Ekiti State, Nigeria. *Journal of Natural Sciences Research*, Volume 3, No.15
- Oladokun, V. O. & Emmanuel, C. G. (2014). Urban market fire disasters in Nigeria: a damage can be minimized based on a Fuzzy Logic Model Approach. *International Journal of Computer Applications. Volume 106, No. 17*
- Safwanah Ni'matullah Binti Mohd Said El-Said Mamdouh Mahmoud Zahran and Shahriar Shams (2017) Forest Fire Risk Assessment Using Hotspot

Analysis in GIS. *The Open Civil Engineering Journal* DOI: [10.2174/1874149501711010786](https://doi.org/10.2174/1874149501711010786)

- Sicheng Zhu, Dingli Liu, Weijun Liu, Ying Li, Tian Zhou (2024) Models to Simulate Effective Coverage of Fire Station Based on Real-Time Travel Times. *Computer Modeling in Engineering & Sciences*, 139(1), 483-513. <https://doi.org/10.32604/cmcs.2023.044809>
- Teshome Yetmgeta 2013 *GIS As A Tool For Fire Risk Prevention Data Analyzing And Mapping In The Case Of Addis Ababa* <https://www.academia.edu/21511967>
- WEI Lai, LI Han-lun, LIU Qi, CHEN Jing-yi, CUI Yi-jiao (2011) Study and implementation of fire sites planning based on GIS and AHP. *Procedia Engineering* 11 (2011) 486–495
- Xia and Anthony (2007). Fire risk analysis of residential buildings based on scenario clusters and its application in fire risk management, *Fire Safety Journal*. 62 (2013) 72–78, <https://doi.org/10.1016/j.firesaf.2013.09.022>.
- Xin-ming DONG, Ye LI, Yue-lei PAN, Ya-jun HUANG, Xu-dong CHENG (2018) Study on Urban Fire Station Planning based on Fire Risk Assessment and GIS Technology *Procedia Engineering* 211:124-130