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Geospatial Analysis of Efficient Fire Brigade Emergency Services in Lahore City Pakistan

Muhammad Zakariya Ayub[a]*, Muhammad Asif Javed[a], Sajid Rashid Ahmad[a], Muhammad Waleed[a] and Arif Pervez Khalid[b]

[a]College of Earth and Environmental Sciences, University of the Punjab Lahore, Pakistan
[b]Suparco: Pakistan Space and Upper Atmosphere Research Commission, Islamabad, Pakistan

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Abstract. The world is witnessing an increase in the number of frequent disasters. According to WHO, 180,000 people die from burns annually throughout the whole world. In our study area, an average of 2230 fire accidents occur every year out of which 100 people die. Lahore is the second largest city in Pakistan. It has 18 rescue stations and a total of 26 working fire brigade vehicles that are un-systematically distributed in the study area. Our study area includes a total of 57 fire hydrants that are distributed un-systematically out of which 4 are non-functional. Geospatial technology has helped us in determining the problems as the new tools are very effective and useful to analyze, investigate, describe, clarify and visualize potential fire-prone areas for effective management with available resources producing realistic results. The result shows that 1% of the study area, which is about 17 km^2, is completely in accessible for the fire brigade vehicles with respect to its dimensions and road width. Accessibility zones are also generated using network analysis, which shows that only 20% of the study area is being reached by the fire brigade vehicles within the incident response time i.e., 7 min. 32% of the area is reached within 8 to 15 min and 47% of the area is reached after 15 min, which is an alarming situation. It has been observed that the planned residential colonies and towns are safe, while the unplanned and poor areas lack the basic facilities and are more prone to fire incidents and are inaccessible for the fire brigade vehicles. Government departments and agencies must perform similar kind of research and work to develop and implement sustainable policies for the betterment of the fire rescue system.

Keywords: accessibility, geospatial, network analysis, zoning

Introduction

World Health Organization (WHO) states that, 180,000 casualties occur due to burns annually throughout the world (Brammer *et al.*, 2022). The main victims of these casualties are undeveloped and low to middle-income countries and about two-thirds occur in south-east Asian and African regions. Disability-adjusted life years (DALYs) are majorly caused by burns in low and middle-income countries (Ramesh and Kosalram, 2023).

Throughout many emergency management systems, the time required to respond to an emergency call is a common problem. This response time depends not only on the resources allocated to fire stations, but also on spatial demand configuration i.e. population and level of vulnerability and supply networks. Spatial accessibility is a significant means of assessing the spatial balance of public service centers and is also extensively used to assess the accessibility of metropolitan rescue services as an efficient system (Mao *et al.*, 2020).

*Author for correspondence; E-mail: zakariya04@gmail.com

In Pakistan 17% of children having burns are temporarily disable and 18% are permanently disable. (Chen *et al.*, 2019). According to a research, mortality rate in Pakistan due to fire burns is 5.8 per 100,000 cases. Injuries due to fire burns are a financial burden as the treatment is very costly (Mashreky *et al.*, 2008).

Lahore is Pakistan's second most populous city and the most populous city of Punjab province has an urban area of about 1772 sq.Km. Lahore city has expanded to almost double its size in the last 14 years yet it is the 42nd most populous city in the world (Rana and Bhatti, 2018).

The population of Lahore is approximately 11 million and it is continuously increasing with a growth rate of about 4.07% (Lei *et al.*, 2021). Due to the migration of people to Lahore from nearby cities, small towns and villages and new human settlements have developed which are continuously developing in an unplanned manner in un-authorized residential colonies that lack basic civic infrastructure and facilities (Malik *et al.*, 2020). These colonies are heavily populated and are

becoming more prone to hazards like fire. Most of the people that migrate belong to rural areas have no or very less knowledge on awareness of fire hazards or fire preventive measures (Chen *et al.*, 2020). Besides, absence or lack of fire preventive measures, the poor infrastructure of colonies, clustered household, narrow streets, meager water supply, heavy traffic, traffic conjunction, inappropriate lying of electricity, gas, fuel and electrical installations and their respective use have increased the fire risk manifold in these areas of Lahore (Molina and Molina, 2004).

According to Rescue 1122 which shown in Table 1 statistics from October 10, 2004 to June 07, 2020 a total of 1,45,883 fire incidents have occurred in Punjab and 36,378 incidents in Lahore with an average of 2,273 every year. Hundreds of people die every year in Lahore because of fire-related incidents. According to a research conducted in Jinnah burn and re-constructive surgery center Lahore from May 2016 to March 2017, a total of 264 patients have been admitted to the burn unit out of which 92 people died (Rehman *et al.*, 2018). Evidence has shown that mostly deaths occurred due to the absence of efficient fire mitigating approaches. This research aims on delineation of accessible and inaccessible areas for fire brigade vehicles based on vehicle dimensions and road/street right of way (Tomar *et al.*, 2020). Preparation of spatial layers and reference maps for accessibility of fire brigade vehicles. Drive better recommendations for improvement in fire brigade efficiency on advanced tools in GIS (Liu *et al.*, 2021).

Rescue emergency departments face major challenges in fire risk management, preparedness and fire mitigation. A city like Lahore should have an efficient firefighting system that can provide awareness, planning, preparation, extenuation, response and management for urban fire risk management (Swathi, 2015). In this scenario fire brigade vehicles hold great responsibility and should have all the essential equipment and most importantly they should reach on time at the place of incident (Chassin and Loeb, 2013). Effective adoption of GIS in fire risk analysis is strongly connected to the evaluations of the current system, the planning of GIS interoperability and management by applying GIS to new challenges (Grigonis and Raskauskaite, 2019).

Table 1. Data and data source

Types of data	Data period	Sources of data
Rescue 1122 locations	November, 2019	Rescue 1122 head office Lahore, Pakistan
Vehicles' capacities and dimensions	December, 2019	Rescue 1122 head office Lahore, Pakistan
Hydrant locations	January, 2020	Water and sanitation agency Lahore, Pakistan
Road network	February, 2020	Open street map-OSM

Materials and Methods

Datasets required are listed below and were received from Rescue 1122 Head office, WASA after the official request and the road network of the study area was acquired from the OSM.

- There is a total of 18 rescue 1122 stations distributed in the study area and are distributed un-systematically. The location data of these stations were acquired from Google earth, Wikimapia and Google map and further it was verified from the Rescue 1122 Head Office Lahore. As shown in Fig. 1(a).
- There is a total of 26 fire brigade vehicles in the study area out of which 2 are HINO (water bowsers), 15 NPR and 10 FTR. As shown in Fig. 1(b).
- A total of 57 hydrants are dispersed in the study area. Hydrants can be divided into two categories. There are 19 Lorry Hydrants and 38 fire Hydrants in the study area out of which 4 are dysfunctional and the coordinate data of these hydrants were acquired from WASA, LDA.

The methodology that has been adopted in this research is elaborated and it is further explained as follows.

- Microsoft's Excel has been used for data entry and making charts and tables. Whereas ESRI's ArcGIS 10.2 was used for all kind of mapping, non-spatial data joining with location coordinates, topological corrections, assigning right of way, overlay analysis, network analysis and service area analysis.
- The road network of the study area was extracted from the open street map OSM. To prepare the data for analysis, topological errors had to be removed first with a cluster tolerance of 0.001 meters as show in Fig. 1(c).
- After the topological correction, the next laborious task was to digitize and assign a width to all the streets and roads present in the study area and also assign names to them as per google earth. A total of 43,319 roads exist in the study area as shown in Fig. 1(d).
- Spatial accessibility was calculated through the ArcGIS Network Analyst tool. It calculates the path and the travel time from the rescue station to the place of the incident. The tool calculates the length of the roads and the velocity of every road has been assigned already. So, the travel time between the station and

incident has been calculated according to the following equation; as show in Fig. 1(e).

Result and Discussion

There are total of 38 fire hydrant installed in the study area, out of which 34 hydrants are functional and area served directly by a default pipe length of 500 feet is only 0.5 square Km which is 0.04% of the total study area in Fig. 2(a).

Figure 2(b) shows accessible and inaccessible regions generated with respect to road/street width and fire brigade vehicles' dimensions. Accessible areas are shown in Table 2, which also shown in green colours

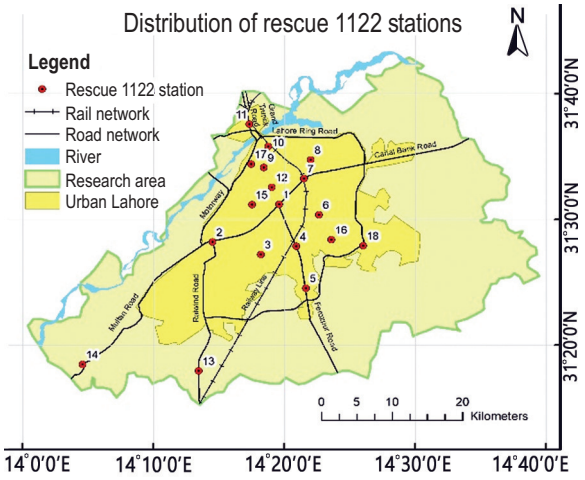

Fig. 1(a). Distribution of rescue 1122 stations.

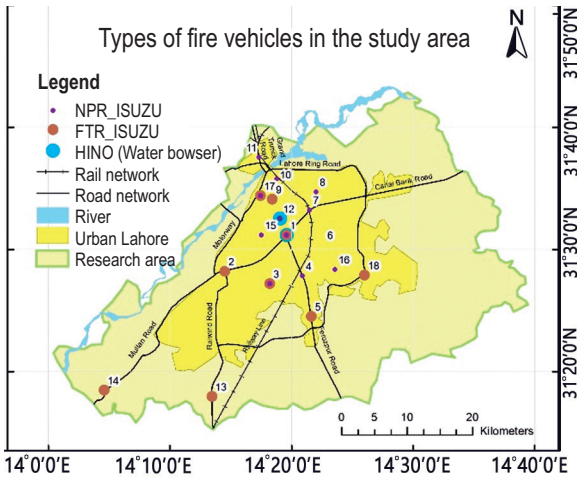

Fig. 1(b). Fire vehicles in the study area.

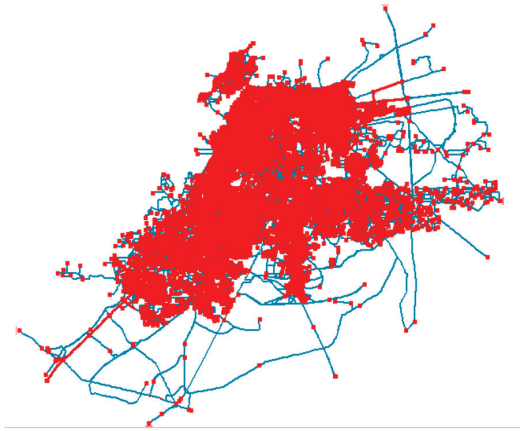

Fig. 1(c). Topological error of road network.

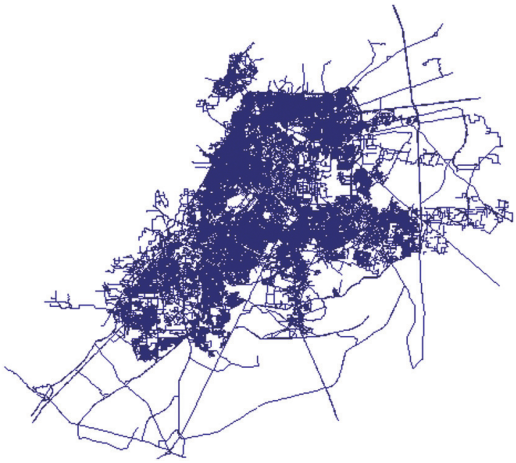

Fig. 1(d). Removal error of road network.

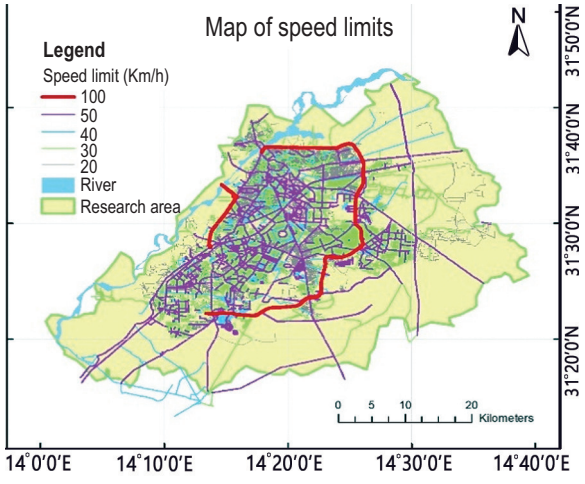

Fig. 1(e). Speed limit of roads.

where the fire brigade vehicles can reach and the inaccessible areas in the red colour and where fire brigade vehicles are unable to reach as the streets are very narrow.

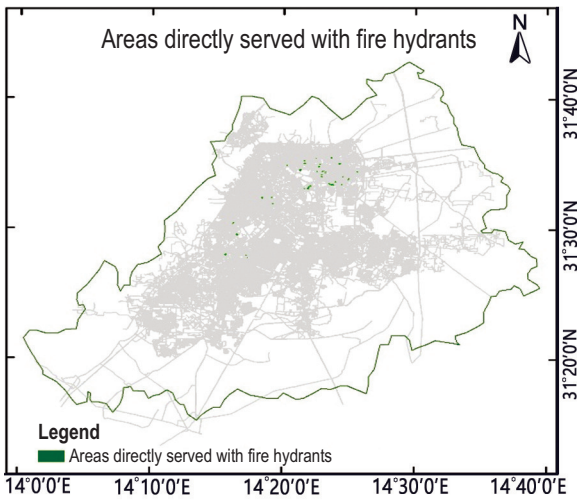

Fig. 2(a). Map of directly seved fire hydrants.

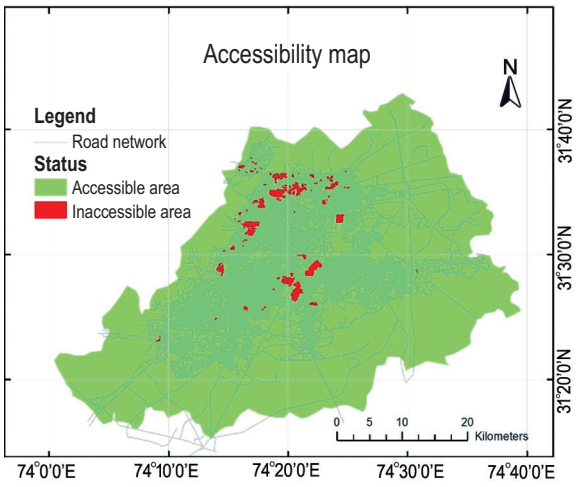

Fig. 2(b). Map of accessibility route for vehicles.

Table 2. Percentage and area of accessible and inaccessible regions

Region	Area (sq Km)	Percentage
Accessible	1675	99
Inaccessible	17	1
Total	1692	100

The above graph shows that the 17 km^2 area comes in the inaccessible zone. The largest area which is inaccessible is near Shera Kot, Nonarian, it is about 697 acres and the fire brigade vehicles cannot enter the area.

Accessibility zones have been shown in Table 3, in which generated using service area analysis. It shows the efficiency of fire brigade vehicles, the green colour in the Fig. 3 shows the area that comes under the safe zone as the vehicles reach there within the incident response time. The pink area shows into Fig. 4, the region where the fire brigade vehicles reach within 8 to 15 min and the red colour shows the area where the

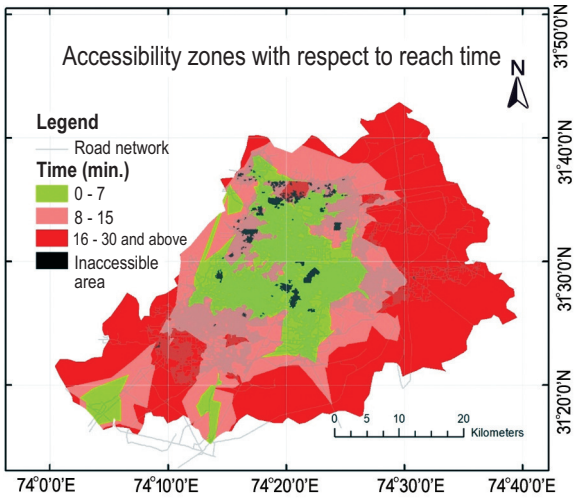

Fig. 3. Map of accessibility route for vehicles.

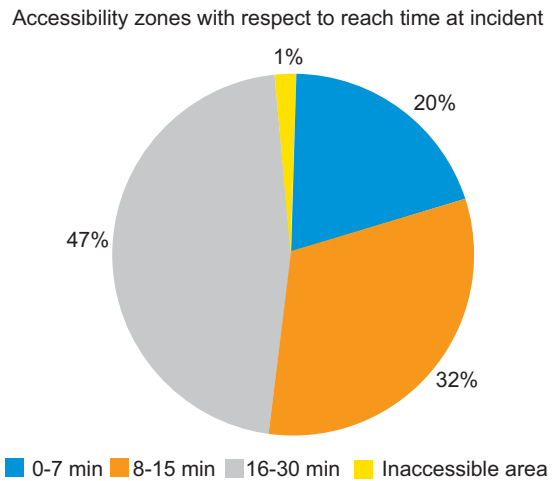

Fig. 4. Percentage graph of accessibility zones with respect to reach time.

Table 3. Area and percentage of accessibility zones

Region (min)	Area (Sq Km)	Percentage
0 – 7	340	20
8 – 15	535	32
16 – 30	800	47
Inaccessible Area	17	1
Grand Total	1692	100

fire brigade vehicles will reach after 16 min that comes under the unsafe zone. The graph shows that the fire brigade vehicles can reach only 20% of the area within 7 min, 47% of the area is reached after 16 min. We know that fire waits for none. It takes about 8 min for a house to completely burn down and yet most of the area is being reached after 10 min or so on.

Conclusions

This research accessibility analysis has been done for fire brigade vehicles in the city of Lahore. Accessible and inaccessible regions were generated using GIS-based overlay analysis and network analysis. It was found that 1% of the study area which is about 17 Km^2 which is completely inaccessible for the fire brigade vehicles as the streets are very narrow that the vehicles are unable to enter them. This research also shows the accessibility zones with respect to the reach time of the vehicles at the place of incident. About 20% of the area is reached within 7 min which is the incident response time of the rescue 1122. A total of 32% of the study area is reached within 8 to 15 min and 47% of the area is reached after 16 min which can cause serious damage to the lives and property of people living in those areas. This research concludes that the rescue stations and the fire hydrants are distributed unsystematically and some of them are not even functional. The fire brigade vehicles are not sufficient and efficient to cover the entire study area within the incident response time.

Inaccessible and farthest regions should be targeted for a more thorough investigation and actions must be taken for the protection of human life and property. Locations of new fire hydrants, proper maintenance and functionality of existing infrastructures. New fire brigade vehicles should be introduced, that are more efficient and have lesser width to reach narrow streets use of Scania (fire brigade vehicle). Strict implementation of existing by-laws and research of similar kind should be done by the students and the related government departments and agencies for the betterment of the fire rescue system. People should give way to the fire brigade vehicles so they can reach the destination as soon as possible without any delay.

Conflict of Interest. The authors declare that they have no conflict of interest.

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