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Analyzing Fire Station Emergency Response with Network Analysis Tool, Kolhapur, Maharashtra

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Abstract

This study sought to improve public safety in Kolhapur city, Maharashtra by examining the emergency response of fire stations using a Network analysis tool. The primary aim of this study was to investigate the reaction of fire stations in several geographical areas when faced with emergency scenarios. The current study provides a compelling example of how the utilization of Geographic Information System (GIS) technology can improve the effectiveness of fire station services and reduce the resulting impacts. For the assessment summation of rank method was employed, summation rank standardized all ratings. The worst conceivable outcome was ranked highest, while the least significant was lowest. All traffic volume data was converted to PCUs for flow analysis. The shortest route between Rajaram Sahakari Sakhar Karkhana and Kasaba Bawada Fire Station was dangerous if it caught fire. The combined Ranks are highest (33). It is long (1881.76 m), narrow (8.12 m), and busy morning and evening (20 PCU). The tiny road and heavy traffic made this the worst emergency route for a fire vehicle. Tiny road width, distance, and heavy traffic made it the worst way for a fire engine to attend an incident promptly. Best route was Tararani Fire Station to Aslam Fabrication with lowest Rank summation (8) because of lowest average-width, short (1859.4 m) route and has only 2 morning and evening PUC flow.

Keywords: Network analysis, Fire station, Emergency response analysis

1.1 Introduction

Accidental fires have posed a danger to lives, property, and the environment for as long as humanity has existed, since we're surrounded by a variety of highly combustible materials in our modern environment **(Johnson, 2000; Irvine et al 2000)** Urban fire is one of the most prevalent issues, affecting both developed and developing nations. **(Nisanci, 2010).** Particularly in India, annually a significant number of property and lives are unfortunately lost due to fire incidents. For instance In India, there were 9,329 documented fire accident instances with over 9,000 fatalities in the year 2020, which is a severe national concern. **(FICCI, India Risk Survey Report, 2021).** The fire department is one of the most crucial emergency services in India. The responsibility for fire services in certain states, namely Maharashtra, Haryana, Gujarat, Chhattisgarh, Madhya Pradesh (except Indore), and Punjab, is with the respective Municipal Corporations. In the remaining states, the responsibility lies within the jurisdiction of the Home Department.**(RMSI Report, December 2011)** The mission of the fire service, which is to save lives and safeguard property, has expanded in recent years. Fire professionals are becoming more strategic towards incorporating technology into their operations. GIS serve as a valuable tool employed by many agencies to effectively manage the complex interplay between demands, uses, and risks in order to uphold environmental sustainability while recognizing and reducing vulnerability **(Sohyda, 2009).** Nowadays the application of GIS and network analysis techniques plays a crucial role in the evaluation and optimization of emergency response times and services. The Network Analyst evaluates the quickest and most effective emergency response routes and response times between fire

stations and incident sites. (Graur, D., & Efros, V. 2017, Ahmed, S., Ibrahim, et al 2017). By employing Geographic Information Systems (GIS), users can efficiently compile and analyze a wide range of data, while also effectively visualizing the results. The technology possesses diverse applications throughout several industries, encompassing healthcare planning, emergency services, and transportation management. **(Dabhade, A., Kale, K. V., & Gedam, Y. 2015).** Spatial analysis on fire emergency response requires street network data, information on hazardous materials locations, and pre-fire survey information such as floor plans or hydrant location and capacity data **(ESRI, 2011).**

Several scholars have undertaken fire service analysis by applying GIS technologies. **Habibi et al. (2008)** used analytical hierarchy approach and GIS to analyse urban fire stations **D. Sarkar (2013)** performed a structural analysis on the road networks and took into consideration such as road density, Beta, Alpha and Gamma indices, Cyclomatic number, and Transportation score overall (ATS) to analyse current road networks **Mezaal et al (2020)**.Conducted a study that examined the significant improvements in response time for the comprehensive service area using GIS and also studied the evaluation of the validity and reliability of both spatial and non-spatial data. GIS is a potent planning tool that provides situational information and enables users to build, edit, display, and analyses locations from the actual world into the virtual one. There are numerous studies carried out globally that make use of GIS-based suitability modeling for site selection and facility allocation in contemporary planning processes. **(Nisanci, 2010)**

This study tried to enhance public safety in Kolhapur city, Maharashtra by analyzing the emergency response of fire stations through the utilization of Network analysis tool. The objective of the study was to examine the response of fire stations in various locations during emergency situations. The present investigation offers a compelling illustration of how the implementation of Geographic Information System (GIS) technology can enhance the efficiency of fire station services and mitigate associated consequences.

1.2 Objective

- To identify how efficiently fire stations in Kolhapur can reach incident sites.

1.3 Material and Methods

1.3.1 Data Capture and Processing

A survey utilizing the Global Positioning System (GPS) was undertaken to establish the coordinates of the fire stations and incident points within the study area. Incident points were designated within the several wards of Kolhapur city, taking into account their significance in terms of residential, commercial, educational, and administrative aspects. Attribute (i.e., non-spatial data) information such as road width and length, location description, and traffic flow statistics were incorporated into the geo-database construction. The collection of traffic flow data was accomplished by conducting on-site surveys during morning hours (9 am to 10 am) and evening hours (5 pm to 6 pm), taking into account the likelihood of encountering high traffic volumes. In order to ensure the availability of fire service during regular working days, holidays such as festival days and Sundays were deliberately avoided. The road network data was obtained from the Open Street Map (OSM) data source. In cases where primary roads were absent, they were located and digitized using Google Earth Pro and QGIS-3.16.16 software, respectively. The road network's topology was established using the Network Topology checker plugin. Subsequently, the shortest pathways were determined using a point-to-point method, facilitated by the network analysis tool in Q-GIS. The intensity of traffic flow was measured using the Summation of Rank Method, and a query was devised to identify the optimal routes by correlating the geodatabase with the shortest route for quick response analysis. The model analysis has been validated by correlating it with the value of traffic flow as determined by summation rank analysis.

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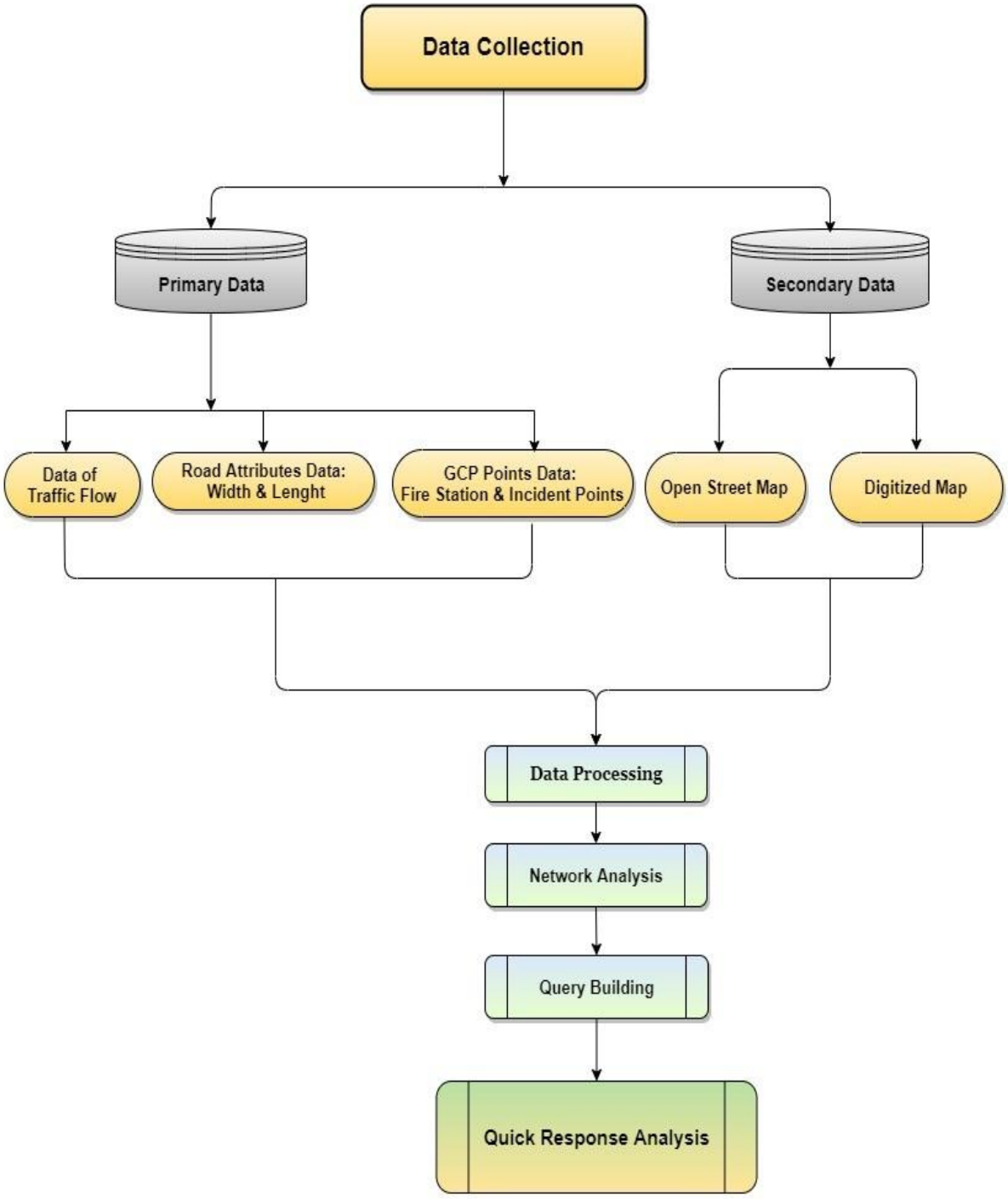

Fig. 1.1: Research Methodology

1.4 Study area

Kolhapur, an emerging urban center situated in the state of Maharashtra. The geographical expanse of the region measures 66.82 square kilometres, accommodating an anticipated populace of around 757,000 inhabitants as recorded in the 2023 census conducted by the Indian government. The urban center is positioned at an elevation of 1790 feet relative to sea level and is located at a geographical coordinate of 16°42' North

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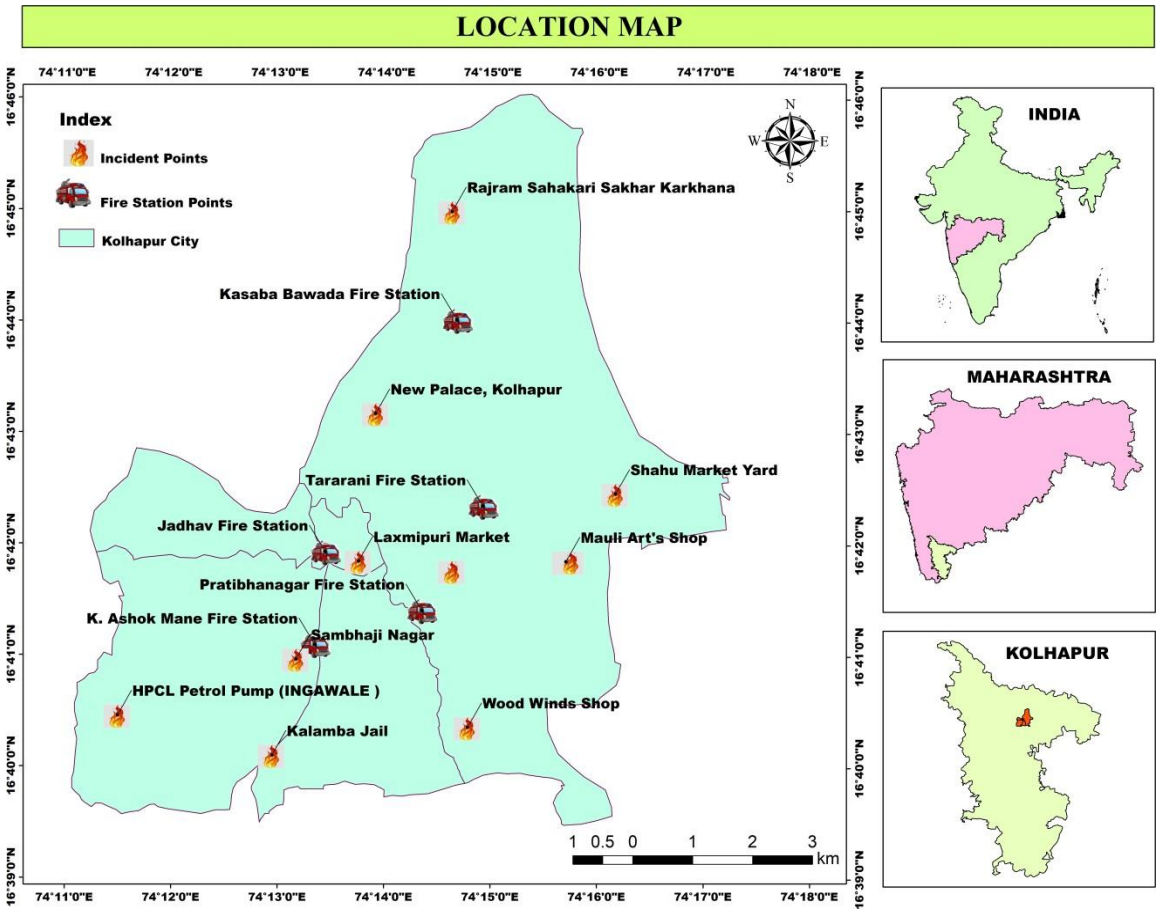
latitude and 74°14' East longitude, adjacent to the Panchaganga River in the southwestern Sahayadri Mountains in Maharashtra (Fig. 1.2).

Fig. 1.2



1.5 Result and Discussion

1.5.1 Network Analysis: shortest Path and quick response analysis

Allocating emergency services strategically to the best locations during times of crisis is crucial for effective management. In order to provide an accurate study of travel patterns, the network analysis layer takes into account geographical elements such the existing transportation infrastructure, as well as journey distance and surface speed. **(Green et al., 2014).Smith et al. (2018)** employed a method to assess the response times of a major urban fire department. Their findings revealed that specific regions experienced considerable delays due to traffic congestion and poorly designed road networks. **Williams et al. (2017)** assessed urban response times using a tool. The authors found that real-time traffic data and other technologies improved the fire department's emergency response. The Network Analyst tool helped the department identify issue areas and execute focused enhancements, improving patient outcomes by reducing response times. In their study**, Papioannou and Martinez (2015)** investigate how the design of public transportation networks influences mode selection, including accessibility and connectivity. Accessibility and connectivity influence the choice of driving mode, so factor analysis and structural equation modeling are utilized. They concluded that accessibility is more crucial to a journey than connectivity factors such as time. By utilizing GIS to evaluate transport accessibility**. Barr et al. (2015)** assessed London's sustainable transportation options. In this study, only employment

accessibility was considered, and accessibility was calculated separately for each mode of transportation. They argue that "parameterization," "visual exploration," and "interpretation" are all facilitated by the GIS-based paradigm.

There are a total of six fire stations actively providing emergency services to the entire city of Kolhapur. These fire stations are the K Ashok Mane Fire Station, Jadhav Fire Station, Phulewadi Fire Station, Kasba Bawada Fire Station, Pratibhanagar Fire Station, and Tararani Fire Station. A conceptual framework is developed in order to comprehend the fire emergency service model inside the city of Kolhapur. Based on the operational value, few points were chosen as the fire incident points within the vicinity of each fire station. The network analyst tool in QGIS was utilized to assess the shortest paths between fire stations and incident spots. The analysis revealed a range of shortest path lengths, spanning from 0.63 km to 4.05 km. This range serves as an indicator of the potential for a prompt response at each location. The shortest observed path length of 0.63km was seen between Jadhav fire station and Laxmipuri market, while the longest path length of 4.05km was detected between K Ashok Mane Fire station and the HPCL Petrol Pump (Table 1.2).

Table 1.1: Fire station to incident points traffic flow analysis

Fire station	Incident points	Traffic flow			
		Near fire station		Near incident points	
		Morning (11 am)	Evening (5 pm)	Morning (11 am)	Evening (5 pm)
KasabaBawda Fire Station	Rajaram Sakhari Karkhana	144	121	120	192
	New Palace	413	243	28	22
Tararani Fire Station	Mauli Art's	547	577	63	39
	Alsam Fabrication	340	276	11	7
Jadhav Fire Station	Laxmipuri Market	254	199	98	117
Pratibhanagar Fire Station	Wood Wind's	189	138	82	80
	Rajarampuri's 5th Lane	142	122	31	33
K. Ashok Mane Fire Station	Kalmba Jail	119	86	61	51
	HPCL Petrol Pump	189	86	48	46

Source: Field survey, 2020-21, Kolhapur

A quick response capability of each fire station was conducted during peak hours in the morning (11:00 AM) and evening (5:00 PM). Based on the findings of a field survey, the presence of heavy traffic was seen to be more prevalent during the morning period compared to the evening, with the exception of Mauli Art's, where the highest traffic flow of 547 was recorded in the morning and 577 during the evening. The area with the least amount of vehicular movement was observed in the vicinity of Phulewadi fire station, with traffic volumes recorded at 17 and 15 units during the morning and evening periods, respectively. The traffic flow in the proximity of the incident was seen to be lower in comparison to the traffic flow in the vicinity of the fire station. The area with the highest traffic flow near the incident point was found at Rajaram Sahkari Sakhar Karkhana, with traffic volumes of 120 in the morning and 192 in the evening. Conversely, the lowest traffic flow was detected at the incident location near Mauli Art's (Table 1.1).

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Table 1.2: Shortest path length (km) and direction of traffic flow between fire stations and incident points

Fire stations	Incident points	Shortest path length (km) & direction of traffic flow
Kasaba Bawda Fire Station	Rajaram Sakhari Karkhana	2.16 Km (Left side of the Vehicle)
	New Palace	2.36 Km (Left side of the Vehicle)
Tararani Fire Station	Alsam Fabrication	2.64 Km (Left side of the Vehicle)
	Mauli arts	1.92 Km (Left side of the Vehicle)
Jadhav Fire Station	Laxmipuri Market	0.63 Km (Left side of the Vehicle)
Pratibhanagar Fire Station	Wood Wind's	2.87 km (Left side of the Vehicle)
	Rajarampuri's 5th Lane	1.08 Km (Left side of the Vehicle)
K. Ashok Mane Fire Station	Kalmba Jail	2.21 Km (Left side of the Vehicle)
	HPCL Petrol Pump	4.05 Km (Left side of the Vehicle)

Source: Field survey, 2020-21, Kolhapur.

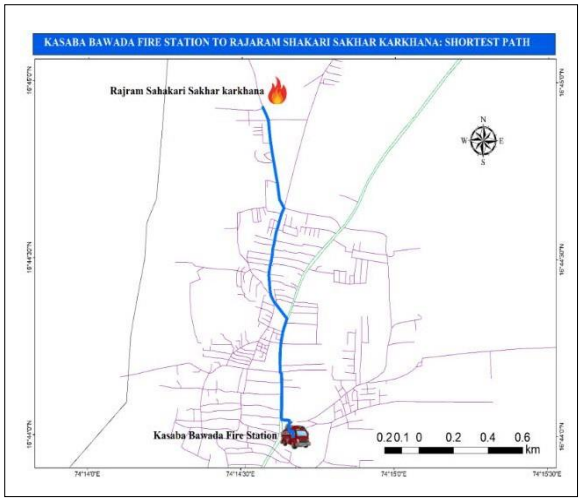

Fig. 1.3 (a)

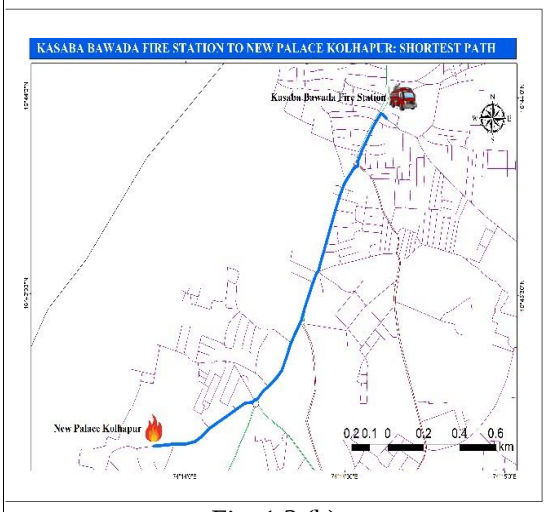

Fig. 1.3 (b)

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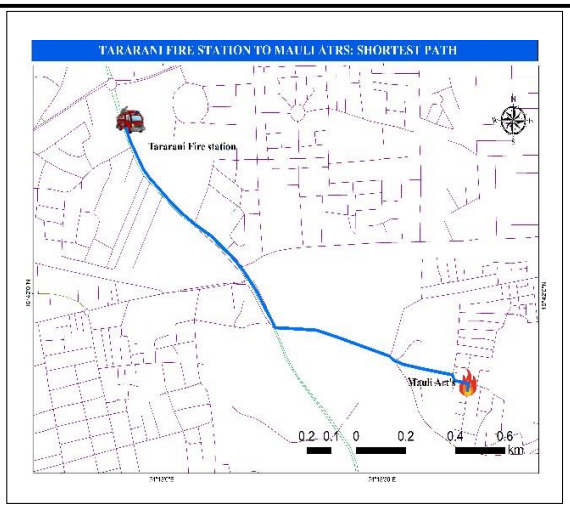

Fig. 1.3 (c)

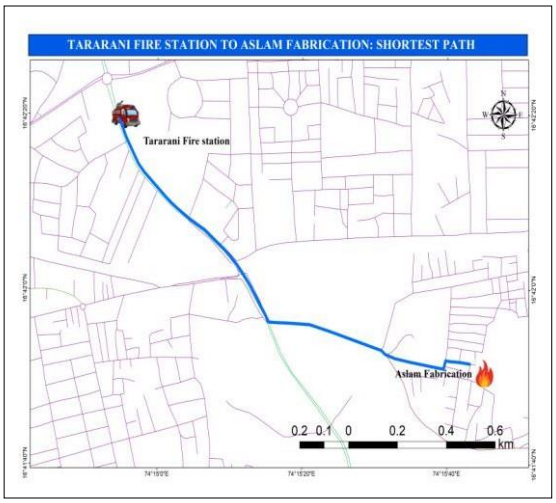

Fig. 1.3 (d)

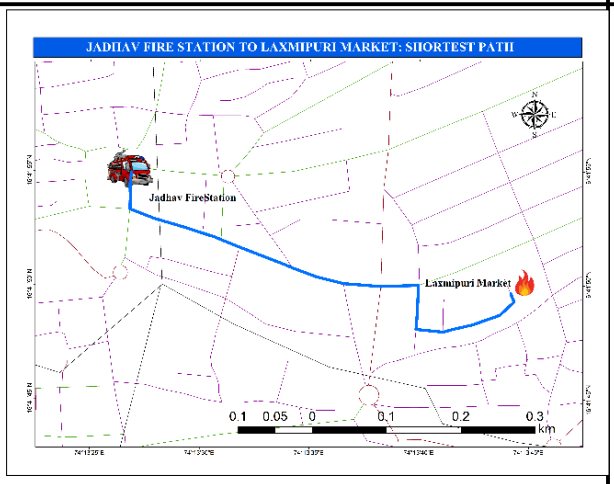

Fig. 1.3 (e)

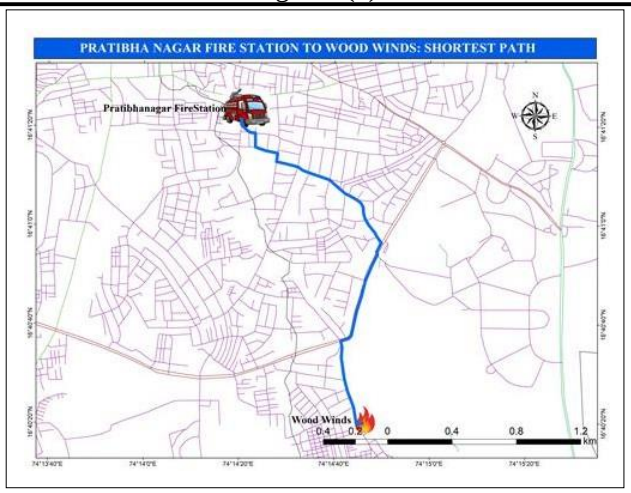

Fig. 1.3 (f)

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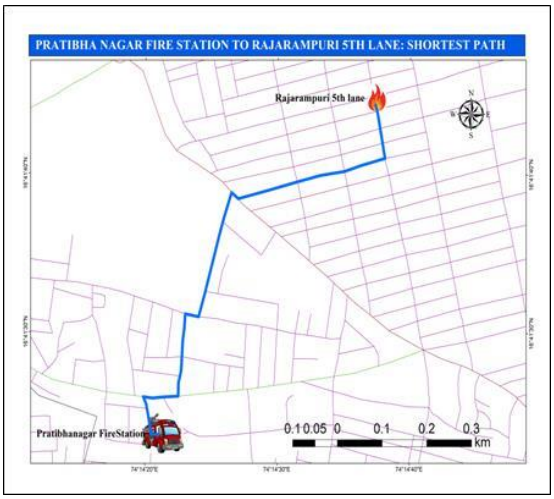

Fig. 1.3 (g)

Fig. 1.3 (h)

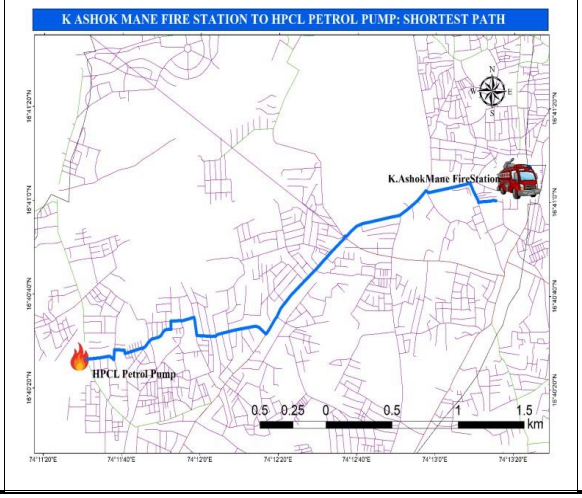

Fig. 1.3 (i)

Source: OSM layer and field survey, 2020-21, Kolhapur

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Table 1.3: Fire station to incident points-Summation rank analysis

		Incident Points	Average Width (m)	Total Road length (m)	Traffic Flow (Passenger Car Unit-PCU)	Width Ranks	Length Ranks	Morning PCU Ranks	Evening PCU Ranks	Sum. of Rank Morning	Sum. of Ranks Evening	Total Sum.	Traffic Flow (Passenger Car Unit-PCU)
1	Kasaba Bawada Fire Station	New Palace	12.91	2225.59	17	18	3	8	3	2	14	13	16
2	Kasaba Bawada Fire Station	Rajram Sahakari Sakhar Karkhana	8.12	1881.76	89	150	7	6	10	10	23	23	33
3	Tararani Fire Station	Mauli Arts Shop	17.63	1777.39	41	23	2	4	5	4	11	10	15
4	Tararani Fire Station	Aslam Fabrication	17.94	1859.4	5	8	1	5	1	1	7	7	8
5	Jadhav Fire Station	Laxmipuri Market	7.62	682.55	58	72	9	2	8	8	19	19	27
6	K.Ashok Mane Fire Station	Kalamba Jail	11.34	2195.89	85	114	4	7	9	9	20	20	29
7	K. Ashokmane Fire Station	HPCL Pump	9.47	4094.55	28	27	6	10	4	5	20	21	25
8	Pratibha Nagar Fire Station	Wood Winds Shop	10.5	2688.67	51	51	5	9	7	7	21	21	28
9	Prathibha Nagar Fire Station	Rajarampuri Lane	7.65	1110.51	16	18.2	8	3	2	3	13	14	16

Source: Field survey, 2020-21, Kolhapur

Conclusion

Summation rank standardized all rating criteria. The worst possible outcome was given the highest ranking, while the least significant outcomes were given the lowest. All data on traffic volumes was converted to PCUs (Passenger car Units) for the flow analysis. The shortest path between Rajaram Sahakari Sakhar Karkhana and Kasaba Bawada Fire Station was risky if it caught fire. It has the highest combined Ranks (33). It is long (1881.76 m), narrow (8.12 m), and has considerable morning and evening traffic (20 PCU). The small road and heavy traffic made this the worst route for a fire vehicle to attend an emergency. This route was the worst for a fire engine to reach an incident quickly due to its narrow road, distance, and heavy traffic. With the lowest Rank summation, the Tararani Fire Station to Aslam Fabrication route was best (8). The average-width, short (1859.4 m) route has 2 PCU morning and evening automobile traffic.

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