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Satellite Imagery-Based AHP Model to Identify the Spatial Heterogeneity of Fire Incidents in Dhaka City Corporation, Bangladesh

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Abstract: *Fire is one of the severe hazards in developing and developed countries, threatening life, structures, property, and the environment. Hundreds of fire incidents occur every year in Bangladesh, causing massive damage. The study identified the spatial distribution of fire incidents in Dhaka City Corporation using satellite imagery and geospatial analysis, which was done through Google Earth Pro (x, y coordinate) and ArcGIS. A dataset is developed, listing fire incident location, time, reason, casualty, and land use from various sources, such as fire stations and newspapers. High-resolution satellite imagery available in Google Earth Pro, sourced from Maxar Technologies and visual representations of Landsat 8 and Sentinel data, was utilized to delineate land cover types around fire incident sites. Manual digitization was performed in ArcMap 10.8, focusing on visually distinguishable features to classify land cover around fire incident sites. The land covers include settlements, vegetation, water bodies, open fields, and roads. Correlation analysis was done using SPSS software to determine the relationship between the fire incident number of settlement density and the fire incident number of settlement type. The AHP model has been applied to measure the weight of different land cover classes according to fire incidents. From the correlation analysis, it is identified that residential buildings are the most vulnerable to fire hazards. The ranking of other settlement types in order of vulnerability includes slums, commercial buildings, service buildings, and industrial buildings in descending order. Therefore, special precautions and actions by the authority and policymakers against fire hazards in residential buildings and slums need to be taken.*

Keywords: Fire, ArcGIS, Satellite Image, AHP, Spatial heterogeneity, Dhaka City Corporation.

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Introduction

Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products (NFPA, 2021). Fire can cause widespread destruction within no time and is one of the most feared scourges of modern civilization (Alam and Baroi, 2003). Among the known natural and man-made disasters, fire disasters are the most devastating events that cost lives and property (Saha, 2024). Fire represents a severe hazard across both developing and developed countries, posing a significant threat to life, structures, property, and the environment (Kodur et al., 2020). Globally, fire-related incidents continue to cause substantial human and economic losses. Every year, more than 180,000 people die in fires or from burn-related injuries worldwide. Alarmingly, over 95% of these deaths and injuries occur in low- and middle-income countries, where the risk of fire hazards escalates in proportion to rapid urbanization, unplanned settlements, and inadequate fire safety regulations (Cvetkovska and Mitrevska, 2024). In developing countries, fires are exacerbated by informal housing structures, high population densities, poor urban planning, and limited emergency response capacities (WHO, 2018). In densely populated urban areas and informal settlements, fires continue to disproportionately affect the poorest and most vulnerable groups (UNDRR, 2022).

Fire hazards have emerged as a significant concern in Bangladesh, especially within metropolitan regions (Uddin, 2023). In 2021, more than 20 thousand fire incidents occurred across Bangladesh, increasing to approximately 24 thousand in 2022 and 29 thousand in 2023 (FSCD, 2021, 2022, 2023). The trend of urban fire is closely related to the level of urbanization of an area, and globally, this urbanization is taking place rapidly. Urbanization is also taking place in Bangladesh very rapidly. Especially in Dhaka, the urbanization rate is very high (Tishi and Islam, 2018). The total area of Dhaka City Corporation is 306.4 km^2 (DCC, 2024), and the total population of Dhaka City is 10.2 million (BBS, 2022). Dhaka City is expanding vertically day by day. The number of high-rise buildings is increasing frequently. Most of these buildings do not follow the Bangladesh National Building Code. There is no proper firefighting and evacuation system in most of the buildings (Chisty and Rahman, 2020). Fire occurrence has become a major source of concern for Dhaka in recent years due to a significant increase in fire incidents (Rahman et al., 2022). Dhaka City, located in the heart of Bangladesh, is part of a lower-middle-income country (World Bank, 2024). The city frequently experiences fire hazards due to its high-density population and the widespread use of combustible building materials. Other contributing factors include narrow roads, an improper water supply system, and a continuous reduction in available water sources. Additionally, hanging electric cables and wires, as well as chemical factories situated within residential areas, increase the risk. Inadequate skills, poor emergency response, and weak preparedness among residents and authorities make the situation worse. (Tishi and Islam, 2018). The average number of inhabitants per 1 career firefighter in Dhaka City is around 12 thousand, the lowest in the world. The average number of fire deaths per 100 fires in Dhaka City is 174 (Brushlinsky et al., 2022). The magnitude of economic losses resulting from fire hazard casualties in Dhaka is much higher than in other cities within Bangladesh. The yearly economic loss or property damage exceeds BDT 4 billion (Islam and Hossain, 2018). As Dhaka is a densely populated city, the people of this city are always at risk of severe casualties and property damage due to fire hazards.

Although fire hazards cannot be fully eliminated, corresponding risks can be minimized by better preparedness and well-planned mitigation strategies developed based on a comprehensive analysis of their spatial, temporal, and causal patterns (Alam and Baroi, 2003). Urban fire incidents are not natural disasters, as they can be predicted, and scientific methods can be applied to reduce the associated risks (Irawan et al., 2024). Different work has been done in the field of fire hazard in the world, including industrial fires, forest fires, and their mitigation strategies. In Bangladesh, there has been some work on fire hazard covering shopping centers, a specific case study, integration with fire stations, etc. But satellite imagery-based land cover classification and significance identification of specific land cover of an area to address fire hazard is never done in Bangladesh.

Recent advancements in Geographic Information Systems (GIS) and Remote Sensing technologies offer promising avenues for addressing urban fire risks (Amoako, 2024). AHP is one of the most comprehensive methods of multi-criteria decision analysis, and it uses a digital approach. It is a powerful and flexible decision-making theory that ranks different features (Çoban & Erdin, 2020). In this study, GIS, Remote sensing, and AHP methods are used to identify the most affected site conditions to fire incidents. This knowledge could help stakeholders and policymakers deal with fire hazards more effectively by improving precautions and mitigation strategies.

Moreover, the results of this study will have long-term implications for municipal authorities, emergency services, and urban planners.

Materials and Methods

Study Area

Dhaka City Corporation is centrally located in Bangladesh, in the southern part of the Dhaka district. Dhaka City, as Dhaka Metropolitan Area, is located almost in the geographical center of Bangladesh at 23°43'0"N and 90°24'0" E. The geographical area of this city is 306.4 square kilometers (DCC, 2024). Several rivers, like Buriganga, Balu, Tongi Khal, and Turag, surround the city from the south, east, west, and north, respectively. However, the Buriganga River has a major share, and it forms the southern and western boundaries of Dhaka city. (Alam et al., 2023).

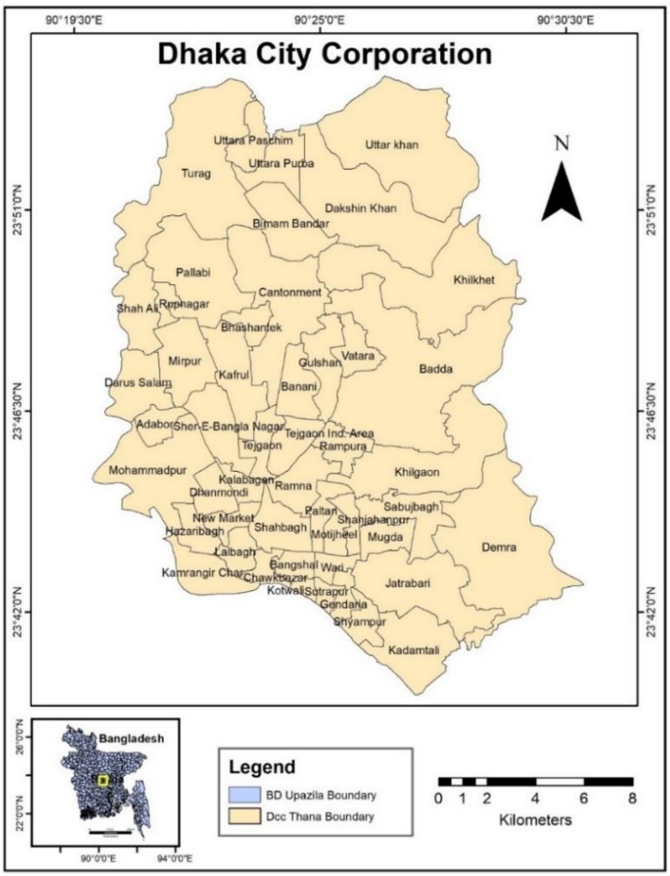

Figure 1: Study Area (Dhaka City Corporation)
Source: Compiled by Authors, adopted from DCC, 2024

Data Sources and Data Types

This study is mainly dependent on secondary data. The secondary data sources include newspapers, fire stations, and Google Earth Pro. Google Earth Pro imagery is sourced from Maxar Technologies and provides visual representations of Landsat 8 and Sentinel data. From these sources, the location, time, reason, land use, and casualty of fire incidents are collected. Additionally, high-resolution satellite images are obtained from Google Earth Pro.

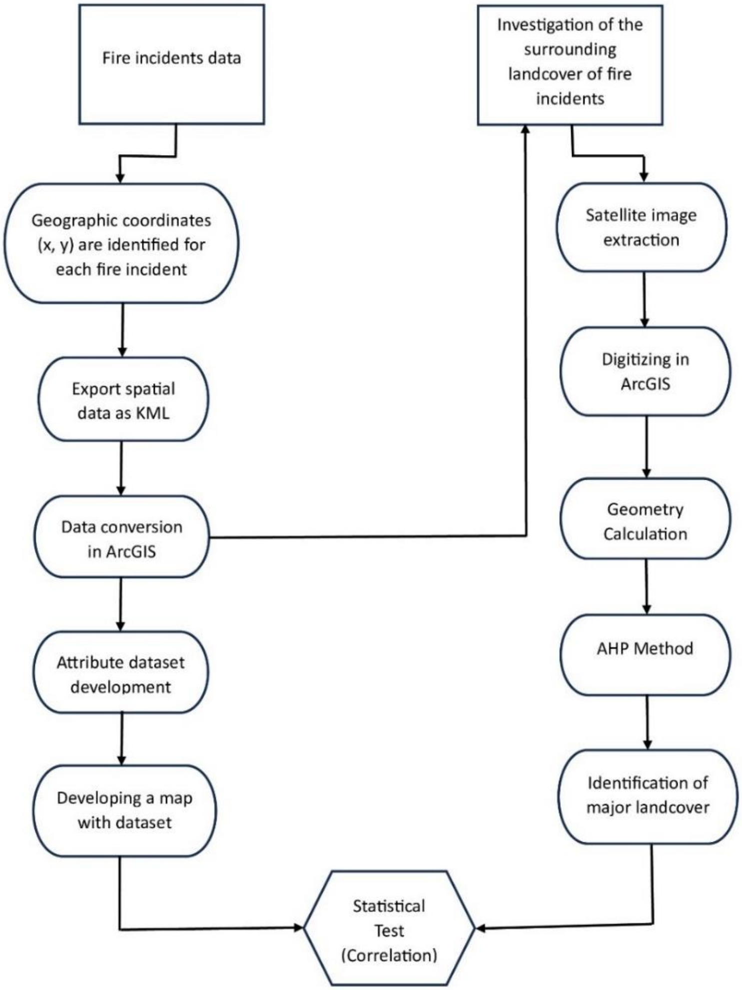

Figure 2: Flowchart of research methodology

Listing the Fire Incidents

Google Earth Pro was utilized to plot the absolute locations of the fire incidents. To begin with, fire incidents that occurred from 2014 to 2023 in Dhaka City Corporation were identified manually. About 262 fire incidents were recorded initially. The absolute locations of these fire incidents were then listed. The latitude and longitude coordinates (x, y) for each fire incident location were pinpointed using Google Earth Pro. Subsequently, the locations of the fire incidents were converted into a KML database within Google Earth Pro. This KML file was then imported into the ArcGIS software, which converted it into a layer, and a point database shapefile was developed. In ArcGIS, the KML file of fire incidents was converted into a layer using the "KML to Layer" tool from the Arc Toolbox. This tool transforms the KML file into a feature class that can be displayed and analyzed within the GIS environment. By this conversion, each placemark in the KML file becomes a point feature on the map, and the associated attributes (such as time, land use, reason of fire, and casualty) are retained as fields within the layer's attribute table.

Developing a Dataset

The dataset for fire incidents was developed within the attribute table of a shapefile for the points in the ArcGIS software. The name field was used in the dataset to list the fire incidents. The year field listed the year of the fire incident. The land use field lists different types of land use for different fire incidents. The reason field was developed to list the reasons for fire occurrences, and the casualty field was built to list the casualties the fire incidents caused.

The listed data in the dataset are:

- Location
- Year of the fire incident
- Land use
    - Residential building
    - Commercial building
    - Service building
    - Slum
    - Industrial building
- Reason for the fire incident
    - Electric short circuit
    - Gas cylinder explosions
    - Gas line leakage

    - Ac blasts, etc.
- Casualty
    - Death
    - Injury
    - Loss (BDT)

Table

All_1

FID	Shape *	Name	Year	Landuse	Reason	Cas_Death	Cas_Injury	Cas_Loss
0	Point ZM	Bangabazar	2023	Market	Cigarette	0	0	1000000
1	Point ZM	Mohakhali, Sattola Bosti	2023	Slum		4	0	0
2	Point ZM	Joy Kali Mandir, Kaptan Bazar	2023	Slum	Gas Line Leakage	2	0	0
3	Point ZM	Gulshan Apartment Fire	2023	Apartment Building	Gas Cylinder Explosion	0	1	0
4	Point ZM	Gopibagh rickshaw garage fire	2023	Garage		0	0	0
5	Point ZM	Science Lab explosion	2023	Commercial Building	Gas Cylinder Explosion	0	3	5000000
6	Point ZM	Tejkunipara slum	2023	Slum	Miscreant	0	0	0
7	Point ZM	Mirpur 13	2023	Apartment Building	Gas Cylinder Explosion	0	2	0
8	Point ZM	Mirpur 1, Shomsher Market	2023	Market	Electric Short Circuit	2	0	0
9	Point ZM	Agargaon, Mirpur	2023	Market	Cigarette	0	0	0
10	Point ZM	Mirpur 14, North Ibrahimpur	2023	Apartment Building	Electric Short Circuit	0	0	0
11	Point ZM	Boubazar, Mirpur 13	2023	Apartment Building	Electric Short Circuit	1	2	0
12	Point ZM	Bhasantek Slum, Mirpur 14	2023	Slum		3	5	0
13	Point ZM	Mirpur 2, Block5-Block c	2023	Apartment Building	Gas Cylinder Explosion	0	0	0
14	Point ZM	Beside Islami Bank, Mirpur 13, Dhaka	2023	Apartment Building	Gas Line Leakage	0	0	0
15	Point ZM	Mirpur 11, Ward no-6	2023	Apartment Building	Gas Cylinder Explosion	1	1	0
16	Point ZM	Ibrahimpur Maddhapara, Mirpur, Dhaka	2023	Apartment Building	Gas Line Leakage	0	0	0
17	Point ZM	Senpara, Mirpur	2023	Apartment Building	Electric Short Circuit	0	0	0
18	Point ZM	Bhasantek Bazar	2023	Market	Market	0	0	0
19	Point ZM	Imamnagar, Mirpur 13	2023	Apartment Building	Gas Cylinder Explosion	0	2	0
20	Point ZM	Mirpur 6	2023	Apartment Building	Ac Blust	0	0	0
21	Point ZM	60 Feet, South pirerbagh	2023	Apartment Building	Gas Cylinder Explosion	0	0	0
22	Point ZM	City Bazar, Seorapara, Mirpur	2023	Market	Electric Short Circuit	0	0	0
23	Point ZM	Rupnagar Resident Area	2023	Apartment Building	Electric Short Circuit	0	1	0
24	Point ZM	Mazar Road, Mirpur 1	2023	Apartment Building	Gas Cylinder Explosion	0	0	0
25	Point ZM	Mirpur 2	2023	Apartment Building	Gas Cylinder Explosion	1	0	0
26	Point ZM	Arambagh, Mirpur 7	2023	Apartment Building		0	0	0
27	Point ZM	Mirpur 10	2023	Apartment Building	Gas Cylinder Explosion	0	0	0
28	Point ZM	Beribadh, Botanical Garden	2023	Botanical Garden		0	0	0
29	Point ZM	Rupnagar, Arambagh	2023	Apartment Building	Gas Cylinder Explosion	1	2	0
30	Point ZM	Mirpur 1, House 6/18, Block D	2023	Apartment Building	Gas Line Leakage	0	0	0
31	Point ZM	House 125, Road 8, Mirpur 12	2023	Apartment Building	Electric Short Circuit	1	0	0
32	Point ZM	Jatrabari	2023	Apartment Building	Electric Short Circuit	0	2	0
33	Point ZM	Mirpur 6, Road 9, Block 6	2023	Apartment Building		0	0	0
34	Point ZM	Sheorapara, Mirpur	2023	Apartment Building	Gas Line Leakage	0	0	0
35	Point ZM	Molla Basti, Mirpur 12	2023	Slum		0	0	0
36	Point ZM	Mirpur 13, Polashnagar, Beltola	2023	Apartment Building		0	0	0
37	Point ZM	House 54, Mirpur 1	2023	Apartment Building		0	0	0
38	Point ZM	Mohammadpur	2022	Apartment Building	Firecracker Explosion	0	1	0
39	Point ZM	Khilgaon	2022	Apartment Building	Firecracker Explosion	0	1	0
40	Point ZM	Lalbagh	2022	Apartment Building	Gas Cylnder Explosion	0	0	0
41	Point ZM	Pashim Rampura	2022	Power Station	Electric Short Circuit	0	0	0
42	Point ZM	Captan Bazar	2022	Market		0	0	0
43	Point ZM	Banglamotor	2022	Commercial Building	Ac Blast	0	0	0
44	Point ZM	Baridhara	2022	Apartment Building	Gas Cylnder Explosion	2	0	0
45	Point ZM	Green road	2022	Apartment Building	Gas Line Leakage	0	0	0

1 (0 out of 257 Selected)

All_1

Figure 3: Dataset for the Fire Incidents in Dhaka City Corporation from 2024 to 2023

In Figure 3, 45 fire incidents are listed in the dataset. The dataset for all 262 fire incidents was developed in the same way.

Investigation of the Surrounding Land Cover of a Fire Incident

Around 500m of a fire incident, the damage is most significant (Alkis et al., 2021). That's why a 500m area on each side of a fire incident is taken in this study to investigate the surrounding land cover. Firstly, satellite images were extracted from Google Earth Pro around 500 m of a fire incident. Then the images were georeferenced in ArcGIS. Georeferencing aims to align the image with real-world coordinates, allowing it to be integrated with other spatial data. After georeferencing, the images were digitized in ArcGIS into five classes, e.g., settlement, waterbody, vegetation, open field, and road. The Digitized images will help us identify which land covers are present around a fire incident. Then, the surrounding land area of a fire incident

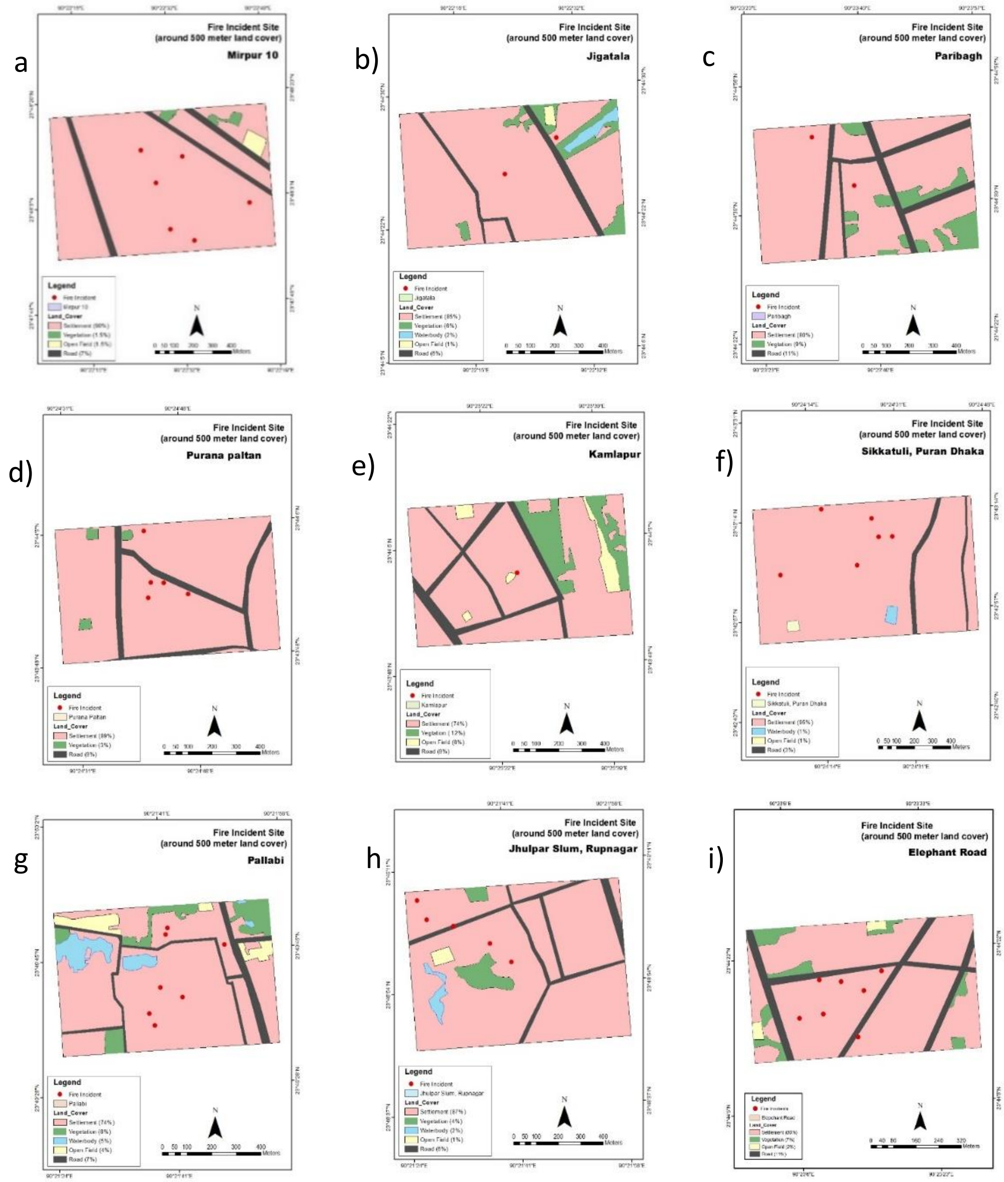

Figure 4: Sample of land cover around the fire incident sites (around 500 meters). a)Mirpur-10, b) Jigatala, c) Paribagh, d) Purana Paltan, e) Kamlapur f) Sikkatuli, g) Pallabi, h) Jhulpar slum, i) Elephant Road.

In Figure 4, we can see a sample of 9 fire incident sites with land cover around 500m. All 262 fire incident sites' land cover is investigated in the same way.

The land cover area has been calculated for each fire incident site and presented as a percentage to show the land cover scenario for each fire incident. For example, on Elephant Road (Figure 4-i), the settlement area for this site is 293,772.8 sqm, the vegetation area is 22,054.42 sqm, the open field area is 4213.63 sqm, and the road area is 45,900.70 sqm.

The formula used for percentage calculation is $= \frac{Part}{Total} \times 100$

The output table for the Elephant Road fire incident landcover investigation looks like this:

Table 1: Land cover (%) around Elephant Road Fire Incident

Location	Settlement (%)	Vegetation (%)	Waterbody (%)	Open Field (%)	Road (%)
Elephant Road	80%	6%	0%	1%	13%

The surrounding land cover of a fire incident is investigated by calculating the percentage of the areas of land cover that a fire incident holds around 500m. The surrounding land cover for all 262 fire incidents that occurred from 2014 to 2023 is investigated in the same way.

Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is among the most systematic multicriteria decision-making techniques. AHP structures the decision problems in the form of a hierarchy, wherein decision-makers can understand and study the interactions between the various elements of the problem. AHP is unique because it synthesizes quantitative and qualitative criteria, allowing for an overall evaluation that bridges the gap between subjective judgments and objective information (Taherdoost, 2021). One of the most significant benefits of AHP is that it simplifies complicated problems by converting them into simpler pairwise comparisons, making it easier to assign relative priorities among alternatives (Terzi, 2019). By breaking down complex decision factors into a series of comparisons, AHP makes decision-making simpler and ensures the consistency and reliability of judgments. Furthermore, its systematic nature allows open and rational decision-making of particular value where several conflicting criteria must be balanced against each other.

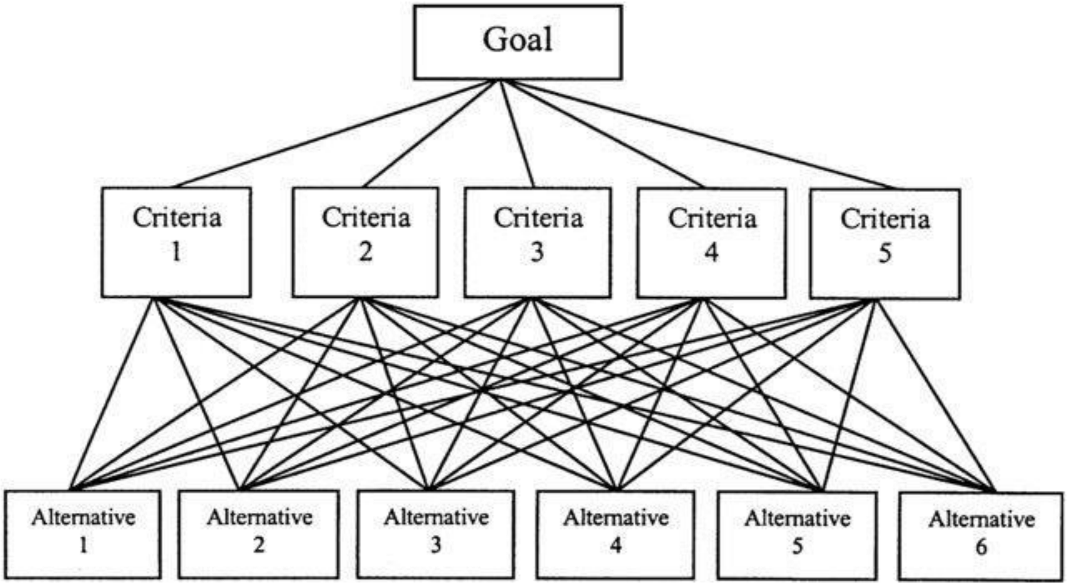

Figure 5: AHP Model
Source: (Badri, 2001)

In this case, the AHP model helps to identify the significant land cover around fire incident sites from the land cover types, e.g., settlements, vegetation, water bodies, open fields, and roads. With the help of the AHP model, we will be able to know which land cover is most influential around a fire incident among the five classes.

Statistical Analysis

A statistical analysis (correlation) was conducted using SPSS Statistics Software to determine the relationship between settlement density incident number and settlement type incident number. Pearson correlation was selected among other correlation coefficients as it provides a clear numerical value that indicates the strength and direction of the linear relationship between two variables. Then, two-tailed significance was selected in the correlation process as it evaluates the possibility of a relationship in both directions (positive and negative).

The formula for correlation, typically denoted as the Pearson correlation coefficient (r), measures the strength and direction of a linear relationship between two variables.

The Formula is:

$$r = \frac{\sum (Xi - \bar{X})(Yi - \bar{Y})}{\sqrt{\sum (Xi - \bar{X})2 \sum (Yi - \bar{Y})2}}$$

Where:

- Xi and Yi are the individual data points of variables X and Y,
- $\bar{X}$ and $\bar{Y}$ are the means of X and Y
- r: Pearson correlation coefficient, ranging from -1 to 1
    - r = 1: Perfect positive correlation.
    - r = -1: Perfect negative correlation.
    - r = 0: No linear correlation.

The degree of correlation with the coefficient gives an idea of which correlation value refers to which level of correlation.

Table 2: Degree of correlation with coefficient

Correlation Coefficient	Degree of Correlation
>0.8	Very high
0.6-0.8	High
0.4-0.6	Medium
0.2-0.4	Low
<0.2	Very low

Source: Pearson, 1895

In this study, the correlation is done between the frequency of settlement density and the frequency of settlement type to see the strength or weakness of the relationship among the variables.

Results

Distribution of Fire Incidents in Dhaka City Corporation (2014-2023)

A map showing the spatial distribution of fire incidents in the Dhaka city corporation from 2014 to 2023. The spatial distribution map shows frequent occurrences of fire incidents in several places. The fire incidents are marked in red dots, and a total of 262 fire incidents are listed on the map.

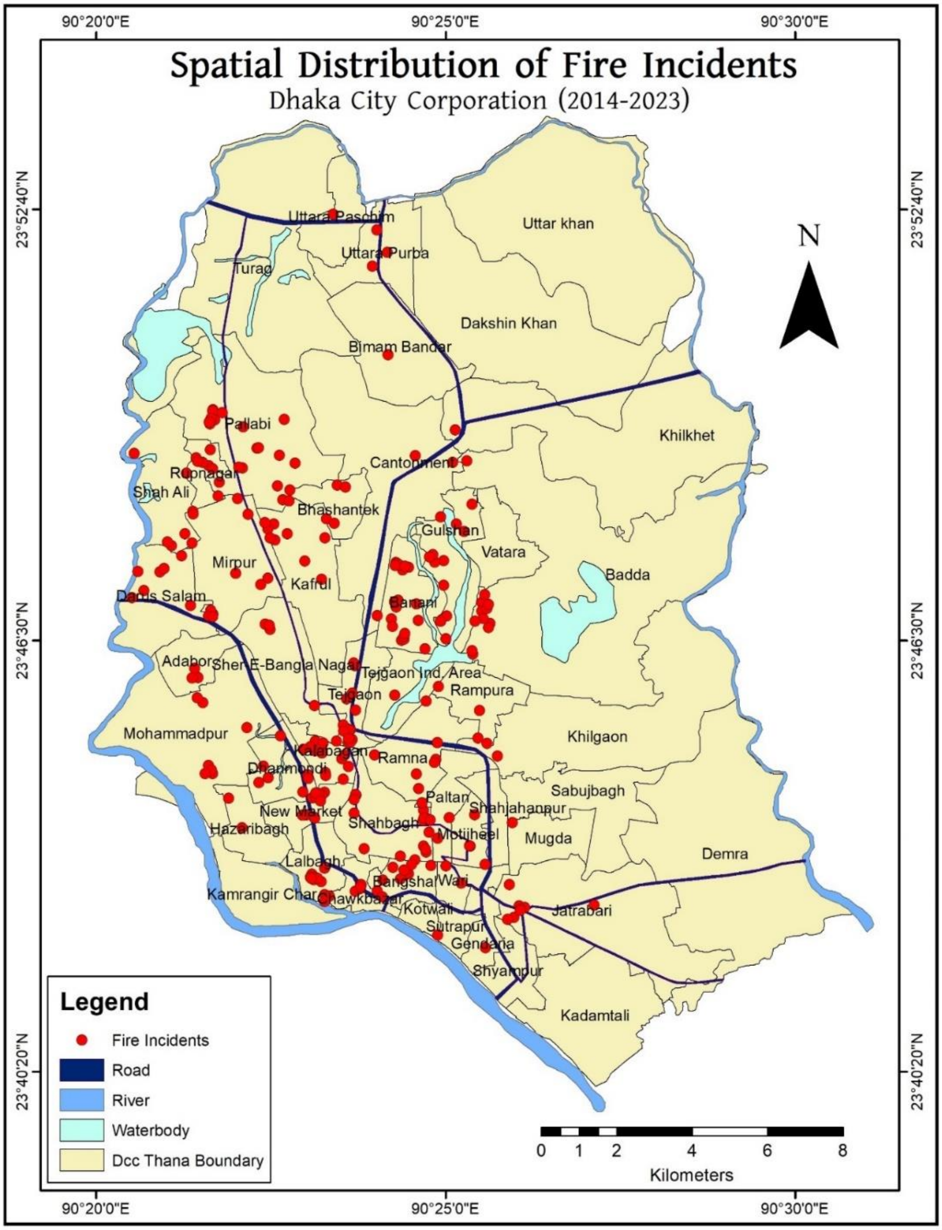

Figure 6: Spatial Distribution of Fire Incidents in Dhaka City Corporation (2014-2023)

Surrounding Landcover Conditions of Identified Fire Incidents

After listing the fire incidents and developing a dataset, the surrounding land cover of the 262 fire incidents is investigated. By investigating the surrounding land cover of a fire incident, the specific land cover that holds a certain percentage around a fire incident site is identified. The surrounding land cover is investigated in five classes, e.g., settlement, vegetation, waterbody, open field, and road, to see which land cover is most prominent around a fire incident site. This may also refer to whether increasing or decreasing specific types of land cover supports a fire incident.

Fire incident sites suggest the land cover range around fire incident sites in Dhaka City Corporation. Around fire incident sites, settlement ranges from 23% to 98%, vegetation ranges from 0-54%, waterbody ranges from 0-24%, open field ranges from 0-60%, and road ranges from 0-44%.

AHP Model

The criterion weights have been calculated for the five land covers around fire incident sites.

Table 3: Calculation of Weights for the Criterion.

Criteria	Waterbody	Vegetation	Settlement	Open Field	Road	Sum	Criteria Weights (Sum/5)
Waterbody	0.0625	0.0363	0.0712	0.0625	0.0555	0.288	0.0576
Vegetation	0.1875	0.1091	0.0915	0.1875	0.2222	0.7978	0.15956
Settlement	0.5625	0.7633	0.641	0.5625	0.5555	3.0848	0.61696
Open Field	0.0625	0.0363	0.0712	0.0625	0.0555	0.288	0.0576
Road	0.125	0.0545	0.1282	0.125	0.1111	0.5438	0.10876

In the Table, the settlement criteria have the most weightage, which is 0.61696. The other weightage for the criteria is 0.15956 for vegetation, 0.10876 for road, and 0.0576 for both waterbody and open field.

Relationship Between Fire Incidents and Land Covers

The settlement is taken for further classification, and calculation is because the settlement has the most weightage among the other land covers in the AHP model. According to a report from the World Bank, if an area has more than 75% settlement, it is an urban area (Dijkstra et al., 2020). That is why in the Table, the settlement density categorization starts at 75% of settlements with an equal interval of five classes and goes to 100%, from very high to very low. The relationship between fire incidents and land covers is been shown in the table with some other factors such as reason for the fire, casualties, and the probability of fire occurrence.

Table 4: Frequency analysis of fire incidents and land covers.

Settlement Density (%)	Incident Number (Settlement Density)	Other Land Covers (%)	Incident Number (Settlement type)	Settlement Type (%)	Reason (%)	Casualty (%)	Probability Of Fire (%)
Very High (95-100%)	23	Vegetation (0-4%)	7	Residential Building (31%)	Gas Cylinder Explosion (37%)	Death (37%)	Very Low (13%)
		Waterbody (0-3%)	6	Commercial Building (26%)	Electric Short Circuit (18%)	Injury (56.5%)	
		Open Field (0-1%)	4	Service Building (17%)	Gas Line leakage (9%)	Loss (6.5%)	
		Road (0-5%)	4	Slum (17%)	Ac Blust (18%)		
			2	Industry (9%)	Others (18%)		
High (90-94%)	35	Vegetation (0-8%)	12	Residential Building (34%)	Gas Cylinder Explosion (38%)	Death (39%)	**Medium** (20%)
		Waterbody (0-6%)	10	Commercial Building (29%)	Electric Short Circuit (23%)	Injury (56%)	
		Open Field (0-8%)	7	Service Building (20%)	Gas Line leakage (27%)	Loss (5%)	
		Road (0-10%)	4	Slum (11%)	Ac Blust (4%)		
			2	Industry (6%)	Others (8%)		
Medium (85-89%)	46	Vegetation (0-10%)	15	Residential Building (33%)	Gas Cylinder Explosion (35%)	Death (53%)	Very **High** (26%)
		Waterbody (0-12%)	13	Commercial Building (28%)	Electric Short Circuit (26%)	Injury (41%)	
		Open Field (0-12%)	5	Service Building (11%)	Gas Line leakage (10%)	Loss (6%)	

		Road (0-12%)	11	Slum (24%)	Ac Blust (7%)		
			2	Industry (4%)	Others (22%)		
Low (80-84%)	44	Vegetation (0-14%)	15	Residential Building (34%)	Gas Cylinder Explosion (50%)	Death (34.5%)	**High** (25%)
		Waterbody (0-15%)	18	Commercial Building (40%)	Electric Short Circuit (38%)	Injury (52%)	
		Open Field (0-16%)	2	Service Building (5%)	Gas Line leakage (6%)	Loss (13.5%)	
		Road (0-14%)	6	Slum (14%)	Others (6%)		
			3	Industry (7%)	Ac Blast (0%)		
Very **Low** (75-79%)	30	Vegetation (0-19%)	5	Residential Building (17%)	Gas Cylinder Explosion (26%)	Death (36%)	Low (16%)
		Waterbody (0-15%)	17	Commercial Building (56%)	Electric Short Circuit (39%)	Injury (45.4%)	
		Open Field (0-12%)	2	Service Building (7%)	Gas Line leakage (9%)	Loss (18.6%)	
		Road (0-18%)	2	Slum (7%)	Ac Blust (9%)		
			4	Industry (13%)	Others (17%)		

In the other land cover column, there are four types of land cover: vegetation, water bodies, open fields, and roads. The percentages of these four land cover types increase with the decrease in settlement density.

The settlement type column is categorized into five types: residential buildings, commercial buildings, service buildings, slums, and industrial buildings. The incident number column shows the incidents of fire in a specific settlement type. The reason column is categorized by gas cylinder explosion, electric short circuit, gas line leakage, AC blast, and others. Other reasons for fire include firecracker explosions, cigarettes, miscreants, chemical reactions, refrigerator blasts, and lift breakage. The casualty column shows the specific settlement density's death, injury, and loss percentage. Lastly, the probability of a fire column is categorized into five types, from very low to very high, which is calculated by dividing the settlement type incident number by and settlement density incident number and making the value in percentage. In the table, all the column is generated according to settlement density classification.

The relation of a specific land use to a fire incident in Dhaka City Corporation is assessed through the statistical correlation test. The correlation is done between the settlement density incident number and the settlement type incident number (residential building, slum, commercial building, service building, and industrial building).

Table 5: Correlation between settlement density incident number and Settlement type incident number

.Correlation					
	Residential Building	Slum	Commercial Building	Service Building	Industry
Total incident according to settlement density	0.896	0.764	0.574	0.037	-0.081
Significance (2-tailed)	0.039	0.133	0.312	0.953	0.896

Discussion

Distribution of Fire Incidents in Dhaka City Corporation (2014-2023)

The map is divided into Thana boundaries in Dhaka City Corporation, where red dots will give a clear idea of the more frequently affected Thanas by fire incidents. In the map, it is evident that the fire incidents are scattered across the space, and certain Thanas have a higher concentration. Among higher concentration Thanas Dhanmondi, Kalabagan, Banani, Gulshan, Banani, Tejgaon, Shahbagh, and Bangshal seem to be prominent.

Additionally, the central and southern parts of Dhaka City Corporation seem to experience a higher frequency of fire incidents compared to the northern and eastern parts.

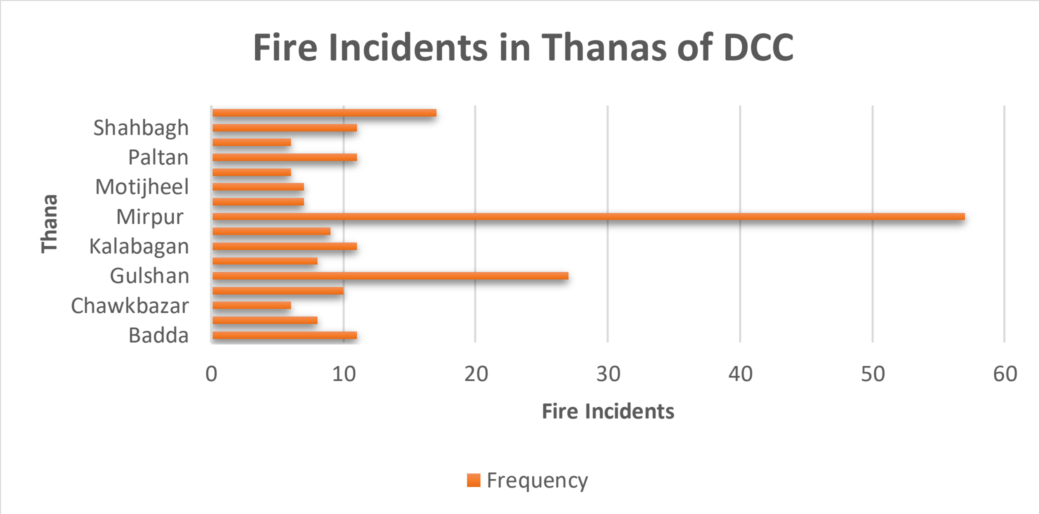

Figure 7: Frequency Distribution of Fire Incidents (2014-2023) in the Thanas of Dhaka City Corporation.

From the figure, it can be seen that Mirpur and Gulshan Thana were the most affected by fire incidents. In Mirpur Thana, 22% of fire incidents occurred among all the Thanas. Moreover, 10% of fire incidents occurred in Gulshan Thana, 6% in Shahbagh Thana, and 4% in Paltan, Badda, Chawkbazar, and Kalabagan Thana.

Surrounding Landcover Conditions of Identified Fire Incidents

From the result, it can be seen that some fire incident sites have high settlement density with minimum vegetation and waterbodies. Around the fire incidents, where the settlement density is lower, the presence of vegetation, water bodies, and roads is higher. So, an inverse proportional relation can be observed between settlement and other land covers.

AHP Model

The output of the Analytical Hierarchy Process (AHP) model presented in Table 3 offers a systematic method to evaluate and rank different land cover weights near fire incident points according to their significance. It is clear from the findings that settlement areas hold the maximum weighting (0.61696) among all other provided criteria. It reflects a high spatial association between human settlements and the incidence or likelihood of fire incidents. This concurs with the long-established knowledge that high-density or urban environments are likely to suffer more fire hazard as a result of human activity, infrastructure density, and fuel accumulation. Also, vegetation is the second with a weight of 0.15956. Vegetation within residential areas can also contribute to danger, as fire can easily spread between natural and built environments. Roads, of medium weight 0.10876, are typically viewed as obstacles to the transmission of fire, but also as avenues for human travel to provide both accidental ignition and improved emergency access. Their intermediate location in this analysis accommodates both these double functions, risk factor and part of the mitigation infrastructure. On the contrary, waterbodies and open fields both registered a low weight of 0.0576, which shows that they made a small contribution to fire occurrence around the study sites. Waterbodies are naturally fireproof zones, which are often in the form of buffers that slow or even stop fire spread. Open fields may possess no fuel continuity or buildings that facilitate large fires and thus will be of little contribution to fire incidents.

Relationship Between Fire Incidents and Land Covers

In areas of very high settlement density, 23 incidents of fire were recorded. Here, the present settlements are residential buildings (31%), commercial buildings (26%), service buildings (17%), slums (17%), and Industry (9%) (Figure 8). The natural vegetation cover is negligible, with only 0–4%, and water bodies are (0-3%). The major initiators of fires in these zones are gas cylinder explosions (37%), followed by air conditioner (AC) blasts and electrical short circuits, and others. The aftermath of such incidents is extensive; in 37% of cases caused death and other impacts include injuries and property damage (Table 4). The result shows how unplanned urbanization, unsafe kitchen appliances, and low-quality building materials increase the incidence of fires and fatalities in densely populated urban areas.

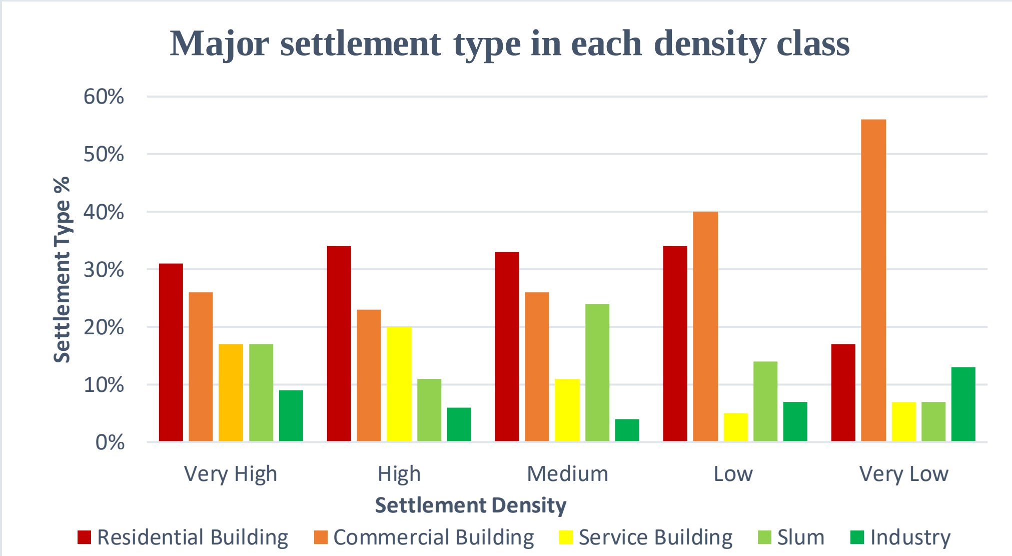

Figure 8: Settlement Density vs Dettlement Type (%)

In areas of high settlement density, where 35 incidents of fire were recorded, the present settlements are residential buildings (34%), commercial buildings (29%), service buildings (20%), slums (11%), and Industry (6%). Fire outbreaks within these areas continue to be led by gas cylinder explosions, with a marginally higher death rate compared to the very high-density areas, reflecting ongoing safety shortcomings. Injuries account for 52%, whereas losses decrease to 9%, which implies that although these departments have the same vulnerability, the structural arrangement can ensure a marginally better fire control ability.

In areas of medium settlement density, where 46 incidents of fire were recorded, the present settlements are residential buildings (33%), commercial buildings (28%), service buildings (11%), slums (24%), and Industry (4%). Land cover is more diverse in these zones, with vegetation cover up to 10%, waterbodies up to 12%, and road cover up to 12%. Causation of fire is identical, with gas cylinder explosions (35%) and electrical short circuits (26%), but the highest death toll of 53% is recorded under this category, indicating that even medium-density areas, which are generally believed to be safer due to being less congested, can suffer high casualties from fires due to their mixed land use and infrastructure.

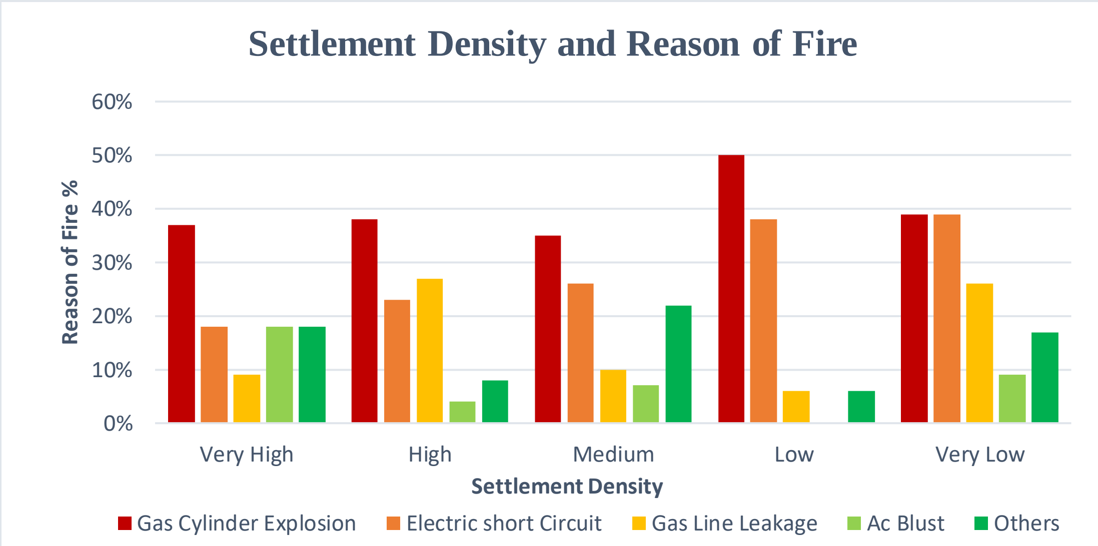

Figure 9: Settlement Density vs Reason of Fire (%)

In areas of low settlement density, where 44 incidents of fire were recorded, the present settlements are residential buildings (34%), commercial buildings (40%), service buildings (5%), slums (14%), and Industry (7%). This shift is reflected in the causes of fire, with 50% of cases falling under gas cylinder explosions above any other category, pointing to unsafe practices in both residential and commercial buildings. However, the death rate is lower, and injuries total 52%, with 13.5% resulting in loss of property, indicating that though fires remain dangerous, the impact may be somewhat mitigated by less dense settlement density.

Lastly, in areas of very low settlement density, where 30 incidents of fire were recorded, the present settlements are residential buildings (17%), commercial buildings (56%), service buildings (7%), slums (7%), and Industry (13%). The setting is marked by the highest variability in land cover vegetation, ranging from 0–19%, waterbodies from 0–15%, and roads up to 18%. The major causes of fire are electric short circuits (39%) and gas cylinder explosions (26%), with fatalities occurring in 36% of deaths and injuries in 45.4%. The region suffers the highest percentage of property loss in all categories at 18.6%.

A correlation between each settlement type and settlement density (incident number) is conducted to identify which settlement type is more prone to fire hazards. In Table 5, the Pearson correlation between the total number of incidents and settlement density with incidents in residential buildings is 0.896, with a significance (2-tailed) value of 0.039. This indicates a strong positive relationship between the two variables. The correlation between total incidents and incidents in slum areas is 0.764, with a significance value of 0.133. This suggests a good relationship between the variables. For commercial buildings, the correlation is 0.574, indicating a moderate relationship. In the case of service buildings, the correlation value is 0.037, reflecting a very weak relationship. Lastly, the correlation between total incidents and incidents in industrial buildings is -0.081, indicating a weak negative relationship. So, it can be said that residential buildings are the most affected by fire hazards, slums are the second most affected, Commercial buildings are third, service buildings are fourth, and Industry is the fifth most affected by fire incidents in Dhaka City Corporation.

Conclusion

Fire incidents have been growing daily, along with their devastating impacts in Dhaka City (Sahebi et al., 2021). This research attempted to identify the ever-growing risk of fire hazards in Dhaka City Corporation by analyzing fire incidents, land use patterns, and surrounding land cover, and developing a model to understand the nature of fire incidents. This study applied a comprehensive geospatial approach, integrating satellite imagery, GIS, and the Analytical Hierarchy Process (AHP), to assess the spatial heterogeneity of fire hazards from 2014 to 2023. The AHP model highlighted settlement areas as the most influential land cover associated with fire occurrences. The findings revealed that residential buildings and slum areas are most vulnerable to fire incidents, with gas cylinder explosions being the predominant cause. Given these findings, several strategic interventions are recommended. First, enhancing fire safety in residential and slum communities through safer gas line installations and strict regulation of gas cylinder usage is crucial. Enforcement of the Bangladesh National Building Code must be prioritized to ensure safer structural development in high-risk zones. Moreover, improving firefighting infrastructure, including accessible road networks, water supply systems, and increasing the number of trained firefighters, can significantly boost emergency response capacity. Community-level awareness programs focused on fire prevention, emergency preparedness, and first-response actions should be expanded, especially in vulnerable settlements. Addressing these areas will be essential to reducing the frequency and impact of fire hazards in Dhaka City Corporation and creating a safer, more sustainable urban future.

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