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Fire Hazards in Kabul City: Causes, Casualty, Capital Losses, and Recommendations for Mitigation- A Review

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Abstract

Fire incidents and associated casualties and financial losses in Kabul city frequently make headlines in national and international media. Usable statistics on fire incidents in the city are unavailable. In this study, data from Kabul's Firefighting Department and scattered pieces of information on fire incidents retrieved from online sources and media outlets were thoroughly reviewed and analyzed for the sources, causes, casualty, and capital losses of fire incidents in Kabul city. The study showed that 55% to 65% of total annual fire incidents in the city occur in residential buildings, followed by 15% to 20% in business markets/stores. 40% to 50% of fire incidents are caused by electricity and 20% to 25% by liquid petroleum gas. From 2010 to 2023, fire incidents caused 62 deaths and 289 injuries, 90% of which are caused by fuel or LPG fires. 52% of fire deaths and 75% of fire injuries were caused by fires that started in fuel/gas stations. Only 16% of fire deaths and 3% of fire injuries happened in residential buildings. During this period, fires caused about 11 million US dollars annual direct monetary losses, 64% of which are due to fires initiated by electricity and 23% by fuel/gas. 79% and 20% of these losses come from fires in commercial markets and fuel stations/tankers, respectively. Poor fire safety provisions, substandard construction, deficient power distribution networks, lack of public awareness, and limited firefighting resources were found to be key elements of the city's fire hazard. To enhance fire safety in Kabul city, this study recommends increasing firefighting resources, improving coordination and response time, enforcing and improving fire safety regulations, and conducting structural safety evaluations of fire affected buildings.

Keywords: Kabul, Fire Hazard, Fire Causes, Fire D`eath, Fire Injury

1. Introduction

As a major part of the civil engineering built infrastructure, buildings are vital in urbanization and indicate the socio-economic standing of a country. They are built to serve their intended purpose for several decades and during their service life, are exposed to numerous hazards. These hazards, that can be natural such as landslides, earthquakes, winds, floods, climatic degradation, etc., or manmade such as fires, explosions, overloading, etc., can impair functionality of buildings and even cause their partial or total collapse. In the event of failure, these buildings can put lives at risk and inflict direct and indirect financial losses. Among others, fire is also a potential hazard that threatens buildings and their inhabitants, especially in developing cities where fire safety is not adequately addressed.

Fire hazard is the potential for accidental or intentional fires that threaten lives and the safety of structures and property in a building. In recent years, fire hazards in buildings have become a source of major concern as they have intensified in severity and diversity of sources of initiation [1]. From 1993 to 2021, over 1.14 million fire deaths have been caused by a total of more than 107 million fire incidents. Over this period, an average of 39,300 fire deaths occurred every year, resulting from approximately 3.8 million fires across the globe [2]. Global fire hazards account for a total annual loss of about 1 percent of the world GDP, approximately US$857.9 billion [3, 4].

The data from World Fire Statistics [2, 5, 6] shows that the majority of fire casualties are caused by a minor portion of the total fires occurring in residential structures. For instance, in 2020, on average, 82.7% of fire deaths and 60.6% of fire injuries were attributed to the 24.2% of fires that occurred in residential structures [5]. In 2021, 23.2% of all fires that happened in residential structures were responsible for 84.6% of all fire deaths and 73.7% of all fire injuries [2]. This means that residential structures are mainly responsible for the majority of the casualties inflicted by fire incidents.

Apart from that, developing countries have higher fire casualties per 100 fires compared to developed countries. For instance, as shown in Table 1, the average number of fire deaths for the USA is 0.27 deaths per 100 fires, while this value is about 0.8 deaths per 100 fires for India, which is about three times larger than the value for the USA [2]. This trend is also shown by [7], where from 2010 to 2014, the highest number of annual fires (600,000 to 1,500,000) and the second-highest number of annual fire deaths (1,000-10,000) occurred in developed countries such as the USA. On the other hand, the highest number of annual fire casualties (10,000-25,000) and the second-highest number of annual fires (100,000-600,000) occurred in developing countries such as India and Pakistan [7].

Table 1 Number of fires, fire deaths and fire injuries in the US from 2011 to 2021 [2,5,6]

Year	Number of fires	Number of fire deaths	Number of fire Injuries	Number of fires deaths per 100 fires	Number of fires injuries per 100 fires
2011	1,389,500	3,005	17,500	0.22	1.26
2012	1,375,000	2,855	16,500	0.21	1.20
2013	1,240,000	3,420	15,925	0.28	1.28
2014	1,298,000	3,275	15,775	0.25	1.22
2015	1,345,500	3,280	15,700	0.24	1.17
2016	1,342,000	3,390	14,560	0.25	1.08
2017	1,319,500	3,400	14,670	0.26	1.11
2018	1,318,500	3,655	15,200	0.28	1.15
2019	1,291,500	3,704	16,600	0.29	1.29
2020	1,388,500	3,500	15,200	0.25	1.09
2021	1,353,500	3,800	14,700	0.28	1.09
Average	1,332,864	3,390	15,666	0.25	1.18

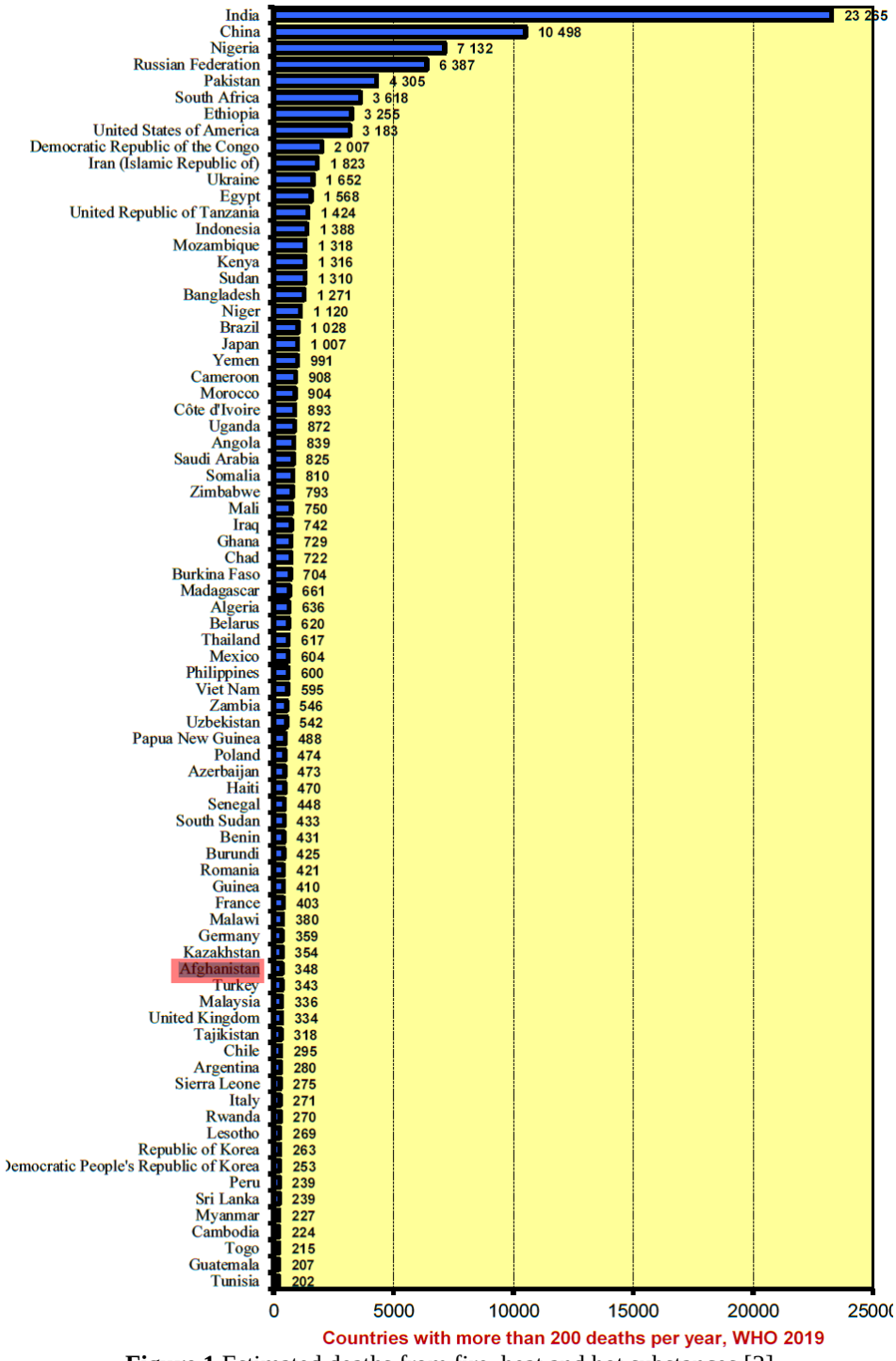


Figure 1 Estimated deaths from fire, heat and hot substances [2]

Although fire outbreaks frequently make headlines in mainstream media, there is very little information available in published literature regarding fire statistics in Afghanistan. Global Forest Watch [8] generally provides fire statistics on fires that

cause deforestation and tree cover losses. According to this source, between January 2012 and December 2023, Afghanistan experienced a total of 6,442 VIIRS Alerts fire alerts, which is equal to an average of 537 annual VIIRS fire alerts. The same source reported that the highest number of fires recorded in a year was 162 in 2020. However, in this article, we are specifically concerned about fire outbreaks other than in forests that result in casualties and financial losses in structures and buildings in major cities like Kabul. According to [2], 348 people died due to fire, heat, and hot substances in the year 2019. If we assume that these deaths are primarily from fire, it would place the country at 59th place among countries with more than 200 fire deaths on average that year, as shown in Figure 1. According to NSIA [9], the country's population was estimated to be 32.2 million in 2019, which means there would be approximately 1.081 fire deaths per 100,000 inhabitants. This puts the country in 20th place, after the USA, among world countries based on the average number of fire deaths per 100,000 inhabitants, as shown in Figure 2.

It should be noted that the reported figure of 348 fire deaths is less likely to reflect the actual average annual fire deaths. Fire cases from provinces may not be reported or accounted for in the data. In some cases, fire outbreaks that result in loss of lives may go unreported or unnoticed. Therefore, the average annual fire deaths are expected to be higher than the figures provided by [2].
As shown in Figure 1, Pakistan, with a population of about 223 million in 2019 [10], had 4,305 fire deaths in the same year. This number is more than 12 times greater than the fire deaths in Afghanistan during the same year, even though Pakistan's population is only about 6 times that of Afghanistan. In other words, the rate of fire deaths for Afghanistan per 100,000 inhabitants is 0.92, while this value for Pakistan is 1.92, more than twice the value for Afghanistan. For India, the average rate of fire deaths per 100,000 inhabitants is 0.90 for the years 2017 to 2019 [2] and 1.56 for the years 2013 to 2015 [11].

The set of practices aimed at preventing the occurrence of fire, managing its growth and effects, and limiting its losses to an acceptable level is defined as fire safety. This is ensured by following applicable building code provisions, which are mostly based on prescriptive methodologies [1]. Fire protection systems can be broadly divided into two categories: active and passive systems. Active systems, such as sprinklers and fire and smoke detectors, detect and control fires at the early stages of an outbreak. Passive protection systems involve designing building components to ensure structural safety, limit the spread of fire during exposures, and provide increased time for fire-fighting and rescue operations.
Considerable mitigation of fire hazards can be achieved by following code of practice guidelines in the design and construction of buildings. However, in developing countries, there may be inadequate attention given to code provisions and construction standards, particularly those related to fire hazard mitigation, due to budget constraints or poor regulations and code enforcement. Additionally, active fire protection systems have inherent limitations, such as high installation and maintenance costs, and concerns

about the reliability of their performance in terms of fire detection and control. Passive fire protection measures focus on protecting individual members and building components, but they are not explicitly integrated into the construction of buildings. In other words, there is a lack of incorporation of passive fire protection provisions into the design and construction of buildings, and fire design is often performed solely to obtain approval from fire safety regulatory bodies [12]. As a result, buildings in developing countries often lack or have inadequate fire safety provisions.

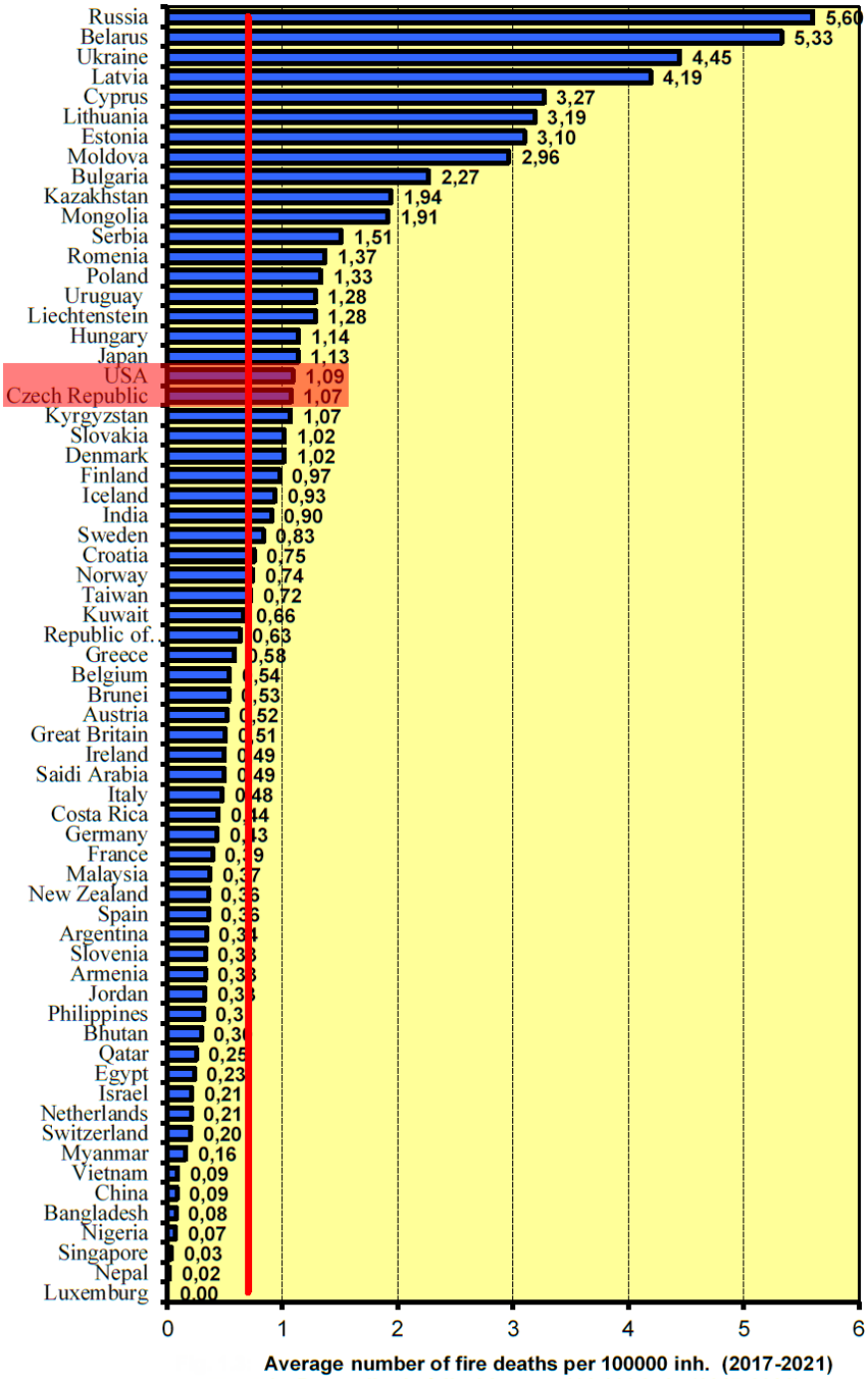


Figure 2 Average number of fire deaths 2017-2021 [2]

2. Methodology

This paper, in the subsequent sections, provides information on fire statistics, causes and sources of fire, fire deaths and injuries, and structural vulnerabilities of buildings in

Kabul city. This study utilizes a mixed-methods approach to gather comprehensive data on fire incidents in Kabul city. The key sources of information include raw data from the Firefighting and Rescue Department of Kabul city, a comprehensive review of online sources and media reports covering fire incidents (Appendix A), questionnaires, and information retrieved from media interviews with authorities and individuals with relevant knowledge or work experience, and field visits. Since the data was not very large in nature or volume, therefore, all of the information/data was analyzed using excel spreadsheets.

The information provided in this study primarily comes from two sources. The first category of information includes fire statistics in Kabul city, which provides details on the causes of fire incidents and the occupancy type of the structure where the fire originated. The details presented in this category are based on the information provided by the Firefighting and Rescue Department of Kabul city for the years 2021, 2022, and 2023. Due to the unavailability of an online database for fire cases, the fire statistics were extracted from the written records of that administration. This information, which shows the number of fires and their causes for the three years (2021-2023), is presented in Table 2 and analyzed in section "3.Sources of Fires in Buildings in Kabul City."

The second category of information presented includes fire deaths, injuries, and a quantitative description of the financial losses caused by each major fire. Additionally, information on the source or cause of the fire and the type of structure where the fire originated is provided. Due to the lack of online or computerized records, this information is obtained through comprehensive reviews of online sources, reports published by international and local media sources, broadcasted media, reliable social media posts, and the websites of relevant governmental offices, such as Kabul Municipality, Afghanistan National Disaster Management Authority (Office of the State Minister for Disaster Management), Ministry of Interior (General Directorate of Disaster Response and Firefighting), Afghanistan Oil and Gas Regulatory Authority, and others. This second category of information on fire deaths and financial losses is provided for the years 2010 to 2023 for Kabul city in the subsequent sections. Additionally, some information and details are obtained through questionnaires, interviews, and physical visits to the affected buildings.

3. Firefighting Resources Kabul

The administration responsible for responding to fire cases in Kabul and throughout Afghanistan is the General Directorate of Disaster Response and Firefighting within the Ministry of Interior (MoI). The key roles of this administration are preventing and controlling fire cases across the country, responding to fire emergencies, planning for and developing strategies to mitigate fire hazards, and ensuring firefighting tools are available in government and non-government buildings [13]. This directorate of the MoI has a firefighting department in each province of the country. There are forty-six firefighting brigades within this directorate, which are active in 34 provinces and 11 ports of the country. As of October 2022, there are a total of 1,730 active employees and 240 firefighting vehicles. According to the information, each team has at least two modern firefighting vehicles and trained operators [13].

The firefighting brigades operate in two distinct aspects: (i) preventing fire outbreaks and (ii) controlling fire intensity and expansion after fire outbreaks. In the case of preventing fire outbreaks, fire brigades conduct operational surveys in different institutions such as offices, shopping malls, business centers, governmental offices, schools, universities, production factories, and residential colonies. They advise and consult respective owners and authorities on fire hazard mitigation and prevention. In the case of controlling the spread of fire, fire brigades are responsible for acting swiftly and controlling the live flames.

The firefighting department responsible for addressing fire hazards in Kabul city has seven local or stationary firefighting stations and eleven mobile firefighting stations allocated specifically to the districts of Kabul province. Kabul's firefighting department has approximately 240 personnel in various roles and a total of 100 firefighting vehicles and trucks. The six firefighting stations are located in the 3rd, 5th, 9th, 10th, 11th and 12th police districts of Kabul city. The central station of Kabul city is located in the 2nd police district. According to the source, these stations have 42 firefighting vehicles [14].

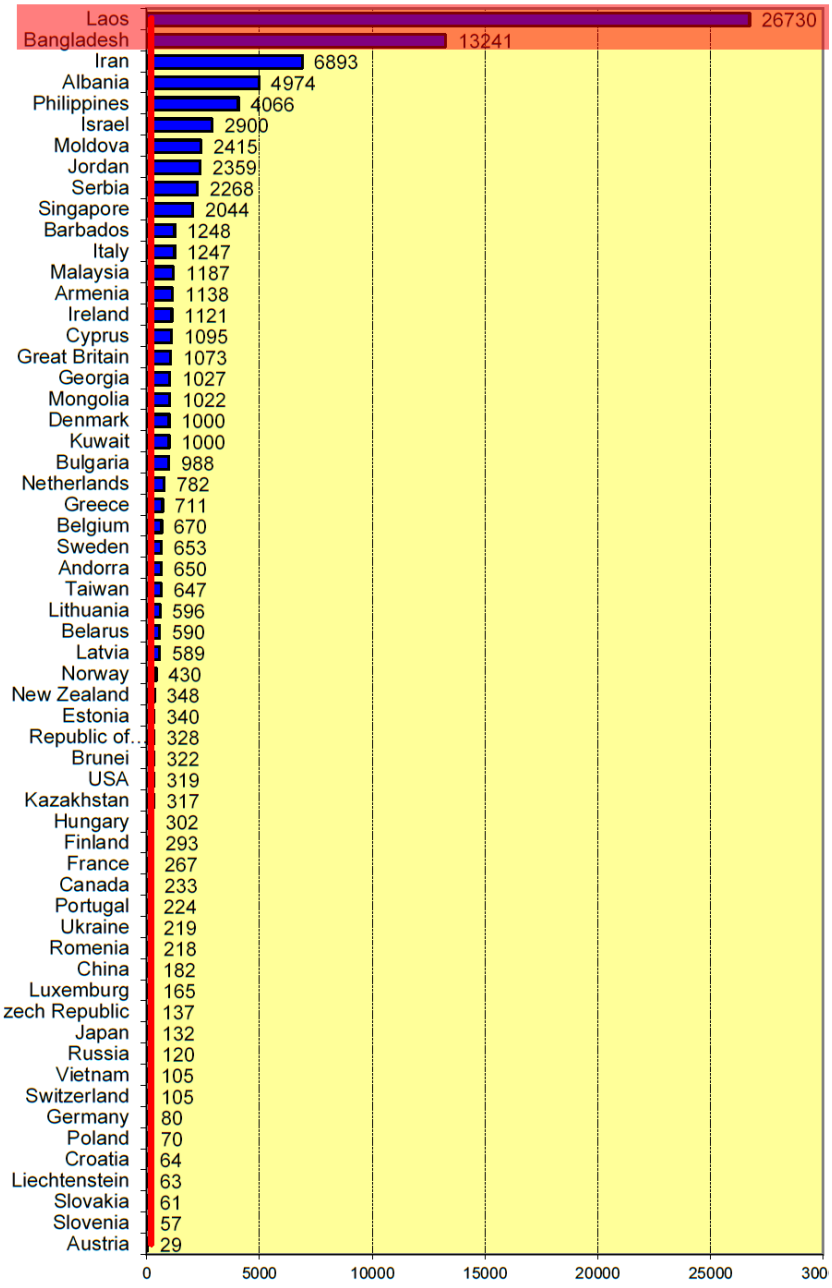


Fig. 1.10: Average number of inhabitants per 1 firefighter (2010-2021)

Figure 3 Afghanistan with 19,829 (inh./ firefighter) have the second highest number of inhabitants per firefighter among listed country of the world [2]

The estimated population for Afghanistan in 2022-2023, according to NSIA [15], is 34.3 million, and for its capital Kabul, it is 5.57 million. In other words, there are 45 fire stations with approximately 240 firefighting vehicles and 1,730 personnel [14,16] addressing fire hazards in Afghanistan, which has a population of 34.3 million. This corresponds to about 5.0 firefighting personnel and 0.70 firefighting vehicles per

100,000 inhabitants of the country. For Kabul, there are 7 fire stations with a total of about 42 firefighting vehicles and 240 personnel [14], addressing fire cases in the capital city with a population of 5.57 million [15]. This corresponds to 4.31 firefighting personnel and 0.75 firefighting vehicles per 100,000 inhabitants of the city.

Additionally, with a population of 34.3 million and 1,730 firefighters, the average number of inhabitants per firefighter is 19,829 inhabitants per firefighter for the country. In the case of Kabul city, with 5.57 million inhabitants and 240 firefighting personnel, the average number of inhabitants per firefighter is 23,208 inhabitants per firefighter. As shown in Figure 3, these values place the country in second place, after Laos, for having the highest number of inhabitants per firefighter among the listed countries in the world.

4. Fire Hazard in Kabul City

All factors present in a building that can cause ignition, aggravate fire severity, reduce the capacity of the building's fire safety provisions, and hinder escape or firefighting and rescue operations constitute fire hazards in a building [1]. Kabul city is full of different types of buildings in terms of their occupancy, including residential buildings, mixed-use buildings (residential and commercial use), and commercial buildings that house shops, markets, stores, banks, educational centers, hotels, restaurants, and offices. Additionally, production facilities, factories, fuel and gas stations, and storages are often located close to population centers within the city, posing serious threats to lives and assets in the case of fire outbreaks. This means that most of the buildings within the city contain various sources of fire hazards, such as electricity malfunctioning, LPG cylinder leakage, burning charcoal, carelessness with matches, stoves, cooking, welding, smoking residue, passerby negligence, arson, blasts, and other direct sources of fire. Furthermore, poor master planning and rapid urbanization of Kabul city have increased the vulnerability of the city to fire hazards [17].

Fuel/gas stations and fuel tanker parking spots are located near residential areas with very limited or no fire safety measures. Storages and warehouses filled with combustible materials such as clothes, fabrics, plastics, and others lack fire safety provisions. These facilities are often situated in congested areas with poor and congested access routes for firefighting and rescue operations [18-21]. Factors such as traffic congestion, lack of parking in the city, a high level of roadside selling and mobile vendors, and a lack of traffic regulatory measures such as traffic signs and pavement markings, as well as old and faulty power lines and electrical equipment, contribute to the intensified fire hazard in Kabul city. The widespread use of LPG cylinders for cooking and heating also increases the potential for fire incidents during handling, filling, and use.

Poor enforcement of construction standards and fire safety code provisions, ignorance regarding maintenance and activation of fire safety measures such as fire extinguishers, fire hydrants, fire alarms, and smoke detectors, inattentiveness and superficial treatment of fire hazards, and a lack of firefighting resources and stations have also significantly contributed to the fire hazard in Kabul city. Therefore, the increased fire hazard

indicates an increased potential and possibility of frequent fires in the city, posing threats to lives, properties, and the environment within the city.

5. Sources of Fires in Buildings in Kabul City

All factors that ignite fires, intensify fire severity, debilitate the performance of fire safety features, and hinder safe evacuation, firefighting, and rescue operations constitute fire hazards. According to the available information in the literature, the leading causes of fires in buildings (residential and non-residential) vary across different countries. For instance, cooking is a leading cause in the USA, short circuits in Kuwait and Pakistan, deliberately lit fires in New Zealand, electrical technical faults in Nigeria and Germany, electricity-related causes in Indonesia and Taiwan, electrical short circuits in India, negligence in Russia, lightning in Sweden, and smoking-related causes in England [2,5,6,22]. Other sources of ignition in buildings include live flames, heaters and hot surfaces, matches, lighters, candles, faulty gas lines, stoves, fireworks, self-ignition, arson, and vandalism. Fire severity is intensified by several factors, including the availability of combustible and volatile flammable chemicals such as LPG, petrol, paints, ammunitions, and combustible building materials and components like timber members and furniture. Additionally, the presence of large openings and windows that provide an adequate supply of oxygen can also contribute to increased fire severity [23,24].

Table 2 presents the causes of fires and the building/facility where the fires started in Kabul city from 2021 to 2023. The table demonstrates that fires have started in various types of buildings, including residential buildings, fuel stations, business markets, shops, storages and warehouses, factories, governmental offices, restaurants, hotels, wedding halls, educational centers, trash bins, hospitals, and others. The information was obtained in November 2023, and the number of fires may have increased beyond the values shown in the table by the end of December.

Table 2 Fire causes and number in Kabul from 2021 to 2023 from Kabul firefighting department.

No.	Facility/ Building	Cause of fire	Number of fires in 2021	Number of fires in 2022	Number of fires in 2023
1	Residential	LPG cylinder	63	47	50
2	Residential	Electrical Short Circuit	50	52	74
3	Residential	Carelessness with matches	30	16	11
4	Residential	Unknown	5	3	6
5	Residential	Cooking	5	0	3
6	Residential	LPG Stove	4	9	0
7	Residential	Wood Stove	3	1	2
8	Residential	Arson	0	1	3
9	Residential	Refueling	0	1	0
10	Residential	Negligence	0	2	0
11	Residential	Burning Charcoal	0	1	0
12	Bakery	Negligence	1	0	0
13	Bakery	Unknown	1	0	0

No.	Facility/ Building	Cause of fire	Number of fires in 2021	Number of fires in 2022	Number of fires in 2023
14	Bakery	Electrical Short Circuit	3	0	0
15	Fuel Station	Negligence	2	1	0
16	Fuel Station	Blast	1	1	0
17	Fuel Station	Unknown	1	2	0
18	Educational Centers	LPG cylinder	1	0	0
19	Electrical Substation	Electrical Short Circuit	17	0	0
20	Storage	Unknown	6	1	0
21	Storage	Cigarette Butt	3	0	0
22	Storage	Electrical Short Circuit	9	4	6
23	Storage	Carelessness with matches	2	0	0
24	Storage	Passerby	2	0	0
25	Storage	LPG cylinder	0	1	2
26	Storage	Negligence	0	1	3
27	Shop	Electrical Short Circuit	14	14	20
28	Shop	Unknown	11	7	3
29	Shop	LPG cylinder Leakage	14	18	6
30	Shop	Negligence	3	1	0
31	Shop	Cigarette Butt	1	1	3
32	Shop	Faulty Electrical Equipment	1	1	0
33	Shop	LPG Stove	1	0	0
34	Shop	Refueling	0	1	0
35	Shop	Arson	0	0	2
36	Shop	Passerby	0	0	1
37	Shopping Mall	Electrical Short Circuit	2	1	1
38	Shopping Mall	LPG	0	1	0
39	Factory	Electrical Short Circuit	3	3	5
40	Factory	Cigarette Butt	1	0	1
41	Factory	Unknown	0	2	1
42	Factory	LPG cylinder Explosion	0	1	0
43	Factory	LPG cylinder Leakage	0	2	0
44	Factory	Burning Charcoal	0	2	0
45	Factory	Negligence	0	0	1
46	Factory	Faulty Equipment	0	0	2
47	Restaurants	LPG cylinder Leakage	2	3	0

No.	Facility/ Building	Cause of fire	Number of fires in 2021	Number of fires in 2022	Number of fires in 2023
48	Restaurants	Electrical Short Circuit	3	2	2
49	Restaurants	Negligence	3	0	0
50	Restaurants	Cooking	0	1	2
51	Hotel	Electrical Short Circuit	0	1	1
52	Hotel	LPG cylinder Leakage	0	0	1
53	Governmental office	Electrical Short Circuit	4	7	8
54	Government office	LPG cylinder Leakage	0	2	2
55	Government office	Cigarette Butt	0	0	2
56	School	Electrical Short Circuit	1	0	1
57	School	Unknown	0	1	0
58	University	Electrical Short Circuit	1	0	0
59	Hostel	Electrical Short Circuit	1	0	0
60	Hospitals	Electrical Short Circuit	3	0	2
61	Kindergarten	Electrical Short Circuit	1	0	0
62	Foreigners office	Electrical Short Circuit	1	0	1
63	Trash Points/ Bins	Passerby	4	0	0
64	Wedding Hall	Unknown	1	0	0
65	Wood Sale Yard	Unknown	1	0	0
Total fire cases			286	216	228

Figure 4 depicts the number of fires that occurred in 2021 in different types of structures where the fires originated. Out of a total of 286 fires (as shown in Table 2), approximately 160 fires, accounting for about 56% (as shown in Figure 5), has taken place in residential buildings. Shopping centers and business markets experienced 47 fires, which represents approximately 16% of the total. In 2021, there were 22 fires (roughly 8%) in storages/warehouses and 17 fires (approximately 6%) in electrical substations.

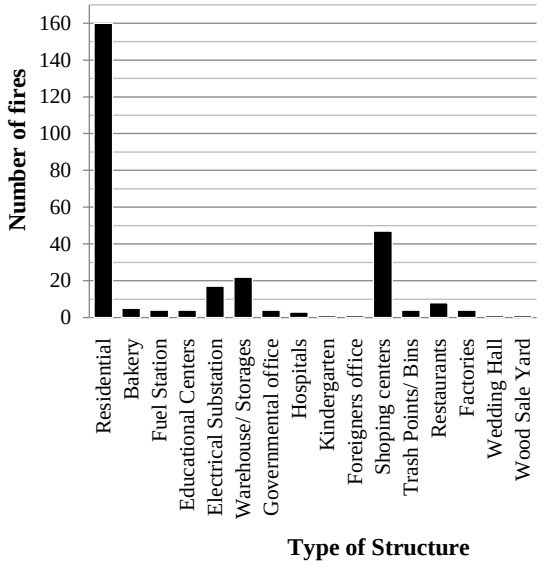


Figure 4 Number of fires in 2021 in different types of structures

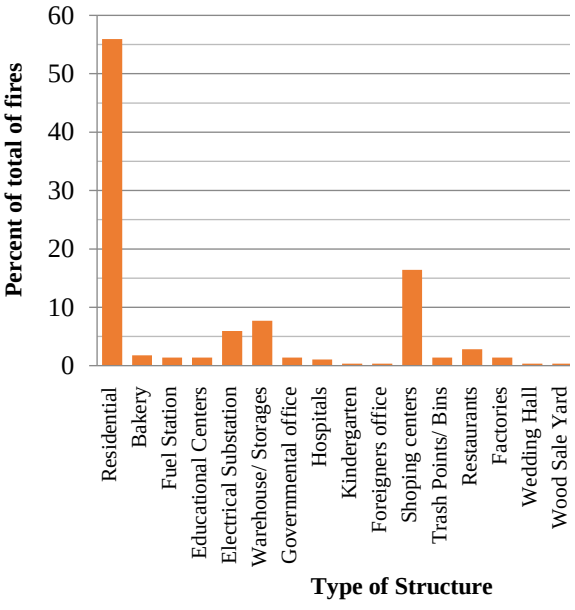


Figure 5 Percentage of fires in 2021 in different types of structures

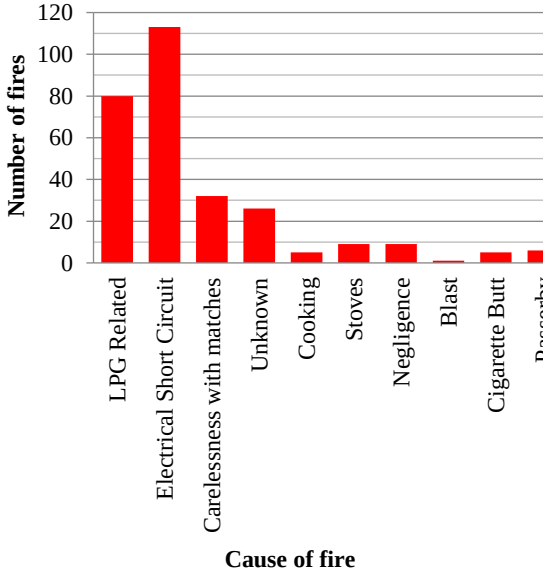


Figure 6 Number of fires by different causes in 2021

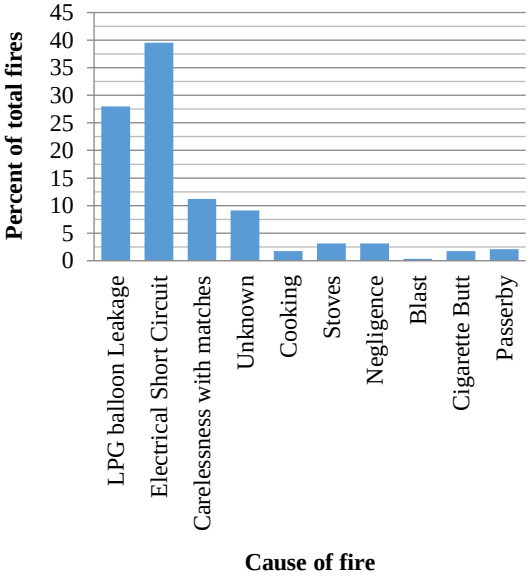


Figure 7 Percentage of fires by different causes in 2021

Figure 6 illustrates the number of fires that occurred in 2021 based on different causes. Out of a total of 286 fires, approximately 113 fires, accounting for about 40% (as depicted in Figure 7), were caused by electrical short circuits or malfunctions. About 80 fires (roughly 28%) were attributed to LPG-related incidents, including LPG cylinder leakage, cylinder refilling or emptying, malfunctioning LPG equipment, LPG tankers, or other relevant interactions. In 2021, 32 fires (approximately 11%) were caused by matches or lighters, and the cause of 26 fires (about 9%) remains unknown or has not been publicized.

The structures in which the fires occurred are categorized as follows: public facilities (including substations, government offices, kindergartens, educational centers, universities, hostels, and hospitals), commercial facilities (such as bakeries, shopping centers and malls, wedding halls, restaurants, and fuel stations), storages (including warehouses, depots, storages, and trash bins), residential buildings (including apartments and individual houses), and factories.

Table 3 Fire numbers in 2021 for different categories of facilities where fire has happened.

Category	Number of fires	Percentage (%)	Facilities within each category
Public Facilities	30	10.5	Substation, government offices, kindergarten, educational center, university, hostel, hospital
Commercial	65	22.7	Bakery, shopping centers and malls, wedding halls, restaurants and fuel stations
Storages	27	9.4	Warehouses, depots, storages, trash bins
Residential	160	55.9	Apartments and houses
Factories	4	1.4	All types of production factories

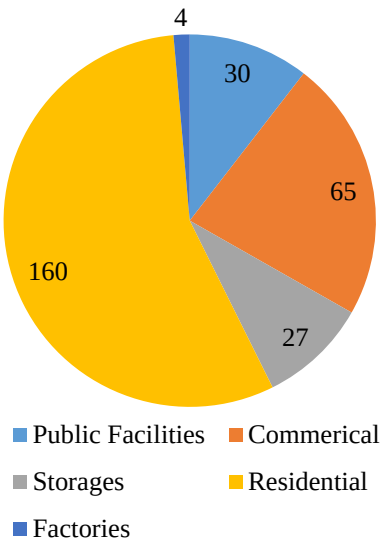


Figure 8 Number of fires in different categories

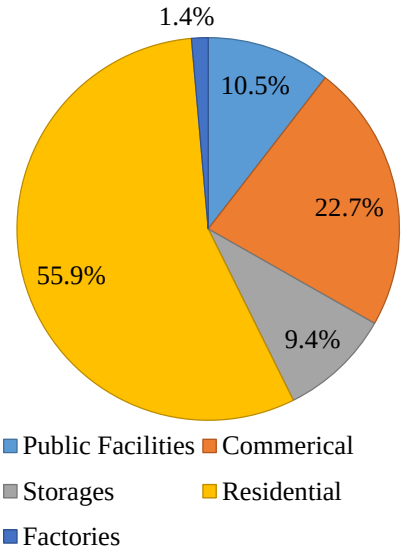


Figure 9 Percentage of fires in different categories

As depicted in Figures 8 and 9, approximately 60% (160 fires) of the fires occurred in residential buildings. About 23% of the fires (65 fires) took place in commercial buildings, 10% (30 fires) occurred in public facilities, and approximately 9% of the fires (27 fires) happened in storages.

Figure 10 displays the number of fires in 2022 according to the different types of structures where the fires originated. From the total 216 fires, around 133 fires accounting for about 62% (as shown in Figure 11) occurred in residential buildings. Shopping centers and business markets experienced 45 fires, which represents approximately 21% of the total. In 2022, there were 10 fires (about 5%) in factories and 9 fires (approximately 4%) in governmental offices.

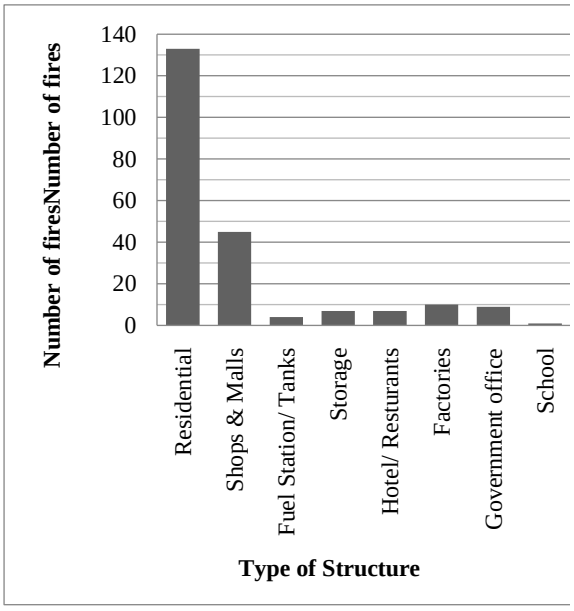


Figure 10 Number of fires in 2022 in different types of structures

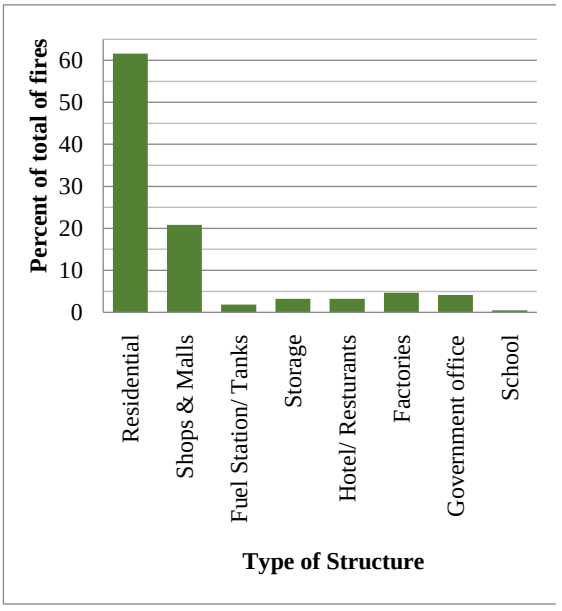


Figure 11 Percentage of fires in 2022 in different types of structures

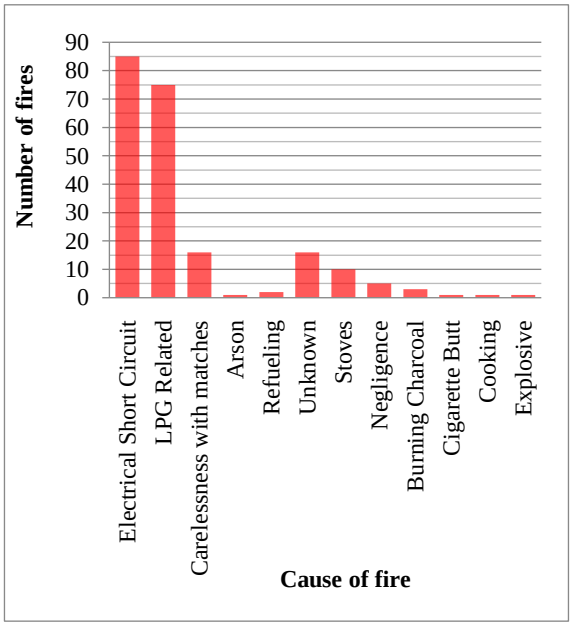


Figure 12 Number of fires by different causes in 2022

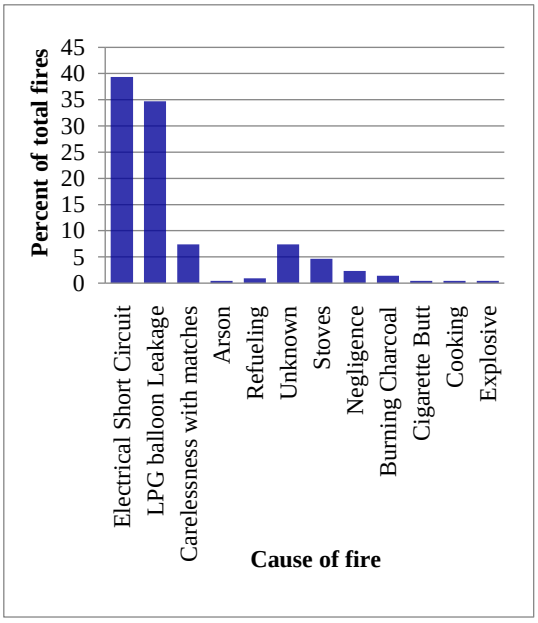


Figure 13 Percentage of fires by different causes in 2022

Figure 12 illustrates the number of fires in 2022 caused by different sources. Out of a total of 216 fires in that year, approximately 85 fires, accounting for about 39% (as shown in Figure 13), occurred due to electrical short circuits or malfunctions. About 75

fires (roughly 35%) were caused by LPG-related incidents, including LPG cylinder leakage, explosion, cylinder refilling or emptying, malfunctioning LPG equipment, LPG tankers, or other relevant interactions. In 2022, 16 fires (approximately 7%) were caused by matches or lighters, and the cause of 16 fires (about 7%) remains unknown or has not been publicized.

The structures where the fires occurred are categorized as follows: public facilities (including government offices and educational centers), commercial facilities (such as shopping centers and malls, fuel stations, hotels, and restaurants), storages (including warehouses, depots, storages, and trash bins), residential buildings (including apartments and individual houses), and factories.

Table 4 Fire numbers in 2022 for different categories of facilities where fire has happened.

Category	Number of fires	Percentage (%)	Facilities within each category
Public Facilities	10	4.6%	Government offices and educational center
Commercial	56	25.9%	Shopping centers and malls, fuel stations, hotels, and restaurants
Storages	7	3.2%	Warehouses, depots, storages, trash bins
Residential	133	61.6%	Apartments and houses
Factories	10	4.6%	All types of production factories

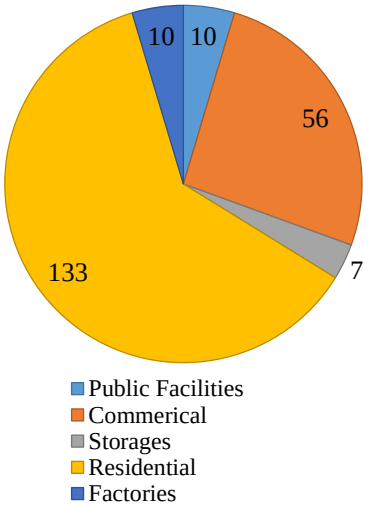


Figure 14 Number of fires in different categories of facilities in 2022

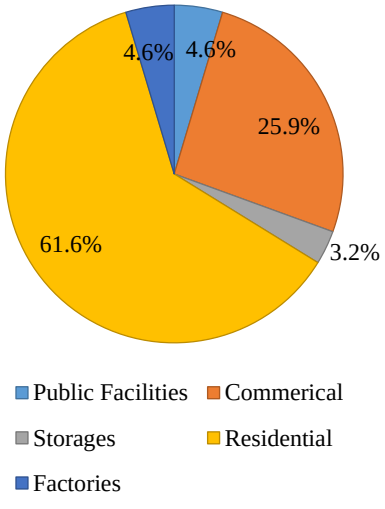


Figure 15 Percentage of fires in different Categories of facilities in 2022

As depicted in Figures 14 and 15, approximately 62% (133 fires) of the fires occurred in residential buildings. About 26% of the fires (56 fires) took place in commercial buildings, around 5% (10 fires) occurred in public facilities, and factories.

Figure 16 displays the number of fires in 2023 according to the different types of structures where the fires originated. Out of a total of 228 fires (as shown in Table 2), approximately 149 fires, accounting for about 65% (as shown in Figure 17), occurred in residential buildings. Shopping centers and business markets experienced 36 fires, which represents about 16% of the total. There were 12 fires (roughly 5%) in governmental offices. In 2023, there were 11 fires (approximately 5%) in storages and 10 fires (about 4%) in factories.

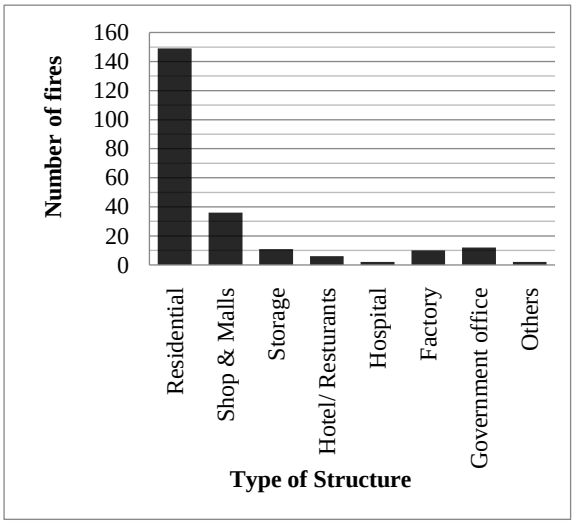


Figure 16 Number of fires in 2023 in different types of structures

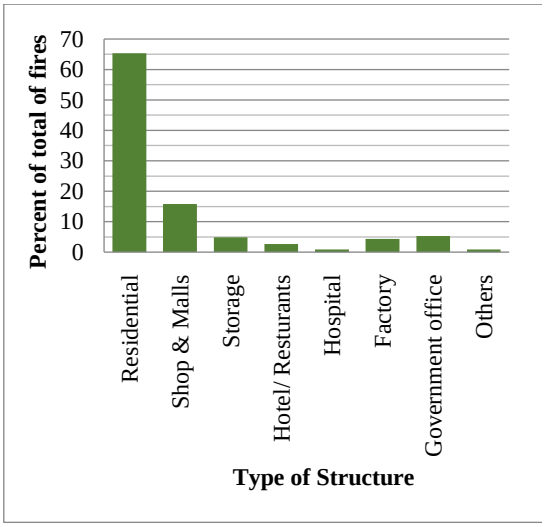


Figure 17 Percentage of fires in 2023 in different types of structures

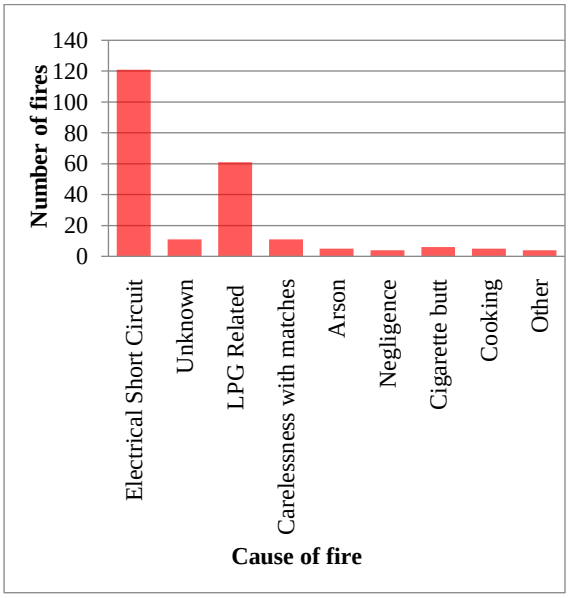
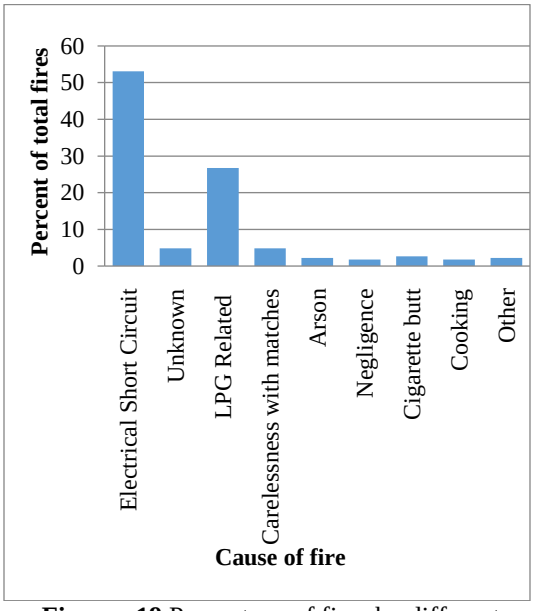


Figure 18 Number of fires by different causes in 2023



Figurer 19 Percentage of fires by different causes in 2023

Figure 18 illustrates the number of fires in 2023 caused by different sources. Out of a total of 228 fires in that year, approximately 121 fires, accounting for about 53% (as shown in Figure 19), occurred due to electrical short circuits or malfunctions. About 61 fires (roughly 27%) were caused by LPG-related incidents, including LPG cylinder leakage, explosion, cylinder refilling or emptying, malfunctioning LPG equipment, LPG tankers, or other relevant interactions. In 2023, 11 fires (about 5%) were caused by matches or lighters, and the cause of 11 fires (about 5%) remains unknown or has not been publicized.

The structures where the fires occurred are categorized as follows: public facilities (including government offices and educational centers), commercial facilities (such as shopping centers and malls, hotels, and restaurants), storages, residential buildings (including apartments and individual houses), and factories.

Table 5 Fire numbers in 2023 for different categories of facilities where fire has happened.

Category	Number of fires	Percentage (%)	Facilities within each category
Public Facilities	16	7.0%	Government offices and educational center
Commercial	42	18.4%	Shopping centers and malls, hotels, and restaurants
Storages	11	4.8%	storages
Residential	149	65.4%	Apartments and houses
Factories	10	4.4%	All types of production factories

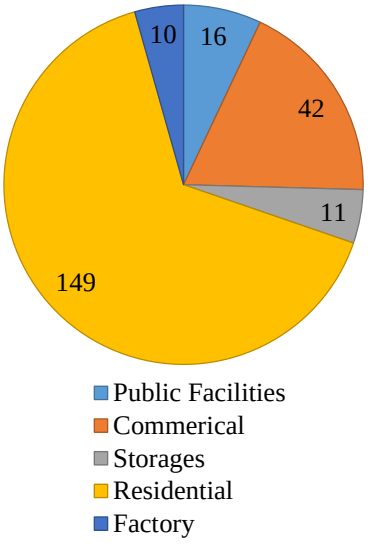


Figure 20 Number of fires in different categories of facilities in 2022

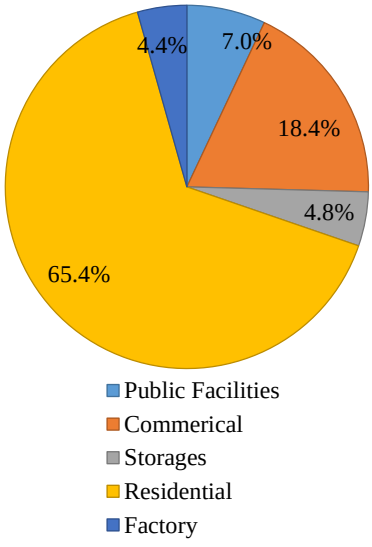


Figure 21 Percentage of fires in different Categories of facilities in 2022

As depicted in Figures 20 and 21, approximately 65% (149 fires) of the fires have occurred in residential buildings. About 18% of the fires (42 fires) have occurred in commercial buildings, while 7% (16 fires) and 4% (11 fires) have occurred in public facilities and storages, respectively.

6. Public opinion on fire hazard in Kabul city

In this section, a public viewpoint is provided on the fire hazard in Kabul city based on two sources of information: questionnaires and a review of public opinions reflected in media reports, news, and interviews.

6.1. Summary of response to questionnaire

To gather public opinions on fire sources, the enforcement of fire safety standards, and the quantity and capacity of firefighting resources in Kabul city, a questionnaire consisting of 12 questions was distributed among 85 individuals, including engineers, architects, and fire hazard responders. The participants were asked to rate the accuracy of the provided statements/questions. The summary of the responses is presented in Table 6 below.

Table 6 Summary of the responses of the questionnaire distributed among Kabul residents

No.	Question	High	Medium	Little	None	No Idea
1	Negligence at kitchen households such as faulty LPG cylinder, heated oil, leaking pipes is a major fire cause in Kabul city.	53.5	34.5	12.1	0.0	0.0
2	Overloaded power lines and wires, panel boards, PDU and other electrical ware are key sources of fire outbreak.	62.1	31.0	3.5	1.7	1.7
3	Fire igniters such as matches, lighters and others are causes of fire outbreak in the city.	36.2	34.5	25.9	1.7	1.7
4	Cigarette but, residue of partially burnt wood and matches boxes can be a source of fire in Kabul.	17.2	20.7	53.5	1.7	6.9
5	Inappropriate storage of combustible chemicals (petrochemicals) plays important role in fire incidents in Kabul city	42.8	31.0	10.7	1.7	13.8
6	One of the main reasons of vulnerability of buildings against fire hazard is poor or no consideration to fire safety standards and regulations during construction of buildings.	63.8	29.3	3.5	0.0	3.5
7	I have seen a building is constructed with full consideration of fire safety requirements per codes and standards.	13.8	15.5	29.3	29.3	12.1
8	I have witnessed the government has enforced consideration of fire safety requirements during buildings construction?	1.7	12.1	22.4	50.0	13.8
9	Firefighting officers responding promptly for firefighting and rescue operations.	5.2	25.9	58.6	8.6	1.7
10	Firefighting officers are skilled and able to fight the fires quickly.	1.7	41.4	29.3	0.0	27.6

11	Firefighting equipment of Kabul Firefighting Department work efficiently.	3.5	48.3	32.8	1.7	13.8
12	The number of firefighting stations in Kabul city are enough	1.7	8.6	56.9	25.9	6.9

More than 50% of the respondents believe that negligence during cooking; overloaded electrical wires, power distribution lines, and malfunctioning equipment are key reasons for fire outbreaks. More than 60% of the responders strongly believe that poorly implemented fire safety measures and a lack of attention to code requirements are the main vulnerabilities of buildings to fire incidents. Additionally, over 55% of the respondents stated that firefighting units are less likely to respond promptly to perform firefighting and rescue operations, and they believe that the number of firefighting stations in Kabul city is insufficient. Furthermore, 50% of the responders stated that they have not witnessed the government enforcing fire safety measures in the construction of buildings.

6.2. Public viewpoint form media sources

In addition to reviewing online media content regarding fire casualties and financial losses, we also collected summaries of public views and expert opinions from published media reports, news bulletins, and relevant interviews with government representatives or subject matter experts regarding different aspects of the fire hazard in Kabul city. The key points we found are:

i. According to the public, firefighting stations often respond late to fight fires and perform rescue operations. This delay results in the spread of fire to adjacent areas. The availability and explosion of gas cylinders and fuel sources at adjacent structures and facilities further intensify the fire spread.
ii. According to the Firefighting Department of Kabul City, delays in responding to fire emergencies are caused by various factors, including traffic congestion, narrow road lanes, road blockages by mobile vendors and security measures, substandard city planning, and a lack of civic sense in assisting firefighting teams.
iii. Substandard construction and a lack of required infrastructure contribute to large-scale fire incidents.
iv. Fire safety and prevention measures are not adequately considered in buildings, especially in vulnerable ones such as commercial markets. The mechanical design of all buildings should account for fire hazards and abide by code requirements.
v. Firefighting operations often last longer than necessary, resulting in increased losses. Quick and coordinated firefighting efforts are necessary to reduce the spread of fire and minimize damages.
vi. Insufficient firefighting resources, including the number of firefighters, vehicles, and water supply, are important factors contributing to increased fire damages in the city.

vii. Security blockades and restrictions on larger trucks entering central areas of the city have resulted in delays in responding to fire incidents.
viii. Lack of an insurance system, limited firefighting resources, a lack of public awareness regarding fire hazards and response, are key factors in large-scale fire incidents.
ix. Negligence by owners of markets and stores is also a significant cause of fire outbreaks.
x. Many fire incidents occur in old markets that lack fire safety measures. The power distribution systems in these old markets are often faulty, with exposed and overloaded wires, inadequate grounding systems, faulty fuses and distribution boxes, and carelessness in power usage. These factors collectively increase the fire hazard level in these markets, leading to devastating fires.
xi. Deliberate fires and arson can be the cause of some major fires in the city.
xii. The current firefighting resources are insufficient considering the city's current population and development stage. According to the needs assessment of the Kabul Fire Department in August 2019, at least 18 firefighting stations are required, while only 7 fire stations are currently active in Kabul city. Additionally, the Directorate of Firefighting has assessed that at least 6,000 firefighting personnel are needed, whereas only 1,730 firefighting personnel are available in the country [25].
xiii. In some cases, fuel storage tanks are installed on the roofs of buildings to operate telecommunication towers. This creates a significant fire hazard.
xiv. Poor law enforcement has led to ignorance and an increased fire hazard and vulnerability of buildings.
xv. Firefighting trucks sometimes lack an adequate amount of water to suppress fires. Additionally, there is a lack of frequent maintenance and servicing of firefighting vehicles.
xvi. Substandard construction makes it difficult for firefighters to access buildings, and poor coordination between firefighters affects the efficiency of firefighting operations.

7. Fire Deaths and Injuries in Kabul

There is no online or computerized database of fire statistics available to analyze fire casualties in Kabul city. However, thanks to the widespread availability of media in the city, including broadcast, digital, and social media platforms, we were able to conduct a comprehensive review of fire incidents. This study aimed to determine fire-related deaths and injuries by examining local and international online media reports, newspapers, social media posts, broadcasted news bulletins, and reports from relevant government agencies from the years 2010 to 2023.

Initially, our intention was to review online sources of information from 2001 to 2023. However, it was observed that there was a scarcity of media reports and online information available for the years 2009 and earlier. This lack of information on fires in the city can be attributed to two reasons. Firstly, Kabul city was in the early stages of

rehabilitation and expansion after 2001, with limited built infrastructure compared to the period starting from 2010 onwards. In other words, there were fewer fire incidents in the city before 2010. Secondly, the limited availability of media outlets before 2010 resulted in minimal coverage of fire cases, while the widespread availability of local and international media in recent years has led to more comprehensive reporting of fire incidents throughout the city.

Therefore, the relevant information before 2010 was not included in the tabulated data in order to better correlate and compare the data from 2010 to 2023. However, any available information on fire cases before 2009 is also presented in the paper.

Table 7 Number of fire deaths and injuries retrieved form the online media sources (Appendix A) for Kabul city from 2010 to 2023

No.	Date	Cause of fire	Facility	Deaths	Injuries
1	Dec 06, 2010	LPG	Fitness Center	0	2
2	Mar 19, 2011	LPG	Bazar/ marketplace	1	0
3	July 01, 2012	LPG cylinder explosion	Pharmaceutical Retail Center	5	30
4	July 04, 2012	LPG cylinder explosion	LPG station at industrial park	17	155
5	June 29, 2014	LPG cylinder explosion	Wood storage yard	0	7
6	July 05, 2014	Car LPG tank explosion	Car	1	0
7	Dec 05, 2015	Electrical Short Circuit	Bazaar/ marketplace	0	6
8	Aug 04, 2016	Unknown	Business Center	1	7
9	July 09, 2016	LPG cylinder explosion	Shop	2	2
10	Sep 20, 2016	Negligence	Fuel Station	1	2
11	Sep 6, 2017	Negligence	Carpet Sales Center	0	1
12	Nov 04, 2017	Electrical Short Circuit	Fabric & Clothes retail shop	1	2
13	Jan 03, 2019	Fuel tanker explosion	Fuel Station	4	46
14	Jan 13, 2019	LPG cylinder explosion	Residential	9	8
15	Jan 02, 2021	LPG cylinder explosion	Bakery	5	0
16	May 02, 2021	Fuel tanker explosion	Fuel Tankers Parking	10	14
17	July 14, 2021	LPG cylinder explosion	Governmental office	1	0
18	Nov 26, 2021	Unknown	Business Center	1	1
19	May 24, 2022	LPG cylinder explosion	Business Center	2	5
20	Oct 15, 2023	Unknown	Residential	1	1
Total				62	289

It should be noted that only fire incidents resulting in deaths or injuries are included in Table 7. Fires with no casualties, as reported, are not listed in the table. Additionally, although not widely covered by the media, lethal fire incidents occurred before 2010. For example, on June 11, 2008, a fire outbreak caused by the explosion of an LPG tanker in Pol-e-Charkhi prison resulted in the death of 4 individuals and injured 3 others, according to officials. Several vehicles and surrounding buildings were also damaged by this fire.

Table 8, as well as Figures 22 and 23, present the number and percentage of fire-related deaths and injuries based on different causes of fires.

Table 8 Number of fire deaths and injuries for different causes 2010 – 2023 for Kabul city

Fire Cause	Deaths	Injuries	% of Deaths	% of Injuries
LPG Related	43	209	69%	72%
Fuel Related	14	60	22%	21%
Electricity Related	1	8	2%	3%
Unknown	3	9	5%	3%
Negligence	1	3	2%	1%
Total	62	289	100%	100%

Table 9 Number of fire deaths and injuries for different facilities 2010 – 2023 for Kabul city

Fire Cause	Deaths	Injuries	% of Deaths	% of Injuries
Commercial Markets/ Stores	13	61	21%	21%
Fuel/ Gas Stations	32	217	52%	75%
Residential	10	9	16%	3%
Other	7	2	11%	1%
Total	62	289	100%	100%

It should be noted that the number of fire-related deaths may be higher than what is presented in the above table. This is because some fire injuries can be severe enough to result in an increased death toll.

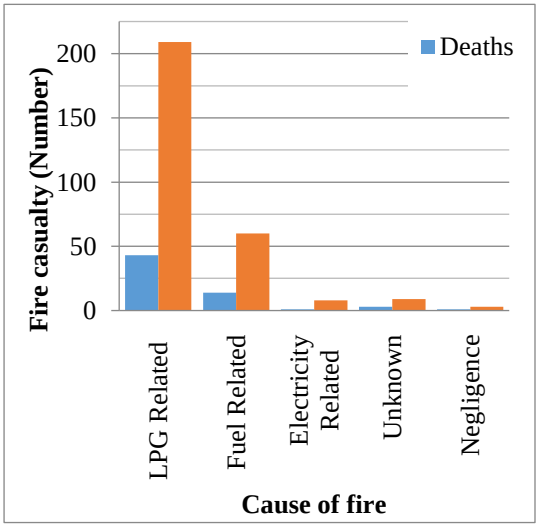


Figure 22 Number of fire deaths and injuries for 2010-2023 for fire of different causes

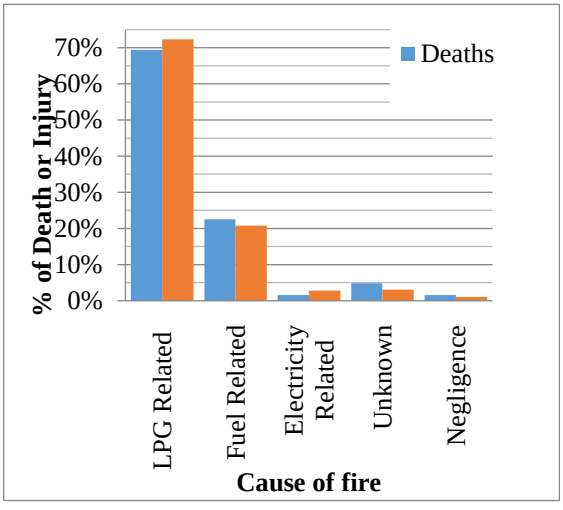


Figure 23 Percentage of fire deaths and injuries for 2010-2023 for fire of different causes

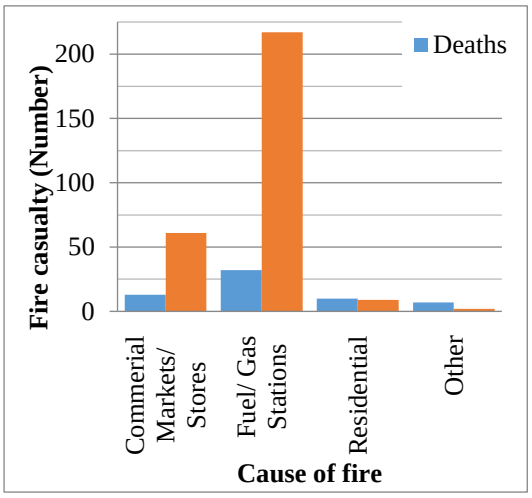


Figure 24 Number of fire deaths and injuries for 2010-2023 at different facilities

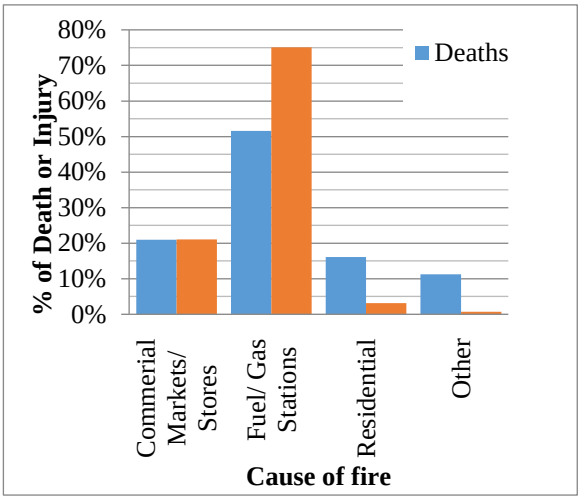


Figure 25 Percentage of fire deaths and injuries for 2010-2023 at different facilities

Table 9, along with Figures 24 and 25, displays the number and percentage of fire-related deaths and injuries categorized by the different structures/facilities where the fires originated.

8. Economic Losses by Fire Incidents in Kabul

A fire can result in varying degrees of property damage, regardless of whether there are any deaths or injuries. The severity and duration of the fire, as well as the materials involved, determine the extent of the asset loss. Therefore, it is inevitable that financial losses occur during fire incidents. These financial losses can include the burning of properties and materials, damage caused by water spray during firefighting efforts, damage to property for the ingress and egress of firefighters and rescue operations, falling debris, and structural damage that requires repair or reconstruction.

Indirect financial losses during a fire incident may include losses due to service closures during the repair period, the demolition of structures, disruptions to adjacent businesses during recovery and reconstruction operations, environmental pollution from smoke and debris, the loss of resources during settlement of disputes and addressing legal issues, and other related factors. Given these factors, it is challenging to estimate financial losses from fires with great accuracy.

As mentioned earlier, there is a lack of online or computerized fire statistics available for Afghanistan, specifically for Kabul city. Therefore, in this study, we relied on reviewing available online media content and literature to gather information on fire losses in Kabul city. The property loss descriptions presented in Table 9 are based on

reviewed reports from local media organizations. In many cases, multiple sources were consulted to enhance the reliability of the information provided.

Table 10 Description of the direct monetary losses incurred from fires that occurred in Kabul city between 2010 and 2023. (Appendix A)

No.	Date	Cause of fire	Fire Location	Description of property losses
1	Dec 19, 2010	Negligence	Carpentry shops	Three cars and five carpentry shops were burned, estimated 30 thousand USD losses
2	Jan 23, 2011	Negligence	Auto parts and repair center	Allegedly the fire caused 500 thousand USD losses to the owner
3	Mar 19, 2011	LPG	Bazar/ marketplace	27 shops burned with estimated 150 thousands USD losses
4	July 03, 2011	Unknown	Factory	One sponge production factory and three houses destroyed by fire
5	July 01, 2012	LPG cylinder explosion	Pharmaceutical Retail Center	About 40 tons of medicine worth more than 3 million USD was burnt by fire
6	July 04, 2012	LPG cylinder explosion	LPG station at industrial park	20 container, numerous shops, factory machinery and 3 LPG tankers were destroyed by fire, at least 10 million USD losses were estimated
7	Dec 23, 2012	Electrical Malfunctions	Congested Bazar/ Market place	At least 600 shops in a commercial market selling shoes, clothes in congested business center of the city burnt down with alleged 36 million USD losses
8	Jan 23, 2014	Electrical Short Circuit	Commercial building	Several shops and a storage selling auto parts were destroyed by fire, allegedly the fire costed 250 thousand USD to the owners
9	May 01, 2015	LPG cylinder explosion	Congested Bazar/ Market place	14 shops in two markets selling dried fruits were burned. The loss was reported hundreds thousands USD
10	Dec 05, 2015	Electrical Short Circuit	Congested Bazar/ Market place	About ۸۲ shops were partially of completely burned with millions of USD estimated losses
11	Aug 04, 2016	Unknown	commercial Market	About 1200 shops in a 12 story commercial building were partially or completely burned. Shops were selling clothes, jewelry, curtains, electrical equipment with estimated losses of about 10 million USD
12	Sep 18, 2016	Electrical Short Circuit	commercial Market	According to reports, 120 shops of wood products and furniture were destroyed by fire
13	July 25, 2017	Electrical Short Circuit	Fresh fruit market	11 shops were partially or completely burned with estimated 300 thousands USD losses
14	Sep 6, 2017	Negligence	Carpet Sales Center	Seven shops of carpets were burned
15	Nov 04, 2017	Electrical Short Circuit	Fabric & Clothes retail shop	More than ten shops and one storage worth approximately 100 thousands USD, selling clothes, were burned.

No.	Date	Cause of fire	Fire Location	Description of property losses
16	Nov 01, 2018	Allegedly Electrical Short Circuit	Commercial markets	More than 500 stores mainly of household electrical equipment, computer, mobile and other burned down in 4 markets at the main business hub of the city with alleged ٥٠ millions USD losses
17	Jan 03, 2019	Fuel tanker explosion	Fuel Station	According to officials, 43 apartments and seven vehicles were burnt in the fire
18	Jan 27, 2019	Negligence	commercial Market	About 350 shops mainly selling shoes were burned resulted in about 2.5 millions of USD losses
19	June 04, 2019	Electrical Short Circuit	Dry fruit market	70 to 80 shops of dry fruit in two markets worth more than 500 thousands USD were burned by fire
20	Oct 08, 2019	Electrical Short Circuit	commercial Market	55 stores of shoes and plastic toes and households worth about 1.5 million USD were burned by the fire
21	July 11, 2020	Unknown	Fuel Station	The complete fuel station was burned, some shops in the neighborhood were affected by the fire with about one hundred thousand USD estimated losses
22	Mar 25, 2021	Negligence	Second hand clothes Sales bazar	About one hundred thousand USD estimated losses
23	May 02, 2021	Fuel tanker explosion	Fuel Tankers Parking	The fire costed about 20 million USD burning vehicles, hotel, residential buildings, fuel station and shopping booths
24	Sep 18, 2022	Negligence	Bakery and Fabric Sales shops	About 50 shops were partially or completely destroyed by fire with alleged tens of thousands of USD losses
25	Oct 5, 2022	Electrical Malfunctioning	commercial Markets	Allegedly about 300 shops selling clothes, jewelry, curtains, electrical equipment and each worth of about 20,000 USD on average were engulfed by fire
26	Oct 30, 2022	LPG cylinder explosion	Bazar / marketplace	More than 11 shops of home appliances, plastic wares, electrical appliance and fruits worth hundreds thousands USD destroyed by fire
27	Dec 16, 2022	LPG cylinder explosion	commercial Market	Four gold-processing factories worth thousands USD were destroyed by fire,
28	July 04, 2023	Unknown	Fuel Shop	5 shops worth more than 100 thousands USD were burnt by the fire

The property losses in the above table have been categorized by different causes of fires and for each year from 2010 to 2023. As shown in the table, three major fire incidents occurred in July and December of 2012, resulting in losses of $3 million, $10 million, and $36 million USD, respectively. In August 2016, a significant fire destroyed 1200 shops in a 12-story commercial building, resulting in approximately $17 million USD in losses. In September of the same year, a fire caused losses of about $1.2 million by burning 120 furniture and wood product shops. In November 2018, a major fire in a

commercial market destroyed an electronic market and caused approximately $50 million USD in losses. Another major fire occurred in May 2021 due to an LPG tanker explosion west of Kabul, resulting in losses of about $20 million USD and the destruction of vehicles, a hotel, residential buildings, a fuel station, and shops. In October 2022, a fire occurred at a commercial building in the same location where a larger-scale fire incident occurred on August 4, 2016. This fire resulted in losses of $5 to $6 million USD.

In total, the direct monetary losses for the major fires reported by media sources, as shown in Table 10, can be estimated to be approximately $153 ± 15 million USD. On average, fire incidents caused direct monetary losses of about $11 million USD per year from 2010 to 2023. The heaviest financial losses occurred in 2012 with a reported amount of $49 million USD, followed by 2018 with a reported amount of approximately $50 million USD, and 2021 with a reported amount of $20 million USD. These four years account for about 90% of the total reported losses in Kabul city from 2010 to 2023.

It should be noted that Table 10 presents figures from major fires reported by published media sources. The reported fire causes may not always be accurately documented. In some instances, arson is indicated as the cause of fire incidents, particularly in commercial buildings, but these claims cannot be verified. On average, over 250 fire incidents occur in Kabul city, each accompanied by financial losses, whether small or large. This implies that the monetary losses due to fires in the city exceed the values reported in this study. Additionally, due to a lack of quantitative information on fire losses in published reports, some fire cases that may have resulted in significant monetary losses are not included in this study.

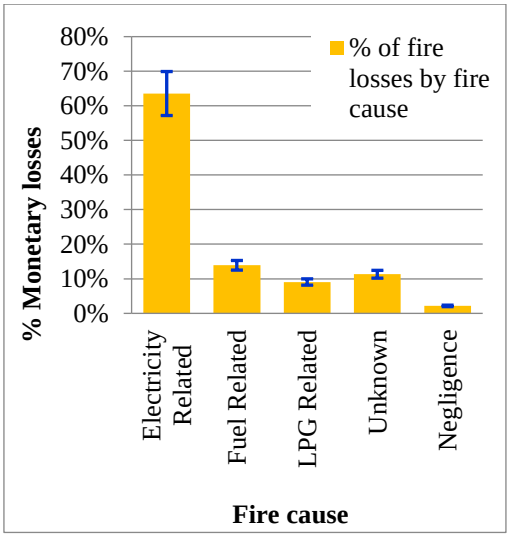


Figure 26 Percentage of property losses by fire source/ cause from 2010 to 2023 in Kabul city

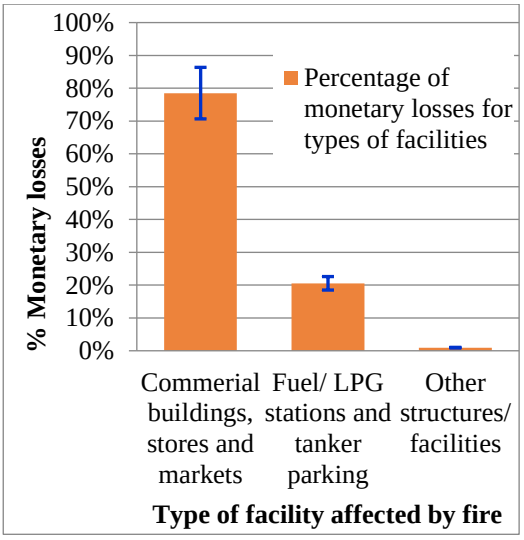


Figure 27 Percentage of property losses by type of facility affected from 2010 to 2023 in Kabul city

Figure 26 illustrates the percentage of monetary losses attributed to different sources or causes of fires, while Figure 25 shows the percentage of fire losses categorized by the type of facilities or structures affected by the fire. On average, it is evident that 64% of fire losses are caused by fires related to electricity, 14% of financial losses are caused by fires related to fuel or petrol, the cause of 11% of fire losses is unknown, and 9% of fire losses are attributed to LPG-related sources. Additionally, Figure 27 reveals that approximately 79% of the financial losses are sustained by commercial markets, stores, and individual shops. Fuel and gas stations, as well as facilities and vehicles associated with them such as parking areas for fuel or gas tankers, account for 21% of fire losses. Only 1% of direct fire losses are sustained by other facilities, including residential buildings. It is important to note that the majority of these fire losses are borne by the private sector and businessmen.

9. Vulnerabilities of buildings and the Environment by Fire

The structural safety of multi-story buildings is at risk during major fire incidents. Fortunately, the majority of multi-story buildings and commercial markets in Kabul city are constructed from reinforced concrete, which offers better fire performance compared to steel or other structural materials. In severe fires, the temperature inside a building can exceed 1,000°C. Such high temperatures can significantly reduce the strength and stiffness of building components and materials, including steel, concrete, wood, CMU, and others [26]. Consequently, the load-carrying capacity of structural members is significantly diminished, potentially leading to partial or complete collapse during or after the fire. While catastrophic failure of concrete structures is rare [23], the degradation of strength and stiffness can increase the likelihood of building failure during the remaining service life, particularly when exposed to natural hazards such as earthquakes and strong winds.

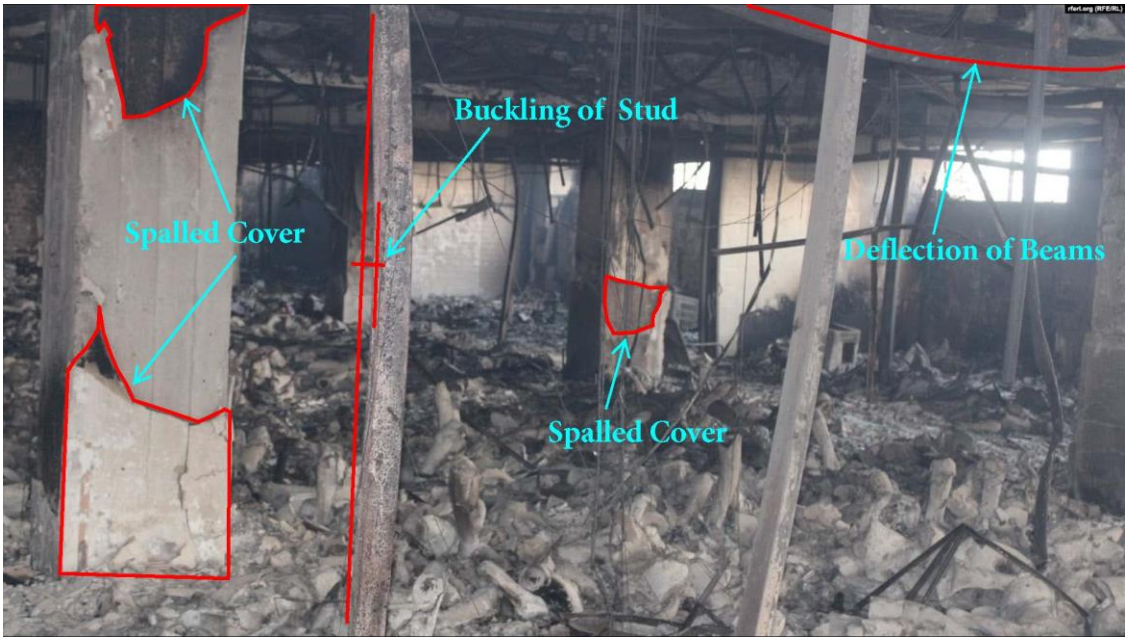


Figure 28 Structural and non-structural elements of building affected by sever fire [28]

Kabul, being a densely populated city, is frequently subjected to strong earthquakes resulting from regional or local seismic activity. However, this earthquake-prone city lacks reliable seismic input data such as seismic maps and seismic records for advanced seismic design. Furthermore, there is a lack of advanced knowledge in earthquake engineering among practitioners in this field, and poor quality control and code enforcement during construction [27].



Figure 29A multi-story reinforced concrete building burnt by fire on January 03, 2019 from explosion of fuel tanker at fuel station [29]



Figure 30 The 12 story commercial reinforced concrete building engulfed by fire on August 04, 2016 [30]

This scenario should be a major concern for buildings affected by severe fire incidents. Poorly constructed structures that have been impacted by fire pose a significant threat to structural safety, especially in areas prone to strong earthquakes.

In reinforced concrete buildings, the cover concrete serves as protection for the reinforcement bars against elevated temperatures during fires. However, in severe fires, the cover concrete can spall off (as shown in Figure 28), exposing the reinforcement cage to fire and high temperatures. Excessive heating of the rebar can lead to significant deformation and bending, which in turn can result in the collapse or failure of structural elements that rely on the rebar for support.

In many cases, structures affected by fire are reoccupied without undergoing thorough investigations into their structural safety. Although the structure may appear intact visually, it is crucial to perform destructive and non-destructive testing such as core cutting, rebound hammer readings, and ultrasonic pulse velocity tests to verify the structural integrity and uniform strength of the affected structures.

10. Fire hazard mitigation in Kabul city

In previous sections, the causes of fires, fire statistics, cost of life, financial losses, and public viewpoints regarding fire hazards in Kabul city were presented. The details provided in these topics offer crucial information for planning fire hazard mitigation in Kabul city and the country.

Regarding Kabul city, fire hazard safety measures can be broadly categorized into two main areas: fire prevention and mitigation of damage levels.

10.1. Fire Prevention

The proverbial saying "prevention is better than cure," meaning that it's better to prevent things from happening rather than having to repair or deal with them afterwards, applies well to the prevention of fire incidents in the city. We have discussed that fire incidents in Kabul city have occurred due to various causes or sources. Eliminating the causes of fire incidents is essentially fire prevention. Adopting preventive measures costs very little for a large portion of residents and can significantly reduce fire hazards. In fact, fire prevention measures reduce the burden on resources needed for firefighting and recovery. Building upon the information from the previous sections on the causes of fire, public opinions on fire hazards, and fire statistics, the following measures can be taken to reduce fire incidents in Kabul city:

i. As shown in Figures 5, 13, and 19, approximately 40 to 50 percent of fire incidents from 2021 to 2023 were caused by electrical issues, primarily electrical short circuits, and occasionally by faulty electrical equipment. Electricity is the leading cause of fire incidents in Kabul. Additionally, Figure 26 indicates that 64% of monetary losses from 2010 to 2023 were caused by fires initiated by electricity. This means that fire incidents and resulting losses can be significantly reduced by evaluating and upgrading/renovating the power distribution system, especially in old markets, according to power demand and applicable standards. Underground

power distribution protects wires from damage and can greatly reduce short circuit cases.

ii. After electricity, LPG has caused the second-highest number of fire incidents in Kabul city. Approximately 25 to 30% of fires from 2021 to 2023 were caused by LPG cylinder explosions, leakage, or incidents during unloading and refilling of tankers. About 70% of fire-related deaths and injuries were caused by fires from LPG incidents (Figure 23), and 20% of monetary losses were caused by fires related to LPG and fuel (Figures 26 and 27). To reduce fire incidents related to LPG, fuel/LPG stations should comply with regulations set by codes and the government. The fire prevention guidelines provided by the government for commercial markets [18] need to be fully implemented. Fire safety measures in line with international standards should be fully enforced in all fuel/gas stations and commercial markets. Fuel stations located close to population centers and residential areas should be relocated to minimize casualties in case of fire incidents. Data from the General Directorate of Disaster Response and Firefighting, as well as data from online sources, suggest that most catastrophic fire incidents result from explosions, leakage, or carelessness during the refilling of LPG cylinders, tankers, and fuel stations. The exact number of fuel stations in Kabul city is not available, but according to data from ANDMA [18], there are more than 250 fuel stations, most of which are privately owned. Some sources indicate a higher number of fuel stations in Kabul city. Frequent catastrophic fires, mostly occurring in fuel stations and commercial markets, prompted the government to investigate fire incidents and provide guidelines for mitigating fire hazards in fuel stations and commercial buildings. Therefore, a joint committee consisting of ten relevant government bodies conducted a technical survey of approximately 250 fuel stations and about 4,800 commercial buildings from March 2019 to June 2021. The survey found that about 60% of the surveyed fuel stations had not implemented the minimum fire safety measures, while about 80% of the surveyed fuel stations were not constructed or operated according to relevant standards [19-21]. The remaining 40% of fuel stations had limited fire safety measures. The committee also prepared proposed guidelines to be followed by fuel stations and commercial markets for mitigating fire hazards in Kabul city [18]. However, due to poor law enforcement and a lack of civic responsibility, the owners have not adequately implemented the fire safety measures required by these guidelines.

iii. Fuel storage should not be allowed in residential and commercial buildings. Power plants and generators should be equipped with fire safety tools. Generators used for lighting in commercial buildings, stores, and residential buildings should not be allowed unless a specific location with all necessary safety measures is designated for power generation for the building.

iv. The adoption of fire safety measures during the design and construction of any new building should be strictly enforced. The Kabul municipality should not issue construction permits until fire safety measures are taken into account according to national and/or international standards. Fortunately, a comprehensive survey of fire safety measures in commercial buildings, towers, and fuel stations has already been

conducted [18-21]. The owners of all these surveyed buildings should be required to install and obtain fire safety tools for their properties. Fire safety tools should include the installation of fire alarms, smoke detectors, fire extinguishers, fire hose cabinets, heat detectors, fire suppression systems, emergency and safety signs, emergency exits, fire hydrants around the building, and more.

v. Negligence and carelessness are also key factors in fire outbreaks. Public awareness is crucial in addressing negligent owners and all those involved in potential fire incidents. Public awareness can also reduce fire incidents caused by heaters, stoves, cigarette residue, and carelessness with matches and lighters. The government should conduct public awareness programs through television, schools, universities, public halls, governmental offices, and mosques during Jumma prayers, among other possible channels. Efforts should be made to increase the coverage of these awareness programs to reach at least one person per family. The programs can cover a variety of fire hazard topics for adults and children, men and women, kitchens, stores, engineers, and owners. Public awareness programs should be continuous, as intermittent programs have little effectiveness. Public awareness among the residents is the most effective tool in addressing fire hazards in the city.
vi. Fire prevention is not solely the responsibility of the government; residents and the public are equally vital in increasing or mitigating fire hazards. Therefore, a sense of civic duty and responsibility should be nurtured among the city's residents. Public awareness programs can also be useful in this regard.

10.2. Fire control and mitigation of damage level

Fire incidents can happen even if fire prevention and safety measures are enforced. Therefore, controlling the fire after its outbreak is vital in responding to fire hazards. Several shortcomings of firefighting resources in Kabul city were pointed out by public opinions and the responders of the questionnaire in section 4.1. With that in mind, the following measures are needed to effectively control already burning fires:

i. The number of firefighting stations and firefighters needs to be increased. Several times, complaints have been made of late arrival and delayed firefighting operations. If the number of stations is increased, distances to possible fire locations decrease and result in a prompt response. There has already been a needs assessment made for the minimum number of firefighting stations and firefighting careers [25] in Kabul city.
ii. Lack of coordination during firefighting operations shall be addressed. This can be accomplished through capacity building and practical training.
iii. Traffic control and regulations, especially around fire-vulnerable areas, should be enforced. Public awareness on how to respond during fire emergencies can be greatly helpful. This may include yielding the right of way to fire trucks and providing space for truck operations, among other measures.
iv. Provision of fire lanes, if possible, especially in vulnerable areas, shall be investigated.

v. The number and quality of firefighting tools, trucks, and vehicles need to be increased. The population growth and expansion of the city require firefighting resources to be increased accordingly.
vi. Frequent maintenance and servicing of equipment, procurement of enough firefighting materials such as water, powder, and others are essential for effective firefighting operations.
vii. In newly constructed buildings, easy and simple access to the site and the building for firefighters shall be ensured at the design and construction phase. Buildings should be easily accessible for firefighting operations.
viii. Fire-affected buildings should be evaluated for structural soundness and safety. The government should not allow re-occupation of the structure until complete structural health monitoring is performed and the acceptance criteria are met.

11. Discussion

11.1. Fire source in the city

Fire causes in this study have been analyzed for the years 2021 to 2023. Approximately 55 to 65 percent of annual fire incidents occur in residential buildings and houses. It should be noted that about 70% of the existing buildings in the city are informal settlements in unplanned areas [17] that lack all kinds of fire safety provisions. Between 15% and 20% of fires have taken place in commercial markets, stores, and individual shops (Figures 5, 11, and 17). Major fire sources/causes are electricity (mainly electrical short circuits), LPG (mainly explosions of LPG cylinders), carelessness with matches and lighters, negligence, cooking, wood stoves, cigarette butts, and others. Approximately 40 to 50 percent of fire incidents in Kabul city are caused by electrical short circuits, faulty electrical equipment, and related sources. LPG-related fires account for about 25 to 30% of the total number of fires. Unknown causes and carelessness with matches and lighters each caused about 5 to 10% of total fires each year 2021 to 2023. Kabul city is highly vulnerable to fire hazards from power sources. Several reasons can be highlighted, such as the development/expansion of the city without accounting for the additional power load being placed on the existing distribution network. In many instances, new power distribution lines are attached to existing power lines that were originally designed for lower capacity. This additional load may be multiple times the capacity at the start of the distribution network. Substandard distribution networks, especially in old markets, exposed wires, aging, and weathering factors, can cause short circuits, which are shown as the main cause of electrical fires. The use of cheap and low-quality electrical appliances such as power distribution units (PDUs), fuses, cables, lights, heaters, and others has also resulted in short circuits. After electricity, LPG (LPG cylinder explosions, leakage, or incidents during unloading and refilling of tankers, and others) has caused the second-highest number of fire incidents in Kabul city. LPG-related fire incidents are concentrated at fuel/gas stations and parking points of LPG/fuel tankers. In residential buildings and houses, LPG fires mostly occur during the winter season when there are more than 10 hours of daily power outages and people

rely on gas for heating and cooking. During winter, electricity is allocated to governmental offices, universities, and business centers.

11.2. Fire Casualty

A total of 62 fire deaths and 289 fire injuries have been reported in Kabul city from 2010 to 2023. On average, based on the reviewed online information from the media, there are about 5 deaths and 21 injuries annually.

Electricity-related fires resulted in 2% of the total fire deaths and 3% of the total fire injuries (Table 8 and Figure 23), while LPG fires caused 69% of the fire deaths and 72% of the fire injuries. LPG and fuel together caused 91% of the fire deaths and 93% of the fire injuries. Essentially, fire deaths and injuries in Kabul city are primarily due to fires caused by LPG/fuel. Although a large number of fire incidents take place in residential buildings, fortunately, a smaller percentage of fire deaths and injuries are caused by these residential fires. Around 16% of fire deaths and about 3% of fire injuries are due to fires in residential buildings and houses. Many fires in residential buildings are relatively small-scale and of reduced severity, resulting in minimal fire casualties. In the past 14 years, 52% of fire deaths and 75% of fire injuries are caused by fires in fuel/gas stations. The high percentage of fire deaths from fuel/gas fires is due to the explosive nature of these materials and the rapid spread of these fires, leaving very little time for evacuation and suppression. In contrast, electricity-related and other fires are more localized in nature, spreading slowly and allowing for evacuation and easier suppression, especially in the initial stages.

It should be noted that not all casualties in a typical fire are a result of direct burns or contact with hot surfaces or objects. During a fire, especially in the pre-flashover phase (from smoldering or flameless combustion to rapid temperature increase), several toxic gases that are highly detrimental to human inhalation, such as carbon monoxide, hydrogen cyanide, and phosgene, are quickly generated from incomplete combustion, burning plastics, and vinyl-based items and materials. The smoke during a fire also contains high concentrations of poisonous vapors and small dust particles, which cause irritation to the eyes, nose, and result in digestive complications. The reduction in oxygen levels from normal quantities due to fire also leads to life-threatening complications in humans. Therefore, smoke results in more fire deaths compared to the actual burning itself [1, 31, 32]. Information on fire and heat can be found in the literature [23].

11.3. Fire economic losses

Approximately 64% of these direct monetary losses are caused by fires initiated by electricity, 14% by fuel/petrol-related fires, and about 10% or less by other types of fires (Figure 26). The high amount of electricity-related fire losses is due to the fact that electricity has primarily caused fires in commercial multi-story buildings and stores. Electricity should always be available at these shopping centers and markets for their operation. Commercial facilities are mostly filled with expensive merchandise, and even small-scale fires can result in huge financial losses. 79% of the total direct monetary losses come from commercial buildings and markets, 20% from fires started at fuel/gas

stations or fuel tankers' explosions, and the remaining 1% from all other structures and facilities (Figure 27). It should be noted that the cost of repairing affected buildings is not included in these figures. The highest amount of economic losses from fires in commercial markets and stores is again due to the fact that fire incidents are economically more destructive in commercial facilities compared to residential buildings, where there is no concentration of assets and property. Even a small number of fires in business hubs are more catastrophic financially compared to the large number of fires in residential areas. Electricity-related fires caused a large amount of financial losses and a small number of casualties, while LPG/fuel-related fires caused a small amount of financial losses and a huge number of casualties compared to electricity-related fires. This is because fires caused by electricity have occurred in facilities with a large concentration of property and assets, such as multi-story markets filled with expensive equipment, carpets, clothes, and jewelry, while fires caused by fuel/gas tankers and cylinders have mostly occurred in open areas such as fuel stations with little property/asset concentration, resulting in fewer economic losses.

11.4. Structural safety of fire-affected buildings

Luckily, most of the commercial multi-story buildings in Kabul city are made of reinforced concrete. Compared to other construction materials such as wood or steel, concrete has good fire-resistant properties. The concrete cover provides protection to the reinforcement cage. However, if the fire is severe and persists for a longer duration, spalling of the cover on the main load-resisting elements can occur. Although rare, spalled cover exacerbates structural safety concerns and can potentially result in the local or even global collapse of the structures.

Mostly, fire-affected structures are re-occupied without undergoing structural safety evaluation and health monitoring. Fire-affected structures that have not been evaluated may sustain life-threatening damages during strong earthquakes. This should be counted as a source of major concern as the city is frequently hit by moderate and strong earthquakes. Already structurally unsound structures can easily sustain large damages and pose threats to the safety of occupants.

12. Summary and Conclusions

In this review paper, the fire hazard, causes of fire incidents, fire casualties, and fire economic losses were investigated for Kabul city. Fire hazards mitigation requires accurate and comprehensive mitigation plans and policies that cannot be effectively made and implemented without knowledge of basic features and statistics of the fire hazard in the city. Therefore, in this study, the available scattered information on fire incidents from various sources was identified, reviewed, categorized, and analyzed to obtain quantifiable measurements of different aspects of fire hazard in Kabul city, leading to the following conclusions:

- The Kabul Firefighting Department has limited resources for fighting fire. Instead of 7, at least 18 firefighting stations are needed for Kabul city.
- The highest number of fire incidents in Kabul city happened in residential buildings (55% to 65%), followed by business markets/stores (15% to 20%).

- 40% to 50% of fire incidents in Kabul city are caused by electricity, while the cause of 20% to 25% of fire incidents is LPG.
- From 2010 to 2023, 62 people were killed and 289 others were injured by fire incidents. LPG and fuel together caused 91% of the fire deaths and 93% of the fire injuries in the city. 52% of fire deaths and 75% of fire injuries are caused by fires in fuel/gas stations.
- On average, from 2010 to 2023, each year fire incidents caused about 11 million US dollars in direct monetary losses. 64% of which are caused by fires initiated by electricity, 23% by fuel/gas, and 11% by other types of fires.79% of the total direct monetary losses come from fires at commercial markets, 20% at fuel stations/tankers, and the remaining 1% from all other structures and facilities.
- Poor or almost completely ignored fire safety provisions, substandard construction with a lack of code consideration, negligence and carelessness, faulty, exposed, and overloaded power distribution networks, lack of public awareness, and others are important causes of increased fire incidents in the city.
- Delays in responding to fire emergencies, congested streets, substandard planning, especially in old markets, security blockades, limited firefighting resources, and lack of coordination between firefighters result in increased damages and fire spread.
- Buildings affected by fires are reoccupied without structural safety evaluations. Future natural hazards, such as earthquakes, can result in large-scale damages and casualties in these affected structures.

Recommendations

Based on the findings presented in the review paper, several recommendations can be made to mitigate the fire hazard and improve fire safety in Kabul city:

1. Increase firefighting resources: The current number of firefighting stations and personnel in Kabul city is insufficient to effectively respond to fire incidents. It is recommended to establish at least 18 firefighting stations and allocate additional personnel and firefighting vehicles to enhance the city's firefighting capabilities.
2. Enhance fire safety in residential buildings and business markets/stores: Given that the majority of fire incidents occur in residential buildings and business markets/stores, it is crucial to focus on improving fire safety measures in these structures. This can include enforcing building codes, conducting regular inspections, and promoting fire safety education among residents and business owners.
3. Address electrical and LPG-related fire risks: Electricity and LPG are identified as significant causes of fire incidents. Efforts should be made to ensure proper electrical installations, regular maintenance, and adherence to safety protocols in residential and commercial buildings. Additionally, promoting safe handling and

storage practices for LPG can help reduce fire incidents caused by this fuel source.

4. Strengthen fire safety at fuel/gas stations: Fuel/gas stations pose a high risk for fire incidents, resulting in a significant number of casualties and economic losses. It is crucial to implement stringent safety measures, conduct regular inspections, and provide appropriate training to station operators and staff to prevent accidents and mitigate potential damages.
5. Improve coordination and response time: Delays in responding to fire emergencies and lack of coordination between firefighters can lead to increased damages and fire spread. Enhancing communication systems, establishing efficient protocols for emergency response, and conducting regular drills and training exercises can improve the overall effectiveness of firefighting operations.
6. Implement and enforce fire safety regulations: The study highlights poor fire safety provisions, substandard construction practices, and a lack of public awareness as contributing factors to increased fire incidents. It is essential to enforce strict fire safety regulations, ensure compliance with building codes, and raise public awareness about fire prevention and response through educational campaigns.
7. Conduct structural safety evaluations after fires: Buildings affected by fires should undergo thorough structural safety evaluations before being reoccupied. This is particularly important to protect occupants from potential hazards during future natural disasters such as earthquakes.

By implementing these recommendations, Kabul city can significantly reduce the occurrence of fire incidents, minimize casualties and injuries, and mitigate the economic losses associated with fires. It requires a collaborative effort from government authorities, firefighting departments, building professionals, and the public to create a safer environment for the residents of Kabul.

The scope of this study was limited to Kabul city only. Future study shall be conducted on fire hazards in other major cities or the country as a whole.

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Abbreviations

AFG	Afghanistan
GDP	Gross domestic product
Inh.	Inhabitants
KPU	Kabul Polytechnic University
LPG	Liquid Petroleum Gas
PDU	Power Distribution Unit
USD	United States Dollar
VIIRS	Visible Infrared Imaging Radiometer Suite

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Appendix A
Links of the online media reviewed for information on fire hazard in Kabul city 2010-2023

Year	Link
2010	http://www.afghanpaper.com/nbody.php?id=17109
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2011	http://www.afghanpaper.com/nbody.php?id=20196
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