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Investigation on Fire Protection System of Highrise Buildings in the Context of Bir Uttam Aminul Haque Avenue in Dhaka, Bangladesh

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Abstract

Rapid high-rise building construction of different occupancies is becoming popular in Dhaka due to its economic gain and functional flexibility. Fire prevention poses a significant difficulty to this type of construction due to its complexity and economic worth as well. Therefore, construction of high-rise building without following the proper fire safety measures, is a common practice at present in the city and it poses a greater threat to urban life considering its associated loss. Even though, most of the owners or authorities do not respect the construction code and the majority of them lack sufficient awareness and basic fire control knowledge and practice. More often, they are unable to comprehend the magnitude and severity of severe fire hazards, and recognize the causes and implementing effective mitigation measures are rare. As a result, the number of fire hazard in high-rise construction is increasing day by day. Hence, investigating the present condition of high-rise buildings (already built) in terms of Fire Protection System is imperative to prevent the upcoming fire hazard. An urban chunk of 33 plots along with Bir Uttam Aminul Haque Avenue, located in Banani, has been chosen for the study area considering its vulnerability to fire hazard. Among these buildings, STAR Tower and HBR Tower, these two high-rise buildings are assessed thoroughly using FRI (Fire Risk Index) Method. The method is semi-quantitative in nature with seventeen parameters associated with fire protection. This assessment represents a scenario in what extent fire codes are being followed in the selected area. It concludes that most of the buildings lack in providing protection against fire hazards for not following the code strictly. This research provides some recommendations which can be followed to improve the fire safety measures in this existing context. It is expected that this research could be a unique addition to firefighting knowledge by contributing to mitigating the consequences of fire related hazards in any densely populated city like Dhaka.

Keywords

Fire Hazard, Fire Safety, High-Rise Buildings, Fire Protection, Fire Risk Index

1. Introduction

Due to certain critical social and economic necessities, the number of high-rise structures has steadily expanded in all areas of the world, owing to technical advancement and scientific advances [1]. Rising urban land prices, technological advancement, and population expansion are some of the factors driving developers' preference for high-rise structures [2]. Air circulation, illumination, and the ease of movement provided by elevators and lifts have given high-rise dwellers the same level of comfort as those in low-rise structures. Despite being built in various locations of the city, the majority of these structures lack proper fire safety and emergency exits [3]. A high-rise structure has intrinsic, intractable issues in addition to standard fire prevention challenges in many occupancies. There are challenges such as inaccessibility by fire equipment due to height; stair egress and smoke stack effects; discordant fire safety management within and between different floors; re-designing and changes from initial intended use; and complex vertical utility services, particularly the heating ventilating and air conditioning conduits (HVCAs).

Many more individuals have been killed or wounded as a result of fires and smoke in high-rise buildings throughout the world. Because of the engagement of a large population in commercial, industrial, and other activities, urban areas across the world are more sensitive to fire hazards. The occurrence of urban fires is frighteningly growing throughout Bangladesh, particularly in bigger metropolitan areas. Dhaka City is now confronting this threat as a result of the uncontrolled development of high-rise structures in the name of urbanization to accommodate the municipal's ever-growing population and the lack of proper safety measures in the city system. Except in a few cases, the majority of these buildings are being built without taking into account the hazard of fire and earthquake as specified in the BNBC [4]. This technique calls into question people's safety from fire threats. According to a 2012 research conducted by the Bangladesh University of Engineering and Technology, the majority of high-rise buildings in Dhaka have insufficient fire protection systems. Furthermore, fire safety procedures in those structures were extremely lax; there were no sprinklers, and fire exits only existed in name. Furthermore, after multiple inspections, it was discovered that the fire stairs were obstructed with stored products and the exit doors were locked [5].

According to a Star Weekend investigation, barely one percent of fire occurrences is ever mentioned in the media. According to the Fire Service Department's data from the previous three years, there are 43 fire occurrences every single day that require firemen to respond to. Some fires have recently occurred at Banani. Because of violations of setback and height limitation restrictions, an increasing number of high-rise commercial buildings are transforming the region into a high-class slum, causing issues such as dampness, shade, disruption of air flow, turbulence of air flow, chillness, and so on [6]. On 28 March 2018, FR Tower fire incidence at Banani, took away 25 human lives and caused many more injuries and damages. According to the Bangladesh Fire Service and Civil Defense, the emergency exit doors on numerous stories of the FR Tower were locked, making escape impossible for many after the fire broke out. Several victims were found dead at the closed escape points after being trapped. Some doors were unlocked, but the hallways were jam-packed with piled-up items. Furthermore, the building's emergency staircase was just 36 inches wide, which was insufficient for a 22-story skyscraper. It is also worth noting that this was not the building's first fire. At least three fires broke out here, including the most recent. The hazards were so great that the Fire Department actually addressed two letters to the building authority in 2017 and 2018 highlighting the inadequacy of fire protection measures in the building [7].

Following the fire at the FR Tower, the HC bench of Justice Syed Refaat Ahmed and Justice Md Iqbal Kabir Lytton issued an order and rule in response to a petition filed by Gulshan Society Secretary General Barrister Sarwar Siraj Shukla challenging the legality of constructing buildings in Dhaka without adequate fire safety measures. Experts in fire safety discovered that the commercial high rise lacked a secure fire escape [8]. A correctly planned fire exit is supposed to keep a person safe from fire, heat, and smoke, but things were different at the Banani building. Following the Gulshan market incident in January 2017, the fire service agency discovered that nearly all of the capital's Banani and Gulshan commercial high rises lacked an authorized fire safety plan [8]. RAJUK has renewed its campaign to check safety measures at multi-story buildings for a third day in the aftermath of the fire at Banani's FR Tower, and has identified three high-rises at danger of fire hazard: the 23-story Iqbal Center, the 21-story BULU Ocean Tower, and the 16-story Delta Dahlia. Before RAJUK's inspection, the fire department had already designated the two high-rises as having a high danger of catching fire. The majority of the buildings lack an emergency escape. Even the vast majority of existing emergency exits are inoperable [9] (**Figure 1**).

Figure 1. FR Tower Fire hazard at Banani (source: Monirul Alam, Apurbo Chowdhury).

Despite the many procedures, laws, and regulations put in place over the years, there are still multiple cases of fire outbreaks in high-rise structures each year, resulting in major losses of lives, livelihoods (through injuries), equipment, and materials [10]. There is a dearth of data on fire safety, as is true in any developing nation, and very few studies have been undertaken in Bangladesh addressing the fire safety of high-rise structures. There has previously been no systematic fire safety evaluation of high-rise structures. Therefore, aim and objective of the study is

- To understand the importance of fire safety codes in High-rise construction.
- To identify the different fire safety rules & regulations for High-rise buildings.
- To analyze the existing fire safety scenario of selected case studies.

2. Literature Review

2.1. High-Rise Buildings in Dhaka

A high rise building has more than 6 floors or a height of at least 20 meters, according to the BNBC 2006 [11]. Early structures ranged in height from 9 to 11 storeys. Then several 15 - 20 story buildings were developed. Today, the bulk of buildings are 15 to 24 stories tall [12]. A highrise building is defined by the National Fire Protection Association as one that is taller than 75 feet (23 meters) measured from the lowest level of fire department vehicle access to the floor of the highest occupiable storey [13]. According to experts, most high-rise structures in Dhaka lack fire protection precautions, which might result in large casualties in the event of a fire. Dhaka now has over 4000 high-rise buildings, the most of which are located in the capital's newer and more affluent districts. According to Islam and Hossian (2018), the majority of fire threats were caused by an electric short circuit [14] (**Figure 2**).

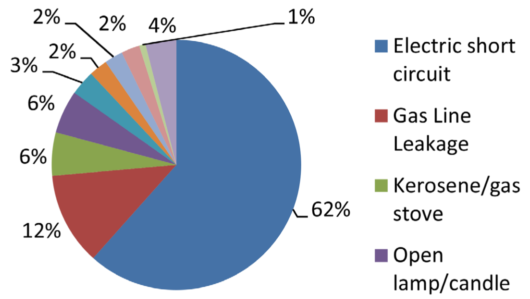

Figure 2. Common fire hazards reasons in Dhaka city (source: Islam & Hossain, 2018).

2.2. Safety Measures for High-Rise Buildings

2.2.1. Means of Escape

A means of escape is an evacuation system with reentry provisions for rescuers and fire fighters, in which a continuous and unobstructed way of exit travel shall be provided from any point within a building to a designated area of refuge for allowable delayed evacuation and ended with the exit termination by reaching a street abutting building or plot or a safe area which is open to air and designated assemblies for evacuees. The path of exit travel within a building from any point along a route of egress should be divided into three sections: 1) exit access, 2) exit, and 3) exit discharge (**Figure 3**).

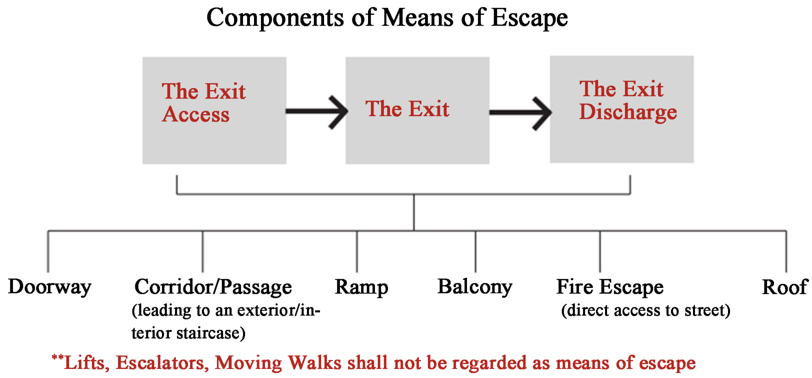

Figure 3. Components of means of escape.

- Stairways

The minimum width of the stairways for occupancy B should be 1.5 m when the occupant load is less than 150 and 2.0 m when the occupant load is greater than 150. (Table: 4.3.3, BNBC 2006) [15]. Stairways used as a means of escape must have handrails on both sides. All exit stairways must be made of fire-resistant materials. Exit stairways must not be erected around lift shafts unless the lift shaft enclosure is substantial and composed of fire-resistant material. A smoke-proof enclosure is made out of an inside stairwell, an exterior balcony, or a ventilated vestibule. The width must be at least 1.1 m. The minimum length is 1.8 m. The walls dividing the smoke proof enclosure must have a minimum fire resistance rating of 4 hours (**Figure 4**).

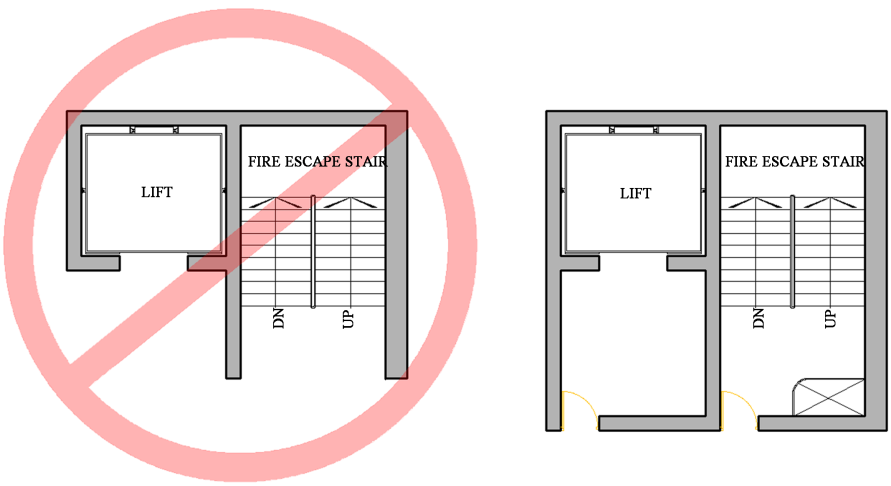

Figure 4. Fire stair.

- Door Ways

There must be at least one exit or exit access door in each room (Figure: 01). The exit door should be of the side swing variety (Figure: 01). Maximum passenger load for Occupancy B is 50, and travel distance for spaces with one exit door is 23 (Table 4.3.3). When the occupant load exceeds 50, the door must swing outward from the chamber. In educational buildings, no sliding, hanging, or revolving doors may be utilized as a route of escape (section 3.9.7, BNBC

2006) [15] (Figure 5).

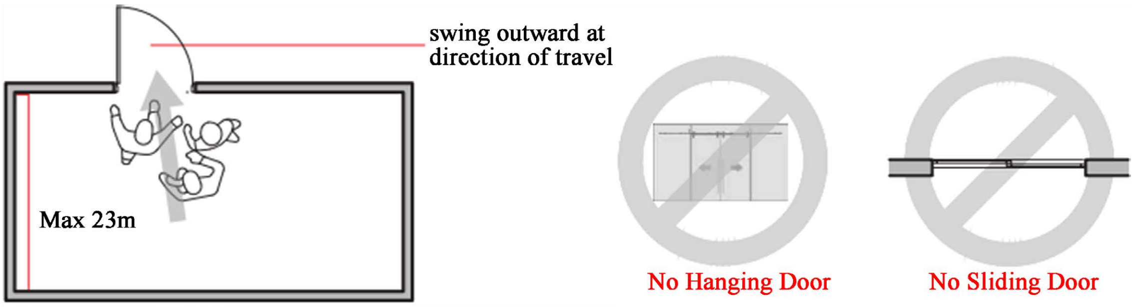

Figure 5. Exit door.

- Ramp

An exit ramp's slope must not exceed 1 in 8, but slopes steeper than 1 in 10 must be paved with certified non-slip material. Both sides of the ramp should have handrails.

- Corridor/Passageway

All escape access corridors must have a fire resistance rating of 1 hour or above. The width of the corridor is determined by the occupant load (Figure 6 & Figure 7).

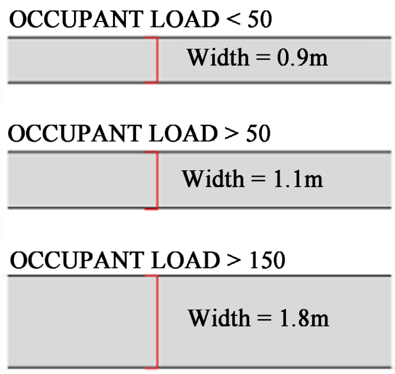

Figure 6. Occupant load & corridor width ratio.

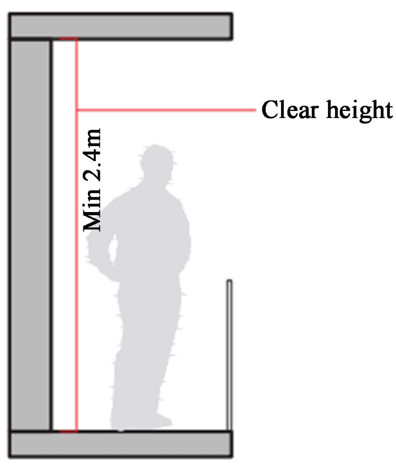

Figure 7. Clear Height of the corridor.

- Length of Travel

Exits must be positioned so that the travel distance from any location in the service area does not exceed 25 m for occupancy B (section 3.15.1, BNBC 2006) [15]. When more than one exit is necessary in a structure, they must be situated as far apart as feasible. Every floor, including the basement, of a commercial or industrial structure must have at least two exits.

- Exit

All structures taller than 20 meters and with a floor area greater than 500 square meters on each level must have at least two enclosed stairs that go directly to the outdoors or the designated space for refuge (Figure: 5). The number of exits is determined by the occupancy load (**Table 1**).

Table 1. Occupant load & number of exits for all buildings (section 3.14.3, BNBC 2006) [15].

Occupant Load	Number Of Exits
500 Occupant Load	Minimum of two exits
501 to 1000 Occupants	Minimum of three exits
More than 1000 Occupants	Minimum of four exits

2.2.2. Fire Detection System

- Fire Alarm System

All structures taller than 20 meters must have a manually controlled electrical fire alarm system as well as an automatic fire alarm system (D17.1, BNBC draft-2015) [16]. Any educational facility with more than two stories must have a manually operated electric fire alarm system (section 5.3.2. BNBC 2006) [15]. The stairwell must have a pressure sensitive automatic fire alarm system installed. The stair roof must be 1 meter above the surrounding roof level. A manually operated electrical alarm system with single or multiple call boxes on each floor must be placed in a building.

- Sprinkler System

The National Planning and Building Regulations, 2014, regulation SS 37, include the legal provision for the provision of an automated water suppression system [17]. With limited exclusions, the Regulation mandates that any structure above 30 meters in height or a basement level of more than 500 m^2 or any other storey exceeding 500 m^2 in total floor area and not supplied with breakable or openable panels be equipped with an authorized sprinkler system. Under the ceiling, sprinkler heads are positioned in a grid pattern. Each sprinkler covers a maximum ceiling area (roof) of 20 square meters. 4.2.4 (BNBC, table: 4.4.6, 4.4.7) [15].

- Heat Detectors

It must be installed between 25 and 150 mm above the ceiling. When the ceiling is spanned by beams or girders with a depth of 250 mm or more to form compartments, detectors must be installed in each compartment. At least one must be positioned within 1.5 meters of hoists, elevators, stairways, wall holes, and other similar openings.

- Smoke Detectors

It should be utilized in enclosed environments with temperatures ranging from 0 to 35˚C and installed such that the sensing elements are between 25 and 100 mm from the bottom of the roof. Buildings with a height of more than 20 meters must have a manually operated electrical fire alarm system as well as an automatic fire alarm system.

2.2.3. Fire Protection

- Fire Lift

In the event of an emergency, one or more elevators must be expressly developed and maintained for the use of firemen. The lifts must be constructed to reach the top levels and be directly accessible from each floor to every home or fire personnel. Load carrying capacity is 545 kg (8 people), with a minimum floor size of 1.4 square meters and an auto closing door. The power supply should be isolated from the main power source. If the usual power supply fails, it should automatically switch to an alternate power supply. This may be performed with a manual switch. Electric wire might be used to raise the lift vehicle to ground level with the door open. The elevator speed must be fast enough to reach the top floor from ground level in one minute (**Figure 8**).

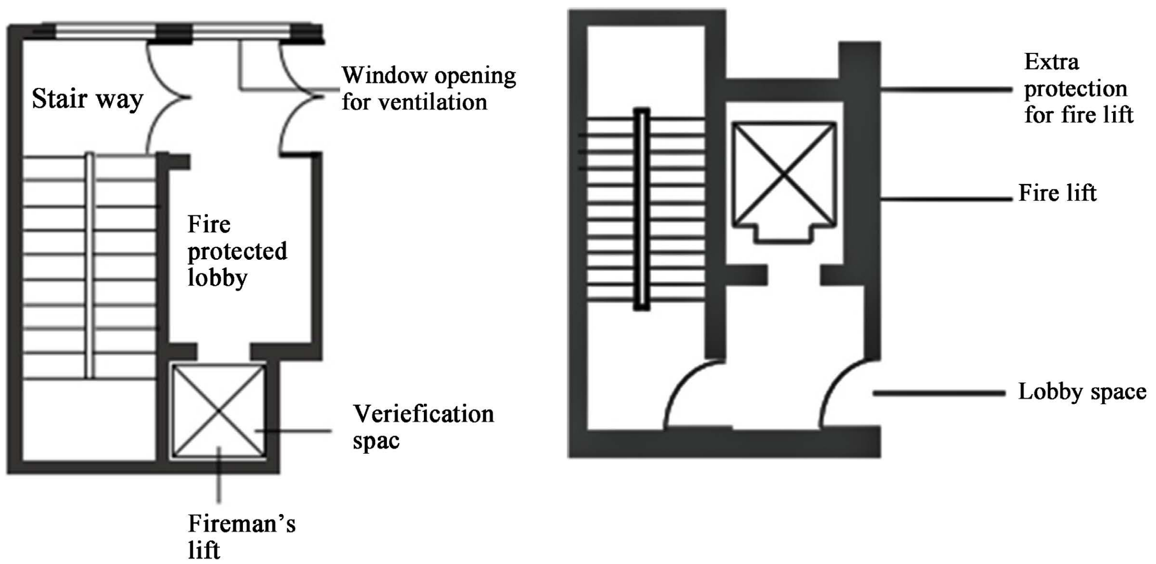

Figure 8. Fire lift.

- Refuge Area

Except for multi-family dwellings, all other structures must provide a provision for refuge area on the external walls in the form of a cantilever projection or another acceptable method. At the height specified below, the refuge area should not be less than 15 sqm.

1) Floors between 20 and 26 m—one refuge space immediately above 20 m.

2) Floors above 26 m—one refuge area immediately above 26 m and then one refuge area every five floors above 26 m.

- Fire Extinguishing System

It should be situated along the exit travel path and easily accessible. Depending on the intensity of the fire, fire extinguishers should be selected. The most typical extinguishers can be portable or stationary.

- ➢ Foam Extinguishing System
- ➢ Carbon Dioxide Extinguishing System
- ➢ Halogenated Extinguishing System
- ➢ Dry Chemical Extinguishing System
- ➢ Wet Chemical Extinguishing System
- ➢ Portable Fire Extinguisher

- Mains, Hose Reels and Hydrants

The National Planning and Building Regulations, 2014 include provisions for riser mains, hose reels, and hydrants for fire protection [17]. Part 1 to 7 of Regulation SS35.1 requires hoses to be installed in any building of two or more storeys in height or in any single storey building of more than 250 m^2 in floor area at a rate of one hose reel for every 500 m^2 or part thereof of floor area of any storey. Regulation SS36.1 mandates them to be installed in any structure taller than 12 meters. The Fire Risk Reduction Rules, Rule No. 29 (1), require occupiers to provide methods of extinguishing fires at the workplace, while Section (4) mandates that, if fire hose reels are supplied, occupiers guarantee that at least one fire hose reel is within a radius of 30 meters [18].

- Fire Brigade Access and Facilities

Rule SS57 provides for fire brigade access and facilities. Section (1) of the regulation states that no building must be built on any site unless such site is supplied with sufficient access for the purposes of firefighting and rescue by the local authority's Fire Services.

- Staircase & Corridor Lights

The stairwell and corridor lights must be linked to a separate independent circuit so that in the event of an emergency, firefighting personnel may activate them from a readily accessible point on the bottom level, regardless of individual management of light options. Staircase and corridor lights must also be linked to an alternate power supply. Staircases and corridors must have emergency lighting (Appendix D 12.4, BNBC 2006) [15].

- Construction Materials

All load-bearing components, such as stairwells, corridors, and facades, must be made of noncombustible materials. Internal staircase walls must be composed of bricks or reinforced concrete with a minimum fire rating of two hours. The use of glass or fire bricks in the stairwell is not authorized. Inner finish materials will be limited to frame spread ability class I materials. (BNBC, Part-4 Appendix D 2.1, D 2.2, and D 2.4) [15].

- Command Station

All buildings above 26 meters in height must have a command center in the entry lobby with a sufficient public address system capable of communicating with all floors and receiving messages from all doors. The command station must have detailed floor plans as well as clearly designated places for fire detection and fire-fighting services, and it must be capable of detecting fire alarms from any floor via the panel board (Appendix D18, BNBC 2006) [15].

- Fire Officer/Care Taker

Buildings taller than 53 meters must maintain one trained fire officer on duty around the clock. He is responsible for keeping firefighting equipment in proper functioning order at all times (Appendix D19, BNBC 2006) [15].

- Fire Drills

In the event of a fire or other disaster, fire alerts or orders must be prepared to meet the standards for firefighting and evacuation. Such alerts and directions must be placed in such a way that the inhabitants are well aware of the necessary action in the case of an emergency. Half-yearly fire drills are conducted at educational (schools, colleges, and universities) high-rise structures (BNBC Drfat-2015, appendix A, page: 4-59) [16].

- Fire Protection Plan

A fire protection plan is required for high-rise buildings or building parts 33 meters or above in height (BNBC Draft 2015, part 4, chapter 5, page 4-46) [16]. The plan must include information such as the building address, height in meters, occupancy rating, and occupant load details. All floors, exits, corridors, partitions functioning as fire separations or compartments, locations and ratings of mandatory enclosures, windowless stair with pressurization, exit discharge, frontage space locations including street width of adjoining land are included on the Key Plan (BNBC Draft 2015, part 4, chapter 5, page 4-47) [16].

3. Methodology

3.1. Selection of the Study Area

Banani is a high-end residential district with a large number of residential high-rise buildings that are being converted over time for various commercial land uses such as offices, schools, colleges, private institutions, stores, banks, clinics, and other public services. Among the urban chunks at Banani, Bir Uttam Aminul Haque Avenue with total 33 plots on both sides has been chosen as the study area since a number of fire occurrences have recently been taken place during the last few years. This is the first high-rise chunk in the urban area and Fire service department has recently marked this chunk as fire risk zone. For time and resource Limitations, among 33 buildings only two buildings selected for thorough investigation. These two buildings are STAR Tower and HBR Tower and these buildings are selected based on the following criteria:

1) Highrise buildings: Both buildings heights are above 33m.

2) Occupancy Load: Maximum user in per sqm gross area since both are of occupancy type B.

3) Location: Minimum one building from each side (**Figure 9**).

Figure 9. Google earth view of the selected urban chunk.

3.2. Method

Conducting research on fire risk analysis for structures is difficult yet necessary. There are several techniques for doing risk assessments on various types of structures. However, most of devices are difficult to use and need extensive understanding of fire and building structures. A rigorous quantitative risk analysis is also expensive and time consuming. A semi-quantitative risk technique, such as risk indexing, is effective in this scenario since it is straightforward to use and offers a quick and simple evaluation of relative fire hazards in buildings by rating various factors. Despite its lack of truth, it might be useful in making judgments concerning building fire safety [19].

For these reasons, the FRI (Fire Risk Index) technique was used for this investigation. Although the approach was developed primarily for timber-frame multi-story apartment complexes in European nations, it may also be used to evaluate concrete structures (Larsson, 2000). The technique includes 17 parameters (**Table 2**), each with a specific weight and changeable grade, to eventually construct a relationship between them using the following formula [11].

$$S = \sum_{i=1}^{n} w_i x_i$$

where S is the fire safety risk index, "W_i" is the weight for parameter "i" and "X_i" is the grade for parameter "i". The weight ranges from 0 to 1, whereas the grade ranges from 0 to 5. As a result, the final score ranges from 0 to 5. A score of 5 indicates the highest level of fire safety in a structure, while a score of 0 indicates the lowest level of fire safety [19] (**Table 2**).

Table 2. 17 Parameters introduced in the FRI method (Larsson, 2000) [20].

Sl No.	Parameter	Sub-Parameter			
		Name	Weight	Description	Weight
P_1	Linings			Possibility of internal linings in an apartment to delay the ignition of the structure and to reduce fire growth	0.0576
P_2	Suppression System			Equipment and systems for suppression of fires	0.0668

Continued

P_3	Fire Service	Capability Response Time Accessibility & Equipment	0.31 0.47 0.22	Possibility of external agencies to save lives and to prevent further fire spread	0.0681
P_4	Compartmentation			Extent to which floor areas are divided into fire compartments	0.0666
P_5	Structure-Separating	Integrity & Insulation Firestops at joints, intersections & concealed spaces Penetrations Combustibility	0.335 0.28 0.24 0.13	Heat, smoke and fire resistance of building assemblies separating fire compartments	0.0675
P_6	Doors	Doors leading to escape route Doors in escape route	0.67 0.33	Fire and smoke separating function of doors between fire compartments	0.0698
P_7	Windows			Windows and protection of windows, *i.e.* factors affecting the possibility of fire spread through the openings	0.0473
P_8	Façade	Combustible part of façade Combustible material above windows Void	0.41 0.30 0.29	Facade material, suppression system etc., *i.e.* factors affecting the possibility of fire spread along the façade	0.0492
P_9	Attic			Prevention of fire spread to and in attic	0.0515
P_{10}	Adjacent Buildings/ Surroundings			Minimum separation distance from other building	0.0396
P_{11}	Smoke Control System			Equipment and systems for limiting spread of toxic and corrosive fire products	0.0609
P_{12}	Detection System			Equipment and systems for detecting fires.	0.0630
P_{13}	Signal System			Equipment and systems for transmitting an alarm of fire	0.0512
P_{14}	Escape Routes	Types of escape routes Dimensions and layout Equipment Linings and floorings	0.34 0.27 0.16 0.23	Adequacy and reliability of escape routes	0.0620
P_{15}	Structure Load Bearing	Load bearing capacity Combustibility	0.74 0.26	Structural stability of the building when exposed to a fire	0.0630
P_{16}	Maintenance & Information	Maintenance of fire safety systems Inspection of escape routes Information	0.40 0.27 0.33	Inspection and maintenance of fire safety equipment, escape routes etc. and education of occupants in suppression and evacuation	0.0601
P_{17}	Ventilation System				0.0558
				SUM	**1.0000**

4. Analysis & Findings

4.1. Star Tower

Star Tower is located at the north side of the Bir Uttam Aminul Haque Avenue. It is 16 storied building. According to Section 2.1.2 in Chapter 3, these are of occupancy type BI (educational facilities). As the building height is more than 33 m, provision of fire stair is a must. There is only one staircase that shares the common lobby space with lifts which will act as a potential smoke well during any fire hazard (**Figure 10**). There is no refuse area or fire protected zone except the roof which remains locked most of the time. Though it is a RCC building, flammable wooden particle boards are used as interior partition wall. Except portable fire extinguishers at each level, there is no other fire protection and detection system.

Figure 10. Plans of star tower.

4.2. HBR Tower

HBR Tower is located at the south side of the Bir Uttam Aminul Haque Avenue. It is 17 storied building. According to Section 2.1.2 in Chapter 3, occupancy type of the building is BI (educational facilities). As the building height is more than 33 m, provision of fire stair is a must but there is no fire stair at all. There are two staircases. One shares the common lobby space with lifts which will act as a potential smoke well during any fire hazard and other one is very narrow (width hardly 3 feet) which is piled up with goods. There is no refuse area or fire protected zone except the roof which remains locked most of the time. Though it is a RCC building, flammable wooden particle boards are used as interior partition wall. This building has some provisions of firefighting appliances. Portable fire extinguisher, fire alarm and fire hose reel box are located at each level (Figure 11 & Figure 12).

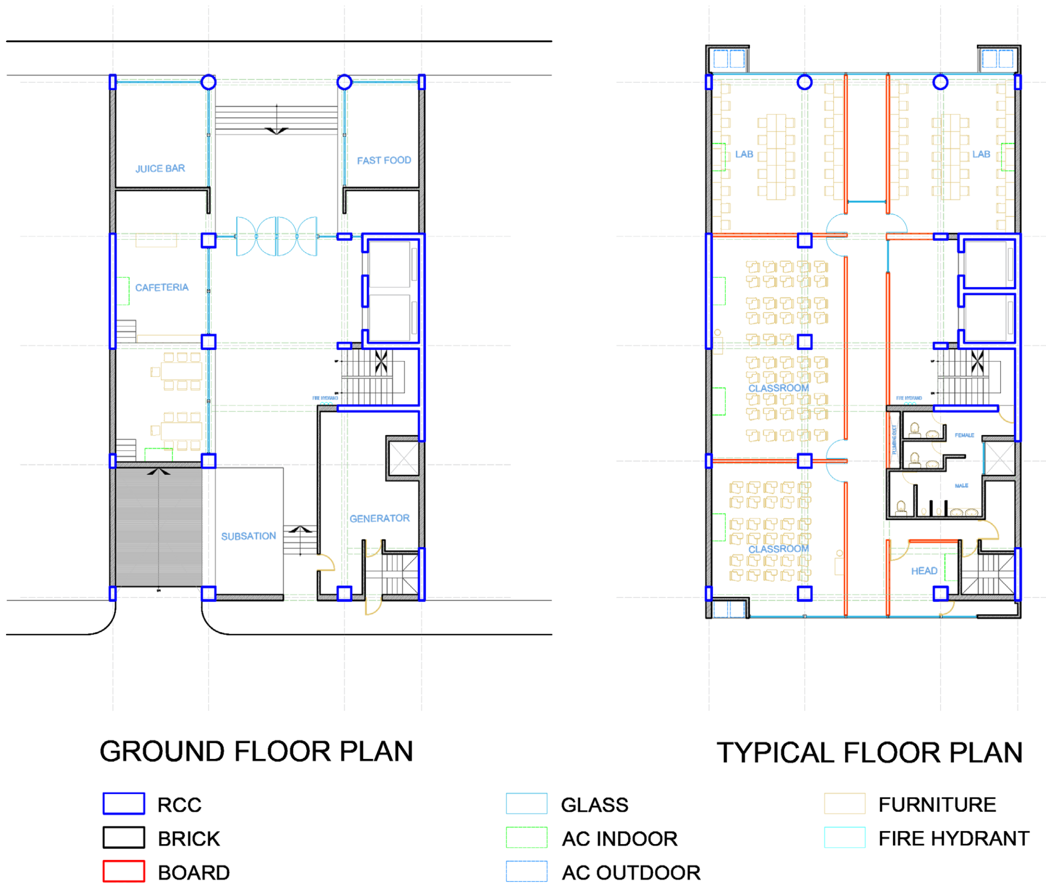

Figure 11. Plans of HBR tower.

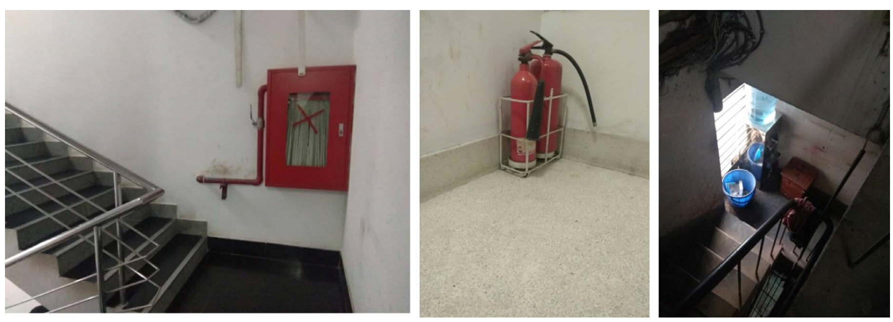

Figure 12. Firefighting appliances & additional escape route at HBR tower.

4.3. Fire Index Calculation

The fire risk index score for Star Tower is 1.5196 (Table 3) and for HBR Tower is 2.1522 (Table 4) which is about 0.6 higher than for the Star Tower building. Provision of fire alarm, fore hose reel box and additional staircase increase the fire index grade of HBR Tower. Despite considering the existing condition, fire index grade still can be increased by introducing more firefighting appliances and other changes according to code for achieving better fire protection system.

Table 3. Fire risk index calculation of STAR tower.

Parameters	Grade for sub parameters	Final Grade	Weight	Weighted Grade
P_1	1		0.0576	0.0576
P_2	2		0.0668	0.1336
P_3	0.31 × 4 + 0.47 × 4 + 0.22 × 4	4	0.0681	0.2724
P_4	0	0	0.0666	0
P_5	0.35 × 0 + 0.28 × 0 + 0.24 × 1 + 0.13 × 1	0.37	0.0675	0.0250
P_6	0.67 × 1 + 0.33 × 0	0.67	0.0698	0.0468
P_7	2	2	0.0473	0.0946
P_8	0.41 × 4 + 0.30 × 3 + 0.29 × 1	2.83	0.0492	0.1392
P_9	1	1	0.0515	0.0515
P_{10}	1	1	0.0396	0.0396
P_{11}	1	1	0.0609	0.0609
P_{12}	0	0	0.0630	0
P_{13}	0	0	0.0512	0
P_{14}	0.34 × 2 + 0.27 × 3 + 0.16 × 1 + 0.23 × 2	2.11	0.0620	0.1308
P_{15}	0.74 × 4 + 0.26 × 4	4	0.0630	0.2520
P_{16}	0.40 × 2 + 0.27 × 1 + 0.33 × 2	1.73	0.0601	0.1040
P_{17}	2	2	0.0558	0.1116
			SCORE:	**1.5196**

Table 4. Fire risk index calculation of HBR tower.

Parameters	Grade for sub parameters	Final Grade	Weight	Weighted Grade
P_1	1		0.0576	0.0576
P_2	4		0.0668	0.1336
P_3	0.31 × 4 + 0.47 × 4 + 0.22 × 4	4	0.0681	0.2724
P_4	0	0	0.0666	0
P_5	0.35 × 0 + 0.28 × 0 + 0.24 × 1 + 0.13 × 1	0.37	0.0675	0.0250
P_6	0.67 × 1 + 0.33 × 0	0.67	0.0698	0.0468
P_7	2	2	0.0473	0.0946
P_8	0.41 × 4 + 0.30 × 3 + 0.29 × 1	2.83	0.0492	0.1392
P_9	1	1	0.0515	0.0515
P_{10}	1	1	0.0396	0.0396
P_{11}	1	1	0.0609	0.0609
P_{12}	4	4	0.0630	0.2520

Continued

P_{13}	4	4	0.0512	0.2048
P_{14}	0.34 × 4 + 0.27 × 3 + 0.16 × 1 + 0.23 × 2	2.79	0.0620	0.1730
P_{15}	0.74 × 4 + 0.26 × 4	4	0.0630	0.2520
P_{16}	0.40 × 2 + 0.27 × 1 + 0.33 × 2	1.73	0.0601	0.1040
P_{17}	2	2	0.0558	0.1116
			SCORE:	**2.1522**

5. Recommendations

5.1. Macro Scale

In our study area, the buildings are located very closely without leaving the required setback areas as per BNBC code (**Figure 13**). Most of the buildings have only one staircase which is not appropriate enough to serve the high-rise buildings. Even these staircases are not properly designed as fire stair according to code. Rather, these staircases along with the lobby spaces act as smoke well during any fire hazard. In the present context of the selected area, required number of means of escape can be ensured by introducing horizontal connectivity between the refuge floors of the adjacent buildings. Refuge area should be incorporated in each building besides this horizontal connection (**Figure 14**). Stair door of roof area should be open for 24 hours.

5.2. Micro Scale

Some recommendations are given below to improve the fire protection system of the selected buildings at micro scale level.

BNBC (Bangladesh national building code) and BCR (building construction regulations) design and construction guidelines should be carefully observed. All existing high-rise structures should be inspected by relevant authorities, and all owners should be subject to BNBC.

- Each high-rise building must have minimum two staircases according to BNBC 2006 [15]. Between these two staircases, one staircase must be designed as fire stair which can acts as a potential escape route during any fire hazard.
- Fire detection system (sprinkler system and fire alarm) should be made mandatory for high-rise buildings. First aid firefighting appliances should be provided and installed.
- The road that will be built next to a high-rise structure should be wider than 30 feet to provide fire trucks easy access.
- Fire lift should be installed in high-rise buildings so that during any fire hazard, fire man can easily perform his rescue operation.
- Noncombustible materials should be chosen for the construction of high-rise buildings. In recent time, flammable wooden particle boards are widely used for interior decoration purpose which should be highly prohibited. Materials of high fire rating should be used in the fire protected zones as per BNBC.

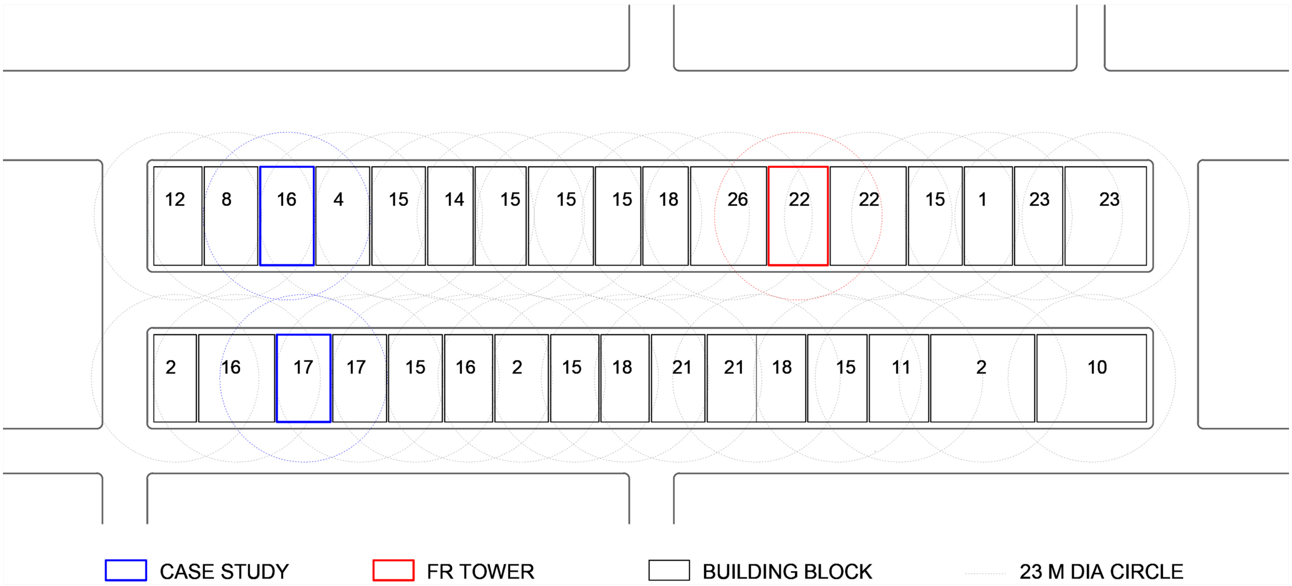

Figure 13. Building heights of the selected area and fire safety radius.

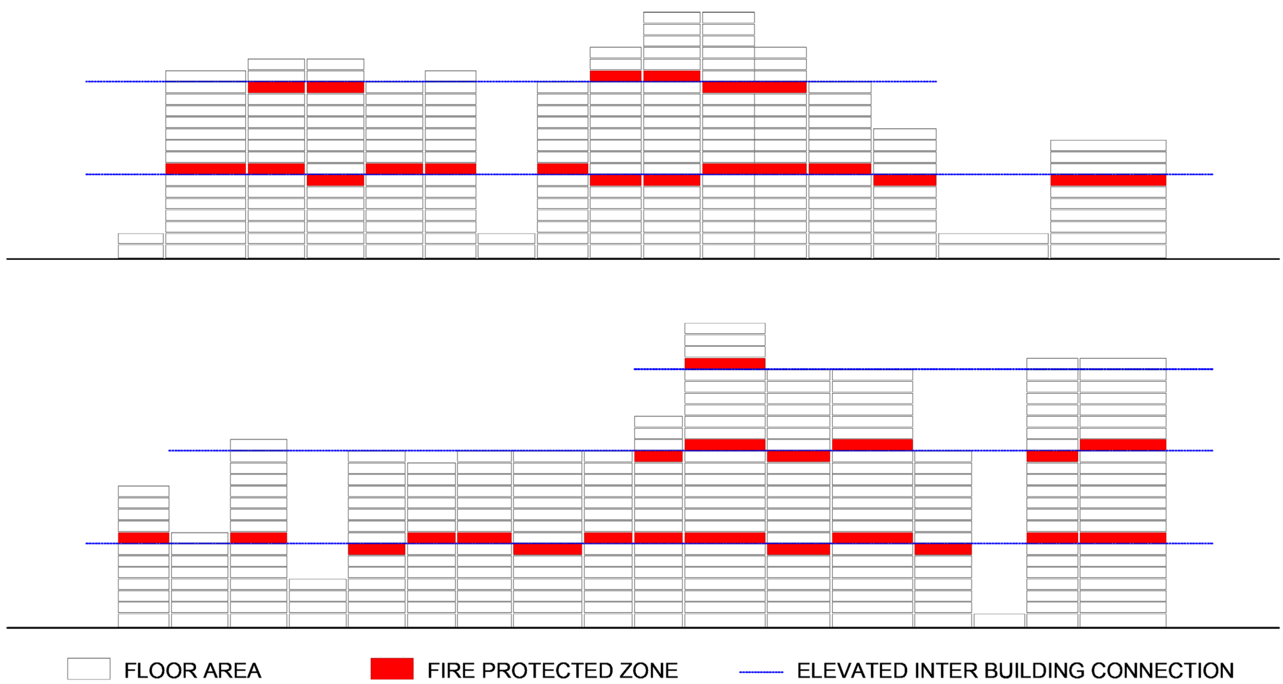

Figure 14. Possible horizontal connection between the fire protected zone.

6. Scope for the Future Research

Bangladesh is very vulnerable to natural calamities such as earthquakes, floods, and fires due to its geographical location. Furthermore, a large population, unplanned and illegal constructions, as well as inadequate utility management and ignorance, contribute to the large number of disasters. Therefore, post-operative risk assessment of earthquake can be a crucial one to be researched for this study area. Moreover, the selected study area has been suffering from lots of problems like lake of parking space or any disaster evacuation path. Elevated urbanism might be a good solution to overcome these problems which poses the scopes for the future research.

7. Limitations

This study focuses solely on fire safety considerations for high-rise structures in the chosen area. To evaluate the inquiry, no public input is taken into account. More time and money are required to analyze more high-rise structures in order to have a more complete picture of fire safety in our country. Considering the amount of structures in Dhaka alone, assessing only a handful is insufficient. However, it is favorable that the majority of buildings in our nation are built in a similar manner.

8. Conclusion

In recent years, fires have occurred often in various high-rise buildings in Bangladesh, resulting in a considerable number of fatalities and property damage. It is concerning that similar incidents continue to occur in highrise structures. Because individuals cannot quickly exit high-rise structures, there are higher losses of life. Second, fighting fires in high-rise structures is difficult. Third, damages may be greater if a fire occurs in a high-rise structure since there is nothing left. When such events occur regularly, a thorough investigation is required to determine the cause. The fundamental issue is that there are no active fire prevention systems or alternate escape routes in the structure. Bangladesh National Building Code includes a single section dedicated to providing fire safety rules for all types of projects. So closely adhering to the BNBC can boost a building's and its inhabitants' ability to control fire threats and prevent casualties. The research provides an overview of the deficiencies that a building may have when compared to the BNBC criteria to ensure fire safety, and some recommendations are made to improve the current state of fire safety measures. Furthermore, not all of the parameters selected in the FRI technique are appropriate for the types of structures built in our country. Following the common structure of a kind of building, it is suggested to get professional advice on adding/removing parameters and calibrating weights and grades appropriate for our building types. It is past time that we prepared for this unpredictable and deadly phenomena. Further scientific study on fire dangers and fire safety is critical in Bangladesh right now.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Jahan, A. (2002) Housing Provision in Dhaka: An Analytical Study of the Role of State and Private Formal Developers. Master's Thesis, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka.

[2] Star Business Reporter (2012) Time to Go Vertical as Land Shrink. *The Daily Star*. https://www.thedailystar.net/news-detail-247987

[3] Islam, M.M. and Adri, N. (2008) Fire Hazard Management of Dhaka City: Addressing Issues Relating to Institutional Capacity and Public Perception. *Jahangirnagar Planning Review*, **6**, 5767.

[4] JICA (2015) Data Collection Survey on Urban Building Safety in the People's Republic of Bangladesh.

[5] Kundu, C.K. (2019) Lessons to Learn from Banani Fire. The New Age Opinion. http://www.newagebd.net/article/69417/lessons-to-learn-from-banani-fire

[6] Islam, M.S. (2019) Effects of Real Estate Development on the Built Environment: A Study on Banani Residential Area in Dhaka City. https://www.bip.org.bd/admin/uploads/bip-publication/publication-9/paper/20140427155646.pdf

[7] Nabi, M.S. (2019) What Are the Reasons behind Frequent Fire Incidents in Dhaka. Dhaka Tribune. https://www.dhakatribune.com/bangladesh/dhaka/2019/03/28/what-are-the-reasons-behind-frequent-fire-incidents-in-dhaka

[8] Star Online Report (2019) HC SEEKS Report on Fire Safety Measures at Dhaka's High-Rise Buildings. *The Daily Star*. https://www.thedailystar.net/city/high-court-seeks-report-fire-safety-measures-at-dhaka-high-rise-buildings-1723306

[9] Staff Correspondent (2019) Iqbal Centre among Three Banani High-Rises Marked as "Fire Risks". https://bdnews24.com/bangladesh/2019/04/03/iqbal-centre-among-three-banani-high-rises-marked-as-fire-risks

[10] Ahmed, J.U. and Hossain, T. (2009) Industrial Safety in the Readymade Garment Sector: A Developing Country Perspective. *Sri Lankan Journal of Management*, **14**, 1-13.

[11] Mallick, A. Islam, M.S. and Hossain, A. (2019) Fire Safety Design of Residential Apartment Buildings in North Dhaka: A Semi-Quantitative Risk Assessment Using Fire Risk Index Method. *Proceedings on International Conference on Disaster Risk Management*, Dhaka, 12-14 January 2019, 594-598.

[12] (2005) High-Rise Buildings in the Urban Context of Dhaka City. CTBUH Book Chapter.

[13] National Fire Protection Association (2007) Higrise Buildings Fire.

[14] Islam, M.Z. and Hossain, K.M. (2018) Fire Hazards in Dhaka City: An Exploratory Study on Mitigation Measures. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, **12**, 46-56.

[15] Bangladesh National Building Code, 2006.

[16] Bangladesh National Building Code, Draft-2015.

[17] National Planning and Building Regulations, 2014.

[18] Fire Risk Reduction Rules.

[19] Watts, J.M. (1991) Criteria for Fire Risk Ranking. *Fire Safety Science Proceedings of the Third International Symposium*, Scotland, 8-12 July 1991, 457-466.

[20] Larsson, D. (2000) Developing the Structure of a Fire Risk Index Method for Timber-Frame Multi-Storey Apartment Buildings. University of Lund, Lund. https://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=1687186&fileOId=1691831