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越南高層住宅火災風險研究

A study on fire risk of high-rise residential buildings in Vietnam

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ABSTRACT

As the population grows, the need for more high-rise residential buildings is also rising. Due to the difficulty of fire fighting and evacuation, the concern about fire risk in high-rise buildings is getting more attention than ever. The aim of this study is to have a clearer view of the fire safety situation of high-rise residential buildings in Vietnam. The study consists of a building observation survey and a questionnaire for residents.

In the observation, ten high-rise residential buildings in Hanoi, Vietnam, were observed and analyzed. These buildings were then given a weighted fire safety score, and the weights were determined by Analytic Hierarchy Process (AHP) methods with experts. The most important aspects from an expert's point of view and the aspects of the observed buildings with poor performance were identified. From the result, the fire safety condition of ten buildings varied. Half of the buildings do not have an emergency elevator, and other issues are also detected.

Next, a questionnaire was given to the residents of several high-rise buildings in Vietnam to check the condition of their buildings, the fire safety management, and the resident's knowledge and awareness of fire safety. After analyzing the result, education level and fire drills are two factors that affect the level of knowledge and awareness the most. The questionnaire also shows that most residents have basic knowledge about fire safety in high-rise buildings, but their preparation for it is not enough. Most of the respondents' buildings are equipped with fire protection systems except for the emergency elevator and refuge floor. The frequency of regular fire safety inspections and drills is not enough.

Based on the literature review and the research results, several suggestions are given to different stakeholders of high-rise residential buildings. The result of this study can be used

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to improve the level of fire safety for high-rise buildings. The analytical framework can be used on a larger scale to check the fire safety conditions of high-rise residential buildings in Vietnam. The approach can be applied to other kinds of high-rise buildings, e.g., office buildings and commercial buildings.

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Chapter 1: Introduction

1.1 Background

With the population continuing to increase while land resources are limited, the construction of high-rise buildings is becoming more and more common worldwide, especially in big cities. The vertical city paradigm is a trend preferred by politicians, planners, and architects all over the world [1]. High-rise buildings provide more living and working spaces. However, at the same time, living in a high-rise building can also have many problems: social and racial segregation, traffic congestion, overcrowding, and fire risk.

Due to the difficulties in putting out the fire and evacuating occupants, a fire in a high-rise building can cause great economic loss and resident casualties [2]. Also, given the potentially high number of individuals involved, a single high-rise building fire could result in a significant number of fatalities, drawing more attention to this type of structure. According to National Fire Association, from 2009 to 2013, there were 14500 high-rise buildings fire in the US, causing 40 deaths, 520 injuries, and $154 million in damage [3]. Due to the great height and the huge number of people living in the same building, it creates many problems for both firefighting and evacuating. Although high-rise buildings are usually equipped with fire protection systems, the complicated behavior of fire in high-rise buildings and the difficulties in evacuating the occupants make high-rise building fire one of the biggest risks for many countries[4]. There have been many big, high-rise building fires in the world that caused a lot of property damage and casualties. Some of the most famous high-rise building

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fires in the world are the CCTV/TVCC Tower fire in 2009 in Beijing, China, and the Grenfell Tower fire in 2017 in London, UK, etc.

As the number of high-rise buildings in the world continues to rise, the concern about high-rise buildings is also increasing. More and more research about different aspects of fire safety is being conducted in many countries. For example, Yau and Ho did a fire risk analysis optimization of fire prevention in Hong Kong [5]. Nimlyat evaluated fire safety issues in high-rise buildings in Nigeria [6], and Rahardjo researched the most important problem of fire safety in Jakarta, Indonesia [7]. Kim et al. found solutions to improve standards for the fire safety performance of externally insulated high-rise buildings in Korea [8]. Depending on the function of the building, the fire safety behavior of it will be different. For residential buildings, occupants are usually not prepared to evacuate immediately and hesitate to leave their property, and information spreads slower [4].

1.2 Fire safety of high-rise buildings in Vietnam

Vietnam's high-rise buildings are facing the same problems. In the period 2010 - 2020, the process of urbanization happens rapidly. As of December 2020, the national urbanization rate reached 40.4%, with 862 cities of all kinds [9]. As a result of rapid urbanization, the number of high-rise buildings in Vietnam has been increasing at a significant speed in recent years. Overview statistics so far show that the country has about 3,000 apartment buildings, which are mainly concentrated in Hanoi and Ho Chi Minh City [10]. From the data of the fire department, the fire situation in the first six months of 2022: 848 fires occurred, killing 41 people and injuring 42 people. Among these, there were 16 apartment building fires

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(accounting for 1.89%) [11]. Although the percentage of high-rise building fires is low, the damage they caused was severe. Some of the serious high-rise building fires in Vietnam can be named: the fire of the ITC building in Ho Chi Minh City in 2002 caused 60 death and injured 70 people [12], and the fire of the Carina Plaza building in 2018 caused 13 death and injured 60 people. [13]. High-rise building fires in Vietnam are no different from other fires in the world, with high risks, complicated treatment, and confusion in handling consequences. Also, other adverse factors appear, coming from many regulatory and legal loopholes.

The responsibility of fire safety belongs to all stakeholders: investors, designers, management boards, residents, and the government. To ensure fire safety, the investor needs to pay attention to fire safety right from the stage of project investment and construction, as well as training the members of the management board of the apartment. The investor must be responsible for strictly complying with the law on ensuring fire prevention and fighting safety. State management agencies strengthen inspection and post-inspection to ensure that the fire protection system maintains regular operation as well as the project does not violate the construction design. The residents, if everyone understands the regulations on fire prevention and fighting, they can prevent a lot of consequences when the incident occurs [14].

According to Colonel Bui Quang Viet - Deputy Director of the Police Department of Fire Prevention and Fighting and Rescue, Ministry of Public Security, Vietnam, with diverse functional characteristics, frequent gatherings of people, high-rise apartments always have the potential hidden danger of loss of fire prevention and fighting safety. In addition, the poor sense of compliance with regulations on fire prevention and fighting of the head of the facility and the apartment operation management unit can also increase the risk of fire [15]. Currently,

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the system of design regulations and standards for high-rise residential buildings is not synchronized. This leads to the need to "apply and create" in the design process by themselves from different design facilities such as Design housing. According to the set of high-rise housing standards, the part of the commercial center is taken according to the design standards of the market, and the commercial center and the office part are taken according to the current office design standards. This gives rise to conflicts about the shared spaces such as the lobby, elevator, stairs, and corridor. Moreover, the current high-rise architecture mainly attaches importance to the external appearance, pursuing investment profits and increasing the floor area sold. Designing too many apartments per floor leads to danger when there is an accident due to too many people living together. Also, due to the savings in utilities to increase the area of the apartment, the design of high-rise buildings with long corridors, which lack pause, light, air circulation, and the accessibility to the exits within a distance of 25 m as prescribed [16].

1.3 Objectives and organization

From what has been discussed above, it is obvious that there are many problems in the fire safety situation of high-rise residential buildings in Vietnam, and the problem comes from all stakeholder faults. There has been much research about fire resistance material and structural and fire protection systems. However, to increase the fire safety level, it is necessary to have harmony between the building facilities and human factors. The aim of this study, therefore, is to evaluate these two aspects to have a basic understanding of the high-rise residential building fire safety situation in Vietnam. Then, the researcher will propose a framework to

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evaluate the fire safety condition of high-rise buildings in Vietnam on a larger scale. Finally, from the finding, several suggestions will be given to different stakeholders to increase the level of fire safety.

This thesis will be organized as follows. Chapter 1 is the introduction of this study and background. In Chapter 2, the related literature is collected and reviewed. In Chapter 3, an evaluation of the fire safety of high-rise buildings in Vietnam is performed by observation and AHP survey with experts. Chapter 4 investigates the knowledge, preparation, and awareness about the fire safety of the residents of high-rise buildings in Vietnam by questionnaire and regression analysis. Then, the role and responsibility of stakeholders are discussed in Chapter 5. Finally, the conclusion, limitations, and recommendations are summarized in Chapter 6.

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Chapter 2: Literature Review

To ensure the fire safety of high-rise buildings, we first need to understand why high-rise buildings have fire risk and what factors affect it. In this chapter, we will review the characteristic of a high-rise building that makes it in danger of fire, factors related to the fire safety of the building like building components, fire protection system, and the human factor that contribute to the fire safety of the whole building.

2.1. Characteristics of high-rise buildings related to fire risk

2.1.1. Definition of high-rise building

Based on fire protection requirements, the starting height of a high-rise building is usually taken according to the maximum reach height of the fire truck equipment (about 23 m to 30 m). According to the National Fire Protection Association [17], high-rise buildings' definition is buildings that are more than 75 feet (about 23 m) tall, measured from the ground level where fire department vehicles may access them to the floor of the highest occupied story. Table 1 shows the starting height of high-rise buildings in some countries [18]:

Table 2.1 Starting height standard for high-rise buildings in some countries

Country	High-rise buildings starting height	Lowest measurements point	Highest measurements point
America	$\geq 23m$ (Or above 7 floors)	Lowest elevation of access road for fire engines	The floor of the top floor is occupied by people
UK	$\geq 24m$	The surrounding ground is on the lowest side	The top floor of the top floor
Japan	$\geq 31m$ (Or above 11 floors)	The road surface in front of the house	Rooftop

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China	$\geq 27m$(Or above 10 floors for residential buildings) $\geq 24m$ (For factory building)	Planned ground elevation	Rooftop surface for flat roof or mid-slope height
Singapore	$\geq 24m$	Road surface elevation for fire trucks	The floor of the top floor is occupied by people
Hong Kong	$\geq 30m$	The road surface on the ground floor	The floor of the top floor is occupied by people
Vietnam	$\geq 28m$ (Or above 10 floors for residential buildings, other kinds of buildings above 7 floors)	Road surface for fire trucks	The bottom edge of top floor window

Although the height definition of high-rise buildings in different countries is slightly different, most of them are similar: the lowest point is the road surface for fire trucks, and the highest point is the floor of the highest occupied floor.

Compared with buildings of lower height, requirements to ensure fire safety according to different aspects of the building are often increased, especially requirements on equipment for fire-fighting elevators and the number of exit stairs. In case of an accident, people may use smoke-free escape stairs equipped with an automatic fire-extinguishing system. In addition, the higher the height of the building, the higher the fire safety requirements must be increased correspondingly to each level.

2.1.2. Building function

Depending on the building's use and design, the evacuation behavior would be different. A high-rise building can be an office building, a residential building, a factory, a hospital, or a

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laboratory. The usage of the building has an impact on several aspects of a high-rise structure's egress performance, including its design, the population's makeup, its education, the staff on hand, the fire safety features, etc. Consequently, it stands for one of the major elements affecting high-rise building evacuations [19].

For office buildings occupants, since they have normally been taught via evacuation drills, are typically dressed, aware, and mostly accountable for themselves, occupants are typically more prepared to flee the building [20]. In contrast, the fact that the occupants may not be prepared to evacuate—for example, if they are asleep or not dressed—will cause a significant delay in the evacuation process. Therefore, pre-evacuation durations are often longer than those for other building occupancies [17, 21]. The fact that occupants in residential buildings often live with their family or loved ones also contributes to the delay in their evacuation, especially for families with babies or elderly residents. Also, occupants in residential buildings are more attached to their belongings and properties in their houses. Therefore, they are more hesitant when evacuating[20, 22]. Additionally, compartmentalization (a psychological defensive mechanism whereby opposing ideas and emotions are kept apart or insulated from one another in the mind. [23]) makes it more difficult for knowledge to spread, and social ties can impede progress. Hence, in this research, the author focuses on residential buildings not only because it is the most common type of high-rise building in Vietnam but also because of the above challenges in the fire safety of residential buildings.

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2.1.3. Structural and material factors

The common structure of high-rise buildings has a core system located in the center, including elevators, elevators, technical pipes, infrastructure, etc., arranged vertically with steel structures or reinforced concrete. In a high-rise building, the presence of a stairwell, elevator shaft, tube well, or other unique construction could result in a stack effect and piston effect during the fire. [24]. Fire propagation paths in the space of floors are in principle always influenced by wind and air. In high-rise structures, they will turn into lofty chimneys, or the channels through which fire spreads, if fire separation is not planned rationally [2]. Therefore, the horizontal fire propagation paths will creep into the corridors. Vertical fire propagation paths will creep into technical pipes, skylights, elevators, and stairs. Due to the differential pressure between inside and outside, fire propagation paths tend to push out to surrounding surfaces, where there is a lot of air, with combustible materials. Excessive fuel loads from numerous stories of occupants are superimposed. Due to their highly flammable nature, furnishings and fixtures installed in high-rise structures have the potential to produce a lot of heat and smoke [6].

Due to the great height of high-rise buildings, it is difficult for firefighters to put out the fire since the normal height of fire trucks is only around 30 meters. Putting out the fire for this type of building depends greatly on the indoor fire apparatuses. The inside fire apparatuses of high-rise buildings are not ideal due to technological and economic limitations, notably for the second class of high-rise structures. High-rise building fires are more challenging to put out because of the intense heat radiation, the rapid development of the fire, the scarcity of firewater, and other factors [2].

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In recent years, due to the need for energy efficiency, exterior walls constructed of organic insulating materials, such as polystyrene, and polyurethane, are utilized extensively in high-rise structures. Concerns about the potential spread of fire between neighboring high-rise building compartments also emerge with these facades due to the high combustibility of these new materials [25].

2.2. Escape means in a high-rise building

Evacuation is one of the biggest problems with fire safety in high-rise buildings for many reasons. Firstly, due to the great height, evacuation takes a long time, causing fatigue, especially for residents on higher floors. Secondly, due to the high density of the resident, the escape routes can easily be overloaded if not designed carefully. Thirdly, once the fire starts, fire and smoke will spread quickly, especially to the vertical opening like stairs or elevators, unable residents to evacuate. Therefore, a high-rise building must have multiple egress components to increase the survival chance for residents.

2.2.1. Escape stair

This is the most common mean of escape in any building. Escape stairs are different from stairs in that they are separated by fire-resistant, heat-resistant walls and doors made of fire- and smoke-proof materials. The design of the stair can be different depending on the regulation of the country. There are two positions for the exit stairs: Either they are arranged centrally in the core area with a safe enclosed space to avoid smoke and fire when there is a fire, or the entrance and the safe space are arranged in the direction of the open space of the

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building or is distributed in the area of the building sides. Many factors affect the design of the escape stair: number of steps, width, length, location, etc.[26, 27]. Besides, there was research on the slope of the stair [28], the values for capacity on stairs [29], and the impact of occupancy levels on stairs [30].

Besides the design, the behavior when evacuating should also be considered. When evacuating, the large number of people using the stair at the same time can cause chaos, so the designer must calculate the merging stream of evacuees when designing the stair. To improve the efficiency of the flows in high-rise structures, [31] recommended that floors be connected to the landing on the side opposite the incoming stair. Another element that has to be looked at during stair evacuations in high-rise buildings is fatigue [32]. The evacuating process may be interrupted due to fatigue and cause a chain delay for the people behind. This problem is more serious for senior residents[33].

Another issue with escape stairs is that people with disabilities could hardly evacuate themselves. The literature has examined many evacuation issues, such as the residents' capacity to use stairs with or without assistance[34]. The Americans with Disabilities Act (ADA) in buildings emphasizes the necessity for an adequate design taking all these difficulties into mind, which should be a component of the safety design [35].

Also, one should be warned not to arrange garbage pipes in the exit ladders because, in Hanoi, the garbage pipes are often also the place where smoke and fire originate from caused by dumping garbage and unburnt materials (burnt coal) [36]. To support the safety of the exit

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ladder, the location of the ladder should pay attention to easy access to open space and fresh air outside the house. That is a very important factor.

2.2.2. Evacuation elevator

Inadequacies in exiting by stairs are also noticed for disabled people, the elderly, and children. Therefore, in some super high-rise buildings, elevators have been arranged for emergency use. These elevators will be powered by their emergency power supply. In Japan, it is specified that about 1500m^2 of floor space will have an emergency elevator [37].

Normally, when a fire happens, the normal elevator system will automatically move to the first floor and then shut down so that no one will use it. Due in large part to the difficulties with evacuation that were revealed by the WTC terrorist assault on September 11, 2001, the topic of applying an evacuation elevator had been brought back to researchers [38]. A speedier and more efficient way to escape tall buildings has replaced the traditional thinking that elevators shouldn't be operated in an emergency.

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Figure 2.1 Emergency elevator [39]

From a design standpoint, there are many issues with the utilization of evacuation elevators. The constrained space in elevators might lead to problems with the crowding of those within, which could occur in constrained places and high-density environments[40]. The elevator shaft might be invaded by flame, heat, and smoke. For instance, the piston effect occurs in moving elevators as a result of negative pressure drawing smoke within the vehicle [41]. Additionally, earthquake safety, the availability of emergency communication systems, and resistance to the spread of pollutants should be taken into consideration while designing evacuation elevators [42].

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Apart from the design requirement, the behavior aspect should also be a concern, such as the inhabitants' readiness to take the elevators rather than the stairs about the floor where they are when the evacuation begins [43].

2.2.3. Refuge floor

Refuge floors are floors designed only for emergency purposes where residents can gather and wait to be rescued. These kinds of floors are often used as technical floors. The refuge floor must have a door connecting to the smoke-free elevator room and must have a door to the fire-fighting elevator. The refuge floor must have its fire-fighting equipment, including indoor fire hydrants, sprinkler automatic fire-fighting systems, emergency lighting, telephones for external communication, radio systems for instructions for escape, etc. It must have better ventilation and fire resistance levels and follow other fire safety standards.

Refuge floors have several benefits from the standpoint of evacuation: (1) they provide a place for evacuees to rest; (2) they lessen the likelihood that stairs or lift shafts will become smoke-filled; (3) they can be used to protect people with disabilities and/or injured evacuees; (4) they can be used as a command center for rescue teams to assist with evacuation; and (5) they can be used as a fire-fighting base [44].

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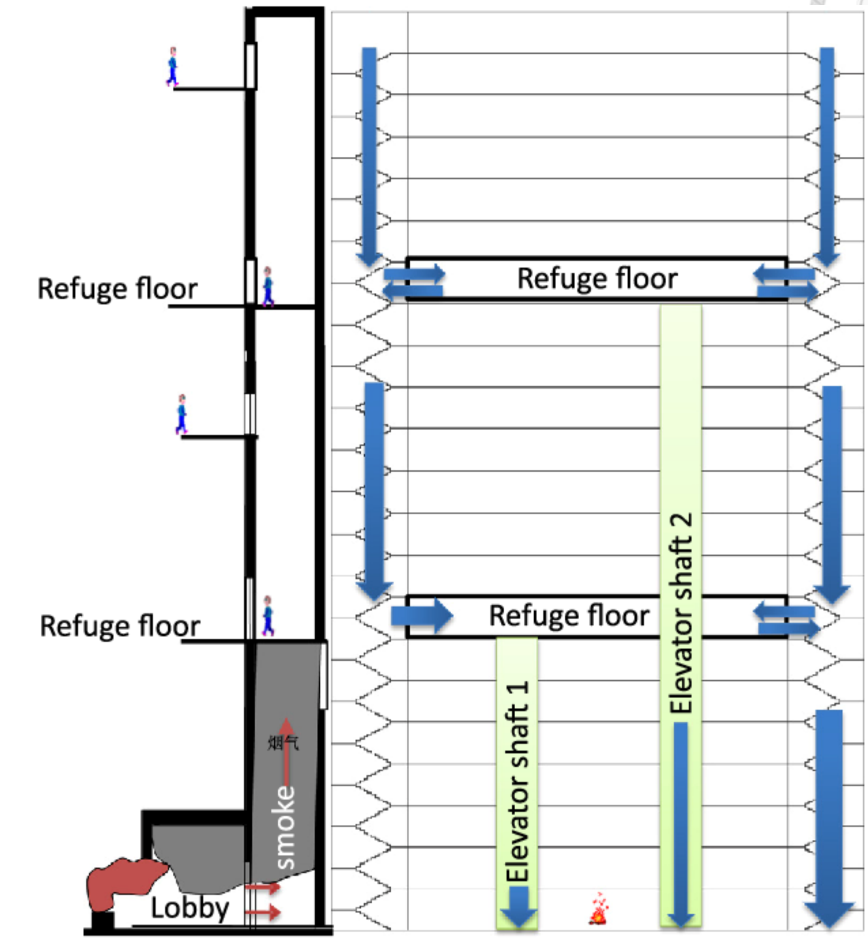

Figure 2.2 Refuge floor [45]

The refuge floor concept, on the other hand, may fail due to several factors, including evacuee actions, human behavior problems (such as overcrowding, under-utilization, occupants' fear of staying in a threatened structure, etc.), cost-effectiveness in comparison to alternative design solutions, sustainability, etc [46].

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2.3. Fire protection system

2.3.1. Passive fire protection system

2.3.1.1. Level of fire resistance

According to the Vietnamese government regulation [47], the fire resistance level of a building element is determined by the time interval (in minutes) from the beginning of the fire resistance test according to the standard heat regime until the appearance of one or several consecutive signs of fire resistance. The limit states specified for a given member are as follows:

– Loss of bearing capacity.

– Loss of integrity.

– Loss of insulation.

Regarding the fire resistance of the structure: the goal is to ensure enough time for the people in the house to escape to the outside with the lowest risks and to allow the fire and rescue forces to carry out their operations and at the same time limit the risk of spreading fire in the burning house as well as surrounding houses.

Qianru Guo researched to create a probabilistic evaluation of structural fire resistance[48]. In a study about UK fire resistance expectations for high-rise apartment buildings, Danny Hopkin found out that the level of fire resistance determination should base on variables other than building height [49]. Additionally, this will save property losses and offer a secure exit,

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doing duties like rescue, evacuation, and fire extinguishing simpler. This may be accomplished by separating fires by region.

2.3.1.2. Compartmentalization and Separation

The National Structure Code of Finland [50] states that creating distinct fire compartments within a structure is a necessary step in preventing the spread of fire and smoke. To prevent the development of fire and smoke spread in the space of high-rise buildings, it is necessary to divide the usable space areas into space parts separated by structures or dividing spaces. There are three measures to prevent division [36]:

- Firstly, use a system of trapdoors made of fire-resistant materials, which can be made of fire-resistant steel or glass, to separate corridors.
- Second, it is possible to use an automatic sprinkler screen formed from the sprinkler system placed on the ceiling, to separate the two different areas,
- Third, it is possible to make an "Air Curtain" system to prevent the spread of fire.

Building fire regulations from different countries offer different specifications for the design of fire separation methods and exits.

2.3.2. Active fire protection system

The equipment used to implement the active protection system can either operate automatically or manually. It is utilized in extinguishing operations by firefighters or building occupants [7]. The system is also used to implement early fire suppression techniques, such as the use of upright pipe systems and hoses, automatic sprinklers, emergency lighting,

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emergency communication tools, fire lifts, fire detection and alarm systems, smoke control equipment, ventilation, automatic and fire-proof doors, and fire control.

Fire protection equipment that needs to be equipped in a high-rise building includes a Fire alarm system, fire fighting, exit ladder, smoke-blocking valves and smoke-blocking doors, exit corridor, emergency lighting system, lights instructions for escape, step-up pressure on stairs, smoke extraction system, interlock between fire protection system and elevator, interlock between fire protection system and announcement speaker, electrical system safety, outdoor fire protection corridor for single access to the fire department, rescue equipment in the building such as rope ladders, hammers, gas masks, fire fighting clothes.

According to the present study, sprinklers are often more successful than other fire prevention tools in containing fires and minimizing fire-related fatalities, injuries, and property loss. There have often been more fatalities, injuries, and property losses in fire accidents when there was no fire protection at all. Due to the relatively low frequency of fire events resulting in fatalities and injuries in installations without fire protection, there are occasions when the obvious benefit of installing fire protection systems compared to those having none at all cannot be observed [51].

2.4. Human factors in fire safety

2.4.1. Building's residents

High-rise building residents also have a part to play in maintaining the greatest possible level of fire safety, which is why it is not just the developers' obligation to safeguard the safety of

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those who live there. If high-rise building occupants are better knowledgeable about fire safety and how the defensive systems-smoke detectors, fire suppression, and fire sprinklers operate, they may contribute to assuring the building's fire safety [6].

In high-rise structures, residents' behavior before and during a fire has a significant impact on fire safety. There is still a clear dearth of understanding regarding the behavioral components involved in a high-rise building evacuation [52]. Residents of high-rise buildings are urged by the National Fire Protection Association [53] to get familiar with the building's fire protection features and evacuation protocols. Residents can create evacuation plans based on this information.

People who are considered to have a high perception of risk in a building emergency are less likely to perform pre-evacuation duties and more likely to start the evacuation process right once. However, those who perceive danger as low remain to work after receiving the first cues or spend more time gathering information or preparing for an evacuation, which results in prolonged pre-evacuation timeframes [54, 55].

Because people do not always see themselves as being in danger of fire or believe that adopting preventative measures may not be helpful, research demonstrates how these attitudes affect fire preparation. Residential high-rise residents' views about fire safety were shown to be significantly influenced by their direct and indirect experiences with high-rise structure fires [56]. The results of the same study revealed that residents of residential high-rise buildings also have a limited understanding of the fire protection aspects of their

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buildings. To increase new residents' understanding of their building's fire safety elements, building managers could think about offering a fundamental orientation to building safety.

For participants in Glauberman's research, the experience of evacuation had a significant impact. Those without such expertise sometimes lacked confidence in their abilities to flee in an emergency or had little understanding of evacuation routes.

2.4.2. Building management board

The goal of fire safety management is to decrease the danger to life and property to extremely low levels that are acceptable to residents and society at large is the goal of fire safety/risk management. By engaging in fire prevention activities that would considerably lower the incidence of fires and implementing passive and active fire protection systems that would reduce damage when a fire occurs, this goal can be accomplished [57].

Technology equipment and other occupations will only make sense and contribute to the building fire safety if they come after proper planning, organizing, supervising, coordinating, and other activities. The majority of the fundamental events that the author suggests in terms of the study of building fire losses may ensure the safety of the building from fire by enhancing and refining the safety management to regulate and remove dangers [2].

The level of leadership on fire safety displayed by a high-rise building has a significant impact on its occupants. A greater trust may be built, which can further encourage high-rise occupant fire safety if building management can deliver reliable fire safety information that suits the requirements and preferences of high-rise occupants [56].

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2.5. Common cause of fire in Vietnam

According to the Vietnam Department of Fire and Rescue [11], the fire situation in the first six months of 2022: 848 fires occurred, killing 41 people and injuring 42 people; Preliminarily estimated assets in cash are about VND 414.73 billion and 40.87 hectares of forest. Among these, there were 16 apartment building fires (accounting for 1.89%). About the causes of the fires: Investigated and clarified the cause of 545/848 cases, due to the system and electrical equipment failure in 398 cases (accounting for 46.93%).

Using the search engine Google, the researcher used keywords like “high-rise buildings fire in Vietnam” to find out about high-rise building fire breaks in Vietnam, gather all the data from many articles, and find out the most common cause. The data are shown in Table 2. Electrical faults are the most common cause of fire for high-rise buildings in Vietnam from both the data of the fire department and from the result of searching online.

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Table 2.2 High-rise buildings fire causes

No	Time	Building name	Cause
1	2002	ITC	Bare fire during maintenance
2	2009	Kumho Asiana Plaza	The gas of the indoor unit system is leaking
3	2010	JSC 34	The fire broke out on the 1st floor, then spread through the garbage road system to the 2nd floor,
4	2014	CT-6, Xa La	Building electrical fault
5	2015	CT4A Xa La, Hà Đông	The incident at the power station in the basement
6	2015	HH4 Linh Đàm	Building electrical fault
7	2015	CT5, Xa La	Building electrical fault
8	2016	Rainbow,	Owner burned incense carelessly
9	2017	HQC Plaza	Building electrical fault
10	2018	Carina Plaza	A vehicle exploded in the basement
11	2018	No1B Linh Đàm	A vehicle exploded in the basement
12	2018	CT3 Vimeco	Fire started from the kindergarden on third floor
13	2018	CT2-A1, Linh Đàm	Owner burned incense carelessly
14	2019	The Pride	Building electrical fault
15	2019	CT05 Phong Bắc	Owner burned incense carelessly
16	2022	An Lạc, quận Bình Tân, TP.H	Electrical fan electrical fault
17	2022	Lavita Charm	Building electrical fault
18	2022	NOCT	Building electrical fault
19	2022	Gemek 2.	Children play with fire
20	2023	M5 Nguyễn Chí Thanh	Electrical fan electrical fault

2.6 Conclusion

This research focuses on residential buildings because it is the most common type of high-rise building in Vietnam but also because of the challenges in the fire safety of residential buildings. After reviewing the characteristic that makes high-rise building have a high risk of fire, we can see what part of high-rise building are related to fire safety, like escape means, and passive and active fire protection system. Also, we look into the human factors that are related to fire safety. We can see that the fire causes can come from both the building faults and resident faults. To ensure the safety goal, we have to ensure harmony between the human

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and building factors. Therefore, in the following, the fire safety of high-rise buildings in Vietnam will be evaluated from these two perspectives.

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Chapter 3: Evaluation of Fire Safety of High-Rise Buildings in Vietnam

3.1. Introduction

In high-rise buildings, the fire risk is much higher compared to other kinds of buildings due to the difficulties when evacuating and the quick spreading of fire in the high-rise building structure. In addition, the huge amount of people gathering in one building also makes the risk higher. Therefore, it is required to ensure the fire safety of high-rise buildings. the safety of a building can come from many aspects such as site planning, the pe means, the acting passive fire protection system, and systems management of the building board. These aspects' inspection is usually carried out by the Vietnam Fire Department. However, the inspection of high-rise building fire safety is often overlooked. So, to check the fire safety condition of high-rise buildings in Hanoi, Vietnam, an observation was carried out. The checklist of the observation was based on similar research and modified with the regulation and safety code of Vietnam. Buildings were given a score based on their condition according to the observation, and then these data were processed to get the final score of the building. Weights were given to each checklist category when calculating the score, and these weights were determined based on an AHP survey with experts in the construction industry.

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3.2. Methodology

In this study, a descriptive qualitative method was used to describe the status of high-rise buildings in Vietnam in terms of building features that contribute to the fire safety of the whole building, such as building planning, fire protection system, and management. The author made indirect observations of 10 buildings in Vietnam. These buildings were all residential high-rise buildings with floors of more than 15 stories. The construction year also varied from old to newly built to make sure the study can get an overall observation of the fire safety issue of high-rise buildings in Vietnam. The observation was carried out by an experienced engineer with more than 15 years working in the industry.

The research method of this chapter was mainly taken or adapted from a similar study on fire safety issues and challenges for high-rise buildings in Jakarta[58]. After using a checklist to observe high-rise buildings, the data was processed using the Analytic Hierarchy Process (AHP), and the Objectives Matrix (OMAX) method.

3.2.1 Observation checklist

The checklist consists of 5 main aspects suggested by [58], as follows.

- Site planning
- Escape means
- Passive protection system
- Active protection system
- Fire safety management

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Under these five main aspects are their sub-aspects, shown in Table 3.1. The main aspects will be the first level and the sub-aspect will be the second level of the AHP method. The checklist in this chapter was developed based on similar research about issues and challenges of fire safety for high-rise buildings in Jakarta [58] and some regulations and building codes of Vietnam[47, 59, 60].

Table 3.3 Assessment criteria

No.	Aspects
1	**Site planning**
1.a	Neighborhood road
1.b	Distance between buildings
1.c	Outside hydrants or other source of water
2	**Escape Means**
2.a	Escape route
2.b	Escape stairs and corridors
2.c	The height of doors and walkways on the escape route
2.d	Fire elevator design
2.e	Solid door system at the exit
3	**Passive protection system**
3.a	Level of Fire Resistance
3.b	Compartmentalization and Separation
3.c	Protection on the Aperture
4	**Active protect system**
4.a	Automatic fire protection system
4.b	Fully equipped with fire extinguishers
4.c	Water supply system
4.d	Arrange rescue means
4.e	Fire Utilities
5	**Fire Safety Management**
	Supervision and Control

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3.2.2 Analytic Hierarchy Process (AHP) method

The AHP method was used to assess the importance of aspects and sub-aspects. The analytic Hierarchy Process (AHP) [61-66] is a theory for addressing challenging economic, social, and technical issues. It makes an effort to eliminate the fragmentation that currently exists, where each problem often has its specific model and nomenclature. Making strategic and sound building decisions may be facilitated by using AHP, which enables decision-makers to assess prospective options quantitatively using a variety of criteria before choosing the best one [67]. The AHP method has been used to determine the criterion weighting for both construction management and risk assessment. For the construction management area, the AHP method has been applied in selecting construction technology [68], improving productivity [69], evaluating supply chain relationships [70], and selecting contractors [71]. For risk assessment, the AHP method has been applied in construction schedule delay risk assessment [72], construction project risk assessment [73], and safety risk assessment [74].

There are three steps in the AHP:

1. Construction of a hierarchy in which the decision objective is contained at the top level and the decision criteria, sub-criteria, and choices for achieving the decision goal are successively broken down at lower levels;
2. Pairwise comparisons - Under the assumption that the elements are independent of one another, decision-makers (usually domain experts) are requested to perform pairwise comparisons of the elements at each level of the hierarchy. Comparisons of

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the relative weights of each pair of criteria at the second level of the hierarchy are done in light of this and the decision aim. The comparison of each pair of sub-criteria for the same criterion (at level 2) continues indefinitely. As illustrated in Table 3.2, these pairwise comparisons are frequently based on a nine-point scale.

Table 3.4 AHP pairwise comparison scale

<< Less important								More important>>
1/9	1/7	1/5	1/3	1	3	5	7	9
Extreme un-important	Un-important	Less important	Slightly less important	Equal important	Moderate important	Strong important	Very strong important	Extreme important

In the standard AHP, the priorities (w_i, *i*=1;2…, n) are obtained by solving the eigenvector problem:

$$Aw = \lambda_{max} w w*_i = (\prod_{j=1}^{n} a_{ij})^{1/n} \ (1)$$

$$w_i = \frac{w*_i}{\sum_{i=1}^{n} w*_i} \ (2)$$

$$\sum_{i=1}^{n} w_i = 1 \ (3)$$

Where *A* is a positive pairwise comparison matrix, λ_{max} is the eigenvector associated with the maximum eigenvalue.

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(Aw)_i}{nw_i} \ (4)$$

3. Verification of consistency – Expert judgments are needed to determine the relative importance of each criterion and any feasible alternatives to achieving the decision

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target. Because AHP permits decision-makers to make subjective judgments, consistency of the judgments is not always ensured. Verifying consistency is therefore crucial to achieving an optimum result. Saaty [75] suggested computing the consistency ratio to regulate the consistency of pairwise comparisons. Decision-makers are compelled to change their initial conclusions at this point if the computed consistency ratio is greater than the threshold of 0.1. Following the completion of all required pairwise comparisons, revisions, and the determination that the consistency ratio is less than 0.1, the judgments may then be combined to order the decision criteria and the relevant sub-criteria.

$$CI = (\lambda_{max} - 1)(n - 1) \quad (5)$$

$$CR = CI/RI \quad (6)$$

Where CI is the consistency index, RI is a random index and CR is the consistency ratio.

3.2.3 Objectives Matrix (OMAX) method

The next stage is to evaluate the assessment data collected in the field using a weighted scoring method known as the Objectives Matrix (OMAX) to establish the accomplishment value of each aspect from the pre-determined objectives. This system, which James L. Riggs developed, links the criteria to the model. This technology, which is effectively employed in manufacturing, may also be used in the building construction industry, particularly for high-rise structures' fire prevention systems. This is because both sectors' performance is evaluated using the same methodology [76]. The Objectives Matrix is used in an evaluation system to

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level the value scale of each indication. Consequently, each parameter's achievement is at the same degree of objectivity.

3.3. Result of AHP

3.3.1. Experts' Opinion

Since the AHP method required the opinions of experts, the researcher asked ten experts with expertise related to the fire safety of high-rise buildings to fill out an AHP survey. The AHP surveys were sent through email. The requirement to choose the experts was working experience in a high-rise building or the construction industry of more than 7 years. Also, their expertise must relate to different stakeholders in a high-rise building project so that the AHP survey can be more diverse. The background of the experts is shown in the table below:

Table 3.5 Experts' background

No.	Expertise	Year of experience
1	Civil construction project	17
2	Industrial urban planning	15
3	Hotel management	25
4	Architect	16
5	Construction contractor	10
6	Real estate	12
7	Industrial, civil, and infrastructure project	27
8	Architect	8
9	Industrial, civil, and building façade project	18
10	Building management	7

Based on the identified aspects in Table 1, the researcher created an AHP survey for the main 5 aspects and each of the sub-aspect (Table 3.4 to Table 3.8). The full explanation of each

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aspect is shown in Appendix A. The experts were asked to compare the factor on the left(A) with the one on the right(B) if factor A is more important than factor B, then A/B>1 and vice versa, if A is less important than B, then A/B<1. If A and B are equally important, then A/B=1. For example, if "Rescue means" are "Unimportant" compared to "Fire utilities" then the expert will tick on 1/7.

Table 3.6 Main Factor

	1/9	1/7	1/5	1/3	1	3	5	7	9	
Site planning										Escape means
Site planning										Active protection system
Site planning										Passive protection system
Site planning										Fire safety management
Escape means										Active protection system
Escape means										Passive protection system
Escape means										Fire safety management
Active protection system										Passive protection system
Active protection system										Fire safety management
Passive protection system										Fire safety management

Table 3.7 Sub-Factors of Site Planning

	1/9	1/7	1/5	1/3	1	3	5	7	9	
Neighborhood road										Distance between buildings
Neighborhood road										Outside hydrants or other sources of water
Distance between buildings										Outside hydrants or other sources of water

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Table 3.8 Sub-factors of Escape means

	1/9	1/7	1/5	1/3	1	3	5	7	9	
Escape route										Safety stair and corridors
Escape route										The height of door and walkway
Escape route										Fire elevator
Escape route										Solid door at the exit
Safety stair and corridors										The height of door and walkway
Safety stair and corridors										Fire elevator
Safety stair and corridors										Solid door at the exit
The height of door and walkway										Fire elevator
The height of door and walkway										Solid door at the exit
Fire elevator										Solid door at the exit

Table 3.9 Sub-factors of Passive protection system

	1/9	1/7	1/5	1/3	1	3	5	7	9	
Level of fire resistance										Compartmentalization and Separation
Level of fire resistance										Protection on the Aperture
Compartmentalization and Separation										Protection on the Aperture

Table 3.10 Sub-Factors of Active fire protection system

	1/9	1/7	1/5	1/3	1	3	5	7	9	
Automatic fire protection system										Fire extinguisher
Automatic fire protection system										Water supply system
Automatic fire protection system										Rescue means
Automatic fire protection system										Fire utilities
Fire extinguisher										Water supply system
Fire extinguisher										Rescue means
Fire extinguisher										Fire utilities
Water supply system										Rescue means
Water supply system										Fire utilities
Rescue means										Fire utilities

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3.3.2. AHP data analyze

To assess the fire safety level of the building, each of the aspects needs to be given a weight for assessment. Each aspect and sub- aspect were weighted based on the difference in the level of importance. This method's main purpose is decision-making in scenarios with many aspects and tiered aspects, where the technique is utilized to blend qualitative and quantitative variables in the overall assessment of potential solutions.

The result of the AHP method is the weight of each aspect according to the level of importance. The value of the consistency factor is 0.0659. After determining the weight for the main aspect, the weight of the sub-aspect for each main aspect was done in the same way and then multiplied with the weight of the corresponding main criteria to achieve the weighting calculation, as shown in Table 3.10. The detailed calculation of weights is shown in Appendix B

Table 3.11 Consistency ratio

	Consistency Ratio (CR)
Main aspect	7%
Sub aspect of **Site planning**	8%
Sub aspect of **Escape means**	10%
Sub aspect of **Active protection system**	7%
Sub aspect of **Passive protection system**	9%

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Table 3.12 Weight of each aspect

No.	Aspects Assessed	Weight
1	**Site planning**	**0.2802**
1.a	Neighborhood road	0.1315
1.b	Distance between buildings	0.0867
1.c	Outside hydrants or other source of water	0.0620
2	**Escape Means**	**0.2444**
2.a	Escape route	0.0914
2.b	Escape stairs and corridors	0.0709
2.c	The height of doors and walkways on the escape route	0.0322
2.d	Fire elevator design	0.0319
2.e	Solid door system at the exit	0.0180
3	**Passive protection system**	**0.2107**
3.a	Level of Fire Resistance	0.1162
3.b	Compartmentalization and Separation	0.0519
3.c	Protection on the Aperture	0.0426
4	**Active protect system**	**0.1599**
4.a	Automatic fire protection system	0.0751
4.b	Fully equipped with fire extinguishers	0.0361
4.c	Water supply system	0.0242
4.d	Arrange rescue means	0.0147
4.e	Fire Utilities	0.0098
5	**Fire Safety Management**	**0.1047**
	Supervision and Control	

From Table 3.10, it is clear that experts consider *Site planning* as the most important factor (with a weight of 0.28) of a high-rise building fire safety, while *Fire safety management* is the least important, almost 1/3 times of *Site planning*. The figure for *Escape means* and *Passive protection systems* are slightly lower, at 0.24 and 0.21, respectively. And finally, the weight of the *Active protection system* is 0.16.

The highest weight of *Site planning* can be explained through the fact that good site planning can give firefighters easy access to the building, and a sufficient number of hydrants to use their fire hosts to put out the fire. A small fire can be handled by the building's fire protection

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system, but a big fire can only be put out with the help of firefighters and their gear. The second highest weight is the weight of *Escape means* that if a fire happens, human life is the most valuable asset, so an easy and safe escape route can help residents escape the burning building as fast as possible.

The top six aspects with the highest weight are:

- 1.a *Neighborhood Road* (0.1315)
- 3.a *Level of fire resistance* (0.1162)
- 2.a *Escape route* (0.0914)
- 1.b *Distance between buildings* (0.0867)
- 4.a *Automatic fire protection system* (0.0751)
- 2.b *Escape stair and corridor* (0.0709)

3.4. Observation of Fire Safety of High-Rise Buildings in Vietnam

3.4.1 Scoring system

To have a look at the fire safety condition of high-rise buildings in Vietnam, an observation was carried out to check if residential high-rise buildings in Vietnam meet the requirement of fire safety. Since the author was studying in Taiwan and was not able to come back to Vietnam to directly do the observation, the observation was carried out by a civil engineer with more than ten years of experience in the construction industry. The survey was done by going to each of the buildings to make a direct observation. The surveyor filled in the

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checklist with a score of 0 to 3 by the installed protection conditions, the description of the score is shown in Table 3.11. In addition, a detailed description of each criterion was also attached to each of the checklists so that the surveyor can easily check the building conditions. This description was based on the regulation and building code of the Vietnam government and the Construction Deputy (TCVN 6160-1996), (TCVN 3890-2021), (QCVN 06:2010/BXD)

Table 3.13 Scoring system

Score	Criteria
0	When required items do not exist/are not installed
1	When the required item exists but does not meet the conditions and/or does not work
2	When the required item is present and functioning but is incompliant with the conditions
3	When required items are by the terms and function properly

3.4.2 Observation result

The researcher selected ten high-rise buildings in Ha Noi, the capital of Vietnam, to observe. By 2018, there were 1075 high-rise buildings in Hanoi [77]. As some of the high-rise buildings required a resident card or employee card to enter, the researcher selected buildings with free access to the observer. These buildings also have different backgrounds, such as finishing year and number of floors. Some of these buildings had fire accidents before, and some of them did not. The purpose of choosing different backgrounds is so that researcher can achieve a more reliable result. The background of the ten buildings is shown in Table 3.12. Then the observations of each aspect are described.

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Table 3.14 Observed building background

No.	Building's name	Shortcode	Finish year	Number of floors	Had fire before?
1	PCC1 Ha Dong	PCC1	2015	15	No
2	Intracom Riverside	Intra	2017	39	Yes
3	Thang Long Garden	TLG	2015	21	Yes
4	HH4B Linh Dam	HH4B	2015	36	Yes
5	CT8B Dai Thanh	CT8B	2013	32	Yes
6	NC2 Cau Buou	NC2	2012	17	No
7	BooYoung Vina	BYV	2018	30	No
8	CT6A Xa La	CT6A	2012	30	Yes
9	Tabudec Thanh Oai	Tabudec	2017	27	No
10	My Dinh Plaza	MDY	2019	30	No

According to Table 3.12, there are five of the ten buildings had a fire in the past. Intracom Riverside building only had one fire on 13/10/2022 [78] while the other four buildings had more than 2 fire accidents since the buildings finished [79] [80-82]. Especially, HH4B and CT6A buildings are built by the same investor, this enterprise is famous for building high-rise apartment buildings with cheap prices and low quality, their buildings continuously had fire in 2015 [83]. The TLG building's fire alarm had not worked for 4 years since the owner sell it to the customer [84]. According to the newspaper, most of these buildings had not passed the fire safety inspection of the fire department for a long time. It is a common issue that the owner tries to deny their responsibility after handover the building to the customer. In addition, a lot of current buildings do not have a management board, so the activities to increase safety levels like fire drills or seminars about fire prevention for residents.

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Table 3.15 Observation result

No.	Aspects	Score	PCC1	Intra	TLG	HH4B	CT8B	NC2	BYV	CT6A	Tabudec	MDP
	Finish year		2015	2017	2015	2015	2013	2012	2018	2012	2017	2019
	Height		15	39	21	36	32	17	30	30	27	30
1	**Site planning**											
1.a	Neighborhood road		3	3	3	2	2	3	2	2	2	3
1.b	Distance between buildings		2	3	2	2	1	3	2	2	2	2
1.c	Outside hydrants or other source of water		1	2	2	1	2	3	3	2	2	3
2	**Escape Means**											
2.a	Escape route		3	3	3	3	2	2	3	2	3	3
2.b	Escape stairs and corridors		3	3	2	3	2	2	2	2	3	3
2.c	The height of doors and walkways on the escape route		3	3	3	3	2	3	2	2	2	3
2.d	Fire elevator design		3	3	0	3	0	0	3	0	0	3
2.e	Solid door system at the exit		3	3	2	3	2	2	3	2	2	3
3	**Passive protection system**											
3.a	Level of Fire Resistance		3	3	3	3	3	3	3	3	3	3
3.b	Compartmentalization and Separation		3	3	2	3	2	0	3	0	0	3
3.c	Protection on the Aperture		3	3	3	3	2	0	3	2	2	2
4	**Active protect system**											
4.a	Automatic fire protection system		3	3	3	3	2	2	3	2	2	3
4.b	Fully equipped with fire extinguishers		3	3	3	3	3	2	3	2	2	3
4.c	Water supply system		3	3	3	2	2	3	3	2	2	3
4.d	Arrange rescue means		2	2	2	2	0	0	2	0	0	2
4.e	Fire Utilities		2	3	2	2	0	2	2	0	0	2
5	**Fire Safety Management**											
	Supervision and Control		3	3	2	2	2	2	3	2	2	3

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Site planning

- *Neighborhood road*: most of the buildings ensure the requirement of this aspect (no score 1), which means fire trucks can enter easily in case of a fire happens.
- *Distance between buildings*: most of the residential high-rise buildings in the list are part of multiple blocks of buildings, so we can understand the result of only two buildings having a score of 3 while most of the rest have a score of 2 (except CT8B with the score 1). Ensuring the distance between buildings makes sure that fire can not spread from one building to another building, causing greater damage to properties and lives.
- *Outside hydrants or another source of water*: PPC1 and HH4B Linh Dam scored 1 on the checklist, which means that these two buildings do not have enough outside fire hydrants required in the standard. When a fire happens, this can bring difficulties to firefighters as they do not have enough water sources to deploy their fire hoists.

Escape means

- As the basic requirement for any building, most of the buildings on the checklist are all scored 2 or 3 in terms of *Escape route*, *Escape stair*, and *corridor*, *the height of the door and walkways on the escape route,* and *Solid door system at the exit*. This means that most of the buildings provide sufficient escape routes by foot for residents.
- However, the score for the *Fire elevator design* is worth considering since only half of the buildings observed have it, while the others do not. Four of these buildings without a fire elevator were built in 2012-2015, only the Tabudec building was built recently (2017). This phenomenon may be the result of the fact that building an extra

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elevator only for emergency purposes costs extra money that investors of the building were not willing to pay. In addition, the regulation about the fire elevator design was not enforced until 2010, so maybe all these building designs finished in 2012-2015 have already been approved at that time.

Active protection system

- *Level of fire resistance*: this is the basic requirement for any building to be built, so all the buildings are scored with 3.
- *Compartmentalization and separation*: three buildings scored 0 in this section: NC2, CT6A, and Tabudec. This may result from the need to maximize the profit of investors so they tend to want as many apartments as possible. Therefore, architects designed these buildings without compartmentalization, which could contribute to spreading the fire more quickly.
- *Protection on the aperture*: only NC2 scores 0 in this category, while other buildings all have a score of 2 or 3

Passive protection system

- As the basic requirement of fire safety items for any high-rise building, all the buildings have *automatic fire protection systems (sprinklers, fire alarms, smoke detectors…), fire extinguishers,* and *water supply systems* for them.
- However, there is no building that meets the requirement for *the rescue means* (a common demolition kit, smoke protection means, masks, and toxic filter covers). There are four building that does not even have this rescue means. Although these

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means are not having a big role when the fire happens, they can still save lives in some cases.

- In terms of *Fire utilities*, only Intra Riverside buildings meet all the requirements according to the regulation, CT8B, CT6A, and Tabudec scored 0 in the category.

Fire safety management

- All the building management boards are holding regular fire drills, fire safety inspections, and training employees with scores all 2 or 3. This can have a big role in improving fire safety for the building residents.

3.4.3 Weighted scorce calculation

The grading system and the weights assigned to each aspect were modified for this calculation. The outcomes of the achievement in each evaluated building can be examined using the OMAX approach. As shown in Table 11, the value gained by direct observation in the field on a scale of 0-3 is changed to a scale of 0-100. Table 3.14 illustrates how the scoring results from the observations were processed using OMAX on Building 1. In Column 1 of Table 3.14, the values for all features that were determined through direct observation in Building 1 are shown. This evaluation was based on Table 1, where each element was given a rating between 0 and 3. There were various numbers of elements for each facet. Each aspect can only have a maximum value of 3. A rating scale that runs from 0 to 100 is set up with OMAX. AHP was used to determine Column 2 in Table 3.14 (the weight of each aspect). By putting the observed scores on the scoring scale (0 points = 0, 1 point = 33.33, 2 points = 66.66, and 3pointst = 100), column 3 is created. As an illustration, the first aspect's observation score reaches 3 when it is plotted

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in the OMAX matrix, which is equal to 100. As a result, Column 3 of the scaled score for the first aspect is 100. The weighted score, which is a component of the building's total worth, is calculated by taking into consideration the weights in Column 2 and the scaled scores in Column 3. The overall weighted score displays the building's total value. This is classified by the standards in Table 3.10. Similar calculations were made using OMAX for each of the ten structures included in the study, as shown in Table 3.15.

Table 3.16 OMAX

BUILDING 1				
	1	**2**	**3**	**4**
Section	Score of observation	Weight	Scaled score	Weighted score
1.a	3	0.1315	100	13.151
1.b	2	0.0867	66.7	5.786
1.c	1	0.0620	33.3	2.063
2.a	3	0.0914	100	9.136
2.b	3	0.0709	100	7.088
2.c	3	0.0322	100	3.222
2.d	3	0.0319	100	3.193
2.e	3	0.0180	100	1.805
3.a	3	0.1162	100	11.620
3.b	3	0.0519	100	5.193
3.c	3	0.0426	100	4.260
4.a	3	0.0751	100	7.514
4.b	3	0.0361	100	3.611
4.c	3	0.0242	100	2.418
4.d	2	0.0147	66.7	0.978
4.e	2	0.0098	66.7	0.656
5	3	0.1047	100	10.467
		TOTAL=		**92.16**

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Table 3.17 Final OMAX result

No.	Building Name	Symbol	Final Score
1	PCC1 Ha Dong	PCC1	92.16
2	Intracom Riverside	Intra	97.34
3	Thang Long Garden	TLG	82.95
4	HH4B Linh Dam	HH4B	83.06
5	CT8B Dai Thanh	CT8B	65.18
6	NC2 Cau Buou	NC2	72.76
7	BooYoung Vina	BYV	88.34
8	CT6A Xa La	CT6A	63.46
9	Tabudec Thanh Oai	Tabudec	68.65
10	My Dinh Plaza	MDY	94.78

From Table 3.15, the researcher decided to divide the buildings into three groups. The first group consists of buildings that have a score above 85 (PCC1, Intra, BYV, and MDY). These buildings have a high score, which means that they meet most of the requirements for fire safety according to the checklist and could ensure the safety of their residents. For these buildings, the manager just needs to regularly check and maintain the fire protection system. The second group consists of buildings whose scores are from 70-85 (TLG, HH4B, and NC2). These buildings all lack some items, or some items did not meet the requirement. These buildings are advised to fix or change the broken and missing items. And the final group consists of the buildings whose scores are under 70 (CT8, CT6A, and Tabudec). These buildings are considered to have a high risk of fire and need to be checked and inspected by the authority until they fulfill all the required safety aspects. Although Intra, TLG, and HH4B had fire before and also did not meet some fire safety requirements in the past, their score is quite high: 97.34 for Intra, 82.95 for TLG, and 83.06 for HH4B. This means that these three buildings have improved their fire safety condition after having a fire in the past. However, the other two buildings that also had a fire (CT8B and CT6A) have a significantly lower

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score: 65.18 for CT8B and 63.46 for CT6A. This means that even after some fire incidents in the building, the safety condition is still poor and has not been improved, giving residents a high-risk living environment.

Table 3.18 Aspects with the lowest average score

No.	Aspects	The average score of observation
4.d	Arrange rescue means	1.2
2.d	Fire elevator design	1.5
4.e	Fire utilities	1.5
3.b	Compartmentalization and separation	1.9
1.b	Distance between buildings	2.1
1.c	Outside hydrants or other source of water	2.1

After calculating the average score of observation for all aspects, the researcher lists 6 aspects with the lowest average score in Table 3.16. *The arrangement of rescue means* like demolition kits or smoke masks, and toxic filters are lacking a lot. These types of equipment are often forgotten, not being purchased or maintained for a long time. *Fire elevators* and *Fire utilities* both have the same issue. These two aspects are the most likely to be ignored by the Vietnam building owner. If the buildings have already been built, it is hard to equip a new fire elevator since it will involve changing the structure of the building. However, items like fire extinguishers, demolition kits, emergency power systems, lighting, speaker, smoke detector, and smoke mask... can easily be purchased and equipped. *Compartmentalization and separation* and *distance between building* also can not be fixed or changed, but the building owner can improve safety by arranging more fire sprinkle or hoist around these places or may install fire resistance wall in endangered position. These two aspects (3.b and

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1.b) together with the *fire elevator* should be inspected at the design step more strictly by the authority so that in the future all the buildings will meet these requirements.

3.5. Concluding Remarks

To evaluate the fire safety situation of high-rise residential buildings in Hanoi, Vietnam, this study proposes a framework to evaluate fire safety on a larger scale. First, five main aspects of fire safety and their sub-aspects were adopted according to related research, fire safety regulations, and building codes. Then, using the AHP method to determine the weight for each aspect of the observation checklist, the researcher found out the six most important aspects from an expert's point of view, i.e., *Neighborhood Road*, *Level of fire resistance, Escape route, Distance between buildings, Automatic fire protection system, Escape stair and corridor.*

Next, an observation of the fire safety aspects has been done on ten high-rise buildings in Hanoi, Vietnam. After getting the observation result, using the weights from the AHP method and the Objective Matrix method (OMAX), the researcher processed the data and achieved the final score for each building. The result shows four buildings in the high score group, three in the medium score, and three in the low score group. Among ten buildings being observed, five of them had fire before, and from the final score, 3 of them have improved the level of fire safety while the other two remain unsafe.

After calculating the average score of each aspect, the author listed six aspects with the lowest score: *Arrange rescue means, Fire elevator design, Fire utilities, Compartmentalization and separation, and Distance between building and Outside hydrants or other source of water*. Some of these aspects can be improved easily, but some of them are hard to fulfill due to the

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need of changing the structure of the buildings. Although the Fire safety management of all buildings scores 2 or 3, they still need to enhance the fire safety behavior of the residents. Local government agencies, building authorities, as well as users and inhabitants of the facility, must appropriately execute fire safety management. Additionally, for the successful application of fire safety management in buildings, a clear legal control must be developed.

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Chapter 4: Questionnaire Survey of the Occupants of high-rise buildings in Vietnam

4.1. Introduction

Most building fires were the result of human carelessness, and most of them could be prevented by improving human knowledge and awareness about fire safety. High-rise building residents' behavior both before and during a fire has a significant impact on fire safety. This aspect is still a new subject in fire safety-related research. Prior research on fire safety mostly focused on the aspect of building structures, fire resistance material, and fire protection systems. Although humans are the most likely to cause a fire and the most likely to suffer from a fire accident the human factor has not been given enough attention. In this research, a questionnaire was conducted for occupants of different high-rise buildings in Vietnam about the fire safety facilities, and fire safety management of the building board from the residents' point of view and also check their knowledge, preparation, and awareness about fire safety.

4.2. Methodology

The respondents came from 34 different high-rise buildings in Vietnam (31 buildings in Hanoi, 1 in Bac Giang, 1 in Ho Chi Minh City, and 1 in Hung Yen) with different ages, educational backgrounds, gender, etc. The survey was carried out in one month in March 2023, originally written in Vietnamese for respondents and then translated to English by the author. The survey was given out using social networks such as Facebook and Zalo. Usually,

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every building has a residents' group where they can update the information about the building situation or notifications in it. After joining these groups, the author uploaded the survey via Google form and ask residents to help fill it in. At the end of March, the author closed the Google form and collected the surveys. The data from each survey were then put in Excel to process and analyze. In this chapter, the content, result, and data analysis of the survey are provided, including a discussion based on the result.

A questionnaire tool with questions that give better information about the entire research and highlight the issues, difficulties, and flaws in high-rise buildings were created to accomplish the intended study findings.

The structure of the survey includes four parts:

- Personal background
- Residents' awareness and preparation
- Residents' knowledge about building fire safety features
- Building's fire safety management

The questionnaire included the following questions:

- Personal background:
    - Age
    - Gender
    - Education level
    - Building name
    - Building height
    - Living floor

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- Years lived in the current building
- Total years lived in high-rise buildings

- Resident's awareness and preparation:
    - Do you think your building is in danger of fire?
    - Has your building ever had a fire incident?
    - Have you ever experienced an indirect fire incident? (Saw another building fire, or have friends or a family member been through a fire incident and then told you about it)
    - Have you ever attended a fire drill in your building?
    - How often do you turn off unused electrical appliances before leaving the house? (e.g., computer, fan, air conditioner, kettle, electric stove, vacuum cleaner, table lamp)
    - Do you have your fire extinguisher in your apartment?
    - Do you have an evacuation plan for yourself and your family in case a fire happens in your building?
- Resident's knowledge about building fire safety feature
    - Do you know the location of the escape stairs in your building?
    - Do you know where those stairs lead to?
    - Are those stairs' doors remained closed most of the time?
    - Do you feel the corridors in your building are wide enough for everyone on your floor to evacuate if a fire happens?
    - Does your building have a fire elevator?

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- Is your building equipped with an automatic fire protection system (fire alarms, smoke detectors, sprinklers)?
- Is your floor equipped with extinguishers and a demolition kit?
- Are there clear exit signs that can help you find the way to the escape stairs, fire elevator, extinguishers, and demolition kit?
- Are there any refuge floors or emergency rooms in your building?

- Building's fire safety management:
  - Does your building have regular fire safety inspections?
  - Does your building have a regular fire drill?
  - Does your building management board often mention fire safety issues during your regular building's resident meetings?
  - Does your building management board provide fire safety tips/information/warnings to residents (put up signs, fliers, and regulations in public space or use the building's communication system to inform residents)?

4.2.1. Proposed hypotheses

4.2.1.1. Dependent variable: Level of Knowledge and Awareness

After analyzing the answer to each question in the survey, it is necessary to take a closer look to see what factors affect the knowledge and awareness of the residents in high-rise buildings. And from this finding, some solutions can be proposed to improve the knowledge and awareness about fire safety.

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The categories to assess the Level of Knowledge and Awareness are 10 questions from 2 parts in the survey: Resident's awareness and preparation and Resident's knowledge about building fire safety features.

Resident's awareness and preparation: these questions provide information on the actions that residents should do improve their fire safety at home:

- Q1: How often do you turn off unused electrical appliances before leaving the house? (e.g., computer, fan, air conditioner, kettle, electric stove, vacuum cleaner, table lamp)
- Q2: Do you have your fire extinguisher in your apartment?
- Q3: Do you have an evacuation plan for yourself and your family in case a fire happens in your building?

Resident's knowledge about building fire safety features: these questions provide information on whether the respondents understand the fire safety features of their building, and from this researcher can evaluate if they can evacuate easily if a fire happens and if they pay attention to the fire safety of the building they live in:

- Q4: Do you know the location of the escape stairs in your building?
- Q5: Do you know where those stairs lead to?
- Q6: Does your building have a fire elevator?
- Q7: Is your building equipped with an automatic fire protection system (fire alarms, smoke detectors, sprinklers)?
- Q8: Is your floor equipped with extinguishers and a demolition kit?

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- Q9: Are there clear exit signs that can help you find the way to the escape stairs, fire elevator, extinguishers, and demolition kit?
- Q10: Are there any refuge floors or emergency rooms in your building?

The factors that affect the Level of Knowledge and Awareness (LKA) of respondents are the respondents' background and experiences with fire, according to the existing studies [6, 56]. .

4.2.1.2. Hypotheses

(1) Age

Age is an independent variable showing the age of respondents. People which different age usually has different thoughts, experiences, and preferences.

H1: Age has a positive impact on the LKA

(2) Living floor

This is an independent variable presenting the current living floor of respondents. Higher-floor residents reported feeling more risk-averse due to the potential of having to go far distances down stairwells in the event of an emergency [56]. It is expected that with this higher risk, residents on higher floors will have more knowledge and awareness.

H2: The living floor has a positive impact on the LKA

(3) Past fire incidents

This is an independent variable presenting whether the building respondent was living in had a fire before. When buying an apartment, if the buyer knows the building had fire before,

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they tend to be more careful with the fire safety of the building. Consequently, has more knowledge and awareness.

H3: Fire incident has a positive impact on the LKA

(4) Indirect fire experience

This is an independent variable presenting whether the respondents have indirect fire experiences or not. Indirect experiences here mean that you saw another building fire or have friends or a family member been through a fire incident and then told you about it. As a result of seeing or hearing about a fire, people began to consider how to prepare for an evacuation in their own homes and/or buildings [56]. We assumed that seeing or hearing a fire risk that close to the respondent can improve their knowledge and awareness.

H4: Indirect experience has a positive impact on the LKA

(5) Fire drill

This is an independent variable presenting whether the respondents attended the fire drills of their building. Attending a fire drill can help a person to gain much knowledge about fire safety. Zmud [85] also looked at how respondents felt about fire drills and how they participated in them. Most residents of high-rise buildings (80%) shared the belief of commercial high-rise residents (89%) that fire drills improve building security.

H5: Fire drill has a positive impact on the LKA

4.2.1.3. Control variables

(1) Gender

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These control variables compare the answers between males and females. In the SPSS software, we assumed male is one and female is zero

(2) Education level

This is a control variable presenting the highest education of the respondents. We divided it into 4 groups: High school, Bachelor's degree, Master's degree, Ph.D. degree

(3) High-rise building living experience

This is a control variable presenting the year of living in a high-rise building of respondents. It is divided into three groups: 1 to 4 years, 5 to 8 years, and above 8 years

4.2.2. Model establishment and regression analysis

Based on the hypotheses and variables, the researcher created a full model. $Level\ of\ Knowledge\ and\ Awareness = \beta 0 + \delta 1\ Gender + \delta 2\ Education + \delta 3\ Living\ experience + \beta 1\ Age + \beta 2\ Living\ floor + \beta 3\ Fire\ incident + \beta 4\ Indirect\ experience + \beta 5\ Fire\ drill + u$

$\beta 0$ is the constant, δ 1- $\delta 3\ and$ $\beta 1$-$\beta 6$ are regression coefficients, and u is a random disturbance. To test each hypothesis, the researcher analyzes the data against the null hypothesis to see if the hypothesis has a significant positive or negative impact on the LKA.

The researcher used Excel to calculate the score for each respondent and then inserted the data into SPSS software to analyze the data with a Multiple regression model. A chi-square test is a statistical test that is used to compare actual outcomes to predictions. The Durbin-Waston test is performed to check the multicollinearity.

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Using the data from the survey with the chosen questions, we prescribe the answers. Question 1 to question 5: if the answer is "Yes", we plus 1 point, "No" is equal to 0 points since the answer to these questions is just Yes or No, representing whether the respondents do it or not and whether they know about it or not. For questions 6 to 10, if the answer is "Yes" or "No", plus 1 point if the answer is "I don't know" then plus 0 points. These questions asked whether the respondents' building has the facilities or not, so if they answer "Yes" or "No" then they do aware of whether the facility was present or not. But if the answer is "I don't know" means that they did not aware of that facility. The maximum score is 10 and the score range is divided into 3 ranges: 0-4 (bad), 5-7 (medium), and 8-10 (good).

4.3. Finding and Discussion

4.3.1. Background

To distribute the survey, the author used social networks: Facebook to distribute the survey to be able to a wide range of respondents from different high-rise buildings. The researcher has received 96 questionnaires from 34 different buildings. According to Table 4.1, out of 96 respondents, there were 53% (51) were male, while the remaining 47% (45) were female.

Table 4.1 Respondents' background

Description	Frequency	Percentage (%)
Age		
18-30	51	53%
30-50	29	30%
50-60	14	15%
>65	2	2%
Gender		
Male	51	53%
Female	45	47%
Education level		

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High school	5	5%
Bachelor	62	65%
Master	21	22%
PhD	8	8%
Living floor		
From 1 to 6	22	22.9%
From 7 to 15	40	41.7%
Above 15	34	35.4%

Most of the respondents were in the age range of 18 to 30: 53% (51), 30% (29) were people in their 30s and 40s, and 17% (16) were older than 50. Most of the respondents had a bachelor's degree, 65% (62), and a Master's degree, 22% (21), while only 8% had finished a Ph.D. degree, and 5% (5) had finished high school.

Among 96 respondents, 22.9% (22) were living on the lower floors (from 1st to 6th floor), 41.7% (40) were living on the medium floors (7th to 15th), and 35.4% (34) were living on higher floors (above 15th floor). Residents who resided on upper levels reported feeling more risk-averse due to the potential for needing to go far distances down stairwells during an emergency. [56]

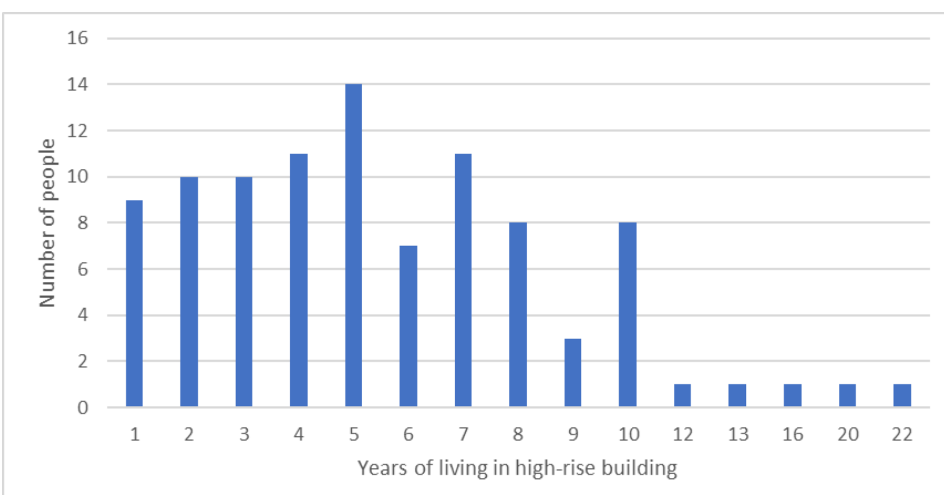

Figure 4.3 Respondents' living experience in a high-rise building

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The experience of living in a high-rise building respondent was varied but mostly from 1 to 8 years since the blooming era of high-rise buildings and urbanization in Vietnam had just started not really long ago. 33,122,548 people live in urban areas in Vietnam, making up 34.4% of the total population, according to the General Statistics Office of Vietnam (Tong cuc thong ke, 2019, para 26). Urban areas experienced an average annual population growth rate of 2.64%/year between 2009 and 2019, which is six times greater than the average annual population growth rate for the same number of rural areas and more than twice as high as the average annual growth rate for the entire nation. Regarding Figure 1, the number of respondents who had lived in a high-rise building for 8 years or less is 80 people, occupying 83% of all respondents.

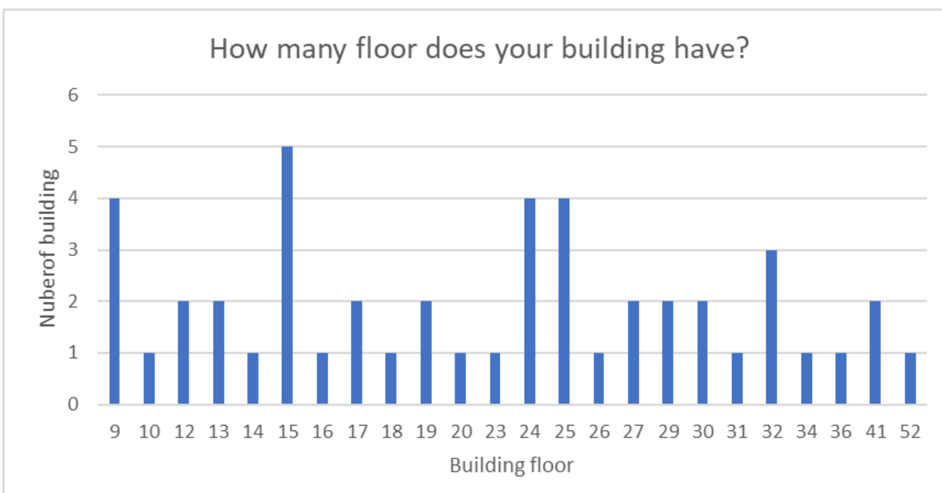

Figure 4.4 Respondents' buildings' floor

From Figure 4.2, the number of floors is different and varied, only 9, 15, 24, 25, and 32 are significantly larger compared to others. With the development of construction technology as well as the increase in the number of urban citizens, the height of high-rise buildings will get higher and higher to meet the demand for accommodation in big cities.

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Figure 4.5 Buildings' construction year

In Hanoi, the capital city of Vietnam, before 1954, the tallest building was 7 floors. Before 1986, the 11-story Hanoi hotel was built. By 2005, opening the era of high-rise buildings in new urban areas, Hanoi had built nearly 60 high-rise buildings (from 9 floors or more). In 2020, the city has over 300 high-rise buildings and the tallest building is Keangnam Hanoi Landmark Tower with 73 floors with 336m (kintedothi, 2022, para 6). Figure 3 shows the year of construction of the buildings in the survey, the time varied but most of the buildings were finished after 2014.

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4.3.2. Resident's awareness and preparation for fire

Table 4.2 Part 2: "Resident's awareness and preparation for fire" surveyed data

No.	Description	Frequency	Percentage
2	**Resident's awareness and preparation:**		
2.1	**Do you think your building is in danger of fire?**		
	Yes	49	51%
	No	16	17%
	Maybe	31	32%
2.2	**Have your building ever had a fire incident?**		
	Yes	19	20%
	No	58	60%
	Maybe	19	20%
2.3	**Have you ever experienced an indirect fire incident? (Saw another building fire, or have friends or a family member been through a fire incident and then told you about it)**		
	Yes	53	55%
	No	43	45%
2.4	**Have you ever attended a fire drill in your building?**		
	Yes	50	52%
	No	46	48%
2.5	**How often do you turn off unused electrical appliances before leaving the house? (e.g., computer, fan, air conditioner, kettle, electric stove, vacuum cleaner, table lamp)**		
	Yes	47	49%
	No	49	51%
2.6	**Do you have your fire extinguisher in your apartment?**		
	Yes	14	15%
	No	81	85%
2.7	**Do you have an evacuation plan for yourself and your family in case a fire happens in your building?**		
	Yes	49	51%
	No	47	49%

Table 4.2 shows the results of the second part of the questionnaire, which is related to residents' awareness and preparation for fire. From the result of question 2.1, although most of the respondents consider the buildings in which they were living have the risk of fire (51%) or maybe in danger of fire risk (32.3%), only 17% say "No". Most of the respondents who

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answered “No” come from recently built buildings or high-quality buildings with expensive maintenance fees. This is worth considering since a fire that happens in a high-rise building can take many lives and cost a lot of damage. Seeing a large proportion of residents consider their living buildings endangered, some actions should be taken to change it. However, if they have some level of fire risk perception, they tend to be more well-prepared for fire safety.

Regarding Question 2.2, only 20% of respondents said that their buildings had experienced fire before. Residents’ awareness of fire safety and their perception of the risk of fire were raised if a fire occurred in their building, and this boosted their drive to prepare their apartments for fires and other crises [56]. This is only a small number since among this 20%, many of them are from the same building. However, although a fire in high-rise buildings rarely happens, they still pose a huge risk if ever happen.

From the result of Question 2.3, 55% of the respondents had their friends, family members, or colleagues tell them about their experience with fire. Having indirect fire experience can increase their knowledge and awareness for them. As a result of seeing or hearing about a fire, people began to consider how to prepare for an evacuation in their own homes and/or buildings. [56]

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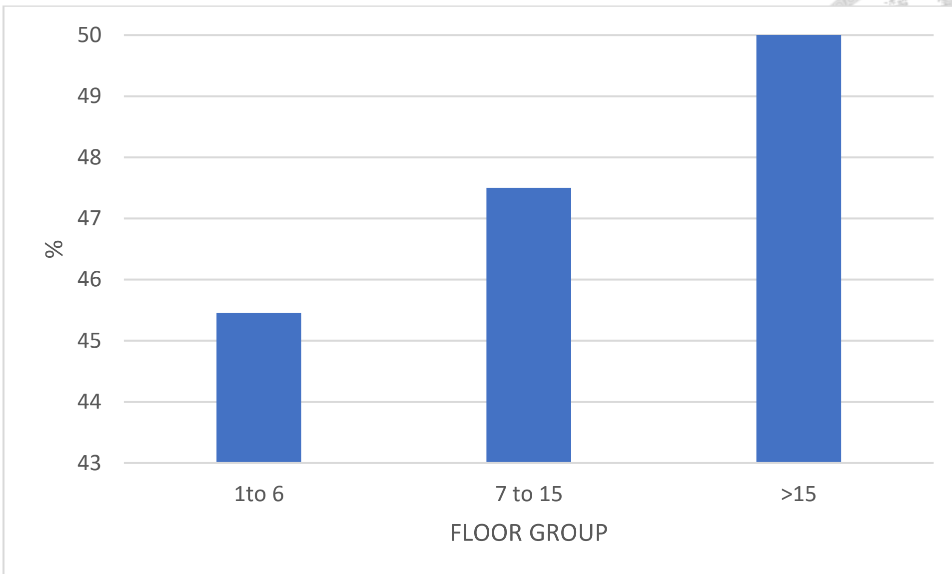

Figure 4.6 Percentage of each age group that participated in the building's fire drill

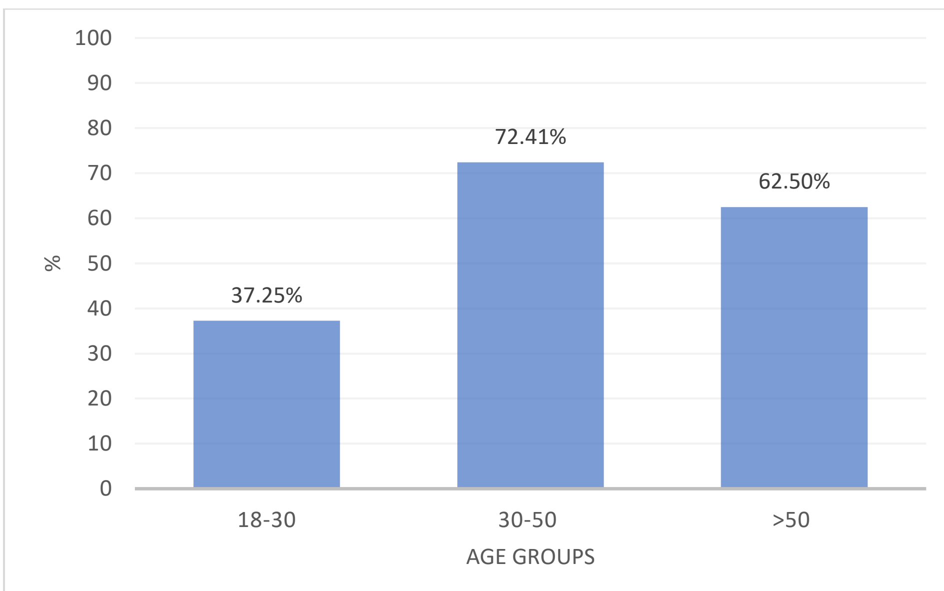

Figure 4.7 Percentage of each floor group that participated in the building's fire drill

The result of Question 2.4 shows that only 52.1% have attended the fire drill in their building, although fire drills are required for every resident in any building. Attending fire drills can give them and their family a greater chance to survive if a fire happens. They may not have spare time to join it, or they just do not care about fire safety, or their building does not

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organize fire drills for residents. From Figure 4.4, respondents who are in the 18-30 age group have a significantly lower percentage of attending the fire drill than other age groups, although 18-30 had the greatest number of people in the survey (53%). This shows that younger residents did not care about their fire safety as much as the older respondent. Another factor that affects the willingness to attend the fire drill is the floor respondents live in, according to Figure 4.5, people who live on higher floors are more likely to join the fire drill. This comes from the fact that the higher floor they live on, the harder to evacuate once there is a fire in the building, so they have a higher fire safety perception than their neighbor on the lower floor.

According to the fire department statistic, electrical fault is the most common cause of fires. However, from the result of Question 2.5, not only in high-rise building fires but also in other kinds of fire 49 % of the surveyees have the habit of turning off electrical devices before leaving home. This shows that even though residents feel the threat of fire risk, there is a large proportion of them do not take any action about it.

The best time to stop a fire is when it just starts. The longer the time, the bigger the fire. Although in most cases, every floor of a high-rise building has at least one fire extinguisher, going out of the room, getting the fire extinguisher, and going back maybe already missed the perfect time to put out the fire. Having a fire extinguisher in each room can increase the safety of the residents and the whole building. However, based on the results of Question 2.6, only 15% of respondents said that they purchased a fire extinguisher for their apartment.

Residents usually take a longer time to evacuate since they have many belongings and valuable assets in their houses compared to office workers who work in high-rise buildings.

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Therefore, an evacuation plan of what belongings to get before evacuating and how to evacuate out of the building is crucial for their safety. From the result of Question 2.7, it is found that only 51% of them have an evacuation plan for their family and themselves in case of fire.

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4.3.3. Residents' knowledge of building fire safety features

Table 4.3 Part 3: "Resident's knowledge about building fire safety features" surveyed data

No.	Description	Frequency	Percentage
3	**Resident's knowledge about building fire safety feature**		
3.1	**Do you know the location of the escape stairs in your building?**		
	Yes	85	89%
	No	11	11%
3.2	**Do you know where those stairs lead to?**		
	Yes	73	76%
	No	23	24%
3.3	**Are those stairs' doors remained closed most of the time?**		
	Yes	47	49%
	No	20	21%
	Maybe	29	30%
3.4	**Do you feel the corridors in your building are wide enough for everyone on your floor to evacuate if a fire happens?**		
	Yes	67	70%
	No	17	18%
	Maybe	12	12%
3.5	**Does your building have a fire elevator?**		
	Yes	21	22%
	No	59	61%
	Maybe	16	17%
3.6	**Is your building equipped with an automatic fire protection system (fire alarms, smoke detectors, sprinklers)?**		
	Yes	83	86%
	No	2	2%
	Maybe	11	12%
3.7	**Is your floor equipped with extinguishers and a demolition kit?**		
	Yes	79	82%
	No	11	12%
	Maybe	6	6%
3.8	**Are there clear exit signs that can help you find the way to the escape stairs, fire elevator, extinguishers, and demolition kit?**		
	Yes	79	79%
	No	13	13%
	Maybe	8	8%
3.9	**Are there any refuge floors or emergency rooms in your building?**		
	Yes	10	10%
	No	54	54%
	Maybe	32	32%

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Table 4.3 shows the results of the third part of the questionnaire, which is related to residents' knowledge about the fire safety features of the building. From Questions 3.1 and 3.2, 88.5% of the surveyees know where the escape stairs are, and 76% of them know where these stairs lead, which is a really good sign since stairs are the main escape means in any high-rise building. The people who do not know the location of the stairs or where they lead often are people living in the upper part of the building since they rarely use stairs and mostly use the elevator, so they do not have to need to know about it.

Based on the results of Question 3.3, 20% of the residents said that the door leading to the escape stair is not closed, which is worth worrying about since if the fire happens, smoke can flow into the stair hole and prevent residents from escaping the building or even help the fire to spread to the higher floor due to the stack effect.

From the result of Question 3.4, 70% of the surveyees think that the width of the corridor is enough for everyone on the floor to evacuate safely at once, so there may be no need to adjust the corridor's width.

As for Question 3.5, although the regulation states that all high-rise buildings must have a special elevator for the firefighters to use in emergency cases, 61.5% of residents said that their buildings do not have one, 21.9% said their buildings have one, and 16.7% said they do not know. This phenomenon may be a result of the fact that building an extra elevator only for emergency purposes costs extra money that investors of the building were not willing to pay. In addition, the regulation about the fire elevator design was not enforced until 2010, so maybe all these building designs finished in 2012-2015 have already been approved at that

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time. Table 4.4 shows the buildings in the survey which has fire elevator, it is clear that most of the buildings are finished after 2015 (except the first two buildings in Table 4).

Table 4.4 Buildings which has fire elevator

No.	Building's name	Year of construction	Floor	Number of blocks
1	HA DO	2011	9	5
2	IMPERIAL SKY GARDEN	2013	24	4
3	FIVE STAR	2016	17	6
4	S1 07 OCEAN PARK	2016	29	3
5	VIET DUC COMPLEX	2017	30	1
6	HOMECITY TRUNG KINH	2018	24	1
7	MY DINH PLAZA	2018	25	7
8	No17-2 SAI DONG	2019	27	2
9	SKY 3 - AQUABAY - ECOPARK	2019	30	3
10	Wesbay Ecopark	2020	32	6

From the responses to Question 3.6, over 80% of surveyees said that their buildings are equipped with automatic fire protection systems, fire extinguishers, demolition kits, and signs to have people find them. This means most of the high-rise residential buildings have enough fire protection facilities. Similarly, from Questions 3.6, 3.7, and 3.8, most of the buildings (80%) meet the requirement of fire extinguishers, demolition kits, and exit signs to escape stairs.

The result of Question 3.9 shows that more than 54% of the buildings do not have a refuge floor or an evacuation room for residents. For a building with a great height (30 floors and above), it is difficult to evacuate everyone at once, so a refuge floor can help save many lives in case a big fire happens. According to some real estate experts, the reason is that restricted by the National Technical Standard on Housing, apartments over 100m high (about 25 floors)

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must have a shelter (also known as a refuge floor) for fire prevention, but almost no investors do. Construction experts believe that the construction of a refuge space requires a lot of costs, making investors afraid to invest in apartment projects. When it comes to fire safety and other incidents, it shows that most of the apartments have holes that are hard to "cover", which is a refuge room for residents. In most fires, residents panic to find a way to escape to the lower floor or the top floor, without a qualified refuge or evacuation room for residents to stay.

4.3.4. Building's fire safety management

Table 4.5 Part 4: "Building's fire safety management" surveyed data

No.	Description	Frequency	Percentage
4	**Building's fire safety management**		
4.1	**Does your building have regular fire safety inspections?**		
	Yes	45	47%
	No	14	15%
	Maybe	37	38%
4.2	**Does your building have a regular fire drill?**		
	Yes	39	41%
	No	32	33%
	Maybe	25	26%
4.3	**Does your building management board often mention fire safety issues during your regular building's resident meeting?**		
	Yes	44	46%
	No	18	19%
	Maybe	34	35%
4.4	**Does your building management board provide fire safety tips/information/warnings to residents (put up signs, fliers, and regulations in public space or use the building's communication system to inform residents)?**		
	Yes	66	70%
	No	15	15%
	Maybe	15	15%

Table 4.5 shows the results of the questions related to the fire safety management of the building. According to the results of Question 4.1, only 46.9% of surveyees said that their buildings are inspected regularly, 14.6% said No, and 38.5% did not know about it. This issue

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is worth noticing since regular inspection of fire safety can help detect problems with the fire protection system: errors, out-of-date, not working, etc. This inspection required the involvement of the authority, the fire department in particular, since the building management board themselves do not usually want to spend extra money on maintenance or purchase new fire protection systems or items. Residents can also contact the fire department themselves to request an inspection if they find anything that can affect the fire safety of the building.

Based on the responses to Question 4.2, only 40.6% of surveyees said that their buildings have a regular fire drill and 26% said they have no idea whether their buildings held it or not, 33.3% said their building did not hold it. This percentage is not meet up with the regulation of the government as a building has to hold a regular fire drill at least once a year. However, this issue can be affected by some reasons. First, it may be the surveyee did not know about the fire drill since they might be busy or missed the notification about it. The second reason is that the COVID-19 pandemic has spread worldwide since 2019. All social activities were postponed so the residents who have lived in the building for under four years (64.6%) did not have a fire drill in their building.

The result of Question 4.3 shows that only 45.8% of people said that the issue of fire safety was mentioned in their building's residents' regular meeting, 18.7% said "No" and 35.4% said that they did not know about it. The people who said they do not know about it could be the ones who did not attend the regular resident meeting. However, the frequency of mentioning fire safety issues in the meeting needs to be improved since it is an event that can gather most of the building's residents in one place, and by doing so, the building management board can raise awareness about this issue for people who live there.

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From question 4.4, 68.8% of surveyees said that their building management board provides fire safety tips/information/warnings to residents (putting up signs, fliers, and regulations in public spaces or using the building's communication system to inform residents).

4.4. Data analysis

The descriptive statistics of the variable are shown in the table below:

Table 4.6 Descriptive statistic

	Mean	Std. Deviation	N
Awareness and Knowledge	2.38	0.7	96
Gender	0.53	0.502	96
Education	1.33	0.706	96
Living experience	1.46	0.679	96
Age	0.64	0.756	96
Living floor	1.11	0.752	96
Fire incident	0.2	0.401	96
Indirect experience	0.55	0.5	96
Fire drill	0.52	0.502	96

Table 4.7 shows the summary result of Hierarchical regression analysis from SPSS software of Model 1 (containing only control variables) and Model 2 (containing all variables). * means $p<0.15$: slightly significant, ** means $p<0.1$: significant and *** means $p<0.05$: very significant. The sample size in this analysis is 96.

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Table 4.7 SPSS RESULT

Model		Unstandardized Coefficients	Standardized Coefficients	p-value	R-squared	Adjusted R-squared
		B	Beta			
1	(Constant)	1.561		0	0.164	0.136
	Gender	0.304	0.218	0.026***		
	Education	0.248	0.25	0.011***		
	Living experience	0.221	0.215	0.028***		
2	(Constant)	1.53		0	0.419	0.365
	Gender	0.335	0.24	0.005***		
	Education	0.215	0.217	0.015***		
	Living experience	0.035	0.034	0.706		
	Age	0.071	0.077	0.435		
	Living floor	-0.129	-0.139	0.116*		
	Fire incident	-0.046	-0.026	0.768		
	Indirect experience	0.166	0.119	0.183		
	Fire drill	0.661	0.475	<0.01***		

For Model 1 with only control variables, the adjusted R-squared is 0.136, which means that the model's explanatory model is 13.6%. The control variables have some level of effect on Model 1. In Model 1, all three variables are very significant to the Level of Knowledge and Awareness.

In Model 2, Gender, Education, and Fire drill all have ***, which means a very significant and also positive correlation. For Gender, since the author assumed that male is 1, female is 0 and the result is a positive correlation so it means that males tend to have better knowledge and awareness about fire safety compared to females. For the Education level, higher education levels are assumed with higher value so it means that the resident with higher educational levels tend to have better knowledge and awareness. For Fire drills, attending fire drills makes residents better knowledge and awareness. The living floor has a * and negative correlation, meaning it is slightly significant and the people living on the lower floor

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tend to have better knowledge and awareness about fire safety. The other four factors: Living experience, Age, Fire incidents, and Indirect experience are not significant. Living experience is very significant in Model 1, but after adding other factors in the Model 2, Living experience become not significant .The adjusted R-squared of Model 2 is 0.365, which means that the model's explanatory power is 36.5%, which is considerable.

The Durbin-Waston coefficient is 1.92, in the range of 1-3, so there is no multicollinearity.

Table 4.8 Correlation

Correlations	LKA	Gender	Education	Living experience	Age	Living floor	Fire incident	Indirect experience	Fire drill
LKA	1								
Gender	0.206	1							
Education	0.256	-0.089	1						
Living experience	0.255	0.05	0.117	1					
Age	0.301	-0.095	0.309	0.391	1				
Living floor	-0.083	0.06	0.046	-0.104	-0.148	1			
Fire incident	-0.117	-0.057	-0.05	-0.105	-0.142	0.238	1		
Indirect experience	0.184	0.077	-0.08	0.146	0.176	-0.03	0.237	1	0.1
Fire drill	0.517	-0.024	0.099	0.249	0.256	0.119	-0.099	0.1	1

Table 4.9 Hypothesis result

Hypothesis	Describe	p-value	Impact	Conclusion
H1	Age	0.435	Not significant	Reject
H2	Living floor	0.116	Slightly significant	Accept
H3	Fire incident	0.768	Not significant	Reject
H4	Indirect fire experience	0.183	Not significant	Reject
H5	Fire Drill	<0.01	Very significant	Accept

4.5. Concluding remarks

After receiving 96 responded surveys from 34 different residential high-rise buildings, the researcher analyzed all the data to get a clearer view of high-rise buildings' residents'

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awareness and preparation for fire, knowledge about buildings' fire safety facilities, and the fire safety management of the building's management board.

For the awareness and preparation aspect, most of the respondents feel their buildings were exposed to fire risk, which is worth concerning. There were 20% of the respondents said that their building had a fire before, which is a quite high percentage for high-rise buildings. Although if a person had a direct or indirect experience with fire, they could gain some level of awareness and preparation, the most effective way is still attending a fire drill. Only then can they know about which is the best way to evacuate in case a fire happens in the building, what they should do, who should they ask for help, and what they could prepare beforehand to increase their level of safety. Although electrical faults are the most common cause of fire in high-rise buildings, half of the respondents said they did not have the habit of turning electrical devices off before they leave home. This could lead to a more severe situation since if the fire breaks out when the door is locked, it would be devastating since it is hard to put out a fire in a locked room. In addition, residents should also check the safety of their household electrical devices regularly to reduce the fire risk. Having a fire extinguisher in each apartment can be a lifesaver since the owner can put out the fire before it spreads out and when evacuating, bringing an extinguisher with them can be very helpful. However, only a very small proportion (15%) of respondents decided to purchase it. And lastly, residents' safety must have an evacuation plan but only half of the respondents came up with it.

In terms of knowledge about building fire safety facilities, most of the respondents had a decent knowledge about their building facilities like the location of escape stairs, fire protection system, fire extinguisher, or demolition kit. From the survey, the author found out that a huge percentage of the respondents' buildings were not equipped with fire elevators

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and refuge floors. This phenomenon was mostly a result of the intention to maximize the profit of the investor since these two designs are rarely used and cause extra money to build and do not bring create any economic benefits. From the result of the multiple regression model, we can see the same background of respondents who had weak knowledge and awareness of fire safety. Building managers can base this study to know which part of residents they should focus more on improving their knowledge about fire safety: the residents who have only finished high school and a bachelor's degree. Another important finding from the multiple regression model is the fire drill has a big part in ensuring the level of awareness and knowledge of fire safety.

For the building fire safety management, almost half of the respondents said that their building had regular fire inspections and fire drills although these activities are important to ensure the fire safety of the building. If not checked and maintained regularly, the fire protection system might have been degraded and damaged as the time when by. While fire safety inspection is the responsibility of the Fire departments, the organization of fire drills is the responsibility of the building management board. The spreading of the COVID pandemic all around the globe since 2019 may be a factor in this issue since all social activities were postponed to remain social distancing. But it also can be a result of the lack of care from both government and the management board, especially the management board of old buildings. Data from the respondent also show that the issue of ensuring fire safety was not given enough care since only half of the respondents noticed that this issue was brought up during their regular resident meetings. While fire drills can teach them what to do when a fire happens, the ways to prevent the fire from happening and how to increase fire safety in each apartment should also be considered. For example, the building management

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can suggest resident check their electrical devices regularly, or warn them not to turn on too many energy-consuming devices like air conditioners, electric heaters, or hot water during busy hours to avoid electrical overload.

The result from the multiple regression shows that Gender, Education level, Living floor, and Fire drill are factors that affect the respondents' level of knowledge and awareness of fire safety in high-rise buildings. Therefore, we can focus on these four aspects to increase the knowledge and awareness of high-rise building residents.

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Chapter 5: Role and Responsibility of Stakeholders

Based on the literature review and the results of previous chapters, this chapter will provide an in-depth discussion of how to improve fire safety for high-rise residential buildings in Vietnam. For this purpose, the five main stakeholders of high-rise buildings are defined so that the author can give specific suggestions to each stakeholder on what they can do to improve fire safety. The five main stakeholders are Investor, the Designer, the Resident, the Building management board, and Government.

5.1. Investors

High-rise building architecture is currently developing massively in Vietnam's major cities. Investors and managers pay great attention to the aesthetic quality and architectural form of buildings and high-rise buildings because these buildings can be the symbol of the city and the brand of the company. However, behind that beauty is a series of strict requirements on technical requirements, in which the requirement of ensuring fire safety is one of the top criteria. In the current context, being well equipped with fire prevention and fighting work also brings efficiency and prestige to investors so that customers will put their trust in works to ensure fire safety. There are some suggestions for investors:

- To ensure fire safety from the beginning, investors should hire a fire safety expert from the design phase. This expert can consult with the design, the purchase option and the construction of the building, installation of the fire protection system. Investors should spend more budget on fire protection systems, fire resistance designs, and materials.

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- In addition, investors often do not approve of fire safety designs like emergency elevators, refuge floors, and better design of compartmentation because they want to maximize the profit (from the result of questions 3.5 and 3.9 in Section 4.3.3 and the result of the observation in Section 3.4.2 that the elevator design and compartmentalization were often ignored). However, with a better design and a high level of safety, buyers are willing to pay more to have a safe living apartment.
- Investors should establish the building management board as soon as possible so that this management board can start their job of managing the building situation. Investors often hold the 5% apartment price as the maintenance fee and do not give it back to the management board. The investor must fully comply with the provisions of the Law on Fire Prevention and Fighting.

5.2. Designers

Besides following all the design standards and regulations of the government, designers should also consult international documents and consider the specific situation of the building. For example, with the old quarters and old streets in the inner of major cities in Vietnam, it is not possible to completely apply the standards and regulations as prescribed due to old traffic infrastructure, and density densely population. It is very difficult to carry out firefighting, rescue, and rescue operations. Therefore, it is necessary to actively invest in fire prevention with the motto "four on the spot": on-site commander, force on site, vehicles on site, on-site supplies, and logistics [86].

According to Table 3.13 , the number of outdoor hydrants in some buildings did not meet the requirement, which could affect the firefighting process. Therefore, the designer should make

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sure that the minimum number of hydrants is enough. In addition, 50% of the buildings observed did not have a fire elevator, although it is required by the regulation. Compartmentalization of three out of ten buildings was also a 0 score. Designers must strictly follow government regulations and standards to ensure the safety of the residents.

According to the Department of Firefighter and Rescue Police [16], designers could follow below suggestion:

Regarding construction architecture, most high-rise buildings are designed in the form of closed blocks. Therefore, when a fire or explosion incident occurs, the apartment corridor and the stairs system are the only escape routes to help people escape. When designing architecture, corridors must be ventilated and take advantage of natural light, and the emergency exit system must comply with regulations.

Proposed solutions need to separate the air escape, escape, and limit fire and explosion in both the horizontal and the height of the high-rise building. It is recommended that the complex of high-rise buildings should be divided into more than two blocks, creating gaps on both vertical and horizontal units, but limiting the use of skylights in the core of buildings.

The garage area for cars and motorbikes often has a high risk of fire and explosion (an example is the Carina building fire in 2018 started from the garage, in the Introduction chapter), so the best solution is to separate the garage area into a separate block from an apartment block to minimize the risk of fire and explosion, encouraging construction according to floating beach architecture with completely open space to ensure ventilation and no smoke and toxic gas.

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On the other hand, it is suggested not to arrange living rooms or crowded rooms in the basement. For apartments, it is advisable to design the kitchen inside, limit the placement of the kitchen adjacent to the apartment door, and face the corridor, and the common hall creating an "energy core" of the building. When there is a fire incident, this "energy core" is easily spread through the central gas system used in daily life. And in this case, the emergency exit stairs system is the first affected object. This is taboo when the vertical exit stairs cannot be used. Also, it is not suggested to arrange transformer rooms or oil tanks in the basements. If the transformer is arranged in the basement, it must be a dry transformer and not exceed the first basement. A fire-proof control room must be arranged for the building, and the watch room must ensure fire prevention in other areas, with direct exits. The exit to the roof is arranged directly from the stairwells, through the attic, or by the fire ladder outside the house.

5.3. Building management board

Management board plays a significant role in ensuring fire safety during the operation phase of a building. They are the bridge between the residents, government, and investors. Their main roles in fire safety are:

- Hold fire drills for residents, inform residents about fire safety issues, hold fire drills for residents
- Make sure the fire protection system in the building works smoothly, and do the regular maintenance
- Cooperate with the fire department to maintain the fire safety

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According to the result of Chapter 4, Gender, Education Level, Living floor and Fire Drill are four factors that affect the level of knowledge and awareness of fire safety the most. Therefore, the building manager should pay more attention to these four factors. For gender, the manager should give more attention to women since they are the group that had poorer results in the survey. For education, the manager should focus more on residents who only had a bachelor's degree or below since, from the survey, this group had a lower level of knowledge and awareness. For the living floor, the result shows that respondents who live on the lower floor tend to have better knowledge and awareness. The manager should make a list of residents in each apartment with their background information and decide which one needs more attention based on the list. The attention here can be texting, mail, or phone call to check the fire safety conditions in the apartment or give safety tips, information, etc. For fire drills, the building management board should hold more fire drills since once a year is not enough. Also, officers from the fire department should be invited to instruct residents and give advice about what to do when a fire happens. A list of who attended should also be recorded so that the manager can check who has skipped the fire drill and required them to join the next one. A tutorial video should also be made so that in case someone can not join, they can still watch and have some knowledge about it.

Also, Glauberman found out that residents' fire safety behavior is deeply affected by their building's leadership [56]. Greater trust between the management board and residents should be built, which can further encourage high-rise buildings' fire safety if building management can deliver reliable fire safety information that suits the needs and preferences of occupants. The building management board can do that by:

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- Hold regular inspection for fire safety facilities in the building, regular maintenance for those facilities, and the building's electricity system since electrical faults is one of the main causes of fire in a high-rise building (result from the statistic in Section 2.5 that the electrical faults are the most common cause of fire in Vietnam).
- Hold regular for building staff, for residents.
- Forbid smoking, use gas for cooking, and monitor closely for any renovation activities of residents.
- Inform residents more about the fire issue in the area, and the building, raise awareness for residents by giving safety tips, and mention it in the regular resident meeting.
- Invite officers from the fire department to the fire training and the regular meeting to educate staff and residents about fire safety.
- Keep a close relationship with residents to take immediate action if any risk happens in the building.
- Keep a close relationship with the fire department or police in the area to have information about any risks that appear in the neighborhood and be able to call them if anything happens.
- Cars, motorbikes, and vehicles containing petrol and flammable liquids stored on the first floor or basements of multi-story houses must be far from sources of fire and heat. Equipment for storing and transporting petrol and oil must be closed and neatly arranged so as not to obstruct the escape route. Do not bring e-bikes up to the floors to charge. Do not arrange a place for charging electric bicycles together with the area

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for motorbikes in the garage area, and must plan an area for charging electric bicycles to a separate area and take appropriate measures to ensure fire safety [16].

5.4. Residents

As the main potential victim if a fire happens and also the ones who can cause fire, residents should comply with the fire safety regulation of the building. Besides attending all the fire drills of the building, residents should also equip themselves with fire safety knowledge, purchase fire safety equipment and plan their evacuation plan. Residents should inform the management board if they find out any sign of fire risk or if any part of the fire protection system is not working.

Based on the situation of fire safety in Vietnam, residents are suggested to do the followings by the Department of Firefighter and Rescue police [16]:

- Do not leave any flammable utensils and goods near the cooking place. Do not store gasoline, oil, gas, and flammable liquids in the house. In case of need to reserve, only store them in minimum quantity.
- Do not use wood, plastic sheets, or foam ... to cover walls, ceilings, or partitions to limit the risk of spreading fire and large fires.
- Self-cutting devices (automat, fuse) must be installed for the electrical system and each large power-consuming device. Flammable goods must not be placed near light bulbs, sockets, circuit breakers, or lamp ballasts. Must regularly check and maintain the automat to always be in good working condition.

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- When using irons, electric stoves, and drying ovens, someone must take care of them. Do not let small children, the elderly, people with disabilities, or people with mental illness use electrical appliances or use fire on floors. Do not use wood stoves or coal stoves with naked flames on the floors. Limit to the maximum extent the use of gas for cooking in high-rise apartment buildings.
- Arrange a reasonable place of worship. The wall on the side of the altar and the ceiling above the altar must be made of non-combustible materials. Lamps, incense, and candles must be placed firmly on non-combustible objects, away from flammable objects, minimize the lighting of candles, and leave votive papers, incense, and candles on the altar. When burning votive papers, they must go down to a separate safe area outside the house on the first floor of the house, must be watched by someone, and must be covered to avoid spreading fire or being swept away by the wind causing fire to spread. Do not burn gold on floors and corridors, which can easily cause false alarms and fire spread. Before going out of the house and before going to bed, check cooking places and places of worship, and turn off unnecessary electrical appliances.
- Do not install iron cages, iron fences at railings, or emergency exits in high-rise buildings. In case of installation, the door must be designed and arranged with an internal latch and not locked. Every family should have a plan for escape situations when a fire occurs. Prepare ladders, rope ladders, and plans for fire fighting and escape, such as self-equipment of tools for demolition to create escape routes, filter masks, wet towels, etc. Houses with young children, the elderly, and disabled people

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must have appropriate escape and rescue measures and must not lock the doors of the rooms of the above-mentioned persons.

- Do not let items such as flower pots, ornamental plants, children's toys, or old damaged items obstruct or occupy the corridors and stairs to escape. Do not block fire doors to prevent smoke accumulation on stairs. Especially the doors to stairs in basement areas and floors with garages to prevent the possibility of smoke contamination entering the stairwells at buildings.
- Doors with multiple locks should use different types of key-type locks to make it easy to distinguish when opening and specify a place where the keys are easy to see and easy to get to ensure quick escape.
- Equip water storage equipment and buckets to carry water to serve both daily life and fire fighting. Equip fire extinguishers and everyone in the family must learn to proficiently use firefighting tools.
- When hearing and seeing fire alarm signals, do not be subjective with false alarm situations (if any) of the fire alarm system. Pay attention to observing, and contact the Security Board, which is responsible for providing accurate information about fire alarm incidents to have a suitable firefighting and escape plan.
- When a fire occurs, find all ways to escape through the corridors into the stairwells to get down to a safe place. Keep calm, do not climb to the balcony, technical pipe to escape. Do not stay and seek shelter in rooms or restrooms; hide in hidden corners that can easily cause smoke inhalation leading to death due to large fires. Do not take the elevator when there is a fire because the elevator is cut off power and stops working when the automatic fire alarm system works, which can easily lead to smoke

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inhalation in the elevator. Participate in firefighting quickly when possible or have to move to escape immediately from high floors to below to ensure safety. The fastest fire alarm lets everyone around know by shouting, pressing the fire alarm button, and calling the Fire Department, the security team, civil defense, local authorities, or the nearest commune and ward police station. At the same time, use means to fight fire and escape according to the expected situation.

- Actively participate in propaganda, training, and practice of fire fighting plans organized by authorities or the Building Management Board. Regularly exchange information for everyone in the family, and propagandize so that everyone in the same building knows the above fire prevention measures to raise awareness, fire prevention skills, and effective escape.

5.5. Government

Fire safety can not be achieved without the involvement of the government. This study, together with other studies, shows that there are still some plot holes in the regulations and standards of the Vietnam government (from Section 1.2 that there are some regulations and standards that are not synchronized). The authorities need to update this regulation and standard with modern technology, materials and the current situation, and international standards. Also, the responsibilities between different ministries and departments must be clear so that there is no overlap of authority.

Although some buildings did not meet the fire safety requirements, they were still able to be put on the market for sale (result from the observation survey in Chapter 3 show that the building in the low score groups are not safe and have a high risk of fire). The authority must

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be stricter with the fine and forbid any building that does not meet the safety requirement to be put into use. An investor that violates the regulation should be heavily fined or suspense a business license. With buildings that have poor safety conditions, the government should force them to renovate, purchase new equipment, or shut down the building to ensure the safety of people. However, some people may need financial assistance with the renovation. The government should also consider this issue.

The government should have more campaigns to raise the awareness and knowledge of people about fire safety by using media, public events, and regulations. Government should force the building management board to hold more fire drills or require high-rise building residents to take a high-rise building fire safety course. The fire department should cooperate with the building manager more about fire safety issues. Universities should put a required fire safety course for the student to equip them with knowledge.

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Chapter 6: Conclusion

6.1. Conclusion

Fire risk is always a threat to high-rise buildings in many countries, and Vietnam is not an exception. This research is to study the high-rise residential buildings' fire safety situation in Vietnam. To investigate this issue, the author approaches this issue in two aspects: the building factor and the human factor.

The result of the observation survey shows that four out of ten buildings scored a high score on the fire safety condition of the building, three had medium scores, and three had low scores. The result from the AHP method shows that *Neighborhood Road*, *Level of fire resistance, Escape route, Distance between buildings, Automatic fire protection system, Escape stairs, and corridor* are the six most important aspects of fire safety facilities from the experts' point of view. After analyzing the data, the six aspects with the lowest score based on the observation are *Arrange rescue means, Fire elevator design, Fire utilities*, *Compartmentalization and separation*, and *Distance between building* and *Outside hydrants or other source of water*. Half of the buildings observed are not equipped with a fire elevator, and three of ten do not meet the condition of *Compartmentalization and separation.*

The result of the questionnaire survey shows that Fire drill and Education level are the two factors that affect the level of knowledge and awareness of fire safety. Most of the respondents felt a level of fire risk in their buildings, but many of them have not had any action or preparation for it like attending fire drills or coming up with an evacuation plan. Most respondents had a basic knowledge of the escape means in the building. Most of the

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respondents' buildings are equipped with automatic fire protection systems except for emergency elevators and refuge floors. For the building fire safety management, almost half of the respondents said that their building had regular fire inspections and fire drills. However, these activities are important to ensure the fire safety of the building.

Based on the finding of these two factors, suggestions were given to different high-rise building stakeholders (investors, designers, residents, building management board, and the government) to improve the level of fire safety. Fire safety can only be achieved if both buildings facilities factor and the human factor are in harmony together. All stakeholders need to cooperate to increase fire safety for high-rise residential buildings in Vietnam. It is everyone's responsibility.

6.2. Limitation and future research

This study only involved a small number of participants and buildings. Therefore, the result of the questionnaire may not represent all the high-rise buildings residents in Vietnam. In addition, the number of respondents from each building is limited, so the answer may not represent the situation of the whole building. The observation survey only consists of 10 buildings, so they also may not represent the general condition of high-rise residential buildings in Vietnam. The observation checklist is conducted according to previous studies and the regulation and standards of Vietnam. It might be some of the aspects that the author missed. Nevertheless, this study provides a good reference for further investigation of high-rise residential buildings in Vietnam on a larger scale. The questionnaire survey and observation survey should be more detailed and more accurate to investigate the overall fire safety situation of the high-rise buildings in Vietnam.

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Next, similar research can be done for high-rise commercial and office buildings since they have different characteristics compared to residential buildings. For example, there are more open spaces and more flammable objects in commercial and office buildings. In addition, this kind of building often has a façade structure or a skylight in the middle. The occupants in this kind of building are also different: they are more prepared to evacuate and often stay in the building during the daytime.

Another direction for future research is to investigate the level of knowledge and awareness of fire safety for different kinds of high-rise building stakeholders: investors, building management boards, government officers, and designers. Knowing their point of view on this issue since they also contribute a big part in the overall fire safety of the building.

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Appendix A: Variable of buildings fire safety

Based on similar study [7], standards and regulations of Vietnam government [47, 59, 60]

No.	Aspects
1	**Site planning**
1. a	Neighborhood road - The path for the outside fire truck must ensure: Running along one side of the building when the width of the building is less than 18m Running along both sides of the building, when the width of the building is equal to or greater than 18m - The path for fire trucks to operate must ensure: Not less than 3.5m wide The reinforced pavement must ensure natural surface drainage. The distance from the wall of the house to the edge of the road for fire trucks to operate is not more than 25m.
1.b	**Distance between buildings** -In case of building with height < 46m The distance between the long sides of the building must be greater than or equal to 1/2 of the height of the building but not less than 7 m. The distance between the gable of the building and the gable or the long side of another building must be greater than or equal to 1/3 of the height of the building, but not less than 4 m. -In the case of buildings with height >= 46 m The distance between the long sides of the structures must be greater than or equal to 25 m; The distance between the gable of the building and the gable or the long side of another building must be 15m or more.
1.c	**Outside hydrants or other sources of water** - Exterior fire hydrants must be arranged along roads, and the distance between poles must not exceed 150m. Fire hydrants outside the building must be located at least 5m from the road and should be located at the junction or crossroads. If poles are arranged on both sides of the road, they should not be more than 2.5m away from the edge of the road, the fire fighting pipe must be divided into segments and calculated so that the number of fire hydrants on each segment is not more than 5 poles. -Pumps used for domestic water supply, production, and fire fighting, whether separately or in combination, must have a backup pump with a capacity equivalent to the capacity of the main pump. ✓ When the number of pumps operating is calculated from one to three, a backup pump is required; ✓ When the number of operating pumps is four or more, two backup pumps are required. The main fire pump must be connected to two separate power sources, either the backup power source at the generating station or the backup motor at the pump station.
2	**Escape Means**
2.a	**Escape route** -In a high-rise building with an area of each floor greater than 300m2, the common corridor or aisle must have at least 2 exits to 2 escape stairs. It is allowed to design an emergency staircase on one side, while the other side must lack a balcony with an outside escape ladder if the area of each floor is less than 300m2. -An escape route is considered safe when it meets one of the following: • Go from the rooms on the first floor directly out or through the lobby to the outside • Go from any room on a certain floor (except for the first floor) to the corridor with an exit: ✓ Safe stairs or safe corridor from which there is a way out of the house ✓ Stairs outside the house, corridors outside the house, there is a way out of the house -Go from any room to the next room on the same floor (except for the first floor) from there, there is an exit as indicated above.

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2.b	**Escape stairs and corridors** • The bearing and covering structures must have a minimum 60-minute fire resistant limit. • Fire doors must automatically close, be constructed of non-combustible materials, and have a minimum fire resistance of 45 minutes. • There is pressurized ventilation and no smoke accumulation in the elevator room • There are incident lights • Ladders must have access to the roof and be ventilated from the ground to the floors.
2.c	**The height of doors and walkways on the escape route** must not be lower than 2m; For basements, the base of the wall is not lower than 1.9m; for basements, the roof is not lower than 1.5m
2.d	**Fire elevator design** -According to the provisions of Section 5.14 QCVN 06:2010/BXD, buildings with heights>28m need to design elevators to transport firefighting forces and vehicles. According to section 4.20, underground garages with more than 2 basements for each fire compartment must have an elevator for fire fighting. -In Section 4.23 of QCVN 06:2010, elevators serving professional fire fighting in buildings must meet fire resistance requirements, have fire resistance limits, and have fire prevention buffer rooms on each floor. Width >1100mm, depth >1400mm, minimum load 630kg. Using fire resistance materials, movement speed from the 1st floor to the highest floor is up to 60 seconds.
2.e	**Solid door system at the exit:** -The entire system of emergency exits must comply with QCVN 06:2010/DXD. Door material for buildings of 15m or more requires strong tempered glass or non-combustible solid doors and has a minimum fire resistance limit of 45 minutes. At the same time, all doors for emergency exits must not use keys, it is best to be left free and can close automatically to facilitate the exit process when a fire or explosion occurs. -In addition, with the door in the stairwell, it is recommended to use the type that can be opened directly from the outside, without sealing the door slot and without the need for a self-closing type. With the path leading to the emergency exit, it is necessary to ensure ventilation.
3	**Passive protection system**
3.a	**Level of Fire Resistance** -Each building element has an appropriate level of Fire Resistance (according to QCVN 06:2010/BXD)
3.b	**Compartmentalization and Separation** - Regarding the zoning of hazardous building contents, there is a vertical and horizontal separation, including the use of LFR-appropriate, compartmentalization-compliant walls. -Building equipment (such as energy supply systems, backup generators, and smoke control systems) and the shaft lift must be housed in separate structures with the proper LFR.
3.c	**Protection on the Aperture** -To prohibit fires from spreading and to ensure the compartmentalization of structures, all openings must be secured, and utility holes must have fire stops. -If openings must be held on the wall, they must be covered with a fire-proof cover that is at least as thick as the TKA wall or floor. -Vertical openings in buildings used for pipe, ventilation, and electrical installation must be fully enclosed with walls from bottom to top and closed on each floor. -Fire doors, fire windows, smoke barriers, and fire closures are examples of means of protection at existing openings that must adhere to applicable regulations.

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4	**Active protect system**
4.a	**Automatic fire protection system** -A fire protection system for a high-rise building meets the standards when it is fully equipped and installed with fire alarm devices and meets the criteria in Section 6.1.3 TCVN 3890:2009 and Section 12.1. TCVN 6160:1996. As follows: • Ability to quickly identify signs of an explosion. • The fire alarm signal is transmitted clearly and accurately. • The equipment installed in the system is guaranteed to have a clear origin and is strictly censored and transparent by the competent state agency. • Periodically, at least twice a year, a maintenance plan must be made for the automatic fire protection system according to TCVN 3890:2009. • Meet the technical requirements of the automatic fire protection system in TCVN 5738:2001
4. b	**Fully equipped with fire extinguishers** All potentially explosive areas must be fully equipped with fire extinguishers, including places where automatic fire protection systems have been installed, and must meet TCVN 3890:2009. The position of the bottle should be arranged scientifically, and the standard capacity of the tank must reach 50 - 150m2/bottle
4. c	**Water supply system** -Each high-rise building needs to arrange an external fire-fighting water supply system, and an internal water supply throat as prescribed in Sections 8.1 & 8.2 TCVN 3890:2009. Technical requirements are specified in detail according to TCVN 2622:1995 and TCVN 4513:1988. In addition, automatic sprinkler fire fighting systems should be designed according to TCVN 3890:2009 to serve in case of need. -With fire hydrants, each building should have 1-2 units and should be installed in aisles, halls, and corridors that are easy to observe and use. Throat flow design ensures 2.5l/s; the center part must be located at a height of 1.25m above the floor surface; has a full set of locking valves, sprinklers, and soft hose reels of the right length according to the design. The most important is to meet TCVN 2622:1995.
4.d	**Arrange rescue means** According to TCVN 3890:2009 prescribed by the fire protection police agency, apartments and high-rise buildings with a height of 25m or more and with more than 50 people on one floor must be equipped with rescue means. Specifically, a common demolition kit, smoke protection means, masks, and toxic filter covers...
4. e	**Fire Utilities** • Emergency elevator • Emergency power system • Emergency lighting and exit signs • Fire control center • Communication devices • Smoke management system
5	**Fire Safety Management**
	Supervision and Control -In addition to the work done by the building inspector, authorized technical organizations, and experts in the field of building and environmental maintenance, adequate oversight is carried out to ensure that the building is always operational. Along with inspecting every installation and every part of its construction, as well as every supporting facility necessary to the system's operation, the factors are also looked at. -Regular inspections are conducted, testing the functionality of all accessible tools and instructing staff on the use of portable fire extinguishers. Regular fire drills are held, and an institution called Fire Safety Management (FSM) is in charge of putting the Fire Emergency Plan (FEP) into action, among other things. Regional laws prohibiting extra combustible material are in place.

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Appendix B: AHP calculation process

Table B-1 Pair-wise comparison matrix of the main aspects

	Site planning	Escape means	Active protection system	Passive protection system	Fire safety management
Site planning	**1.00**	1.40	1.60	2.05	1.85
Escape means	0.71	**1.00**	1.73	1.93	1.80
Active protection system	0.63	0.58	**1.00**	2.40	2.23
Passive protection system	0.49	0.52	0.42	**1.00**	3.20
Fire safety management	0.54	0.56	0.45	0.31	**1.00**
Sum	**3.37**	**4.05**	**5.20**	**7.70**	**10.09**

Table B-2 Normalized pair-wise matrix of the main aspects

	Site planning	Escape means	Active protection system	Passive protection system	Fire safety management	**Criteria weight**
Site planning	0.30	0.35	0.31	0.27	0.18	**0.2802**
Escape means	0.21	0.25	0.33	0.25	0.18	**0.2444**
Active protection system	0.19	0.14	0.19	0.31	0.22	**0.2107**
Passive protection system	0.14	0.13	0.08	0.13	0.32	**0.1599**
Fire safety management	0.16	0.14	0.09	0.04	0.10	**0.1047**

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Table B-3 Pair-wise comparison matrix of Site planning

	Neighborhood road	Distance between buildings	Outside hydrants or other sources of water
Neighborhood road	**1.00**	2.03	1.63
Distance between buildings	0.49	**1.00**	1.87
Outside hydrants or other sources of water	0.61	0.54	**1.00**
Sum	**2.10**	**3.57**	**4.50**

Table B-4 Normalized pair-wise matrix of Stie planning

	Neighborhood road	Distance between buildings	Outside hydrants or other sources of water	Criteria weight in Sector 1	**Criteria weight in the whole observation**
Neighborhood road	0.48	0.57	0.36	0.47	**0.1315**
Distance between buildings	0.23	0.28	0.41	0.31	**0.0867**
Outside hydrants or other sources of water	0.29	0.15	0.22	0.22	**0.0620**

Table B-5 Pair-wise comparison matrix of Escape means

	Escape route	Safety stairs and corridors	The height of doors and walkway	Fire elevator	Solid door at the exit
Escape route	**1.00**	2.53	3.00	2.93	2.93
Safety stair and corridors	0.39	**1.00**	3.60	3.40	3.80
The height of door and walkway	0.33	0.28	**1.00**	1.97	1.80
Fire elevator	0.34	0.29	0.51	**1.00**	3.73
Solid door at the exit	0.34	0.26	0.56	0.27	**1.00**
Sum	**2.41**	**4.37**	**8.66**	**9.57**	**13.27**

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Table B-6 Normalized pair-wise matrix of Escape means

	Escape route	Safety stair and corridors	The height of door and walkway	Fire elevator	Solid door at the exit	Criteria weight	**Criteria weight in the whole observation**
Escape route	0.41	0.58	0.35	0.31	0.22	0.37	**0.0914**
Safety stair and corridors	0.16	0.23	0.42	0.36	0.29	0.29	**0.0709**
The height of door and walkway	0.14	0.06	0.12	0.21	0.14	0.13	**0.0322**
Fire elevator	0.14	0.07	0.06	0.10	0.28	0.13	**0.0319**
Solid door at the exit	0.14	0.06	0.06	0.03	0.08	0.07	**0.0180**

Table B-7 Pair-wise comparison matrix of Passive protection system

	Level of fire resistance	Compartmentalization and Separation	Protection on the Aperture
Level of fire resistance	**1.00**	3.00	2.13
Compartmentalization and Separation	0.33	**1.00**	1.60
Protection on the Aperture	0.47	0.63	**1.00**
Sum	**1.80**	**4.63**	**4.73**

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Table B-8 Normalized pair-wise matrix of Passive protection system

	Level of fire resistance	Compartmentalization and Separation	Protection on the Aperture	Criteria weight	**Criteria weight in the whole observation**
Level of fire resistance	0.55	0.65	0.45	0.55	**0.1162**
Compartmentalization and Separation	0.18	0.22	0.34	0.25	**0.0519**
Protection on the Aperture	0.26	0.14	0.21	0.20	**0.0426**

Table B-9 Pair-wise comparison matrix of Active protection system

	Automatic fire protection system	Fire extinguisher	Water supply system	Rescue means	Fire utilities
Automatic fire protection system	**1.00**	4.40	3.53	4.60	4.60
Fire extinguisher	0.23	**1.00**	2.60	3.60	3.33
Water supply system	0.28	0.38	**1.00**	2.87	2.73
Rescue means	0.22	0.28	0.35	**1.00**	2.53
Fire utilities	0.22	0.30	0.37	0.39	**1.00**
Sum	**1.95**	**6.36**	**7.85**	**12.46**	**14.20**

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Table B-10 Normalized pair-wise matrix of Active protection system

	Automatic fire protection system	Fire extinguisher	Water supply system	Rescue means	Fire utilities	Criteria weight of Aspect 4	**Criteria weight**
Automatic fire protection system	0.51	0.69	0.45	0.37	0.32	0.47	**0.0751**
Fire extinguisher	0.12	0.16	0.33	0.29	0.23	0.23	**0.0361**
Water supply system	0.15	0.06	0.13	0.23	0.19	0.15	**0.0242**
Rescue means	0.11	0.04	0.04	0.08	0.18	0.09	**0.0147**
Fire utilities	0.11	0.05	0.05	0.03	0.07	0.06	**0.0098**

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Appendix C: OMAX calculation result of ten buildings

Table C-1 Building 1

BUILDING 1								
	1	**2**				**3**	**4**	**5**
Section	Score of observation	Scoring scale				Weight	Scaled score	Weight score
		0	33.3	66.7	100			
1.a	3	0	1	2	3	0.1315	100	13.151
1.b	2	0	1	2	3	0.0867	66.7	5.786
1.c	1	0	1	2	3	0.0620	33.3	2.063
2.a	3	0	1	2	3	0.0914	100	9.136
2.b	3	0	1	2	3	0.0709	100	7.088
2.c	3	0	1	2	3	0.0322	100	3.222
2.d	3	0	1	2	3	0.0319	100	3.193
2.e	3	0	1	2	3	0.0180	100	1.805
3.a	3	0	1	2	3	0.1162	100	11.620
3.b	3	0	1	2	3	0.0519	100	5.193
3.c	3	0	1	2	3	0.0426	100	4.260
4.a	3	0	1	2	3	0.0751	100	7.514
4.b	3	0	1	2	3	0.0361	100	3.611
4.c	3	0	1	2	3	0.0242	100	2.418
4.d	2	0	1	2	3	0.0147	66.7	0.978
4.e	2	0	1	2	3	0.0098	66.7	0.656
5	3	0	1	2	3	0.1047	100	10.467
						TOTAL=		**92.16**

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Table C-2 Building 2

BUILDING 2									
	1	**2**				**3**	**4**	**5**	
Section	Score of observation	Scoring scale				Weight	Scaled score	Weight score	
		0	33.3	66.7	100				
1.a	3	0	1	2	3	0.1368	100	13.683	
1.b	3	0	1	2	3	0.0903	100	9.026	
1.c	2	0	1	2	3	0.0645	66.7	4.300	
2.a	3	0	1	2	3	0.0878	100	8.779	
2.b	3	0	1	2	3	0.0681	100	6.811	
2.c	3	0	1	2	3	0.0310	100	3.097	
2.d	3	0	1	2	3	0.0307	100	3.068	
2.e	3	0	1	2	3	0.0173	100	1.734	
3.a	3	0	1	2	3	0.1159	100	11.592	
3.b	3	0	1	2	3	0.0518	100	5.180	
3.c	3	0	1	2	3	0.0425	100	4.250	
4.a	3	0	1	2	3	0.0722	100	7.216	
4.b	3	0	1	2	3	0.0385	100	3.854	
4.c	3	0	1	2	3	0.0246	100	2.463	
4.d	2	0	1	2	3	0.0154	66.7	1.027	
4.e	3	0	1	2	3	0.0086	100	0.857	
5	3	0	1	2	3	0.1040	100	10.403	
						TOTAL=		**97.34**	

Table C-3 Building 3

BUILDING 3									
	1	**2**				**3**	**4**	**5**	
Section	Score of observation	Scoring scale				Weight	Scaled score	Weight score	
		0	33.3	66.7	100				
1.a	3	0	1	2	3	0.1368	100	13.683	
1.b	2	0	1	2	3	0.0903	66.7	6.020	
1.c	2	0	1	2	3	0.0645	66.7	4.300	
2.a	3	0	1	2	3	0.0878	100	8.779	
2.b	2	0	1	2	3	0.0681	66.7	4.543	
2.c	3	0	1	2	3	0.0310	100	3.097	
2.d	0	0	1	2	3	0.0307	0	0.000	
2.e	2	0	1	2	3	0.0173	66.7	1.157	
3.a	3	0	1	2	3	0.1159	100	11.592	
3.b	2	0	1	2	3	0.0518	66.7	3.455	
3.c	3	0	1	2	3	0.0425	100	4.250	
4.a	3	0	1	2	3	0.0722	100	7.216	
4.b	3	0	1	2	3	0.0385	100	3.854	
4.c	3	0	1	2	3	0.0246	100	2.463	
4.d	2	0	1	2	3	0.0154	66.7	1.027	
4.e	2	0	1	2	3	0.0086	66.7	0.572	
5	2	0	1	2	3	0.1040	66.7	6.939	
						TOTAL=		**82.95**	

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Table C-4 Building 4

BUILDING 4								
	1	**2**				**3**	**4**	**5**
Section	Score of observation	Scoring scale				Weight	Scaled score	Weight score
		0	33.3	66.7	100			
1.a	2	0	1	2	3	0.1368	66.7	9.127
1.b	2	0	1	2	3	0.0903	66.7	6.020
1.c	1	0	1	2	3	0.0645	33.3	2.147
2.a	3	0	1	2	3	0.0878	100	8.779
2.b	3	0	1	2	3	0.0681	100	6.811
2.c	3	0	1	2	3	0.0310	100	3.097
2.d	3	0	1	2	3	0.0307	100	3.068
2.e	3	0	1	2	3	0.0173	100	1.734
3.a	3	0	1	2	3	0.1159	100	11.592
3.b	3	0	1	2	3	0.0518	100	5.180
3.c	3	0	1	2	3	0.0425	100	4.250
4.a	3	0	1	2	3	0.0722	100	7.216
4.b	3	0	1	2	3	0.0385	100	3.854
4.c	2	0	1	2	3	0.0246	66.7	1.643
4.d	2	0	1	2	3	0.0154	66.7	1.027
4.e	2	0	1	2	3	0.0086	66.7	0.572
5	2	0	1	2	3	0.1040	66.7	6.939
						TOTAL=		**83.06**

Table C-5 Building 5

BUILDING 5								
	1	**2**				**3**	**4**	**5**
Section	Score of observation	Scoring scale				Weight	Scaled score	Weight score
		0	33.3	66.7	100			
1.a	2	0	1	2	3	0.1368	66.7	9.127
1.b	1	0	1	2	3	0.0903	33.3	3.006
1.c	2	0	1	2	3	0.0645	66.7	4.300
2.a	2	0	1	2	3	0.0878	66.7	5.856
2.b	2	0	1	2	3	0.0681	66.7	4.543
2.c	2	0	1	2	3	0.0310	66.7	2.065
2.d	0	0	1	2	3	0.0307	0	0.000
2.e	2	0	1	2	3	0.0173	66.7	1.157
3.a	3	0	1	2	3	0.1159	100	11.592
3.b	2	0	1	2	3	0.0518	66.7	3.455
3.c	2	0	1	2	3	0.0425	66.7	2.835
4.a	2	0	1	2	3	0.0722	66.7	4.813
4.b	3	0	1	2	3	0.0385	100	3.854
4.c	2	0	1	2	3	0.0246	66.7	1.643
4.d	0	0	1	2	3	0.0154	0	0.000
4.e	0	0	1	2	3	0.0086	0	0.000
5	2	0	1	2	3	0.1040	66.7	6.939
						TOTAL=		**65.18**

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Table C-6 Building 6

BUILDING 6									
	1	**2**				**3**	**4**	**5**
Section	Score of observation	Scoring scale				Weight	Scaled score	Weight score
		0	33.3	66.7	100			
1.a	3	0	1	2	3	0.1368	100	13.683
1.b	3	0	1	2	3	0.0903	100	9.026
1.c	3	0	1	2	3	0.0645	100	6.446
2.a	2	0	1	2	3	0.0878	66.7	5.856
2.b	2	0	1	2	3	0.0681	66.7	4.543
2.c	3	0	1	2	3	0.0310	100	3.097
2.d	0	0	1	2	3	0.0307	0	0.000
2.e	2	0	1	2	3	0.0173	66.7	1.157
3.a	3	0	1	2	3	0.1159	100	11.592
3.b	0	0	1	2	3	0.0518	0	0.000
3.c	0	0	1	2	3	0.0425	0	0.000
4.a	2	0	1	2	3	0.0722	66.7	4.813
4.b	2	0	1	2	3	0.0385	66.7	2.571
4.c	3	0	1	2	3	0.0246	100	2.463
4.d	0	0	1	2	3	0.0154	0	0.000
4.e	2	0	1	2	3	0.0086	66.7	0.572
5	2	0	1	2	3	0.1040	66.7	6.939
						TOTAL=		**72.76**

Table C-7 Building 7

BUILDING 7								
	1	**2**				**3**	**4**	**5**
Section	Score of observation	Scoring scale				Weight	Scaled score	Weight score
		0	33.3	66.7	100			
1.a	2	0	1	2	3	0.1368	66.7	9.127
1.b	2	0	1	2	3	0.0903	66.7	6.020
1.c	3	0	1	2	3	0.0645	100	6.446
2.a	3	0	1	2	3	0.0878	100	8.779
2.b	2	0	1	2	3	0.0681	66.7	4.543
2.c	2	0	1	2	3	0.0310	66.7	2.065
2.d	3	0	1	2	3	0.0307	100	3.068
2.e	3	0	1	2	3	0.0173	100	1.734
3.a	3	0	1	2	3	0.1159	100	11.592
3.b	3	0	1	2	3	0.0518	100	5.180
3.c	3	0	1	2	3	0.0425	100	4.250
4.a	3	0	1	2	3	0.0722	100	7.216
4.b	3	0	1	2	3	0.0385	100	3.854
4.c	3	0	1	2	3	0.0246	100	2.463
4.d	2	0	1	2	3	0.0154	66.7	1.027
4.e	2	0	1	2	3	0.0086	66.7	0.572
5	3	0	1	2	3	0.1040	100	10.403
						TOTAL=		**88.34**

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Table C-8 Building 8

BUILDING 8								
	1	**2**				**3**	**4**	**5**
Section	Score of observation	Scoring scale				Weight	Scaled score	Weight score
		0	33.3	66.7	100			
1.a	2	0	1	2	3	0.1368	66.7	9.127
1.b	2	0	1	2	3	0.0903	66.7	6.020
1.c	2	0	1	2	3	0.0645	66.7	4.300
2.a	2	0	1	2	3	0.0878	66.7	5.856
2.b	2	0	1	2	3	0.0681	66.7	4.543
2.c	2	0	1	2	3	0.0310	66.7	2.065
2.d	0	0	1	2	3	0.0307	0	0.000
2.e	2	0	1	2	3	0.0173	66.7	1.157
3.a	3	0	1	2	3	0.1159	100	11.592
3.b	0	0	1	2	3	0.0518	0	0.000
3.c	2	0	1	2	3	0.0425	66.7	2.835
4.a	2	0	1	2	3	0.0722	66.7	4.813
4.b	2	0	1	2	3	0.0385	66.7	2.571
4.c	2	0	1	2	3	0.0246	66.7	1.643
4.d	0	0	1	2	3	0.0154	0	0.000
4.e	0	0	1	2	3	0.0086	0	0.000
5	2	0	1	2	3	0.1040	66.7	6.939
						TOTAL=		**63.46**

Table C-9 Building 9

BUILDING 9								
	1	**2**				**3**	**4**	**5**
Section	Score of observation	Scoring scale				Weight	Scaled score	Weight score
		0	33.3	66.7	100			
1.a	2	0	1	2	3	0.1368	66.7	9.127
1.b	2	0	1	2	3	0.0903	66.7	6.020
1.c	2	0	1	2	3	0.0645	66.7	4.300
2.a	3	0	1	2	3	0.0878	100	8.779
2.b	3	0	1	2	3	0.0681	100	6.811
2.c	2	0	1	2	3	0.0310	66.7	2.065
2.d	0	0	1	2	3	0.0307	0	0.000
2.e	2	0	1	2	3	0.0173	66.7	1.157
3.a	3	0	1	2	3	0.1159	100	11.592
3.b	0	0	1	2	3	0.0518	0	0.000
3.c	2	0	1	2	3	0.0425	66.7	2.835
4.a	2	0	1	2	3	0.0722	66.7	4.813
4.b	2	0	1	2	3	0.0385	66.7	2.571
4.c	2	0	1	2	3	0.0246	66.7	1.643
4.d	0	0	1	2	3	0.0154	0	0.000
4.e	0	0	1	2	3	0.0086	0	0.000
5	2	0	1	2	3	0.1040	66.7	6.939
						TOTAL=		**68.65**

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Table C-10 Building 10

BUILDING 10									
	1	**2**				**3**	**4**	**5**
Section	Score of observation	Scoring scale				Weight	Scaled score	Weight score
		0	33.3	66.7	100			
1.a	3	0	1	2	3	0.1368	100	13.683
1.b	2	0	1	2	3	0.0903	66.7	6.020
1.c	3	0	1	2	3	0.0645	100	6.446
2.a	3	0	1	2	3	0.0878	100	8.779
2.b	3	0	1	2	3	0.0681	100	6.811
2.c	3	0	1	2	3	0.0310	100	3.097
2.d	3	0	1	2	3	0.0307	100	3.068
2.e	3	0	1	2	3	0.0173	100	1.734
3.a	3	0	1	2	3	0.1159	100	11.592
3.b	3	0	1	2	3	0.0518	100	5.180
3.c	2	0	1	2	3	0.0425	66.7	2.835
4.a	3	0	1	2	3	0.0722	100	7.216
4.b	3	0	1	2	3	0.0385	100	3.854
4.c	3	0	1	2	3	0.0246	100	2.463
4.d	2	0	1	2	3	0.0154	66.7	1.027
4.e	2	0	1	2	3	0.0086	66.7	0.572
5	3	0	1	2	3	0.1040	100	10.403
						TOTAL=		**94.78**

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Appendix D: Questionnaire survey

Survey about fire safety in high-rise building from resident point of view

Personal background

1. How old are you?

   Mark only one oval.

   - 18-30
   - 30-50
   - 50-65
   - >65
   - Tùy chọn 5

2. What is your gender?

   Mark only one oval.

   - Male
   - Female
   - Prefer not to say

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3. What is the highest level of education you have completed?

Mark only one oval.

- High School Diploma
- Bachelor Degree
- Master Degree
- Phd Degree
- Other

4. Name of your current living building

5. How many floor does your current building have?

6. What floor do you live on?

7. How many years have you lived in your current apartment building?

8. How many years have you lived in other high-rise building?

Resident's knowledge and preparation for fire

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9. Do you think your building is in danger of fire?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ May be

10. Have your building ever had fire before?

Mark only one oval.

- ◯ Yes
- ◯ No

11. Have you ever experienced indirect fire incident? (Saw another building fire, or have friends or family member been through fire incident and then told you about it)

Mark only one oval.

- ◯ Yes
- ◯ No

12. Have you ever attended the fire drill in your building ?

Mark only one oval.

- ◯ Yes
- ◯ No

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13. Do you often turn off electrical devices when you leave the house(e.g. computer, fan, air conditioner, kettle, electric stove, vacuum cleaner, table lamp)?

Mark only one oval.

- Yes
- No

14. Do you have your own fire extinguisher in your apartment?

Mark only one oval.

- Yes
- No

15. Do you have a evacuate plan for your self and family incase a fire happen in your building?

Mark only one oval.

- Yes
- No

Resident's knowledge about building fire safety facilities

16. Do you know the location of the escape stairs in your building?

Mark only one oval.

- Yes
- No

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17. Do you know where those stairs lead to?

Mark only one oval.

- ⬭ Yes
- ⬭ No

18. Are those stairs remained closed most of the time?

Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ I do not know

19. Do you feel the corridors in your building is wide enough for everyone on your floor to evacuate if a fire happens?

Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ I do not know

20. Does your building have a fire elevator?

Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ I do not know

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21. Is your building equipped with automatic fire protection system (fire alarms, smoke detectors, sprinklers)?

Mark only one oval.

- Yes
- No
- Yes, but not enough

22. Is your floor equipped with extinguishers and demolition kit?

Mark only one oval.

- Yes
- No
- I do not know

23. Are there clear exits signs that can help you find the way to the escape stairs, fire elevator, the extinguishers and the demolition kit?

Mark only one oval.

- Yes
- No
- I do not know

24. Are there any refuge or emergency room on your floor?

Mark only one oval.

- Yes
- No
- I do not know

Building's fire safety management

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25. Does your building have regular fire safety inspection?

Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ I do not know

26. Does your building have regular fire drills for residents ?

Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ I do not know

27. Does your building management board often mention fire safety issue during your regular building's resident meeting?

Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ I do not know

28. Does your building management board provide fire safety tips/information/warning to residents (put up signs, fliers, regulation in public space or use building's communication system to inform residents)?

Mark only one oval.

- ⬭ Yes
- ⬭ No
- ⬭ I do not know

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Appendix E: SPSS results:

Table E-1 SPSS Correlation result

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.603	3	2.534	5.994	.001[b]
	Residual	38.897	92	.423		
	Total	46.500	95			
2	Regression	19.466	8	2.433	7.830	.000[c]
	Residual	27.034	87	.311		
	Total	46.500	95			

a. Dependent Variable: Awareness and Knowledge

b. Predictors: (Constant), Living experience, Gender, Education

c. Predictors: (Constant), Living experience, Gender, Education, Fire incident, Fire drill, Living floor, Indirect experience, Age

Table E-2 SPSS Model Summary

Model Summary[c]

					Change Statistics					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.404[a]	.164	.136	.650	.164	5.994	3	92	.001	
2	.647[b]	.419	.365	.557	.255	7.635	5	87	.000	1.920

a. Predictors: (Constant), Living experience, Gender, Education

b. Predictors: (Constant), Living experience, Gender, Education, Fire incident, Fire drill, Living floor, Indirect experience, Age

c. Dependent Variable: Awareness and Knowledge

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Table E-3 SPSS Collinearity Diagnostic

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions								
				(Constant)	Gender	Education	Living experience	Age	Living floor	Fire incident	Indirect experience	Fire drill
1	1	3.331	1.000	.01	.03	.02	.01					
	2	.426	2.795	.01	.83	.08	.02					
	3	.170	4.428	.00	.05	.60	.51					
	4	.073	6.770	.98	.09	.31	.46					
2	1	5.959	1.000	.00	.01	.00	.00	.01	.01	.00	.01	.01
	2	.926	2.536	.00	.00	.00	.00	.07	.01	.50	.01	.02
	3	.597	3.160	.00	.36	.00	.00	.21	.02	.12	.02	.01
	4	.449	3.642	.00	.16	.01	.00	.05	.12	.00	.28	.20
	5	.375	3.987	.00	.00	.09	.00	.10	.01	.01	.23	.52
	6	.280	4.617	.01	.37	.03	.00	.17	.08	.32	.32	.17
	7	.204	5.399	.01	.01	.16	.08	.35	.62	.04	.01	.03
	8	.153	6.236	.01	.05	.45	.51	.00	.01	.00	.07	.05
	9	.057	10.217	.96	.03	.26	.40	.05	.12	.00	.05	.00

a. Dependent Variable: Awareness and Knowledge

Table E-4 SPSS Coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1.561	.206		7.567	.000		
	Gender	.304	.134	.218	2.270	.026	.988	1.012
	Education	.248	.096	.250	2.593	.011	.977	1.023
	Living experience	.221	.099	.215	2.230	.028	.983	1.018
2	(Constant)	1.530	.206		7.420	.000		
	Gender	.335	.117	.240	2.868	.005	.955	1.047
	Education	.215	.087	.217	2.483	.015	.874	1.144
	Living experience	.035	.094	.034	.378	.706	.805	1.242
	Age	.071	.090	.077	.784	.435	.701	1.427
	Living floor	-.129	.081	-.139	-1.587	.116	.875	1.144
	Fire incident	-.046	.156	-.026	-.295	.768	.833	1.201
	Indirect experience	.166	.124	.119	1.343	.183	.852	1.174
	Fire drill	.661	.122	.475	5.399	.000	.864	1.157

a. Dependent Variable: Awareness and Knowledge

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