Preventive Measures for Fire Accidents in Apartment Buildings in Sri Lanka

GPRC Abeysekara[1#] and C Allis[1]

[1]*Sri Lanka Institute of Information Technology, Sri Lanka*

[#]chathupama@yahoo.com

Abstract*: Owing to the increasing population, lands have become scarce. Therefore, the prices of land also have increased. To address this issue people, tend to buy apartments than have their plots of land and construct a house. The height and complexity of these residential buildings may easily lead to fires and there will be property losses, injuries, and deaths every year worldwide. Mostly nowadays people are looking at the fire safety of all these apartments due to these incidents. The research aims to identify a better preventive measure for fire accidents in residential buildings in SL. An extensive Literature review was carried out to discover the current practice in worldwide fire prevention. This study was conducted using a Questionnaire survey with apartment building occupants to identify the fire safety measures currently practice in the SL context regarding the ICTAD fire regulations. Simultaneously, statistical data related to fire incidents in SL for the past few years and major reasons for SL apartment building fires were collected from the fire department. The collected data were analyzed based on three building height categories. From the findings, faulty wirings were identified as the major reason for apartment fires, most of the occupants are unaware of these regulations and some of the buildings are also not facilitated with required fire safety. Finally, it was highly recommended to conduct demonstration programs for public awareness and do practice the fire regulations.*

Keywords: *Apartment Buildings, Fire Regulations, High-Rise*

1. Introduction

The potential for an accidental or planned fire to endanger life, structural, and property safety in a building is referred to as a fire hazard in a building (Kodur et al., 2019a). Due to high population density and land values, high-rise and super-high-rise buildings have become increasingly popular as the urban economy develops (Liu et al., 2012). Along with their height, complicated structure, and numerous activities, high-rise structures are more likely to be caught fire (Nimlyat, 2017). Even a minor fire might be devastating if it spreads to the dwellings (Yatim, 2009).

In most residential complexes with many tenants, fires can result in higher injury or death owing to emergency evacuation complications (Shokouhi,2019). A high-rise building's vertical travel distance is also considerable, making evacuation more difficult (Ma & Guo, 2012).

Due to the extreme damage, it causes to buildings and infrastructure, fire can have severe consequences for human society. In relation, numerous people are killed or seriously injured as a result of fires (Shokouhi, 2019). According to the United States fire department, a fire breaks out in a residential area every 85 seconds, accounting for about 80% of all fire-related deaths. In London, fires in apartment buildings are responsible for 78 % caused by unintentional fires. Between 2007 and 2010, residential areas accounted for approximately 39% of all fires in China. (Shokouhi, 2020). According to surveys, at least 75% of fires are avoidable. (Shokouhi, 2019).

The Marco polo apartment fire (Honolulu), The Torch Tower fire (Dubai), and the Grenfell Tower fire (London) can be described as three

simply preventable fires. On June 14, 2017, a tragic fire broke out at the 24-story Grenfell Tower in west London, killing at least 80 people. The 86-story Torch Tower in Dubai caught fire for the 2nd time in 2 1/2 years on August 3, 2017. The fire started on the 26th story and quickly spread to the roof. According to reports, the tower's 38 flats and 64 outside levels were destroyed. The fire is said to have started when cigarette butts were thrown into a potted plant (Wieczorek, 2017).

The selected research topic is more important with the higher demand for residential buildings in Sri Lanka as well as worldwide. With better safety of the residential building environment, people will tend to buy apartment complexes than have their plots of land and construct houses. Since much research has been done on fire hazards in buildings only a few studies have been done on fire prevention and at the same time, only one has been found with a residential building's fire. That is one of the main significance of this research.

The research aims to suggest preventive measures for fire accidents in apartment buildings in Sri Lanka. Identifying the reasons for fires in residential buildings in Sri Lanka, the current situation in SL residential buildings fire prevention, the current situation in worldwide residential buildings fire prevention, and establishing fire preventive methods for residential buildings in SL are considered the pillars toward this aim.

2. Literature Review

With the rapid development of cities today, more and more multi-storied skyscrapers are rising to greater heights (Zhang, 2017). Complicated structures and high heights of buildings may result in more likely to catch fire (Nimlyat et al., 2017). In recent decades, residential building fires were on the upswing, and several incidents, casualties, and other fire indexes represent a higher percentage of overall fires (Zhou, 2017).

According to the statistical data of WHO, more than 300,000 deaths happen yearly, and more than 95% occur in low- and middle-income countries (Shokouhi et al., 2019). In accordance with the surveys 75% of fires are preventable (Shokouhi et al., 2019).

The Grenfell tower fire in west London, the Torch tower fire in Dubai, and the Marco Polo apartments in Honolulu can be identified as tragic residential fire incidents that happened in the recent decade and were identified as simply preventable fires. On June 14, 2017, the Grenfell Tower which consists of 24 stories experienced a tragic fire that broke out with a minimum number of 80 deaths. According to the reports, the source of the fire was a refrigerator on the fourth level and there were no automated fire sprinklers to keep the interior fire under control. The fire grew and spread to the external surfaces. When started, the highly flammable modern building cladding allowed the fire to quickly spread up and along and eventually throughout the whole structure (Wieczorek, 2017).

The existing fire preventive measures can be classified under four groups: general fire safety strategy, building regulations, and standards, building safety features, and firefighting operations (Kodur et al., 2019c).

A. Preventive Measures for Fire in Residential Buildings Taken by Worldwide

This fire prevention involves preventing the fire from starting, controlling extinguishing fires once they start, and preventing fires from spreading within a facility (Kironji, 2015; Benson, 2020). The fire prevention measures topic are included fire-safety furniture, fire-safety materials, fire resistance structures methods of escape, and methods of access (Chow, 2004). Buildings required firefighting equipment, fire detecting equipment (alarm systems), suppression (automatic s prinkler systems), fire protection and prevention systems (fire sand buckets, fire extinguishers, fire blankets, hydrants, horse reels, wet and dry risers) that are not mostly available in 3rd world countries (Murage, 2012; Kihila, 2017; Nestory, 2017). Fire preventive measures commonly used in worldwide residential buildings with

regard to fire alarms, detections sprinklers, etc... are listed out below respectively (Lamont, 2018)

Table1: Façade-related fire preventive measures used worldwide (Lamont, 2018)

Characteristicsof the building	**Construction**	**Concrete & structural steel**
The Protected mean of Evacuation &alert	Fire Alarms	Even though common pathways have a fire alarm system that can sound from all levels, it is known "stay put" if there is no "all out" fire alarm option where the alert sound in every condominium. This is since an alert in a common passage may go unnoticed by the apartment occupants. The establishment of a well-maintained fire alarm system, as the early discovery of fire, allows inhabitants to be noticed, allowing them to escape.
	Fire Detection	Automatic and manual detecting systems should lie within the structure.
	Height of the building	With the height, the preventive measures should vary as the height and the evacuation time is having a proportional relationship.
	Management	All the active and passive fire systems are to be maintained properly.
	Control of Smoke	Smoke controls should place on the evacuation routes to make the route clear from smoke.
Extinguishersand containment	Sprinkler system	These sprinklers should place throughout the building but not outdoors and on balconies and properly maintained.
	Fire access	The perimeter access should be with the building and easily accessible.

Furthermore, Passenger elevators cannot be used during a fire evacuation as it's frequently de-energized because of the fire. Due to that, elevators with specific equipment (capacity of at least 1000 kg) for rescue should be installed when developing high-rise structures (Poliakova & Grigoryan, 2018). Fire protection systems must be regularly maintained, inspected, and tested to remain operational (Kironji, 2015).

Table 2: Mandatory fire protection measures

Purpose Group	**Height**	**Portable Fire Extinguishers**	**Horse reels**	**Landing Valves**	**Sprinkler system**
1. Resi	Up to 18 m @floor area <800m^2	Relevant	Not Relevant		
	Up to 18m&floor area >800m^2	Relevant		Not Relevant	
1. (a)	18-30 m	Relevant			Not Relevant
	More than 30m	Relevant			
1. (b)	Up to 18m	Relevant	Not Relevant		
1. (c)	Floor area < 300 m^2	Not Relevant			

(*Colombo Municipal Council*, 2018)

B. Classifications and fire standards in Sri Lankan Residential Buildings

The Fire Department of SL has classified the residential buildings for the mandatory fire protection purposes

I.A.1 Purpose group classification

1. Residential (Dwelling)

1(a). Apartments or flats - multiple residencies in a single block of the complex that shared facilities.

1(b). A residential Unit- A flat with a single or many residencies in a single block of construction that exceeds 300m^2 / usable floor height from the ground that exceeds 6m but less than 18m

1(c). A single house is defined as a unit with a floor area of no more than 300m^2 and a usable floor height, of not more than 6m. (*Colombo Municipal Council*, n.d.)

Mandatory fire protection measures to be included in the proposed residential buildings in Sri Lanka by Fire Service Department (Colombo Municipal Council)

Table 3: Mandatory fire protection measures 2

(Colombo Municipal Council, 2018.)

Purpose Group	**Height**	**Manual call points**	**Fire Detection**	**Voice Examination**	**Fireman Communication**
1. Resi	Up to 18 m @floor area <800m^2	Not relevant			
	Up to 18m & floor area >800m^2	Relevant	Not relevant		
1. (a)	18-30 m	Relevant		Not relevant	
	More than 30m	Relevant			
1. (b)	Up to 18m	Not relevant			
1. (c)		Not relevant			

2. Methodology

This shows the pathway which was utilized to achieve the aim and objectives of the study. It describes the design approach, research methodology, and techniques used in data collection including analysis. Journal Articles, electrical publications, and e-books were referred to gather information on the specific study area for literature review. The data is gathered from Fire Department SL and the questionnaire survey was conducted with close-ended questions. The purpose of the questionnaire survey is to collect data regarding the practice of ICTAD fire regulations currently in SL high-rise residential buildings. Finally, the recommendations for issues in current fire regulation practice are discussed.

3. Research Findings and Analysis

This chapter aims to implement a well-structured quantitative analysis of the collected data. The Survey was based on the Fire Regulation codes published by ICTAD for buildings. The primary objective of the survey is to find out the fire preventive measures currently practice in SL residential buildings by the fire regulations. The survey was done using 35 people who live in Apartment buildings all over SL. It included 21 questions under 5 sections, the General Section (Apartment Location, Stories and no of Apartment units, etc.…), Means of Escape, Gas Installation, Fire Extinguishers, and Alarm system.

The following table shows the data collected from the Fire department for the fire incidents reported for the past five years and the major reasons.

Table 4: Fire incident report from 01.01.2015 to 31.12.2020

	BUILDING FIRES	APARTMENT FIRES	%
2015	113	14	12.5
2016	116	16	13
2017	122	19	16
2018	182	41	23
2019	152	26	17.5
2020	143	23	16.5

Faulty electric wiring, unawareness, ignorance, children's activities, gas leakages, and failure in electrical equipment can be identified as Major reasons for occurring Fires in Sri Lanka

A. Questionnaire Survey

Fire regulations published by ICTAD for Apartment Buildings are categorized based on the building heights. As it was not practicable to obtain the total building height from the occupants, the number of floors in each apartment was obtained and an assumption was made as the floor height is 3.5 m including slab thickness for the ease of data analysis.

Table 5: Building categorization based on no of floors

Height	No of Floors
Up to 18 m	5
18 m – 30 m Height	6 - 8floors
More than 30 m	9 story upwards

Each data was analyzed based on the above categorization.

1) Up to 18 m

From the responses for the General Section, none of them experienced a fire drill at the apartments. When considering the building location, 50% of the buildings are in bit-traffic areas, 33.33% and 16.67% are in high-traffic areas and non-traffic areas respectively. At the same time, 66.67% of the buildings have perimeter access. For the question of assembly points, 33.33% of the buildings do not have an emergency assembly point, 50% are on the ground floor and 16.67% are in Top floor.

Responses for the section "means of escape" derive that, only 33.33% of the buildings are equipped with sprinkler systems, and all the testing and maintenance are done once a year.

By ICTAD fire regulations each building should have at least consist of 2 staircases. Nevertheless, only 33.33% of the buildings are having 2 staircases and at the same time, only 16.67 % have more than 2 staircases. On the other hand, if the building is not sprinkled the maximum distance between the apartment and the staircase/s shall be 30 m. 33.33% of the buildings comply with this regulation and still, 33.34% is not. In the count of passenger lifts, 50% of the buildings in upto 18 m category are not facilitated with passenger lifts, with 33.33% and 16.67% having "less than 1000kg" and "more than 1000 kg" lifts respectively. Simultaneously fire doors are only provided with 33.33% of the building and from that, all are self-closing and opening in the direction of escape.

The findings for the section, installation of gas, described that all the buildings in this category only consist of individual cylinders, and according to the regulations if any building consists of individual cylinders shall place outside the building in an open area. The count for this question, for "no", was equal to the answer "yes".

Responses for the section, fire extinguishers, and alarm systems, illustrated that only 33.33% of the buildings are provided with fire alarms in common corridors, rest o66.67% of the buildings are not provided with fire alarms. "Yes", accounted for 16.67% of the count of hydraulic horse reels provided in the building, and all the horse reel cabinets are locked. At the same time, only 16.67% of the building provided Fire Extinguishers 1m above height as it is not mandatory with buildings up to 4 stories.

I.A.2 18 m – 30 m Height

The categorization findings for apartments with 6-8 floors are discussed below.

According to the general section, of the questionnaire "never" had the highest count of fire drill experience at 70%, followed by "once a year" at 20% and "once in 6 months" at 10%. 50%of the buildings are in bit traffic areas and 40% are in high-traffic areas. In the consideration of the building perimeter access, 70% accounted for "yes" for the count of building perimeter access. In the count of the emergency assembly points, for both "ground floor" and "no emergency point" was equal to 50%.

Under the Section, means of escape for the given 18m-30m height building category, 60% were not having sprinklers, which means they are not by the guidelines. All the frequency of testing and maintenance of the sprinkler systems accounted equally for never, once a month, and once a year 33.33%. At the same time, only 30% of the buildings are having two staircases and the rest 70% of the buildings consist of only one stairway. Only 50% of the unsprinklered buildings are designed with approximately 30 m travel distance according to the fire regulations and still, 10% are not. Less than 1000 kg, and 1000 kg or more than 1000 kg tied for the highest count of the capacity of the passenger lift/s with 40%, followed by no passenger lifts at 20%. In consideration of the fire doors, only 60% of the buildings have been provided with fire doors. Nevertheless, 33.37% are not self-closing and opening in the direction of escape.

In the consideration of LPG installation, 70% of the buildings have individual cylinders which is higher than the count of the centralized gas system at 30%. Nevertheless, only 14.29% of the individual cylinders placed in an open area on the exterior comply with the fire regulations.

Common corridors had the highest count of fire alarms and location at 50%, followed by no fire alarms at 40% and each apartment at 10%. On the other hand, only 60% of the buildings in this category have hydraulic horse reels and count for "is the horse reel cabinet locked?" Both "yes" and "No" accounted for 50% equally. In the consideration of fire extinguishers both "no fire extinguishers provided" and "one meter above floor level" was 50% equally.

I.A.3 More than 30 m

This is the final building category in the ICTAD Fire Regulations. According to the responses for the fire drill experience, 71.43% of the occupants had never experienced it, and 21.43% and 7.14% experienced it once a year and once in 6 months respectively. On the other hand, only 21.43% of apartments are located in non-traffic areas. The count of the building perimeter access, for "yes" (71.43%) was higher than "No" (28.57%). The count of emergency assembly points, "ground floor" had the highest count at 57.14%, followed by intermediate floors, top floors, and no emergency at 21.43%, 14.29%, and 7.14% respectively.

In the consideration of sprinkler systems 85.71% of the buildings are sprinkled which is mandatory for this building category. 58.33% of the sprinklers are tested and maintained once a year. Nevertheless, 25% accounted for "never" in the count of the frequency of testing and maintenance. At the same time, 42.86% of the

buildings consist of more than two staircases. 35.71% and 21.34% accounted for two stairways and only one stairway respectively. The maximum travel distance of apartments which are having one stairway is 14.29%

"1000 kg / more than 1000 kg" capacity lifts accounted for 78.57% which is mandatory for high-rise buildings for the safe evacuation in fire incidents and 7.14% of the buildings consist of both "less than 1000 kg "and "1000 kg / more than 1000 kg" capacity lifts. 92.86% provided with fire doors. Nevertheless, 7.69% of them are not self-closing and opening in the direction of escape.

Centralized gas systems accounted for 71.43% and only 28.57% of the buildings provided individual cylinders. Nevertheless, 25% of the individual cylinders are only placed in an open area on the exterior to comply with the fire regulations.

To the responses given, 71.43% of the buildings do have fire alarms in common corridors which is higher than the count of fire alarms in each apartment unit (21.43%), simultaneously 7.14% are yet there with no fire alarms. At the same time, all the buildings above the 30 m height category are equipped with hydraulic horse reels which are mandatory in ICTAD fire regulations. Nonetheless, 71.43% of the horse reel cabinets are locked. The count of Fire extinguishers and their location, one meter above floor level accounted for 78.57% and 5 m above floor level accounted for 14.49% respectively. At the same time, 7.14% of the building still do not equip with fire extinguishers

4. Conclusion

A. Up to 18 m

Occupants never experienced a fire drill. The majority of the buildings are not sprinklered (66.66%). Equally 33.33% of the buildings do not have emergency assembly points & perimeter access.50% of the buildings consist of only 1 stairway. 50% of the un-sprinkled buildings have more than 30 m travel distance. 50% & 33.33% of the buildings have no passenger lifts & less than 1000 kg lifts respectively. No Fire doors for 66.66% of the buildings. Only 50% of the individual gas cylinders are placed in an open area on the exterior. The majority of the buildings do not have Fire Alarms, Hydraulic horse reels as well as Fire extinguishers. Buildings are provided with a Hydraulic horse reel; all the cabinets are locked.

B. 18-30 m Height

70% never experienced a fire drill. No emergency assembly points & perimeter access for 50% & 30% respectively. 60% of the buildings are not sprinklered & 70% consist of only 1 stairway. 40% & 20% of the buildings have less than 1000kg & no passenger lifts respectively. 60% are not provided with fire doors & 33.33% of provided fire doors are not self-closing and opening in the direction of escape. Only 14.29% of the Individual cylinders are placed in an open area on the Exterior. Nor fire alarms & fire extinguishers for 40% & 50% of the buildings respectively. Hydraulic hose reel only provided with 60% and 50% of the cabinets are locked

C. More than 30 m Height

More than 70% never experienced a fire drill which is critical. 57.14% of the buildings are having emergency assembly points on the ground floor, 14.29% on the top floor, and 14.29% yet with no emergency assembly point. 28.57% do not have building perimeter access.14.29% of the buildings are not sprinklered & 25% of the sprinklered buildings, 25% are never tested or maintained. 21.43% responded to only one stairway. 14.49% of the buildings have less than 1000 kg passenger lifts. No fire doors for 7.14% & 7.69% of the provided fire doors are not self-closing and opening in the direction of escape. 28.57% are provided with Individual cylinders & only 25% of them are placed in an open area on the exterior. 7.14% are not provided with Fire Alarms & 71.43% are provided in Common corridors. No fire extinguishers are provided for 7.14% & 14.29% are provided with 5m above floor level. Although all the buildings provided Hydraulic

Horse reels 71.43% of the horse reel cabinets are locked.

Furthermore, according to the findings from the fire department, annual apartment building fires are also in a considerable range. Unawareness and the ignorance of the building occupants were identified as major reasons for the fire and it was further confirmed by most of the responses to the questionnaire survey.

5. Recommendation

Recommendations of the research can be summarised as follows;

- Fire drill practice is recommended once in 6 months or at least once a year which is not experienced in any day of some apartments.
- Apartment buildings are recommended to construct in bit traffic areas or no traffic areas with perimeter access for the easily accessible at an emergency of fire.
- The ground floor and top floor is recommended as emergency assembly points for buildings up to 18m & 18-30 m height category. If the emergency assembly point designed at the top level, it shall be easily assessable to the fire fighters. It is mandatory to design buildings more than 30 m with intermediate emergency assembly points as it is not practical to climb downall the stairs at an emergency and it is also important that all the occupants are aware on these assembly points which was found that some tenants are not aware on that.
- It is a mandatory requirement for all high-rise buildings to be equipped with sprinklers and recommended for testing and maintenance once a month (inspection maintenance) and once a year (mechanical and electricalmaintenance) respectively.
- According to the ICTAD Fire regulations, each building shall consist with of atleast 2 staircases. It is recommended for more than 2 stairways for the buildings with more height.
- If the building is not sprinklered the max travel distance to the stairways are recommended as apx 30 m and for the sprinklered buildings, it is apx 45 m. The passenger lifts are recommended with at least 1000 kg or more withspecial equipment.
- Fire doors which are self-closing and opening in the direction of escape are recommended each floor for all the high-rise residential buildings.
- Any building that consists of with more apartments will be required to install a centralized gas system.
- If the Individual cylinders are used it is recommended to place in an open area on the in exterior. Cylinders should not be located near exits, stairways or in areas normally used.
- It is recommended to have alarms in each condominium (all out fire alarm) than in common corridors (stay put) as the alarm sound in common corridors can be unnoticed by the apartment occupants.
- According to the mandatory requirements, it is highly recommended to equip all the buildings with portable fire extinguishers in 1m above floor level.
- It is highly recommended for buildings more than 18 m to equip with hydraulic horse reel at least one-horse reel on each floor and the horse reelcabinet should not be locked in emergency use.

❖ Since most of the occupants are un awarded on regulations and safety measures especially with building fire safety facilities it is recommended to have demonstration programs for public awareness for occupants.

This research was carried out about the current practice of ICTAD fire regulations in apartment buildings in SL to uncover unanswered questions by the researchers. Better fire preventive measures related to façade systems in SL, The selection of the most suitable fire safety design for high-rise residential buildings in SL can be recommended for further research

studies.

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Authors Biography

Chathupama Abeysekara is a professional Quantity Surveyor with a concluded degree of B.Sc (Hons) in Quantity Surveying awarded by Liverpool John Moores University- UK. She studied at SLIIT from the year 2019-2022 and completed her bachelor's degree by obtaining the Best Performance Award for the batch of 2022 with a First class.

Chamari Allis is a lecturer in the Quantity Surveying department at SLIIT. She is a graduate of the University of Moratuwa in the field of Quantity Surveying. She is a charted quantity surveyor of IQSSL. Her research areas are health and safety, professional liability, and cost management.