The Most Critical Issues and Challenges of Fire Safety for Building Sustainability in Jakarta

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The Most Critical Issues and Challenges of Fire Safety for Building Sustainability in Jakarta

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Abstract

Fire incidents negatively affect the function and sustainability of buildings. This study aimed to determine the most critical issues and challenges associated with fire protection for building sustainability in Jakarta. Fifty high-rise buildings were observed and analyzed. Data were processed using the AHP, OMAX, and traffic light system methods. The results indicate that, in terms of building fire protection systems, only 42% of the total number of high-rise buildings in Jakarta are reliable, while 40% are less reliable and 18% are not reliable. The main issues are unavailability of access for fire officers and poor roads. The inconsistencies are also related to the poor performance of the active and passive protection system, which in most cases fails to function in accordance with fire safety standards. The results of this study are useful for increasing the awareness and concern of interested parties in building sustainability.

Keywords: fire safety, building management, maintenance issues, fire challenges

Introduction

Fire outbreaks in buildings create a huge negative impact on the buildings, which could be detrimental to the safety of life and property (Wahab 2015; Rubaratuka 2013). It also has enormous economic and social impacts. For example, families who lose their homes due to fires are subjected to living in refugee camps. Furthermore, fire victims are faced with food, health, psychological, and financial challenges.

When a building is attacked by fire, its sustainability is directly affected, which in turn affects the surrounding environment and the welfare of the community. Therefore, the hazards associated with fire outbreaks in buildings need to be addressed efficiently and effectively. This can be done through fire safety practices and awareness campaigns on the causes of fire, prevention and suppression techniques, and the provision of adequate firefighting equipment (Ebenehi et al. 2017).

Jakarta residents are not adequately educated on fire safety measures. Thus, they are not much concerned about the fire hazards that can occur in the environment where they live. Jakarta has recorded more than 500 fire outbreaks per year in the past five years (see Figure 1). In 2017, the number increased to 698 incidents, after having previously decreased from 779 events in 2015 to 607 events in 2016.

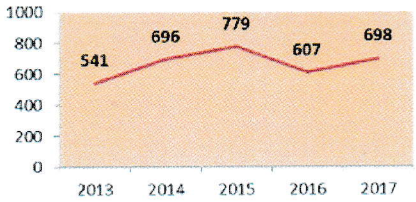

Figure 1. Number of fire incidents in the past five years

The fire incidents in 2017 resulted in 19 deaths, 152 injured people, and 8,801 displaced people in 65 evacuation points. Homes, shops, warehouses, multi-story buildings, and other properties lost were estimated at 276 billion rupiah (Fire Prevention and Rescue Agencies of Metropolitan Jakarta 2018). The main causes of fire outbreaks in Jakarta are poor electrical connections, gas cylinder leakages, indiscriminate burning of garbage and candles (Fire Prevention and Rescue Agencies of Metropolitan Jakarta 2018). Therefore, serious attention needs to be paid to the fire protection systems in buildings, bearing in mind that the fires have also hit several tall buildings. In 1992, there was a fire outbreak at the Min Sin Nationality School and Abdullah Munshi National Secondary School on Penang Island in Malaysia, (Nadzim and Taib 2014) and the Redoutensal, Hofburg Palace in Vienna, Austria. Similarly, Pont de la Chapelle in Lucerne, Switzerland experienced a severe fire outbreak in 1993. Namdaemun Gate in Seoul, South Korea, and Castello di Moncalieri in Turin, Italy, were razed down by fire in 2008 (Nurul Hamiruddin and Ghafar 2009). Meanwhile, high-rise buildings continue to be constructed every year in Jakarta. The number of high-rise buildings in Jakarta in 2005 was 237, which increased to 477 in 2010 and almost doubled to 861 in 2017 (Emporis 2018). Figure 2 shows the development of high-rise building construction in Jakarta from 2000 to 2017 for hotels, residential buildings, and office buildings.

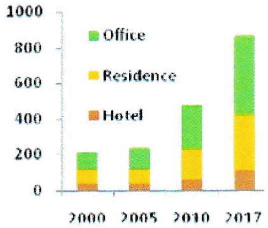

Figure 2. Trend in high-rise development

Figure 3. High-rise buildings in Jakarta

Figure 3 illustrates the state of high-rise buildings in Jakarta. Ideally, high-rise buildings should have a good fire hazard protection system. The failure to handle fire incidents in either low- or high-rise buildings is not always due to inadequate fire protection installed in the building. Generally, fire protective devices are installed in high-rise buildings in line with the age of the building and the standards set by the government. Sometimes these devices do not function because of prolonged non-usage. Some of the problems related to fire protection in buildings are problems in law enforcement, lack of automatic systems, poor planning, maintenance, and management of fire safety issues (Woon Chin Ong and Mohd Zailan Suleiman 2015). Preventing fire incidents in buildings contributes to preserving the functioning and existence of the building itself. The three components that support building sustainability are environmental, social, and economic aspects (Mohamed and Ta Wee 2016). This research investigated fifty high-rise buildings, which included office buildings, hotels, shopping malls, and commercial buildings. Meanwhile, previous research was based on fire protection systems in one or a few buildings: for example, research involving one school building (Nadzim and Taib 2014), one hostel building (Agyekum 2016), several hospital buildings (Woon Chin Ong and Mohd Zailan Suleiman 2015), and one heritage building (Nurul Hamiruddin and Ghafar 2009).

This study sought to answer the following question: "Are high-rise buildings in Jakarta equipped with the right and adequate fire protection system devices?" The objectives of this study were to analyze the various issues and challenges related to fire protection in high-rise buildings and to identify the most critical one. This is very important because it involves human safety, protection of property, and the sustainability of buildings that were originally planned to function for a long time. Finally, this study would be useful to readers and those intending to increase public awareness about the importance of the proper installation of fire protection system equipment in buildings.

Research Method

The descriptive qualitative method was used to conduct this study. This method is generally used to describe the state of buildings that are objectively observed with regard to fire protection systems and management.

The study began with a literature review in order to obtain the right assessment criteria to be adopted. In conducting the research, the authors made direct observations of fifty high-rise buildings in Jakarta. These included office buildings, hotels, malls, and commercial buildings. The hotels and offices were made up of more than ten floors, while malls and other commercial high-rise buildings had a total area of more than 25,000 m^2. These types of high-rise buildings were chosen because they are not permanently inhabited by residents. Office buildings are utilized according to office hours, hotels are dependent on the number of guests staying, while shopping malls are dependent on their opening times. High-rise buildings contain many people, sophisticated equipment, properties, and work devices. As a result, a fire outbreak is a great risk to life and property.

This study was limited to fire protection system devices, in accordance with the standardized standards of fire prevention and rescue agencies of metropolitan Jakarta, Indonesia. The variables of "building safety" and "health framework" were classified into "design variables" and "management variables" (Ramli, Akasah, and Masirin 2013). According to the regulations of the Ministry of Public Works in Indonesia, the variables of building fire safety used in this study are as shown in Table 1. The complete checklist related to the assessment criteria or the variable of building fire safety is shown in Appendix A. Greenhouse effects, comfort, and information technology were not included in this assessment. In addition to collecting data from direct observation, interviews with building engineers and building managers related to and knowledgeable about the fire protection system of the building were also conducted. Interviews were not conducted with visitors to the buildings (Abdul Rahim, Taib, and Othuman Mydin 2014) as this was a technical study about the conditions of the fire protection systems of the buildings. Data were processed using the Analytic Hierarchy Process (AHP), the Objectives

Matrix (OMAX), and the traffic light system methods. The flow of inspection conducted directly in the field is illustrated in the flow chart in Figure 4.

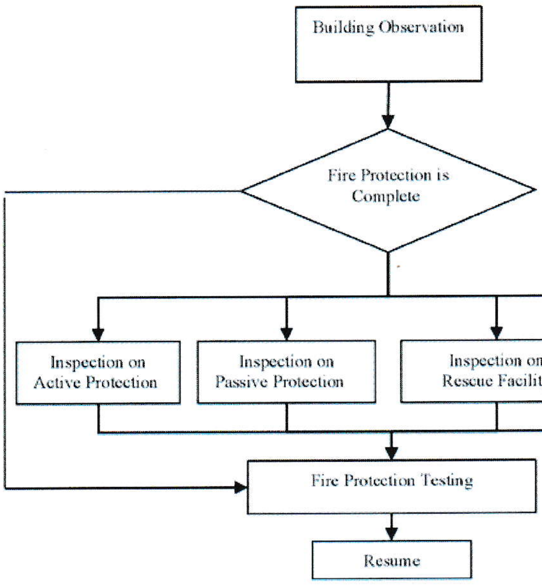

Figure 4. Inspection flow chart

Table 1 shows the assessment criteria.

Table 1. Assessment Criteria

No		Aspects Assessed
1		Site Planning
	1.1	Neighborhood Road
	1.2	Distance between buildings
	1.3	Aperture access for fire officers
	1.4	Access for fire officers in the building
	1.5	Outside hydrants or other sources of fire water
2		Exit Road
	2.1	Design review
	2.2	Components of Exit Facilities
3		Passive Protection System
	3.1	Fire Resistance Level and Stability
	3.2	Compartmentalization and Separation
	3.3	Protection on the Aperture
4		Active Protection System
	4.1	Fire Detection and Alarm Systems
	4.2	Light Fire Extinguisher and Portable Fire Extinguisher

	4.3	Fire Suppression System (Hydrant and Sprinkler)
	4.4	Fire Water Supply
	4.5	Siamese Connection
	4.6	Fire Utilities
5		Fire Safety Management
	5	Supervision and Control
		Total Score

Sources: Fire prevention and rescue agencies of metropolitan Jakarta, Indonesia

The assessment criteria and sub-criteria weights were determined using the AHP. The AHP is a structured technique developed by Saaty in 1980 for organizing and analyzing complex decisions (Sutterfield et al. 2015). It provides a comprehensive and rational framework for structuring a decision (Ameri 2013). It reduces favoritism in the decision-making process as it helps to capture both the subjective and objective assessment measures of the alternative options available (Dalalah, Al-oqla, and Hayajneh 2010). By applying the AHP method, it is possible to identify the weight of the main criteria and the sub-criteria (Marfuah and Widiantoro 2017).

To find out the achievement value of each criterion from the predetermined objectives, the next step is to process the assessment results obtained in the field with a weighted scoring system known as the Objectives Matrix (OMAX). This system, which was discovered by James L. Riggs, connects the criteria with the model (Wibowo and Sholeh 2015). This method is used successfully in manufacturing, and it can also be applied to the building construction sector, especially to the fire protection system in high-rise buildings. This is because the same framework is used to measure the performance of both sectors (Pharne and Kande 2016). An assessment system with the Objectives Matrix is used to equalize the value scale of each indicator. Therefore, the achievement of each parameter is at the same level of objectivity (Mubin 2016). This method can also quickly compare and determine the position of each parameter (Priyanto 2015).

The final calculation is presented using a traffic light system method, which is used to determine the performance of each building with regard to the existing fire safety system. It functions as an indicator, which indicates the position or performance of each building in the specified assessment category. The traffic light performance system works in a way that is similar to the transportation traffic light system (Islam and Rahman 2013) and is used widely in in-line inspection (Chowdhury and Haque 2013). Most literature sources discuss the application of traffic light systems on product packaging in order to warn consumers, increase visual intention, and ensure consumer safety (Larrivee, Greenway, and Johnson 2015; (Koenigstorfer, Groeppel-Klein, and Kamm 2014) (VanEpps, Downs, and Loewenstein 2016). Similar to traffic lights in the transportation system, the traffic light system includes three quality signal colors: green, yellow, and red. For fire safety in high-rise buildings, the green traffic light indicates that the building is reliable, the yellow traffic light indicates that it is less reliable, and the red traffic light indicates that the building is not reliable. By using the traffic light system method, we can create a sense of consistency, reduce confusion, and avoid time-wasting in determining a building's safety category (Russell, Williamson, and Hobson 2017), with the aim to improve the quality of awareness among building managers.

Data Analysis

Physical Observation and the Fire Protection System

A fire protection system is a prevention and suppression technique adopted in the designing of a building (Kironji 2014). There are two fire protection systems adopted in Indonesia, especially in Jakarta: the active and the passive protection systems. The active protection system is implemented by using equipment that can work automatically or manually. It is used by occupants or firefighters in conducting extinguishing operations. In addition, the system is used in carrying out early fire countermeasures, including upright pipe systems and hoses, automatic sprinklers, emergency lighting, emergency communication devices, fire lifts, fire detection and alarm systems, smoke control devices, ventilation, automatic and fire-proof doors, and fire control (Government of Jakarta 2008). On the other hand, the passive protection system, according to the abovementioned local regulations, is implemented by arranging building components from architectural and structural aspects in such a way that its occupants and objects are protected from physical damage in the event of a fire outbreak. This includes building materials, building construction, compartmentalization, fireproof doors, firestop, fire retardant, etc., which serve to prevent and limit the spread of fire, smoke, and building collapse.

Physical observations and inspections of these buildings are conducted using a fire safety risk assessment checklist (Ministry of Public Works 2006) – which is still valid today – and documents (inspection/maintenance reports, improvement orders), and by interviewing the managers and engineers of the building.

Calculation of criteria weight

In the checklist used to assess the building, criteria and sub-criteria were the bases for assessment. Each criterion assessed was weighted on the basis of the difference in the level of importance. The AHP method was used to determine the weight. The primary function of this method is to make decisions in multi-criteria cases and tiered criteria, where the method used combines qualitative and quantitative factors in the overall evaluation of available alternatives. Figure 5 illustrates the levels of criteria applied to several alternative buildings to obtain the results of the assessment.

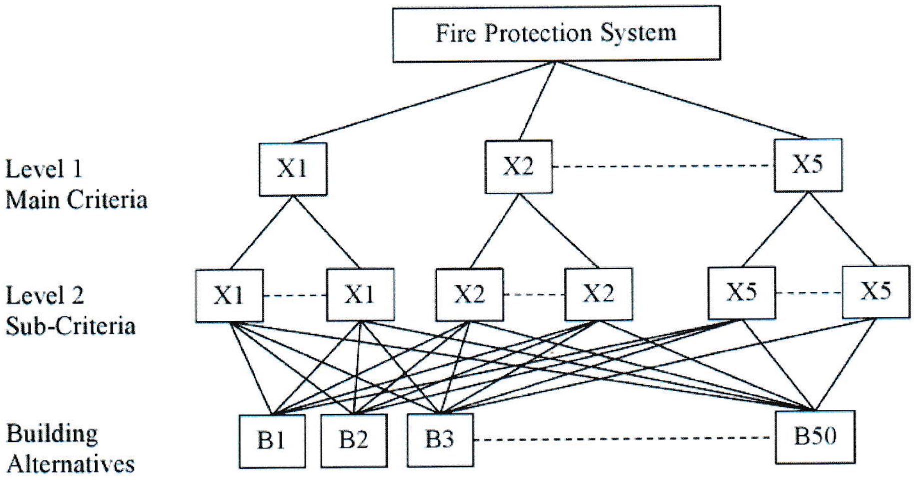

Figure 5. Levels of criteria of AHP

The final output of the AHP method is the prioritized sequence for the alternatives that exist to meet the main objective of the problem. In determining the priority order, it is necessary to weight each criterion or activity according to the level of importance. Meanwhile, the assessment of alternatives under certain criteria involves pairwise comparisons using a certain scale so that the weights for each criterion are produced as a basis for decision making. The results of the weighting calculations for the main criteria with a value of consistency factor of 0.0008 are shown in Table 2.

Table 2. Main criteria

No	Aspects Assessed	Weight
1	Site Planning	0.12
2	Exit Road	0.25
3	Passive Protection System	0.12
4	Active Protection System	0.39
5	Fire Safety Management	0.12

Using the same calculation method, the sub-criteria weight is obtained for all existing main criteria, as shown in Table 3.

Table 3. Main and Sub-Criteria

No		Aspects Assessed	Weight
1		Site Planning	0.120
	1.1	Neighborhood Road	0.006
	1.2	Distance between buildings	0.018
	1.3	Aperture access for fire officers	0.048

1.4	Access for fire officers in the building	0.018
1.5	Outside hydrant or other sources of fire water	0.030
2	Exit Road	0.250
2.1	Design review	0.125
2.2	Components of exit facilities	0.125
3	Passive Protection System	0.120
3.1	Fire Resistance Level and Stability	0.030
3.2	Compartmentalization and Separation	0.030
3.3	Protection on the Aperture	0.060
4	Active Protection System	0.390
4.1	Fire Detection and Alarm Systems	0.078
4.2	Light Fire Extinguisher and Portable Fire Extinguisher	0.0585
4.3	Fire Suppression System (Hydrant and Sprinkler)	0.0975
4.4	Fire Water Supply	0.0585
4.5	Siamese Connection	0.0195
4.6	Fire Utilities	0.078
5	Fire Safety Management	0.120
5	Supervision and Control	0.120

Scoring system

Field checks are conducted by trained personnel who are experienced in fire protection system inspection in high-rise buildings. Among the authors of this research was an experienced auditor from the fire department service and disaster management in Jakarta. However, it was necessary to provide utility pictures and prepare the form (checklist, see Appendix A) for the inspection/evaluation of the reliability of the building prior to recording the physical condition of fire prevention and combating components into the forms available.

The physical condition check data recorded on the form are used for processing and determining the value of reliability in terms of fire protection and control. The reliability level of the fire protection system (as in the checklist [see Appendix A]) is assessed and determined using scores between 0 and 3 in accordance with the installed protection conditions. The scores are related to the existing conditions in the field and grouped as shown in Table 4.

Table 4. 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 in accordance with the terms and function properly

The provisions on the assessment of the reliability of buildings on the safety aspect of fire hazards are indicated in Table 5.

Table 5. Result Scoring Group

Average Score	Category
80–100	Reliable
60–80	Less Reliable
<60	Not Reliable

Fire prevention and protection components are said to be "reliable" if the total value is not less than 80; "less reliable," if the total value is not less than 60; and "not reliable," if the total value is less than 60. After proper assessment, a recommendation regarding the evaluation of the components of fire prevention and handling was given. This recommendation is intended to return the "less reliable (LR)" and/or "unreliable (NR)" condition to "reliable (R)." The recommended steps must be associated with each of the following conditions:

- Recommendations for the R condition: Periodic inspections, periodic maintenance, and periodic improvements;
- Recommendations for the LR condition: Adjustment and/or repair;
- Recommendations for the NR condition: Reform or replace with a new one.

Calculation of weighted score using OMAX

The results of the field assessment were then processed using the Objectives Matrix (OMAX) method. In this calculation, adjustments were made to the rating scale and the weights that existed in each criterion. With the OMAX method, the results of the achievement in each assessed building can be seen. The value obtained from direct observation in the field, on a scale of 0 to 3 as depicted in Table 4, is converted to a scale of 0 to 100 so that it can be categorized as illustrated in Table 5. Table 6 is an example of the processing of the scoring results obtained during the observations, using OMAX on Building 1.

The values obtained from the direct observation in Building 1 for all criteria are shown in Column 1 of Table 6. This assessment was based on the guidelines shown in Table 2, where the rating scale is between 0 and 3 for each element assessed. Each criterion had a different number of elements. The maximum value for each criterion is as stated in Column 2 (Max). With OMAX, a rating scale is arranged, which ranges from 0 to 100, as shown in the assessment categories of Table 3. Column 3 in Table 6 (the weight of each criterion) is obtained using AHP. Column 4 is obtained by plotting the scores observed on the scoring scale. For instance, in the first criterion, the score of observation reaches 3 after being plotted in the OMAX matrix, which is equivalent to 50. Therefore, the scaled score for the first criterion is 50, as shown in Column 4. This number also shows the category of the condition of the building for the first criterion (Not Reliable), according to Table 5, because the number is smaller than 60.

Taking into account the weights in Column 3 and the scaled scores in Column 4, the weighted score, which is a part of the overall value for the building, is obtained. The total weighted score shows the total value of the building concerned. This is categorized according to the guidelines in Table 3. In Building 1, for example, a total weight score of 81.08 means that the building is in the "Reliable" category, according to Table 5. This is because its value is above 80. In the same way, calculations were carried out using OMAX for all the 50 buildings that were a part of the study.

Table 6. OMAX

BUILDING 1													
1	2										3	4	5
Score of Observations	Min	Scoring Scale								Max	Weight	Scaled Score	Weighted Score
	10	20	30	40	50	60	70	80	90	100			
3	0.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6	0.006	50	0.3
2	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3	0.018	70	1.26
12	2.1	4.2	6.3	8.4	10.5	13	15	17	19	21	0.048	60	2.88
0	0.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6	0.018	10	0.18
2	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3	0.03	70	2.1
25	3	6	9	12	15	18	21	24	27	30	0.125	80	10
18	2.4	4.8	7.2	9.6	12	14	17	19	22	24	0.125	80	10
6	0.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6	0.03	100	3
7	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9	0.03	80	2.4
11	1.2	2.4	3.6	4.8	6	7.2	8.4	9.6	11	12	0.06	90	5.4
9	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9	0.078	100	7.8
12	1.2	2.4	3.6	4.8	6	7.2	8.4	9.6	11	12	0.0585	100	5.85
7	1.2	2.4	3.6	4.8	6	7.2	8.4	9.6	11	12	0.0975	60	5.85
11	1.2	2.4	3.6	4.8	6	7.2	8.4	9.6	11	12	0.0585	90	5.265
8	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9	0.0195	90	1.755
19	2.4	4.8	7.2	9.6	12	14	17	19	22	24	0.078	80	6.24
11	1.2	2.4	3.6	4.8	6	7.2	8.4	9.6	11	12	0.12	90	10.8
											TOTAL		81.08

Result and Discussion

The results, based on the weight of each criterion, were displayed using the traffic light system method. The red color indicated the "not reliable" condition, yellow indicated the "less reliable" condition, and green indicated the "reliable" condition. The classification is shown in Table 5 (Result Scoring Group).

The direct observation of high-rise buildings conducted in the field showed that not all high-rise buildings fall into the "Reliable" category. This means that not all high-rise buildings in Jakarta have reliable fire protection systems. All assessment results are summarized in Table 7 and Figure 6. Unfortunately, only 42% of all the objects examined were reliable, 40% were less reliable, and 18% were unreliable. Therefore, the results of the observation indicate that high-rise buildings in Jakarta are less reliable in terms of fire outbreaks. This is also reinforced by the average value for the whole building, which was only 75.95 (less than 80), thus falling within the "less reliable" category.

Table 7. Assessment results

Building		Final Score	Building		Final Score	Building		Final Score	Building		Final Score	Building		Final Score
Building	1	80.94	Building	20	86.05	Building	48	89.31	Building	29	70.89	Building	50	76.82
Building	3	84.15	Building	22	83.39	Building	5	60.01	Building	31	76.09	Building	2	48.78
Building	9	80.33	Building	26	87.58	Building	6	65.58	Building	32	75.46	Building	4	53.87
Building	11	82.97	Building	27	81.36	Building	7	65.89	Building	33	67.11	Building	8	55.29
Building	14	85.73	Building	28	83.10	Building	10	66.25	Building	34	68.12	Building	13	54.96
Building	15	83.75	Building	30	81.09	Building	12	79.45	Building	35	69.81	Building	36	58.50
Building	16	84.88	Building	39	85.23	Building	21	69.17	Building	37	75.39	Building	41	50.22
Building	17	84.85	Building	44	81.74	Building	23	72.54	Building	38	75.46	Building	42	55.76
Building	18	85.09	Building	46	83.62	Building	24	78.81	Building	40	72.67	Building	43	51.98
Building	19	82.30	Building	47	88.60	Building	25	76.77	Building	49	78.32	Building	45	59.91

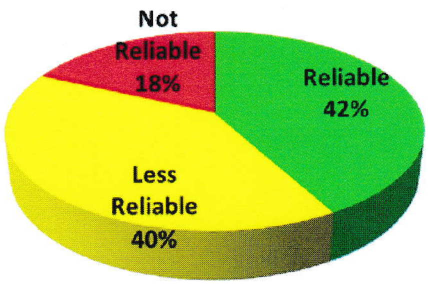

Figure 6. Assessment result

For the entire building being reviewed, the performance of the assessed aspects formed a configuration as shown in Figure 7 below.

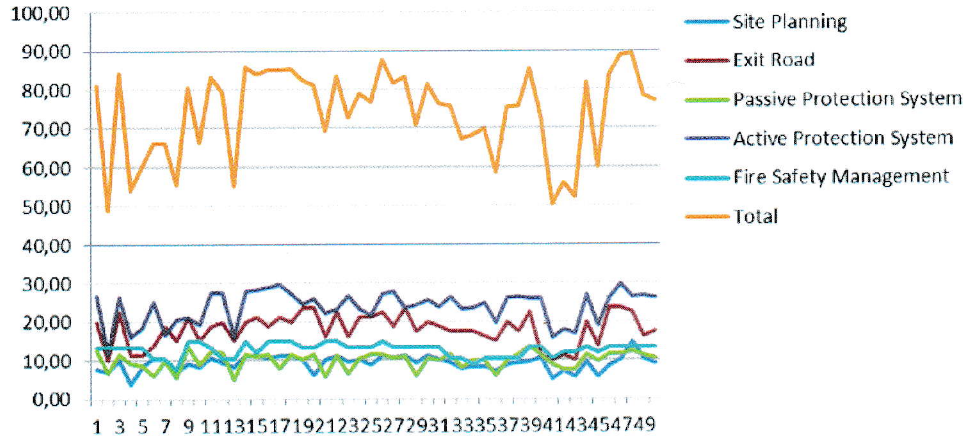

Figure 7. The scoring result configuration

From the graph in Figure 7, it can be seen that the fire protection system conditions in each building fluctuate greatly. With regard to the assessment results for each analyzed building, the condition of the building can be ascertained by comparing the weakest building with the strong ones. Of the fifty high-rise buildings studied, the five lowest mean values for each component were regarded as the most critical issues and challenges of fire safety for building sustainability in Jakarta (Table 8). The following specific aspects were identified: access for fire officers in the building; neighborhood road; fire suppression system (hydrant and sprinkler); protection on the aperture; and exit facilities.

This study identified access for fire officers as the main problem for several reasons, including the unsupportive design of the architectural layouts due to limited land in the center of a big city such as Jakarta.

Additionally, indiscriminate smoking of cigarettes should be checked, with announcements displayed in every building prohibiting smoking in and around the building. Eye-catching smoking ban boards should be placed in front of the building, as shown in Figure 8. Furthermore, efforts to maintain the safety of the occupants of the building from terrorist activities should be made by building inspection shelters at the entrance of the building, as shown in Figure 8. In addition, fire officers should not be hindered from entering the buildings.

Figure 9 shows the average score of fifty buildings that were observed. Similar to the traffic light system, the red color indicates the "not reliable" category. Five aspects were assessed, which included the red color or the "not reliable" condition. Those five aspects, which were ranked lowest (see Table 8), were assessed as the most critical issues and challenges of fire safety for building sustainability in Jakarta.

Figure 8. Entrances to buildings

Table 8. The most critical issues and challenges of fire safety for building sustainability in Jakarta

Rank	Aspects Assessed	Score
1	Access for fire officers in the building	11.0
2	Neighborhood Road	43.6
3	Fire Suppression System (Hydrant and Sprinkler)	55.4
4	Protection on the Aperture	56.6
5	Components of Exit Facilities	63.0

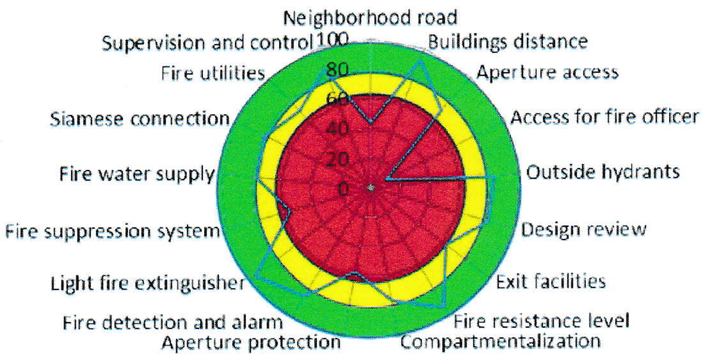

Figure 9. Average score on each criterion

An analysis of Figure 9 shows that access for fire officers is the weakest aspect. While the possibility of a safe escape is the most crucial aspect of a building's fire safety feature (Kobes et al. 2010), we also need to ensure the evacuation of mixed-ability populations, including assistance rendered to the evacuation of occupants, overtaking, and contra-flows (Shields and Boyce 2009). An evacuation strategy is concerned with defining the time required to safely evacuate all occupants (Cowlard et al. 2013). However, it should be kept in mind that the route selections of people are dependent on the amount of information that they possess about the building and its surrounding environment (Chen et al. 2013). Therefore, it is also necessary to conduct regular education and training with occupants (Agyekum 2016).

Although Supervision and Control (Fire Safety Management) are among the strongest (the fifth and last in Table 1), the establishment of safety behavior still needs to be enhanced. Fire safety behavior and lifestyle need to be developed from people's initiatives. In order to provide total safety for buildings, fire safety management must be properly implemented by local government authorities, building authorities, as well as the users and occupants of the building (Nadzim and Taib 2014). In addition, clear legal control must be established for the successful implementation of fire safety management in buildings (Abdul Rahim, Taib, and Othuman Mydin 2014). Fire safety management is also related to the efforts of sustainable development, where knowledge is a very important factor that influences the understanding of building sustainability (Wee 2016).

Conclusion

The results of this study showed that the fire protection system conditions for each building were different. For this reason, efforts are needed to raise awareness about the importance of managing fire protection systems in buildings. The results also showed that only 42 percent (less than half) of the sample buildings were reliable in terms of fire safety. Thus, the steps that need to be taken, besides raising awareness, include increasing control by the responsible authorities to carry out field investigations related to fire protection systems in the buildings periodically.

Meanwhile, the variables that were used as the assessment criteria are still sufficient to be applied as a tool to assess the fire protection system in buildings. This means that the current regulations are still relevant for use. Building management awareness and the commitment of building owners to always pay attention and maintain the fire protection system in the building so that it always functions properly need to be improved. In addition to training, penalties need to be imposed on those who are negligent in managing the fire protection system.

The issues and challenges revealed by the results of this study are not solely on firefighting equipment and facilities in buildings. The existing problems are also related to technical factors, especially in the planning-engineering design aspects and environmental factors that influence the design of the plans made. The environmental aspect is related to the level of building density that initially existed. In addition, all fire-related protection equipment needs serious attention. Furthermore, awareness of the importance of fire protection systems in high-rise buildings should be improved. Although the control or management aspects are satisfactory, education and training need to be imparted on a regular basis. Thus, all parties involved in building planning, engineering design, development, management, or maintenance need to have the same concern about the importance of the buildings' sustainability.

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Appendix A

Variables of building fire safety

No		Aspects Assessed	Score
1		**Site Planning**	
	1.1	**Neighborhood Road**	
		Choose according to existing conditions:	
		A floor with a height of <10 m is not provided with a protective layer, but an operational area of 4 m wide is needed along the side of the building where the access is open. A maximum of 45 m from the entrance of the fire vehicle is required.	
		A floor with a height of >10 m (other than Class 1, 2, & 3 buildings) requires a pavement layer, and in the non-residential buildings, access points must be provided from the pavement layer for a building with a volume of 7,100 m^3 (at least one sixth of the yard).	
		There are markings on all four corners of the pavement layer and line markings: "FIREFIGHTING PATTERNS - DO NOT DISCONTINUE."	
	1.2	**Distance between buildings**	
		Choose one of the following conditions:	
		Building height up to 8 m, minimum distance between buildings = 3 m	
		Building height >8–14 m, minimum distance >3–6 m	
		Building height >14–40 m, minimum distance >6–8 m	
		Building height >40 m, minimum distance >8 m	
	1.3	**Aperture access for fire officers**	
		There is an open access marked "ACCESS TO FIRE EXTINGUISHERS - DON'T BE BLOCKED"	
		There is 1 access opening for every 620 m^2	
		If there are more than 1 access openings, they must be placed far apart	
		Portal/entrance height of at least 4.5 meters	
		Portal/entrance height of at least 4.5 meters	
		Round radius of at least 9.5 meters	
		The minimum radius is 10.5 meters	
	1.4	**Access for fire officer in building**	
		There is a fire extinguisher safe (in which there is a lobby, an elevator, and stairs)	
		At least one fire extinguisher must be provided for every 900 m^2 of floor area.	
	1.5	**Outside hydrants or other sources of fire water**	
		Choose according to existing conditions:	
		Car path 50 m from the city fire hydrant; if there is no city fire hydrant, a yard hydrant must be provided.	

		If there is no yard hydrant then there must be a fire well or reservoir of water, and so on, that makes it easy for the fire department to use, so that every house and building can be reached by a fire extinguisher from the neighborhood road.	
		Water supply for yard hydrants or other water sources must be at least 2,400 liters per minute at a pressure of 3.5 bar, and it must be possible to drain water for at least 45 minutes	
2		**Exit Road**	
	2.1	**Design review**	
		The exit has a separate construction with a level of fire resistance (LFR) of at least one hour, has a standard fire door, is protected continuously until the release of the exit	
		Not used for other disturbing purposes including warehouses, safe from fire hazards and interior finishing according to rating.	
		Corridor as an exit access with an occupancy load of >30 people, must be a separate building with 1-hour LFR	
		The height of the outlet means > 200 cm	
		Changes in height level not more than 50 cm	
		The capacity and number of exits is in accordance with the occupancy load (occupancy load up to 500 = 2 exits, 500 to 1000 = 3 exits, and >1000 = 4 exits)	
		The arrangement of paths towards the exit s appropriate (the exits are separated from each other with a distance of more than half the length of the building's diagonal)	
		Distance to the exit is within the boundary (45 m for nonprofessional buildings and 60 m for professional buildings)	
		Illumination and marking of the appropriate means of escape (clearly visible and easy to read)	
		Directional signs illuminated from outside must be illuminated not less than 54 lux (5 ft-candle)	
	2.2	**Components of Exit Facilities**	
		The doors are allotment (non-rating, fire door, and smoke-proof door), with a net width of 80 cm, the difference in floor height on the two sides of the door should not be more than 12 mm, the swing direction is not obstructing and is easy to open (does not require a special key)	
		The standard ladder has a net width of 110 cm (or 91 cm if the occupancy load is <50), the maximum height of the stairs is 18 cm, the minimum depth of stairs is 2.8 cm, the minimum height is 200 cm, and the maximum height between stairs is 3.7 m.	
		Exit means more than 75 cm above the floor or underground must be equipped with a safety fence and hand rails on both sides	
		The room is enclosed in smoke-proof and fire stairs pressurization in accordance with requirements	
		Existing horizontal exits support fire compartmentalization with a TKA of at least one hour	
		Existing ram according to the requirements of the means of escape	
		For exits that do not exit directly to the release exit outside the building, a protected exit channel is used.	
		There are protected areas that meet the requirements (smoke and fire)	
3		**Passive Protection System**	
	3.1	**Fire Resistance Level and Stability**	
		Construction type according to building class:	

		Each building element has an appropriate LFR (according to Regional Regulation 8 of 2008)	
	3.2	**Compartmentalization and Separation**	
		The maximum size of the fire and atrium compartments complies with the following conditions:	
		There is a vertical and horizontal separation in relation to the zoning of hazardous contents of the building including the use of walls that have appropriate LFR and meet the requirements of compartmentalization.	
		Shaft lift and building equipment (electricity supply systems, emergency generators, smoke control systems) must be in separate buildings with appropriate LFR.	
	3.3	**Protection on the Aperture**	
		All openings must be protected, and utility holes must be provided with fire stops to prevent fires from spreading and ensure the separation and compartmentalization of buildings.	
		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.	
		If openings must be held on the wall, they must be protected with a fire-proof cover that is at least the same as the TKA wall or floor.	
		Means of protection at existing openings (fire doors, fire windows, smoke barriers, and fire closures) must meet applicable requirements	
4		**Active Protection System**	
	4.1	**Fire Detection and Alarm Systems**	
		There is a fire detection and alarm system that operates well and is maintained	
	4.2	**Light Fire Extinguisher & Portable Fire Extinguisher (PFE)**	
		There are PFEs with type, size, and distribution according to hazard classification	
		There is an inspection, maintenance, and refilling PFE	
	4.3	**Fire Suppression System (Hydrant and Sprinkler)**	
		Fire Pump (according to regional regulation of DKI No. 92 of 2014)	
		Extinguishing systems exist in special hazard areas including kitchens and other danger areas	
	4.4	**Fire Water Supply**	
		Reservoir fire water supply capacity	
		Placement	
		Water sources use treated water or water from water companies	
		Restrictions on other consumption water	
	4.5	**Siamese Connection**	
		Buildings installed with upright pipes and automatic sprinkler systems must have an inlet for pumping equipment at a distance of 18 m from the fire extinguisher connection ("siamese").	
		Building height of 24-40 m may be dry upright pipes, while a height of >40 m must be wet upright pipes.	
		Marking and access	
	4.6	**Fire Utilities**	

		There is a fire lift installation	
		There is an emergency power system that can be used for fire protection systems and escape facilities	
		There are emergency lighting and exit signs	
		There is a fire control center	
		Means of fire communication	
		Smoke management system	
		There is a lightning protection system	
5		**Fire Safety Management**	
	5	**Supervision and Control**	
		Adequate supervision is carried out in addition to that done by the building inspector as well as the authorized technical agencies and consultants in the field of building and environmental maintenance so that the building is always functioning. The aspects examined are in addition to carrying out checks on all installations and their construction as well as all supporting facilities that support the operation of the system.	
		Inspections are carried out periodically, including tests of the operation of all available equipment, as well as training employees on the use of PFE	
		There are regular fire drills	
		There is a Fire Safety Management (FSM) organization that implements, among others, the Fire Emergency Plan (FEP). There are regional regulations free of excess combustible material and there are smoking bans	
		Total Score	

Source: Regulations of the Ministry of Public Works Indonesia

The Most Critical Issues and Challenges of Fire Safety for Building Sustainability in Jakarta

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