Evaluation of the Implementation of Fire Safety Management Based on Work Breakdown Structure for High-Rise Apartments

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Abstract

The growing population makes the presence of apartments in Jakarta inevitable. The supply of apartments in Jakarta for the period 2020-2023 is considered to reach 49,200 apartment units. One of the problems that often arises related to high-rise apartments is fires. Fire safety management is required to analyze, evaluate and control fire safety. The purpose of this research is to find out the implementation of fire safety management in apartments in Jakarta. Four dimensions of fire safety management according to Furness & Muckett consisting of fire prevention in buildings, safety of people in the event of a fire, monitoring, auditing and reviewing the fire safety systems, reactive monitoring-reporting, recording and investigation based on Work Breakdown Structure were used as an indicator to evaluate the application. Field observations were made on the implementation of fire safety management using checklist sheets and filled by building managers in various apartments in Jakarta. The results showed that on average 91% of apartment buildings in Jakarta have implemented four fire safety management indicators with the highest application rate of 95% in fire prevention in buildings and the lowest at 89% in reactive-monitoring, reporting, recording and investigation.

Keywords
Apartment, Fire Safety Management, Fire, and Work Breakdown Structure.

1. Introduction

According to (Auerbach and Wan 2020) the number of skyscrapers has increased by 8% every year since 1950. Urban population growth is predicted to exceed seven million people in the world by 2050 making the need for the number of vertical buildings will continue to add up. It is predicted that there will be 41,000 skyscrapers with a height of more than 150 meters and 40 floors by 2050. Property consultant Savills Indonesia assessed that the supply of apartments in Jakarta for the period 2020-2023 reached 49,200 apartment units, of which in 2020 alone the number of new apartment project completions reached more than 26,000 units. Savills research results, based on the type of project, the upcoming supply in Jakarta, is Transit Oriented Development or mixed scale. Future stock is concentrated in South Jakarta (31%), followed by West Jakarta (25%), North Jakarta (17%), East Jakarta (15%), Central Jakarta (7%) and CBD by 5% (Investor Daily Indonesia 2020).

One of the problems that often arises related to tall buildings is fires. Fire disasters are one of the most common problems in the world and belong to the most destructive disasters especially in developing countries. Tall buildings have a greater risk of fire due to several factors such as building height, complex building structures, more diverse functions, and so on (Nimlyat et al. 2017). In Jakarta itself, there were 1335 fire incidents in 2019 obtained from the official website of the DKI Jakarta Provincial Fire and Rescue Service. There are also statistics on the number of fires based on the cause: 557 incidents caused by electricity, 51 incidents due to cigarettes, 102 incidents due to stoves, and 645 incidents due to other causes. Losses due to fires in Jakarta in mid-2019 reached 137.8 billion rupiah.

The Government through Regulation of the Minister of Public Works No : 20/PRT/M/2009 issued technical guidelines for urban fire protection management. In it there is a statement that every public building including apartments, which have a minimum of 500 people, or that has an area of at least 5,000 m^2, or has a building height of more than 8 floors, is required to implement MPK (Fire Protection Management). It is just that the fulfillment of fire department access to buildings in Jakarta is still not good. The components of the access that are not fulfilled are the unmet creation of a

special marking for the access point of the fire engine, the unavailability of pavement environmental roads around the building to be traversed by firefighting vehicles, and also no special marking for the combustion line (Kurniawan 2014). In addition, the high-rise buildings in Jakarta do not meet the fire protection system. Head of the Fire and Rescue Service of DKI Jakarta, Subedjo said that out of a total of 897 buildings or tall buildings in Jakarta, there are 280 tall buildings that have not met the fire protection system. While the rest, 617 tall buildings have complied with the system (Lenny Tristia Tambun 2018). According to (Fauzi 2015) so far, of the thousands of high-rise buildings in Jakarta that are eligible for protection systems from the Fire Department about 60 percent. While nearly half are not yet eligible.

The good implementation of fire safety management is the right effort in fire management, starting from the planning stage to follow-up. This action is very necessary in Indonesia considering Indonesia is one of the countries that often have fire disasters (Nugraha 2019). According to (Furness and Muckett 2007), the implementation of fire safety management in buildings consists of four indicators, namely:

1. Fire Prevention in Buildings
2. Safety of People in The Event of a Fire
3. Monitoring, Auditing, and Reviewing Fire Safety Systems
4. Reactive Monitoring (Reporting, Recording, Investigation) After A Fire

Because of the importance of fire safety management in tall buildings, careful planning is required before the implementation of the project. Fire safety in a building can be maximized if each activity in the building is defined in detail.

In the 6th edition of PMBOK (2018), the stages in project scope planning include: 1) Collecting requirements; 2) Determine the scope of work; and 3) Creating the WBS (Work Breakdown Structure). Supriadi et al. (2017) stated that WBS is the framework for project execution, as well as a means to plan, monitor and control projects. WBS is a recurring process that can be used as a template for future projects. According to Herzanita (2019) The smallest level of WBS is the work package, which brings up various groups of activities where the activities are scheduled, estimated, monitored and controlled. Firefighting jobs included in level 4 of Mechanical work in Work Breakdown Structure (Supriadi et al. 2017). In Ajizah (2018) Firefighting work is at level 3 in Electrical Mechanical work.

The objective of this study is to evaluate the implementation of fire safety management in high-rise apartments in Jakarta using four indicators including Fire In Buildings, People Safety At The Time of Fire, Monitoring, Audit, and Review of Fire Safety Systems, and Reactive Monitoring (reporting, recording, investigation) after fire incidents based on Work Breakdown Structure is expected to produce an accurate level of implementation.

2. Literature Review

The Causes of Fire

According to Rahmadini (2002) the definition of fire is the occurrence of unwanted fire hazards, which can bring losses in the form of materials and souls. In buildings inhabited by many people, the potential for fire is likely to be greater. If the occupant consciously or unconsciously ignores the possibility of fire in the building, then the building and its occupants have been endangered by fire hazards.

Fires occur because there are fires that arise due to friction between objects that are in the air. Friction is energy, it can come from the motion of objects that rub against each other, or because of the potential energy of objects. Then the energy is used by the atoms of oxygen in the air, so that the energy in the oxygen atoms increases. The energy is also used by the electron in oxygen atoms to rise to the higher skin (excitation). But the process is only brief, then the electron will return to its original state by removing its excess energy as light (photon). Energy obtained from friction is also utilized by oxygen to be able to react with flammable substances to start the combustion process (activation energy) (Septiana 2011).

Fire Safety Management

In (Furness and Muckett 2007), implementation of fire safety management in buildings consists of four indicators, namely:

1. Fire Prevention in Buildings
2. Safety of People in The Event of a Fire

3. Monitoring, Auditing, and Reviewing Fire Safety Systems
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Primariawan (2004) said that in accordance with its function and usefulness, fire prevention in buildings consists of two parts, which are passive protection system and active protection system. Passive protection system requirements as per SNI 03-1736-2000 are as follows: passive system performance requirements, terms of use of building materials, requirements for fire resistance of building structure components, compartmentalization and separation requirements, and protection requirements for indoor openings or penetration.

According to Ibrahim et al. (2011) Active protection system to detect fires has the following attributes: detection and alarm system, automatic suppression system, fire hydrant, portable fire extinguisher, emergency lighting, hose reel and standpipe, and communications.

In (Li et al. 2018) there are 4 quantification indexes in conducting fire risk assessments, which are:

1. Physical fire protection facilities: fire extinguishing system, smoke control system, fire lift, fire automatic alarm, fire emergency broadcast and fire communication system
2. Fire safety evacuation capability owned by the building: evacuation route, stairs, evacuation distances, evacuation path pointer indicator, and reliability of backup plans for evacuation
3. Building fire performance: building layout, material resistance of building structures to fire, and divisions that understand smoke and fire performance
4. Building safety status against fire hazards in construction units: implementation of relevant regulations, the existence of regulations, education training, and building capability against emergencies.

People's safety at fire incidents in buildings depends on the availability of emergency procedures created with the building's fire safety design features and paying attention to the behavior of residents when faced with emergency situations (Furness and Muckett 2007).

Here are human perceptions and behaviors of fire incidents according to Furness and Muckett (2007):

1. Principle of sensory perception: detection, interpretation, and perception vs reality
2. Time it takes to escape the fire: pre-movement behaviours and travel behavior
3. Characteristics of people who affect the evacuation process: sensory conditions, physical conditions, state of consciousness, initial reaction, stakeholding, flame translucence, and building design features
4. Solid movement: human flow rate, spatial awareness, movement of smoke, and ergonomics.

The purpose of monitoring and measuring performance security is to provide information to organizations about the current status of a policy, its procedures, and progress until it is completed (Furness and Muckett 2007). The type of fire safety system monitoring procedures used is proactive monitoring. By Furness and Muckett (2007) the success of this type of monitoring depends on applicable standards, monitoring frequency, monitoring actors, and required results or actions. The stages of the audit process on fire safety are as follows: approve a protocol, create audit scope, preparation, collection of audit evidence, and report findings. As for the review process, what should be done consists of initial status review, regular review and annual reviews and reports.

Reactive monitoring allows an organization to identify and correct deficiencies in response to a specific incident or trend. Reactive monitoring is the same as tracking unwanted events (Hopkins 2009). By (Furness and Muckett 2007), there are 4 indicators in reactive monitoring after a fire, namely:

1. Investigation: investigation of fires, investigative procedures and investigation of causes and impacts
2. Fire management response: monitoring system, training staff, recommendations, and information and instruction
3. Fireman performance: fire team capabilities and response
4. Data reporting: Regulation, Reports, Recording, and System

Work Breakdown Structure (WBS)

WBS can be used as a planning approach to improve project performance, the practice is reported to reduce quality performance rework — largely related to reduced work scope changes and increased on-site control for industrial construction projects. WBS standardization framework is also recommended to support integrated planning and supervision (Supriadi et al. 2017). Firefighting work which is a fire prevention and safety measure is included in the

work section of mechanical and electrical works and is at level 4 of WBS (Supriadi et al. 2017). Ajizah (2018) has made a standardized WBS for electrical and mechanical work in apartments which includes fire safety components.

3. Methods

The research method used was descriptive research with research objects that are high-rise apartments in Jakarta. Here are the stages of research in general:

1. Conducting literature study on Work Breakdown Structure (WBS) for electrical and mechanical work, four indicators of implementation of fire safety management implementation according to (Furness and Muckett 2007) namely Fire Prevention in Buildings; Safety of People In The Event of A Fire; Fire System Monitoring, Audit, and Review; and Reactive Monitoring (Reporting, Recording, Investigation)
2. Making a standardized WBS of apartment buildings with implementation in accordance with 4 indicators of fire safety management
3. Evaluating 4 indicators of fire safety management based on Work Breakdown Structure for high rise apartments in DKI Jakarta Province
4. Processing Questionnaire results by descriptive analysis, by processing from the answer "yes (apply)" to a value of 1, and "no(not apply)" to a value of 0. The data was then tabulated with Microsoft Excel and calculated how many respondents with 1 answer from each indicator. A percentage of respondents' answers were performed.

The independent variables in this study are standardized Work Breakdown Structure on electrical and mechanical work for high rise apartments and 4 indicators of the implementation of Fire Safety Management. The dependent variable in this study is the percentage of the implementation of 4 indicators of fire safety management based on Work Breakdown Structure in high-rise apartments in Jakarta.

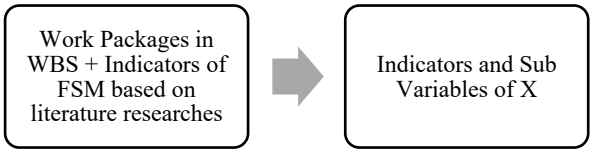

Figure 1. Variable and sub variables of X

Figure 1 shows that all work packages in the standardized Work Breakdown Structure will be combined with the indicators of fire safety management based on literature researches and they become the indicators and sub-variables of X of this research.

4. Data Collection

Initial and final validations of the questionnaire were conducted by three experts with experience working in the field of electrical and mechanical works and fire safety for a minimum of ten years. After that, the pilot survey was conducted on ten respondents who worked in the field of apartment building management. The criteria of respondents in this study were people who worked as building managers with a minimum educational background of bachelor degree and work experience of at least 5 years in high rise apartments. 40 respondents were successfully obtained by filling out questionnaires online through google form and offline by filling out the questionnaire directly.

5. Results and Discussion

5.1 Numerical Results

By conducting a literature study on fire safety management, the author added work packages into the WBS to create a standardized WBS for electrical and mechanical work with the implementation according to the fire safety management. The author validates WBS with three experts and produces the standardized WBS for electrical and mechanical works as shown in Table 1.

Table 1. Standardized WBS for mechanical and electrical work with FSM implementation

WBS LEVEL 1	WBS LEVEL 2	WBS LEVEL 3	WBS LEVEL 4
PROJECT TITLE	WORK SECTION	SUB-WORK SECTION	WORK PACKAGE
Project Title	Mechanical-Electrical	Fire Fighting	Fire Pump (Diesel pump, electric pump, jockey pump)
			Solar tank
			Fire panel control
			Power cable & control cable
			Piping (hydrant pipes and sprinkler pipes)
			Valve & accessories
			Accessories of Hydrant (hydrant box, hydrant pillar, Siamese connection)
			Sprinkler Head
			Fire extinguishers
			Fire Suppression System
			Pillar Hydrant
			Fire testing & commissioning
		Fire Alarm	Main Control Fire Alarm
			Annunciator
			Grounding System
			Wiring
			Detector
			Manual Break Glass Push Button
			Alarm Bell
			Firemen Telephone
			Terminal Box
			Cable Tray
			Testing and Commissioning of Fire Alarm
		Sound System	Paging
		Building Autosystem	Monitoring centre (specifically for smart building)
		Elektrikal	emergency lighting
		Air system	Pressurized Fan
		Hauling equipment (lift dan escalator)	Fire Lift

The work packages in the WBS become sub variables X where the variables X in this study are shown in Table 2, Table 3, Table 4, and Table 5:

Table 2. Variables and sub variables of X1

X1 : Fire Preventions in Buildings			
No	**Sub Variables**	**No**	**Sub Variables**
1	Preventive measures against fires	30	CCTV system
2	Means of rescue	31	Security monitoring centre
3	Fire retardant structure element material	32	Emergency power
4	Compartment	33	Manual fire alarm
5	Protective measures against fire	34	Fire Pump (Diesel pump, electric pump, jockey pump)
6	Active protection system	35	Solar tank
7	Passive protection system	36	Fire control panel
8	Openings in compartmentalization	37	Power cable & control cable
9	Means of exit	38	Piping (hydrant pipes and sprinkler pipes)
10	Allocation and number of building occupants as planned	39	Valve & accessories
11	Rescue distance	40	Hydrant accessories (hydrant box, hydrant pillar, Siamese connection)
12	Exit signs	41	Sprinkler Head
13	Detection of Concealed spaces (roof spaces, behind decorative panels)	42	Fire extinguishers
14	Prevention of fire spread (outer wall material, roof covering material)	43	Pillar Hydrant
15	Safe evacuation time	44	Fire testing dan commissioning
16	Procedure of evacuation	45	Main Control Fire Alarm
17	Placement of residents based on Occupant Characteristics (number, density, distribution)	46	Annunciator
18	Availability of Rescue routes	47	Grounding System
19	Emergency lighting	48	Wiring
20	Means of detection, warning	49	Detector
21	Outdoor rescue routes/neighborhood roads	50	Manual Break Glass Push Button
22	Disability rescue facilities	51	Alarm Bell
23	Smoke control and ventilation (ventilation: mechanical, natural; emergency lighting)	52	Firemen Telephone
24	Signs	53	Terminal Box
25	Heat/fire detectors	54	Cable Tray
26	Alarm system	55	Testing dan Commissioning of Fire Alarm
27	Smoke detectors	56	Paging
28	Facilities and access for fire teams (environmental roads, inlets and upright pipe outlets,	57	Pressurized Fan
29	Maintenance and testing of fire safety systems	58	Fire Lift

Table 3. Variables and sub variables of X2

X2 : Safety of People In The Event of A Fire			
No	**Sub-variables**	**No**	**Sub-variables**
1	Reactions that residents should take during a fire	12	rehearsal
2	Fire detection methods	13	Competent staff
3	Information on the time it takes to save yourself	14	Prosedur evakuasi darurat
4	Characteristics of people who affect evacuation (sensory condition, physical, conscious condition of the person, initial reaction, stakeholding, fire and smoke in the building, building design (design influence to the time of evacuation)	15	Help to disabled residents to save themselves
5	Ordinances of massive Movement	16	Fire warden of building
6	Actions needed to address behavioural problems and shutdown evacuation of people	17	Evacuation of people in public areas
7	Emergency plan	18	Stairwell Intercom Systems
8	Detection system	19	Voice Communication and Building Public Address System
9	Signal warning	20	Fire Department Voice Communication Systems
10	Rescue route layout	21	Fire command center
11	Emergency instruction		

Table 4. Variables and sub variables of X3

X3 : Monitoring, Audit, dan Review of Fire Safety Systems			
No	**Sub-variables**	**No**	**Sub-variables**
1	There is an active safety monitoring procedure	18	Audit report (object strength and deficiency)
2	application of applicable standards (proactive monitoring)	19	Auditors and teams (adequate skills)
3	Monitoring of protection systems is carried out with a certain frequency	20	Auditor experience
4	the work of each fire guard officer is clear	21	Training for auditors
5	anticipation to prevent fires	22	Implications of internal/external auditors
6	Safety inspection /checking (Proactive monitoring methods and techniques)	23	Performance review (initial status review)
7	Audit standards include protection systems	24	Identification of regulatory needs
8	Periodic checking	25	Develop fire safety management guidelines
9	Conducting workplace inspections (inspection records)	26	Consultation and dissemination of FSM information to organizations
10	Job description inspector clearly arranged	27	Identification, anticipation of hazards, risks in the workplace and environment
11	Equipment Maintenance Procedures	28	FSM performance measurement and evaluation
12	Equipment system maintenance	29	Assurance of efficiency and effectiveness of resources in FSM
13	Inspection output for risk reduction	30	Regular review (training and fire training)

Table 4. Variables and sub variables of X3 (cont.)

X3 : Monitoring, Audit, dan Review of Fire Safety Systems			
No	**Sub-variables**	**No**	**Sub-variables**
14	Fire safety management system audit process (object agreement: documents/procedures/instructions to be audited)	31	Review of fire safety system
15	Level and detailing to be audited, due to the organization or size of the building	32	Review of fire safety inspection report
16	Recording discrepancies	33	Review of annual report
17	Submission of audit findings		

Table 5. Variables and sub variables of X4

X4 : Reactive Monitoring (Reporting, Recording, Investigation)			
No	**Sub-variables**	**No**	**Sub-variables**
1	Investigation Into Fire	11	Basic investigative procedures (information, information analysis, identification of risk control measurements, implementation of action plans)
2	Legal requirements to record and report bad things (steps during a fire)	12	Investigation of fire-related incidents
3	Training for the staff involved	13	The ability of the fire service to gather information with the aim of dealing with emergencies elsewhere
4	Events can be recognized by residents	14	Fire team's ability to investigate fire causes
5	The incident was reported by residents	15	Identify causes and risk control measures (elimination of causes)
6	How to conduct a clear investigation	16	Training, instruction, information about fire safety
7	Possibility of using a 3rd party in an investigation	17	What to do after a fire (access prevention for unauthorized people)
8	Recommended considerations	18	Reduce flammable materials
9	How to implement recommendations	19	Reduce the chance of theft
10	The availability of monitoring system		

Based on the results of a survey conducted on high-rise apartments in Jakarta, the percentage of the implementation of fire safety management in terms of Fire Prevention in Buildings is 95%, Safety of People at The Event of A Fire is 91%, Monitoring Audit and Review of Fire Safety System is 90% and Reactive Monitoring (Reporting, Recording, Investigation) is 89%.

5.2 Graphical Results

Fire Preventions in Buildings

Figure 2 shows that the preventive level against fire, exit facilities, rescue routes available, smoke control and ventilation (ventilation: mechanical, natural; emergency lighting) is fully applied (100%). This happens because these parts are the most crucial thing in a building. The building manager also said that it must be fulfilled to get a Letter of Function from the government for the building they built. Placement of residents based on characteristics of residents: number; density; distribution and fire lift are two indicators with the lowest evaluation rate of 75%. This happens because the apartment does not classify the floor of the apartment to live in based on the needs of the occupants. For fire lifts, some apartments combine ordinary elevators used by residents with fire elevators because in the event of a fire, residents are not allowed to use the elevator so that the elevator will be used by the fire team.

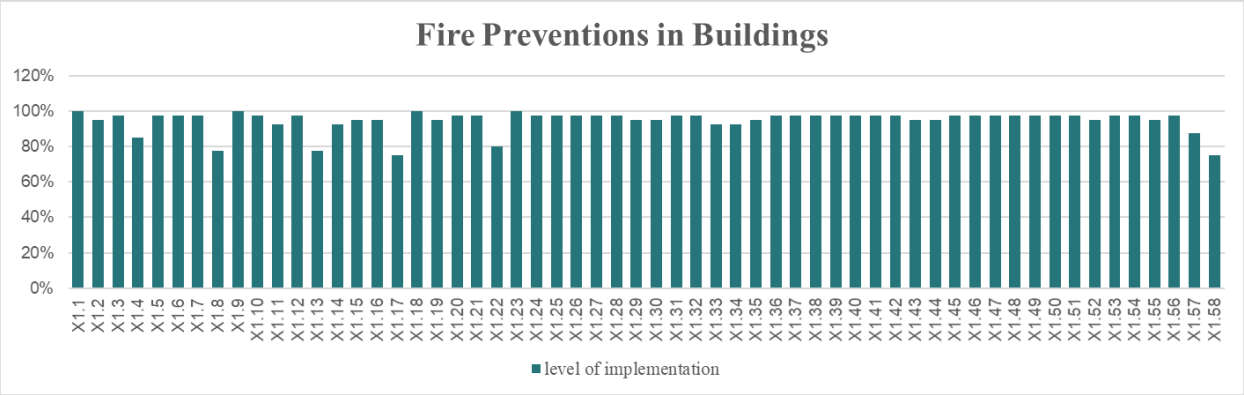

Figure 2. Percentage of implementation of fire preventions in buildings

Safety of People At The Event of A Fire

Figure 3 shows that the emergency plan, detection system, signal warning, rescue route layout, emergency instruction, and evacuation process of people in public areas are applied by 98%. These items are the main items of people's safety measures in the event of a fire. If these items are not fully applied, then the success rate of evacuations during fire events is low and allows for death. The lowest level of implementation to the safety of people in the incident of fire is fire warden building by 80%. This happens because the apartment manager considers the job desk for the building fire warden to be done by the safety officers.

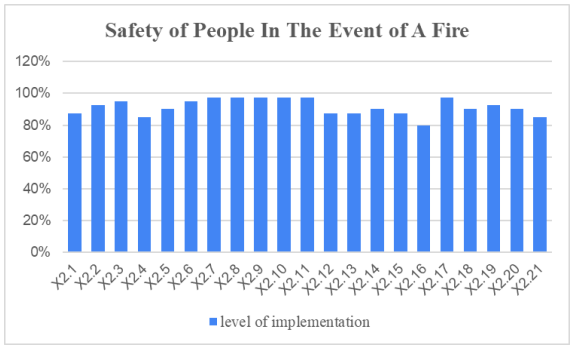

Figure 3. Percentage of implementation of safety of people in the event of a fire

Monitoring Audit and Review of Fire Safety System

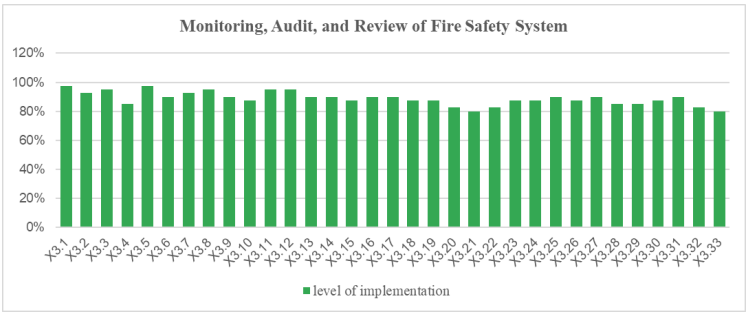

Figure 4. Percentage of implementation of monitoring, audit, and review of fire safety system

It is shown in Figure 4 that there is an active safety procedure obtaining an application rate of 98%. The fulfillment of active protection facilities in buildings and the environment is very efficient to reduce fires that are increasingly widespread and provide convenience for building residents to extinguish fires in case of fire and also make it easier

for firefighters to conduct firefighting. The lowest level of application in monitoring, auditing, and review of fire safety systems is 80%, contained in the training for auditors and review and annual report. Some apartment managers consider training for auditors unnecessary because the role is usually done by a third party (not part of the apartment management team) to get a neutral audit result. Special reviews and annual reports for firefighters are usually included in the review and annual report for a thorough evaluation of apartment buildings.

Reactive Monitoring (Reporting, Recording, Investigation)

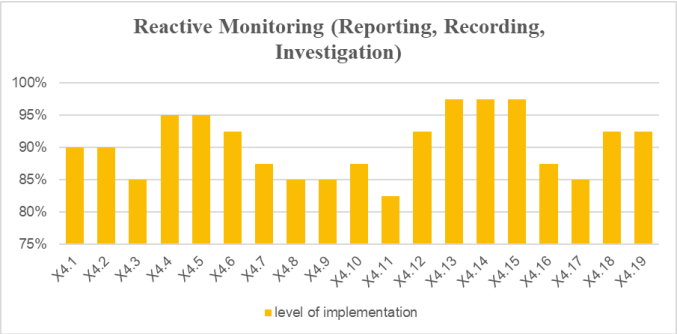

Figure 5. Percentage of implementation of reactive monitoring (reporting, recording, onvestigation)

Figure 5 shows that occurrences can be recognized by residents and incidents reported by residents get the highest implementation rate of 95%. Based on the experience of fire incidents in the apartments surveyed, residents quickly report the incident to the apartment manager so that emergency evacuation can be taken. The lowest level of application to reactive monitoring (reporting, recording, investigation) is in the basic investigative procedures (information, information analysis, identification of risk control measurement, implementation of action plan) of 83%. The process of information analysis and risk control measurement has not been carried out in detail by some apartment managers.

5.3 Proposed Improvements

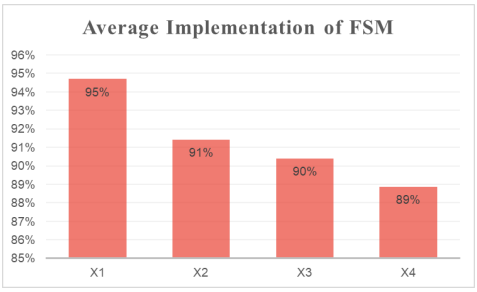

Figure 6. Percentage of implementation of reactive monitoring (reporting, recording, investigation)

As shown in figure 6, the average percentage of the implementation of fire safety management in high-rise apartments in Jakarta is 91%. Fire prevention in buildings obtains the highest level of application because the indicators contained in it are crucial to fire prevention such as the availability of fire extinguishers and evacuation facilities. Reactive monitoring (reporting, recording, investigation) obtains the lowest value compared to three other indicators because some apartment managers consider the items on reactive monitoring can be combined with monitoring audit and fire safety system review. But when assessing each sub variable, the lowest application rate is in placement of residents based on characteristics of residents: number; density; distribution) and fire lift. Both indicators are at the lowest level with the lowest evaluation rate of 75%. This happens because the apartment does not classify the floor of the apartment to live in based on the needs of the occupants. For fire lifts, some apartments combine ordinary elevators used by residents with fire elevators because in the event of a fire, residents are not allowed to use the elevator so that the elevator will be used by the fire team.

5.4 Validation

The implementation of fire safety management based on Work Breakdown Structure rate in high-rise apartments in Jakarta is 91%. This value is categorized as a good category. However, from the survey, it appears that the apartments in Jakarta have not fully fulfilled the implementation of FSM. This is in line with previous research by Winarningsih (2002).

6. Conclusion

Evaluating the implementation of fire safety management based on work breakdown structure produced detailed indicators covering all parts of the building. Overall, the rate of implementation of fire safety management in high-rise apartments in jakarta is 91% with the percentage of implementation of fire prevention in building buildings is 95%, people's safety at the time of fire is 91%, monitoring audit and review of fire safety system is 90% and reactive monitoring (reporting, recording, investigation) is 89%. Reactive monitoring (reporting, recording, investigation) obtains the lowest value compared to three other indicators because some apartment managers consider the items on reactive monitoring can be combined with monitoring, audit and review of fire safety systems. Measures such as the identification of risk control measurements have not been carried out in detail by some apartment managers. The level of implementation that has not been fully able to be done due to the psychological and emotional condition of the safety team and residents during training with the time of fire is often different. More detailed socialization of fire safety management measures is needed, especially in the indicators of monitoring audit and review of fire safety systems and reactive monitoring in high-rise apartments to obtain optimal application level.

References

Ajizah, N., Perencanaan sumber daya pada pekerjaan mekanikal dan elektrikal bangunan gedung apartemen berbasis WBS (work breakdown structure), *Undergraduate thesis*, Department of Civil Engineering, Faculty of Engineering, University of Indonesia, 2018.

Auerbach, J., and Wan, P., Forecasting the urban skyline with extreme value theory, *International Journal of Forecasting*, vol. 36, no. 3, pp. 814-828, 2020.

Furness, A., and Muckett, M., *Introduction to Fire Safety Management*, 1st Edition, Elseiver, U.K., 2007.

Herzanita, A., Penggunaan standard WBS (Work Breakdown Structure) pada proyek bangunan gedung, *Jurnal Infrastruktur*, vol. 5, no. 1, pp. 29-34, 2019.

Hopkins, A., Thinking about process safety indicators, *Safety science*, vol. 47, no. 4, pp. 460-465, 2009.

Ibrahim, M. N., Ibrahim, M. S., Mohd-Din, A., Abdul-Hamid, K., Yunus, R. M., and Yahya, M. R., Fire risk assessment of heritage building–perspectives of regulatory authority, restorer and building stakeholder, *Procedia Engineering*, vol. 20, pp. 325-328, 2011.

Fauzi, I., 40% gedung di Jakarta tak penuhi syarat sistem proteksi kebakaran, Available: https://www.medcom.id/nasional/metro/8koGngRk-40-gedung-di-jakarta-tak-penuhi-syarat-sistem-proteksi-kebakaran, Accessed on October 10, 2020.

Kurniawan, A., Gambaran manajemen dan sistem proteksi kebakaran di gedung Fakultas Kedokteran dan Ilmu Kesehatan UIN Jakarta Tahun 2014, *Undergraduate thesis*, Public Health Study Program, Faculty of Medicine and Health Science, State Islamic University Syarif Hidayatullah Jakarta, 2014.

Li, S. Y., Tao, G., and Zhang, L. J., Fire risk assessment of high-rise buildings based on gray-fahp mathematical model, *Procedia Engineering*, vol. 211, pp. 395-402, 2018.

Nimlyat, P. S., Audu, A. U., Ola-Adisa, E. O., and Gwatau, D., An evaluation of fire safety measures in high-rise buildings in Nigeria, *Sustainable Cities and Society*, vol. 35, pp. 774-785, 2017.

Nugraha, R., Penerapan sistem manajemen kebakaran di PT. Adiluhung Saranasegara Indonesia, Bangkalan, *The Indonesian Journal of Occupational Safety and Health*, vol. 7, no. 3, pp. 378-386, 2018.

Primariawan, E. A., Kinerja design sistem proteksi pasif pada bangunan tinggi perkantoran terhadap bahaya kebakaran, *Undergraduate thesis*, Department of Civil Engineering, Faculty of Engineering, University of Indonesia, 2004.

Septiana, P., Gambaran sarana penyelamatan jiwa dan sistem proteksi aktif terhadap pengamanan bahaya kebakaran di Rs. Pondok Bambu, *Undergraduate thesis*, Occupational Health and Safety Department, Faculty of Public Health, University of Indonesia, 2011.

Winarningsih, Y. R., Pemodelan pengaruh sistem proteksi kebakaran terhadap premi asuransi kebakaran pada bangunan tinggi di Jakarta, *Undergraduate thesis*, Department of Civil Engineering, Faculty of Engineering, University of Indonesia, 2002.

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