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University building safety index measurement using risk and implementation matrix

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Abstract. Many high rise building constructed in several universities in Indonesia. The high-rise building management must provide the safety planning and proper safety equipment in each part of the building. Unfortunately, most of the university in Indonesia have not been applying safety policy yet and less awareness on treating safety facilities. Several fire accidents in university showed that some significant risk should be managed by the building management. This research developed a framework for measuring the high rise building safety index in university The framework is not only assessed the risk magnitude but also designed modular building safety checklist for measuring the safety implementation level. The safety checklist has been developed for 8 types of the university rooms, i.e.: office, classroom, 4 type of laboratories, canteen, and library. University building safety index determined using risk-implementation matrix by measuring the risk magnitude and assessing the safety implementation level. Building Safety Index measurement has been applied in 4 high rise buildings in ITS Campus. The building assessment showed that the rectorate building in secure condition and chemical department building in beware condition. While the library and administration center building was in less secure condition.

1. Introduction

High-rise building management has a responsibility to identify and evaluate any risk in order to avoid injury and damage or losses of building facilities [1]. Safety inspection as regular program must be conducted as part of building management responsibilities [2]. The number of occupant who live or work and number of floors of the high-rise building is the complicated factors to be managed during evacuation process and may lead to the big number of death or losses [3].

In last decades, many high-rise building constructed in several University in Indonesia. Land utility, energy efficiency, and green environment mission become most of the consideration to build the high-rise building in University. However, safety management is not implemented and supporting facilities for the emergency condition also not installed follow the minimum safety standard for the high-rise building. Some fire accident was made big losses in the university such as agriculture technology building in Bogor Agricultural Institute (2017), the chemical laboratory in University of Indonesia (2015), and industrial engineering building in Bandung Institute of Technology (2013). These facts showed that the potential hazards inside the high rise building must be controlled. Some security issues in university high rise building in Indonesia such as student murderer and robbery should warn the management that safety regulation must be implemented in order to reduce some possible security threat inside the building.

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Safety assessment or audit tools have been published by many different techniques and most of them have similar phases i.e.: hazard identification, risk assessment, and risk control [1]. Risk assessment should be able to provide the future projection of safety status or condition [2]. Considering the historical safety data does not enough to analyze the threat of the hazard. The present condition of safety implementation must be audited and should be considered as the important aspect in evaluating the building safety condition [3].

Safety checklist techniques may become the most practical tools apply by safety auditor to meet the ease to use and generalization [4]. Unfortunately, specific safety checklist for University high-rise building only present partially, still not completely covered the part of university rooms such as chemical laboratory, mechanical laboratory, library, etc. This paper introduces the university high-rise building safety index measurement tools by considering not only the risk mapping but also the safety implementation level. A modular checklist based on the specific room in University has been developed where the entire building safety index can be measured aggregately.

2. Methodology

Risk assessment result and evaluation of safety implementation in observed high-rises building are considered to determine the building safety index. The building safety index measure based on the aggregate index of each room in the observed building. Building Safety Index (BSI) = Average (Safety index room (1 to i)) if the observed building has i number of rooms. Figure 1 presents the general phases of high-rise building safety index measurement. Matrix and checklist models are applied in this safety audit framework in order to simplify the measurement.

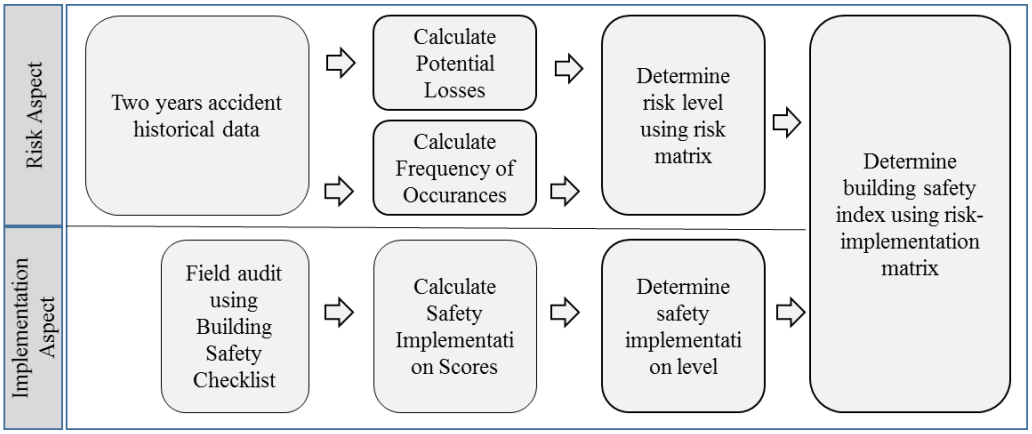


Figure 1. Framework for high-rise building safety index

2.1. Risk Aspect

Risk aspect measured by identifying the previous actual accidents occurred in the building. Two years historical data are required to determine the risk magnitude. The fundamental formula of risk magnitude in any risk assessment exercise is the multiplication of the frequency (how often) and the consequences (how big the impact) of each risk [1]. The accident occurrence rate table is defined to determine the frequency of occurrence as presented in table 1.

Table 1. Accident occurrence rate classification

Extremely Frequent	Frequent	Occasional	Rare	Very Rare
Number of accident more 6 times in a year	Number of accidents 2-6 times in a year	Number of accident only 1 in 1 year	No accident in 1 year	No accident in 2 years

The potential losses if the accident occurred may be measured by identifying the severity received by the victims in the accident. Besides, the losses also may be measured by measuring the duration

losses or production/services opportunity losses as the effect of an accident. Five grades of potential losses are presented in accident losses classification as provided in Table 2.

By determining the potential losses grades and the accident occurrence rate, the risk level of each room can be defined using risk matrix. There are five level of risk based on below risk matrix i.e.: very low (5), low (4), moderate (3), high (4), and very high (5). The risk matrix is depicted in table 3.

Table 2. Accident losses classification

	Catastrophic	Major	Moderate	Minor	Insignificant
Human	1 or more fatality or death accident	1 or more accident made loss part of body	1 or more accident made loss 10 of day of works	1 or more accident made loss 1-3 of day of works	1 or more incident and without any working hour interruption
Production/ Service Opportunity	All line production or services must be stop in several days	All Production or services must be stop about 1 day production or 1 shift of work	One line of production or service must be stopped	One machine or facility stop and the others run normally	One machine or facility has been stopped for a short of time

Potential Losses	Frequency of occurrence: Extremely Frequently	Frequently	Occasionally	Rarely	Very Rarely
Catastrophic	**1** Extreme Risk	**1** Extreme Risk	**1** Extreme Risk	**2** High Risk	**3** Moderate Risk
Major	**1** Extreme Risk	**1** Extreme Risk	**2** High Risk	**2** High Risk	**3** Moderate Risk
Moderate	**1** Extreme Risk	**2** High Risk	**2** High Risk	**3** Moderate Risk	**4** Low Risk
Minor	**2** High Risk	**2** High Risk	**3** Moderate Risk	**3** Moderate Risk	**4** Low Risk
Insignificant	**3** Moderate Risk	**3** Moderate Risk	**4** Low Risk	**4** Low Risk	**5** Very Low Risk

Figure 2. Risk matrix (potential losses against frequency of accident)

2.2. Implementation Aspect

The implementation of safety management in university high-rise building must be audited in order to evaluate the safety regulation and standard fulfillment. The proposed building safety checklist has been reconstructed from some regulation and standard including Indonesia National Safety and Health law and regulation [5][6][7][8]. Table 4 presents the detailed university building safety checklist.

Table 3. General university high-rise building safety checklist

	SAFETY ASPECTS	Office	Classroom	Library	Canteen/Cafe	Laboratory			
						Chemical	Mechanical	Electrical	Computer
Organization and Administration for Safety									
A1	Official safety team	□	□	□	□	□	□	□	□
A2	Yearly budget for safety programs	□	□	□	□	□	□	□	□
A3	Accident and incident reporting and recording	□	□	□	□	□	□	□	□
A4	Safety training and socialization programs	□	□	□	□	□	□	□	□
A5	Emergency preparedness and mitigation plan	□	□	□	□	□	□	□	□
A6	Safety facilities inspector	□	□	□	□	□	□	□	□
Emergency Equipment and Hazard Detectors									
B1	Fire alarm and sensors detectors	□	□	□	□	□	□	□	□
B2	Automatic sprinkler system	□	□	□	□	□	□	□	□
B3	Fire extinguisher	□	□	□	□	□	□	□	□
B4	First aid kits	□	□	□	□	□	□	□	□
B5	Water hydrant installation	□	□	□	□	□	□	□	□
Emergency Planning									
C1	Evacuation routes	□	□	□	□	□	□	□	□
C2	Assembly points and signs	□	□	□	□	□	□	□	□
C3	Emergency call center and evacuation procedure	□	□	□	□	□	□	□	□
C4	Electrical power for emergency condition	□	□	□	□	□	□	□	□
Building Safety Facilities									
D1	Smoking room	□	□	□	□	□	□	□	□
D2	Stairs	□	□	□	□	□	□	□	□
D3	Corridors	□	□	□	□	□	□	□	□
Exit and Communication									
E1	Exit doors	□	□	□	□	□	□	□	□
E2	Evacuation map and room location	□	□	□	□	□	□	□	□
E3	Communication system and facilities inside the building	□	□	□	□	□	□	□	□
E4	Road access for fire truck to reach the building	□	□	□	□	□	□	□	□
Occupant knowledge about emergency preparedness									
F1	Knowledge about operating the fire extinguisher and hydrant	□	□	□	□	□	□	□	□
F2	Knowledge about performing the first aid	□	□	□	□	□	□	□	□
F3	Knowledge about emergency response plan	□	□	□	□	□	□	□	□
Procedure and Equipment for personal protection									
G1	Operating procedure to use the equipment and materials					□	□	□	□
G2	Personal Protective Equipment					□	□	□	□
G3	Hazard warning signs	□	□	□	□	□	□	□	□
G4	Access control and limitation for each rooms	□	□	□	□	□	□	□	□
G5	Electrical socket, cable, and switch	□	□	□	□	□	□	□	□
G6	Electrical and gas stove equipment				□	□	□	□	
G7	Explosive and flammable gas or materials management					□	□		
G8	Toxic materials management					□	□		
G9	Chemical Inventory management system					□	□		
G10	Mechanical equipment in Laboratory					□	□		
G11	Noise and vibration					□	□		
G12	Air conditioning at server room							□	□
G13	Material handling devices for transportation of good/materials	□	□	□	□	□	□	□	□
G14	Staircase for working at height	□	□	□	□	□	□	□	□

The safety implementation checklist divided into 8 modules which represented the common university room. Those checklist modules are office [7], classroom, library, canteen/cafe, chemical laboratory, mechanical, laboratory, electrical laboratory, and computer laboratory. Each modules considered some safety aspects on each checklist i.e.: Organization and Administration for Safety [3] [5][7][9][10], Emergency Equipment and Hazard Detectors [5][7][9][10][11], Emergency Planning [4][5][7][9][10][11], Building Safety Facilities [5][7][9][10][11], Exit and Communication [5][7][9][10][11], Occupant knowledge about emergency preparedness [12][13], and Procedure and Equipment for personal protection [4] [7][9][10][11] [13].

Building safety scorecard has been developed as detailed guidelines for auditor during building assessment. Each safety aspects scaled with 5 confirmatory question in building safety scorecard. There were 2 assessed conditions for each safety aspect which presented the requirement for each aspect to be fulfilled. The most complete or ideal condition would be marked as 5 points and the incomplete or worse condition would be marked as 1 points. Table 5 shows the 5 grades design for each aspect on the scorecard. An example of the question in building safety scorecard is shown in table 6.

Table 4. Grades of each safety aspect on building safety scorecard

1	2	3	4	5
Both condition has not been achieved	One Condition has been achieved partially, other condition has not been achieved.	Both condition has been achieved partially	One Condition has been achieved perfectly, other condition has been achieved partially	Both condition has been achieved perfectly

Table 5. Example of building safety scorecard

No	Aspect	1	2	3	4	5
E.1	Exit Doors	All the width of exit door < 70 cm. All exit door open against the direction of escape corridor	Not all the width of exit door ≥ 70 cm. All exit door open against the direction of escape corridor	Not all the width of exit door ≥ 70 cm. Not all exit door open in the direction of escape corridor	All the width of exit door ≥ 70 cm. Not all exit door open in the direction of escape corridor	All the width of exit door ≥ 70 cm. All exit door open in the direction of escape corridor

The level of building safety implementation can be determined by calculating the average scores of building safety assessment result. There are also 5 level of safety implementations i.e.: Neglect (scores: 0.00 – 1.00), Poor (1.01-2.00), Growth (2.01-3.00), Advance (3.01-4.00), and Sustain (4.01-5.00).

2.3. Building safety Index (BSI)

Safety status of each observed room in the building whether in secure or dangerous condition can be determined using risk-implementation matrix. Table 123 is depicted the safety status by plotting the previous risk level and the safety implementation level results. There are 5 statuses of safety i.e.: very dangerous, dangerous, beware, less secure, secure, relief.

3. Building Assessment Results

Building safety measurement has been applied in 4 high-rise building in ITS Campus. The building safety assessment conducts by 2 observers and conducted the audit for 2 days. Th result of building safety exercises depicted in table 7. The assessment result showed that the Rectorate building under secure condition. However, Chemical department building must improve their building safety management. The rectorate building as the head quarter of university provides with proper safety facilities, get higher attention from the building safety manager and even have no high-risk type of room. Chemical department manages several chemical laboratories where the potential hazards have a significant contribution to building safety awareness. These assessment results have shown that the proposed building safety index delivered appropriate assessment result.

Table 6. Four buildings safety assessment in ITS Campus, Surabaya

Building	No of floors	Number and type of rooms	Implementation		Risk		BSI	
			score	level	score	level	score	Status
Rectorate	4	16 offices, 4 classes, 3 pantries,	3,2	Advance	5	Very low	4.1	Secure
Library	6	5 offices, 7 classes, 2 canteens, 5 library, 3 computer lab.	2.9	Growth	5	Very low	3.9	Less Secure
Administration Centre	2	16 offices, 5 classes	2,2	Growth	5	Very low	3.6	Less Secure
Chemical Department	4	1 office, 3 classes, 1 pantry, 1 library, 7 chemical lab	2,7	Growth	3	Moderate	2.8	Beware

The auditors in this assessment able to finish their observation less than 2 days for visiting 2 big building in the university. Based on the auditor's experiences, the building safety scorecards is easy to apply and very fast to get the final result by following the BSI matrix.

		IMPLEMENTATION LEVEL				
		1 Neglect	2 Poor	3 Growth	4 Advance	5 Sustain
RISK LEVEL	1 Extreme Risk	1 Very Dangerous	1 Very Dangerous	2 Dangerous	2 Dangerous	2 Dangerous
	2 High Risk	1 Very Dangerous	2 Dangerous	2 Dangerous	3 Beware	b Beware
	3 Moderate Risk	2 Dangerous	2 Dangerous	3 Beware	4 Less Secure	4 Less Secure
	4 Low Risk	3 Beware	3 Beware	4 Less Secure	4 Less Secure	5 Secure
	5 Very Low Risk	4 Less Secure	4 Less Secure	4 Less Secure	5 Secure	5 Relief

Figure 3. Risk-Implementation Matrix

4. Conclusions

High rise building safety index in a university can be measured modularly by assessing each typical room with specific safety scorecards. Implementation aspect on high rise building safety assessment consists of the safety organization, safety facilities, occupant's knowledge, and personal protection from any hazard. Risk-Implementation matrix can be applied to determine the building safety index. The safety checklist module may be extended to other laboratories types such medical laboratory, biological laboratory, etc.

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