MANAGEMENT SYSTEM FOR BUILDING RELIABILITY ASSESSMENT BASED ON SAFETY RULES ON FIRE HAZARD PROTECTION

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ABSTRACT

Safety of buildings and their environment against fire hazards is a must in the design of building reliability. Decision-making on the design of hazard assessment and prevention systems in buildings is very necessary, to determine the level of reliability. The purpose of this study is to make a decision-making analysis for the assessment of building reliability systems in fire prevention and environmental safety. Decision-making analysis of building reliability assessment systems for fire prevention and environmental safety using the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) method. The main criteria used are the prevention system and prevention management. The main criteria use sub-criteria in the form of prevention, limitation, and extinguishing of fire hazards. Assessment of the system design is carried out by questionnaires to expert respondents who understand the problem of fire. The results of the research on building reliability system weight assessment show that the weight on the Fire Prevention System is 59% and the weight on the Prevention Management is 41%. In more detail the weights of importance on the design criteria of Prevention Management and Systems are Inspection and maintenance 32%, Coaching and training 26%, Emergency planning 21%, and Housekeeping 21%. The results of the final assessment on the reliability value of the building are 94.06%, meaning that the building reliability system is in the "Less Reliable" category for fire prevention and environmental safety, so it is necessary to make several improvements and recommendations to increase the reliability of the building on environmental safety.

Keywords: Fuzzy AHP, Building System Reliability, Fire Prevention, Environmental Safety.

INTRODUCTION

Buildings are physical manifestations of the results of construction work that are integrated with their domicile, partially or wholly functioning as residences or residences, as well as other activities. The need for open or closed space is needed to carry out all activities, along with the development of the organization. The development of building construction makes developers and building owners consider safety aspects, one of which is fire safety. Fire hazards can occur in the building where the building is located. Fire is an unwanted event because it can result in losses, both material and moral. Fire is a hazard caused by an uncontrolled flame that can threaten the safety of human life and property.

To carry out the functions and uses, the building consists of several systems, the system

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consists of sub-systems that form integrally in a single unit. Fire prevention is one of the building systems, which aims to save lives, property, and objects as well as the environment from fire hazards. Preparedness and handling before a fire occur is a very important factor to prevent fires. Based on Law No. 28 of 2002, one of the building safety requirements is the ability of the building to prevent and overcome fire hazards. Fire safety, which involves inspection, maintenance, maintenance, fire safety audits, and fire fighting training activities must be carried out periodically, as part of the maintenance of fire prevention facilities in buildings. The problem of maintaining fire protection equipment is one aspect of building management (Fire Protection Management) because wrong management results in poor building management and maintenance.

Reliability against fire hazards and environmental safety is the building's ability to resist to minimize the possibility of fire so that resistance runs optimally. Inspection of fire prevention equipment from various aspects is very necessary, both in new buildings or those that have been used, to ensure the safety of buildings and the environment. Inspection and maintenance of fire protection facilities and equipment, both active and passive, must be carried out systemically and periodically and follow the applicable provisions and standards. The results of periodic inspections of facilities and equipment determine that a certificate is suitable for use for a certain period. For this reason, a guideline is needed that can be used in the examination of fire prevention in buildings, to face the demands of increasingly complex office and residential developments as well as control and supervision of fire hazards.

Fire prevention is one aspect of building environmental safety. To know and assess the level of reliability of a building against fire hazards, the formulation of the problem in this study is as follows:

1. How are the criteria for making decisions about the reliability inspection system for fire hazards and environmental safety in buildings.
2. How to apply prevention management systems and fire prevention systems to the reliability value of environmental safety systems in buildings.
3. How is the reliability value of fire safety and building environmental safety based on the analysis of the AHP Method and the Indonesian PU Balitbang Guidelines PD-T-11-2005-C.

The purpose of this study is to make decisions from assessing the level of reliability of a building against fire hazards and environmental safety, which include:

1. Get decisions about the criteria for the reliability inspection system of fire prevention and environmental safety in buildings.
2. Obtain prevention management systems and fire prevention systems on the reliability value of environmental safety systems in buildings.
3. Obtaining the reliability value of fire safety and building environmental safety based on the analysis of the AHP Method and the Indonesian PU Balitbang Guidelines PD-T-11-2005-C.

MATERIALS AND METHODS

Reliability Concept

The definition of reliability according to Bauer et al (2009) is "*the probability that when*

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the operation is under certain environmental conditions, the system will show its ability following the expected function within a certain time interval". Reliability is a probability that is always associated with the accumulation of time in which a device operates without being damaged under certain environmental conditions (Doguc and Ramirez-Marquez, 2009). Damage occurs when a device does not function as intended. The notion of reliability is a clear criterion for determining the damage to a system, namely if the system does not function as it should (Lisnianski, 2007).

Reliability of Building Concept

The building is a physical form resulting from construction work that is integrated with its domicile, partially or wholly located above and/or in the land and/or water, which functions as a place for humans to carry out activities, either for housing or residence, religious activities, business activities. , social, cultural, and special activities (Mahadevan and Raghothamachar, 2000). To carry out its functions and uses, the building has a completeness that supports each other both directly and indirectly, the completeness is divided into systems that support each other for the smoothness and comfort of the building (Suharyo et al., 2017). The building is a system, the system is defined as an arrangement of parts that are interconnected or interdependent that form a complex whole and apply to one function. (Regulation of the Minister of Public Works (Kementerian PU) No. 24/PRT/M/2008). The system formed in the building can be seen in Figure 1.

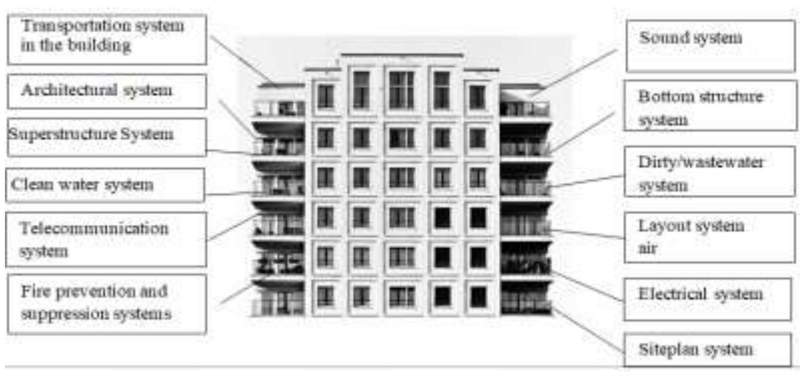

FIGURE 1
THE BUILDINGS SYSTEM ASPECTS

Buildings can be grouped based on their function and designation such as performances, business/commercial, education, factories, institutions, settlements, storage/warehouses, and other environmental functions. Buildings have different risks of fire, depending on the function of the building itself (Wu et al, 2006). Every building must have administrative and technical requirements according to its function, one of the technical requirements is reliability requirements (Smith et al, 2016).

Building reliability is the level of perfection of the condition of protective equipment that ensures the safety, function, and comfort of a building and its environment during the service life of the building. Reliability requirements include requirements for safety, health, comfort, and

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convenience which are determined based on the function of the structure (Suharjo, 2019). Meanwhile, building safety requirements include the requirements for the building's ability to support loads, as well as the building's ability to prevent and cope with fire and lightning hazards (Law No: 28 of 2002). The criteria for assessing the reliability of buildings based on fire prevention variables are divided into three levels, namely: GOOD=B, MEDIUM or ENOUGH=C and LESS=K. The equivalent value of B is 10, the value of C is 8 and the value of K is 60 can be seen in Table 1.

Table 1
ASSESSMENT LEVEL OF BUILDING RELIABILITY COMPONENTS

Value	Assessment Level of Fit	Reliability
>80–100	As the requirements	Good (B)
60-80	Installed but there is a small part of the installation that does not meet the requirements	Enough (C)
<60	Does not match the requirements at all	Less (K)

Fire Prevention Checks on Buildings

Table 2
PREVENTION SYSTEM IN BUILDINGS

No	Component	Sub of Component
I	Site Equipment System	a. Water sources b. Environmental road c. Distance between buildings. d. Page hydrant
II	Rescue Means System	a. Way out b. Exit construction c. Helicopter runway
III	Active Protection System	a. Detect and alarm b. Siamese connection c. Light fire extinguisher d. Building hydrant e. Sprinkler f. Overflow suppression system g. Smoke control h. Smoke detection i. Smoke exhaust j. Fire elevator k. Emergency light and directions l. Emergency electricity m. Operation control room
IV	Passive Protection System	a. Fire resistance of building structures b. Room compartmentalization c. Aperture protection

Inspection and maintenance of fire protection facilities and equipment, both active and passive, must be carried out systematically and periodically and following applicable regulations and standards. The results of periodic inspections of facilities and equipment determine whether a certificate is suitable for use for a certain period (Ruspianof et al., 2017). The building

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reliability inspection system in fire prevention has been carried out in the Certification and Labeling of Building Reliability Against Fire Hazards. The aim is to provide the concept of a certification and labeling mechanism in the context of evaluating functions as regulated in Law No. 28 of 2002 concerning Buildings. The review is based on the main parameters of the Building Safety System Reliability (KSKB) which are analyzed according to the Decree of the Minister of Public Works (Kementerian PU) No: 26/PRT/M/2008 can be seen in Table 2.

Table 3
RECAPITULATION OF WEIGHTING SUB COMPONENTS OF BUILDINGS PREVENTION SYSTEM

No	Component	Weight (%)	Sub of Component	Weight (%)
I	Site Equipment System	25	a. Water sources	27
			b. Environmental road	25
			c. Distance between buildings.	23
			d. Page hydrant	25
II	Rescue Means System	25	a. Way out	38
			b. Exit construction	35
			c. Helicopter runway	27
III	Active Protection System	24	a. Detect and alarm	9
			b. Siamese connection	8
			c. Light fire extinguisher	9
			d. Building hydrant	9
			e. Sprinkler	9
			f. Overflow suppression system	8
			g. Smoke control	9
			h. Smoke detection	7
			i. Smoke exhaust	7
			j. Fire elevator	9
			k. Emergency light and directions	8
			l. Emergency electricity m. Operation control room	8
IV	Passive Protection System	26	a. Fire resistance of building structures	36
			b. Room compartmentalization	32
			c. Aperture protection	32

Recapitulation of weighting according to Indonesia Balitbang PU PD-T-11-2005-C, Fire prevention system can be seen in Table 3.

Assessment of Fire Prevention Systems in Buildings

Building safety is a criterion that must be met by a building because, in addition to affecting the safety of the building itself, it also involves the soul of the building user and the environment (National Standardization Body Indonesia, 2000). The reliability of the building in fire prevention has a hierarchy based on the level of influence on the continuity and quality of the building and its ability to provide fire prevention for its users. To determine the priority scale on the fire prevention system, a scoring is made based on the objectives of the action on security and safety which is divided into three, namely:

1. Prevention of fire by reducing the possibility of fire.

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2. Limiting fires by reducing the area of the fire.
3. Firefighters by securing humans, animals, and buildings/goods from fire hazards.

Based on the purpose of fire prevention, a fire prevention system is developed in the building. The priority order of fire prevention is based on the five systems, namely site completeness means of rescue, passive protection systems, active protection systems, and fire prevention management based on the three aspects mentioned above (Xu et al, 2010).

Fuzzy Analytical Hierarchy Process (Fuzzy AHP) Methods

To assist decision-making in the weighting of the fire prevention system and the sub-system of fire prevention management, this study uses the Fuzzy Analytical Hierarchy Process (Fuzzy AHP) method, which is one method for interpreting qualitative data into quantitative, unbiased, and more objective data. FAHP is considered an appropriate method for determining a choice from various criteria (Astanti et al., 2020). This method is used to obtain a scale of comparison or weighting with discrete or continuous pair comparisons. Fuzzy AHP has particular concerns about deviations from consistency, measurement, and dependence within and between groups of structural elements (Saaty, 1993).

The decision-making model using the Fuzzy AHP method in principle covers all the shortcomings of the previous models. The advantages of Fuzzy AHP compared to others according to Ayyildiz and Gumus (2020) are as follows:

1. Has a hierarchical structure from the selected hierarchy to the lowest sub-criteria.
2. Validity is calculated up to the inconsistency tolerance.
3. Take into account the robustness of decision-making sensitivity analysis.

Fuzzy Analytical Hierarchy Process (Fuzzy AHP) is an integration of Fuzzy theory and AHP initiated by Saaty (1993). This method has been widely used by previous researchers on issues of reliability (Gündoğdu et al, 2021). The description of fuzzy AHP steps can be explained as follows: Change the linguistic variables in the form of fuzzy numbers. Questionnaire data in the form of linguistic variables are converted to the form of fuzzy numbers (Kaviani et al, 2014). Examples of fuzzy numbers for triangular fuzzy numbers (Triangular Fuzzy Number or TFN) are shown in Table 4. The linguistic variable is converted into a three-level fuzzy, low (c); medium (b); and high (a).

Table 4
SCALE VARIABLE TFN IN LINGUISTICS

Scale Linguistics	Value ResoluteAHP	Fuzzy TFN Scale (a, b & c)	Inverse
Both elements are equally important	1	(1,1,1+Δ)	(1,1,1/1+Δ)
Elements of the approach are a little more important than any other element	3	(3-Δ,3,3+Δ)	(1/3+Δ,1/3,1/3-Δ)
Elements of the approach are more important than others	5	(5-Δ,5,5+Δ)	(1/5+Δ,1/5,1/5-Δ)
One element of the absolute approach is more important than other elements	7	(7-Δ,7,7+Δ)	(1/7+Δ,1/7,1/7-Δ)
One element is absolutely important than other	9	(9-Δ,9,9)	(1/9,9,1/9-Δ)

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elements			
Values between two adjacent considerations	2,4,6,8		

Develop a pairwise comparison matrix between all the elements/criteria in the dimension hierarchies based on assessment system linguistic variable (Kusumawardani & Agintiara, 2015).

$$\tilde{A} = \begin{pmatrix} 1 & \tilde{a}_{12} & \cdots\cdots \tilde{a}_{1j} \\ \tilde{a}_{21} & 1 & \cdots\cdots \tilde{a}_{2j} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{i1} & \cdots & \cdots\cdots 1 \end{pmatrix} = \begin{pmatrix} 1 & \tilde{a}_{12} & \cdots\cdots \tilde{a}_{1j} \\ 1/\tilde{a}_{21} & 1 & \cdots\cdots 1/\tilde{a}_{2j} \\ \vdots & \ddots & \vdots \\ 1/\tilde{a}_{i1} & \cdots & \cdots\cdots 1 \end{pmatrix}$$

$$\tilde{a}_{ij} = \begin{cases} \tilde{1},\tilde{3},\tilde{5},\tilde{7},\tilde{9} & \textit{Criteria i relative importance to j} \\ 1 & \textit{Criteria i equally important to j} \\ \tilde{1}^*,\tilde{3}^*,\tilde{5}^*,\tilde{7}^*,\tilde{9}^* & \textit{Criteria i is less important to j} \end{cases}$$

Calculate the geometric mean of the respondents' assessment. The next step is a recap of all respondents' assessment results and calculates the geometric average of the lower limit value (c); a middle value (a); an upper limit value (b) of the total respondents. Here is the formula used to calculate the geometric mean (Rathi et al., 2015).

$$c = \sqrt[n]{c1, c2, \dots cn}$$
$$a = \sqrt[n]{a1, a2, \dots an}$$
$$b = \sqrt[n]{b1, b2, \dots bn}$$

Defuzzification: After calculating the geometric average, these results do defuzzification to obtain crisp values of the value of the geometric mean fuzzy numbers to be processed again in the AHP (Shaverdi et al, 2014). One defuzzification technique is the Centre of Gravity (COG). The formula of defuzzification is as follows:

$$COG = \frac{\frac{1}{(a-c)}\left[\frac{1}{3}x^3 - \frac{c}{2}x^2\right]_c^a + \frac{1}{(a-b)}\left[\frac{1}{3}x - \frac{b}{2}x^2\right]_c^b}{\frac{1}{(a-c)}\left[\frac{1}{3}x^2 - cx^2\right]_c^a + \frac{1}{(a-b)}\left[\frac{1}{3}x^3 - bx^2\right]_c^b}$$

Calculate the weight value by AHP: Weight calculation is done if the results of the questionnaire proved to be consistent, if the value Consistency Ratio (CR) <0.1, to get the CR calculation Consistency index (CI) in advance. Here's the formula for calculating CI:

$$CI = \frac{\lambda max - n}{n-1}$$

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λmax = The maximum eigenvalues
n = The size of the matrix
CI = Consistency Index

The CI value is compared to the value Ratio Index (RI) following the size of the matrix so that the value Consistency Ratio (CR). Matrix is otherwise consistent if the CR value is not more than 0.1

RESULT AND DISCUSSION

Criteria Assessment and Prevention Management System

Buildings are composed of systems that work and function in a building. Each system is broken down into sub-systems, for example in the fire prevention management prevention system which is developed into 4 sub-systems each. To calculate the weighting of each fire prevention system, it is necessary to first know the condition and weight of each system in a building. The weight calculation in this study uses the Fuzzy AHP method. The calculation is done by comparing the value of each sub-component against each of the criteria used. The hierarchical structure of fire prevention can be seen in Figure 2.

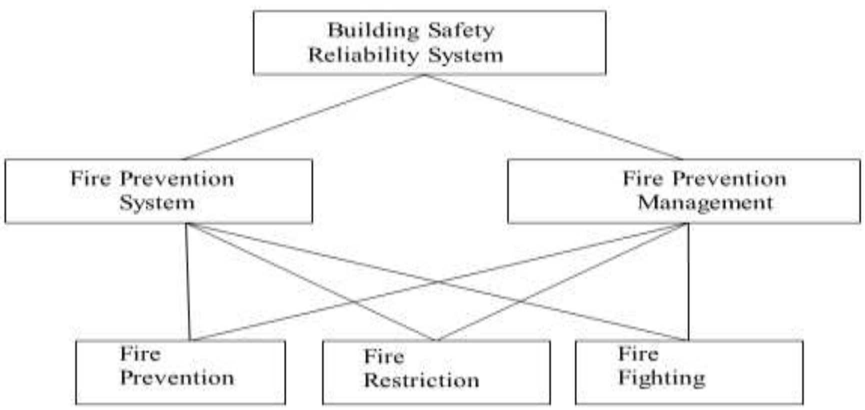

FIGURE 2
MODEL SCHEMATIC-CRITERIA FOR BUILDING SAFETY RELIABILITY SYSTEM

The results of the weighting using the Fuzzy AHP method on the Building Reliability System Criteria in the form of the Prevention and Management System criteria are shown in Table 5 below:

Table 5
THE WEIGHTING OF BUILDING RELIABILITY SYSTEM CRITERIA BASED ON FUZZY AHP

No	Reliability System Criteria	Expert Respondent						Amount	Avg. Value	Weight %	Result
		1	2	3	4	5	6				
1	Prevention System	0.60	0.65	0.59	0.61	0.58	0.50	3.53	0.5879	58.79	**59 %**

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2	Prevention Management	0.40	0.35	0.41	0.39	0.42	0.50	2.47	0.4121	41.21	**41 %**

From the weighted data above, the percentage value of the Building Safety System Reliability is obtained:

1. Fire Prevention System: 59 %.
2. Fire Prevention Management: 41%.

From the results of the Reliability System weight values above, the fire prevention system has a very large influence on the reliability of the building safety system compared to fire prevention management. But the two systems are interrelated in determining the Reliability of the Building Safety System. The weighting of the fire prevention sub-system is shown in Figure 3. and Table 6.

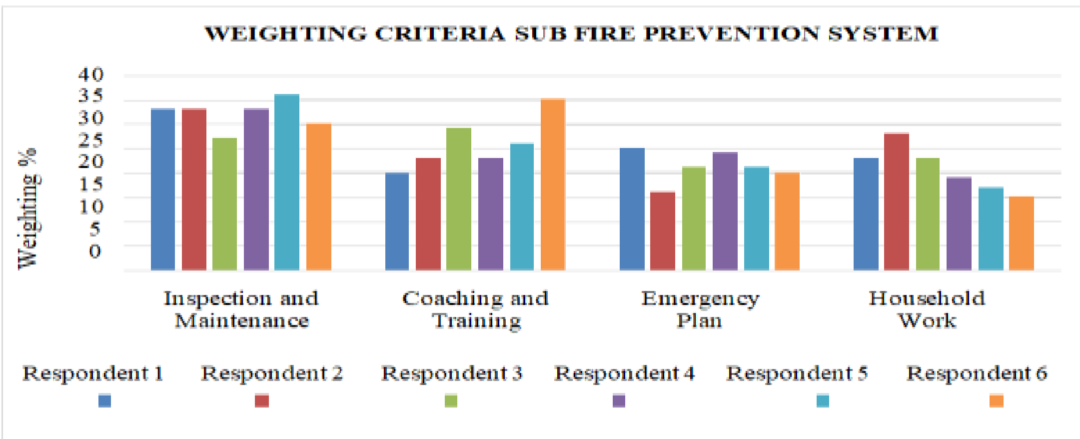

FIGURE 3
THE RESULTS OF THE WEIGHTING OF THE FIRE PREVENTION SUB SYSTEM

Table 6
WEIGHTING CRITERIA FOR FIRE PREVENTION SUB-SYSTEMS BASED ON FUZZY AHP

No	Fire Prevention Sub System Criteria	Expert Respondent						Amount	Avg. Value	Weight %	Result
		1	2	3	4	5	6				
1	Inspection and Maintenance	0.33	0.33	0.27	0.33	0.36	0.30	1.92	0.32	32.06	**32**
2	Coaching and Training	0.20	0.23	0.29	0.23	0.26	0.35	1.55	0.26	25.76	**26**
3	Emergency Plan	0.25	0.16	0.21	0.24	0.21	0.20	1.26	0.21	21.07	**21**
4	Household work	0.23	0.28	0.23	0.19	0.17	0.15	1.27	0.21	21.10	**21**

Based on the data above, the percentage value of the fire prevention system is:

1. Inspection and maintenance: 32%
2. Coaching and training: 26%

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3. Emergency plan: 21%
4. Household work: 21%

Housekeeping Arrangements (Fire safe housekeeping)

Housekeeping arrangements are always monitored for 24 hours, because they involve building security, by carrying out comprehensive supervision and interior arrangements. The summary of the Prevention Management Assessment can be seen in Table 7.

Table 7
ASSESSMENT OF PREVENTION MANAGEMENT SUB SYSTEMS BASED ON FUZZY AHP

No.	Prevention Management Sub System Criteria	Rating result	Rating Standard (%)	Weight Results (%)
1	Inspection and Maintenance	B	100	32
2	Coaching and Training	B	100	24
3	Emergency Plan	B	100	21
4	Housework	B	100	23

Based on the results of the prevention management sub-system assessment, it can be concluded that the standard operating procedures have been implemented properly by the building management.

The Results of the Assessment of the Reliability of the Building Safety System

The value of the reliability of the building safety system in this study can then be seen in Table 8.

Table 8
VALUE OF BUILDING SAFETY SYSTEM RELIABILITY

No	Fire Prevention System	Appraisal Value (%)	Weight (%)	Total Value of Reliability (%)
I	Site Equipment	22.50		
II	Rescue Means	25.00	59	53.06
III	Passive Protection System	24.34		
IV	Active Protection System	18.10		
Amount		89,93	89.93	
I	Inspection and Maintenance	13.12		
II	Coaching and Training	9.84	41	41.00
III	Emergency Plan	8.61		
IV	Housework	9.43		
Amount		41,00	41.00	
Value of Reliability of Fire Prevention in Buildings/Buildings (NKA):				**94.06**
LESS RELIABLE				

Interpretation:
The level of reliability against fire prevention is considered:
a. Reliable, if NKA is not less than 95% or (95%<=NCA<=100%)
b. Less Reliable, if NKA is worth: 75%<=NKA<=95%
c. Unreliable, if NKA is below 75%

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Some recommendations that can be implemented by building managers to improve environmental safety and security in buildings are as follows in Table 9:

Table 9
RECOMMENDATIONS FOR RELIABILITY OF BUILDING SAFETY SYSTEM REQUIREMENTS

No	System/Sub of System	Component	Recommendation
I	Site Equipment	Page Hydrant	Need to install a new system
II	Rescue Means	Way out and construction	To be maintained for the condition of the exit in a free and loose condition that is not blocked if passed by a fire engine in a state of emergency
III	Passive Protection System	Aperture protection	Need additional doors fireproof at the entrance to each floor.
IV	Active Protection System	a. Detect and alarm	Need to be equipped in each room.
		b. Siamese connection	Needs new installation.
		c. Sprinkler	Need a new install
		d Smoke control	Need a new install
		e. Smoke Detection	Need a new install
		f. Smoke exhaust	Need a new install
V	Management System	a. Inspection And Maintenance	To carry out periodic inspections and maintenance of fire prevention components
		b. Coaching And Training	Coaching and training are carried out at least 2 times a week so that vigilance remains awake.
		c. Emergency Plan	To always carry out checks regarding the duties and responsibilities of each personnel blackout team.
		d. Household Work	To always check and update signs indicating evacuation routes and emergency routes that can be passed by building occupants in a state of an emergency fire.

CONCLUSION

In this research, an application using the Fuzzy AHP method has been obtained for assessing the reliability of building systems that affect Environmental safety and security. The conclusions that can be drawn based on data analysis and processing are as follows:

The preparation of system criteria and weighting criteria for building reliability assessment in fire prevention can be done using the Fuzzy AHP method. Based on the results of questionnaires that have been filled in by 6 experts in the field of fire protection and prevention management as well as analysis using the Fuzzy AHP method, a Building Safety and Environmental System Reliability Value is generated, which can then be used to assess and inspect buildings for preventive measures against fire hazards that affect on the value of building reliability.

The application of Fuzzy AHP can be carried out on the assessment of the weight of the Fire Prevention System and Fire Prevention Management to determine the level of Reliability of the Building Safety System. The results showed that the weight obtained was 59% on the Fire Prevention System and 41% on the Fire Prevention Management. Of the two systems, the Fire

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Prevention System has a greater weight than the Prevention Management system, but both have a relationship in assessing the reliability of the building safety system by meeting the requirements according to the rules.

The inspection and reliability assessment that has been carried out by the building management in this study is following the conditions in the field, so that the total reliability value of the building is 94.06%, and is in the Less Reliable category. Based on the Indonesian PU Balitbang Regulation PD-T-11-2005-C, the limit for the Less Reliable Reliability Level is 75%<94.06%<95%, so there is a need for recommendations and improvements to be carried out in the research building.

RECOMMENDATION

The Building Management party must carry out several follow-up works based on the results of inspections and assessments in the field so that the Building reliability system becomes the Reliable category. The following are some future work that must be carried out:

1. The Building Manager can re-weight the fire prevention and safety management systems in the building for the sake of the perfection of the building's reliability system.
2. To use a reliability inspection system in fire prevention, it is necessary to involve experts who know the field of fire prevention management and fire protection in buildings.
3. The existing Building Safety System Reliability Checking System can be used as a reference to check the reliability of other buildings.

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