



## Analytical Hierarchy Process (AHP) for Maintenance Management at Bali Mandara Hospital

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### ABSTRACT

The absence of an assessment of the level of damage and the condition of the Bali Mandara Hospital building makes the maintenance management plan contained in the umbrella contract only based on the damage that occurred in the previous year. Therefore, it is very difficult to determine which building infrastructure components require maintenance and repair first. This study examines the priority scale of infrastructure maintenance at Bali Mandara Hospital using the Analytical Hierarchy Process (AHP). In this study, researchers used a quantitative-descriptive approach. The assessment of the building condition index value is then determined by the priority scale of each component using the Analytical Hierarchy Process (AHP) method with the help of the Expert Choice Version 11 application and the SWOT Method. The results showed that the index value for the infrastructure condition of the Bali Mandara Hospital building was 89.492 with very good condition criteria and was in zone I, while the highest priority scale was faucets, namely 1,000, and the lowest priority was action on a scale of 0.050, where this priority scale can be used in planning. Standard Operating Procedure (SOP) and efficient maintenance management. So based on the results of this study, with SWOT analysis, maintenance management can develop a more effective and efficient maintenance plan and Standard Operating Procedure (SOP) by the building condition index and existing priority scale.

## 1. Introduction

Community needs continue to grow, such as the need for health services, because health is one of the most important necessities of life. Increasing public awareness of health's importance is one reason that the need for health infrastructure is increasing [1]. So hospital building is one of the health infrastructure needed to provide medical services to the surrounding community. So, the community needs the hospital, so it is necessary to have maintenance activities, both in terms of medical equipment and buildings [2].

To maintain the function and condition of the building [3], [4] prevent damage to the building [5], extend the life of the building [6], ensure safety [7] and user comfort [8], and support good service to the community [9], [10] It is necessary to maintain the building and its facilities properly. Limited resources in managing the maintenance system for facilities and infrastructure can affect hospital services' continuity, efficiency, and effectiveness [11].

According to The Committee on Building Maintenance, building maintenance is an activity performed to maintain, renew, and repair all existing facilities as part of a building, including both service facilities and the environment around the building, for them to remain in a condition that meets applicable standards and maintain the usability and value of the building [12]. Therefore, building maintenance aims to review whether the planned building and all existing facilities are running properly. In addition, maintenance also plays a role in ensuring the comfort, security, and safety of the building's users. However, in reality, maintenance is only used as a complementary activity every year without regard to the maintenance function itself [13].

The Bali Mandala Regional General Hospital (RSUD) is a type B hospital owned by the Bali Provincial government. Bali Mandara Hospital uses an umbrella contract procurement system to select partners to plan the care and maintenance of buildings based on field surveys over a one-year work implementation period. In addition, the Minister of Health No. 24 of 2016 also states that hospitals provide maintenance costs of at least 15% of the value of hospital buildings and infrastructure [14].

Several previous studies, including Watty et al. [15], Mohamad Budi & Ratnaningsih [16], Adeswantoto [17], Arifin, et al. [18], and Purwaamijaya et al. [3], mention that a building can be assessed for its condition by setting the index value of the condition of the building. The condition index value of 69 (medium) requires analysis to determine the appropriate action in dealing with the problem of building damage. This building condition index assessment becomes the basis for compiling documents in building maintenance and maintenance management to determine the priority of building infrastructure maintenance and maintenance activities that have effectiveness and sustainability values or sustainable development [19]. The maintenance management planning contained in the umbrella contract is only based on the damage that occurred in the previous year. This is due to the absence of assessment of the level of damage and the condition of the building Bali Mandara Hospital. This causes a lot of damage to new building components that are not stated in the umbrella contract, which requires a new procurement process to be carried out. This also makes it hard to decide which parts of a building's infrastructure need to be fixed and maintained first.

In research conducted by [9], it was stated that based on an assessment of the condition of the hospital building, the IKB was obtained at 97.66, including zone 1, with the condition that there is some minor damage, including in maintenance priority 10. Under these conditions, immediate maintenance action is not required. An Analytical Hierarchy Process (AHP) solves a complex problem that is not structured into several components in a hierarchical arrangement. This method involves giving subjective scores about the relative importance of each variable and determining which variable has the highest priority to affect the situation's outcome. This study aimed to examine the priority scale for the basis of maintenance management and management of building infrastructure at Bali Mandara Hospital using the Analytical Hierarchy Process (AHP). Through this assessment, a sequence of existing infrastructure maintenance will be carried out, so knowing these results can be used in planning an efficient maintenance management standard.

## 2. Research Method

In this study, the researcher used a quantitative descriptive approach and the method used in determining the index value of the condition of the building for each component. The priority scale uses the Analytical Hierarchy Process (AHP) method with the help of the Expert Choice application Version 11. This research was conducted at the Bali Mandara Regional General Hospital (RSUD), its address at Jalan Bypass Ngurah Rai Number 548, Sanur Kauh Village, South Denpasar District, Denpasar City, Bali Province.

### 2.1 Data Collection

Primary data was obtained through direct research at Bali Hospital Mandara and by an interview method conducted on the parties involved in the maintenance and care activities of Bali Mandara Hospital. In addition, a questionnaire method was used by involving selected respondents by purposive random sampling. The selected respondents knew and understood the ins and outs of building care and maintenance at Bali Mandara Hospital and had competence in handling building maintenance and maintenance activities at Bali Mandara Hospital. The expert respondents selected were: 1 (one) Head of Hospital Facility Maintenance Installation (IPSRs) at Bali Mandara Hospital; 1 (one) Building Maintenance Coordinator at IPSRS Bali Mandara Hospital; 1 (one) person at the IPSRS Building Maintenance Unit, Bali Mandara Hospital; 1 (one) administrative person at IPSRS RSUD Bali Mandara; and 1 (one) Director of Contractor Maintenance for Bali Mandara Hospital Building. Secondary data in this study was also obtained directly from the Bali Mandara Hospital, including floor plan data, building size and

area, data on building infrastructure maintenance for the 2021 Building, and parties involved in building maintenance and care.

## 2.2 Identification of Building Damage

This identification of damage refers to the PUPR Ministerial Regulation No. 22/PRT/M/2018 and Permen PU No. 24/PRT/2008 and obtains building elements that suffered heavy, moderate, and light damage. In addition, the volume of damage and the percentage of damage to elements are also obtained.

### 1) Index Condition

This damage identification becomes the basis for determining the condition index of the existing building infrastructure at Bali Mandara Hospital. According to Suparjo [20], building damage assessment was carried out by direct surveys in the field. So that the assessment of the condition of the building is done by calculating the value of the building condition index, which is a combination of two or more component condition values multiplied by their weight. With Element Condition Index (IKE) assessment, Sub Component Condition Index (IKSK) assessment, Component Condition Index (IKK) assessment, and Building Condition Index (IKB) assessment.

### 2) Scala Priority

Meanwhile, to analyze the priority scale of maintenance activities in this study, using AHP (Analytical Hierarchy Process) with the help of the Expert Choice V.11 application, The Analytic Hierarchy Process (AHP) method is a statistical approach first developed by Saaty (1980), which is used in making multi-parameter decisions, Multi-Criteria Decision Making (MCDM) [20] [21]. AHP is based on pairwise comparisons of each element of the hierarchy [22], [23], and the weight values can be sorted by rank [24]. The Expert Choice application aims to facilitate problem analysis in decision making with many alternatives and a relatively large hierarchy [25] because there is no need to do manual calculations. Hence, the error rate is relatively low.

## 2.3 SWOT Analysis

The SO strategy, the WO strategy, the ST strategy, and the WT strategy are the four cells of the analysis matrix that result from a SWOT analysis. The resultant alternative solutions are used to develop an organizational structure and maintenance management plan that considers preexisting regulatory requirements and references pertinent to hospital building maintenance. As a result, the maintenance management team at Bali Mandara Hospital conducts

a SWOT analysis, considering both internal and external issues. For the strategy and Standard Operating Procedures (SOP) to be useful at Bali Mandara Hospital, they must be prioritized in line with the building condition index and priority scale, which can be seen in the SWOT column.

### 3. Results and Discussions

#### 3.1 Building Condition Index

The assessment of the building condition index includes the assessment of the Element Condition Index (IKE), the assessment of the Sub Component Condition Index (IKSK), the assessment of the Component Condition Index (IKK), and the assessment of the Building Condition Index (IKB).

##### 3.1.1 Elemental Condition Index Assessment (IKE)

IKE is used as a reference to determine how well the building conserves energy. An example of calculating the ceiling IKE using the formula is as follows:

$$IKE = 100 - \sum_{i=1}^P \sum_{j=1}^P \lambda (T_j, S_j, D_{ij}) \times F (t_i d)$$

$$IKE = 100 - (25 \times 1)$$

$$IKE = 100 - (25)$$

$$IKE = 75$$

IKE calculation for the other elements is done in the same way. The IKE value of each component of the Bali Mandara hospital building can be seen in **Table 1**

**Table 1.** IKE Bali Mandara Hospital Building

Component	Sub Component	Element	Damage Volume	FK	NP	Condition Index (IKE)		
A	B	C	D	E	F	G=100 – (F x E)		
Structure	Upper Structure	Roof truss	0%	0	0	100-(0) = 100		
	Upper Structure	Roof Cover Plate	0%	0	0	100-(0) = 100		
		Column	0%	0	0	100-(0) = 100		
	Bottom Structure	Beam	0%	0	0	100-(0) = 100		
		Foundation	0%	0	0	100-(0) = 100		
		Sloof	0%	0	0	100-(0) = 100		
Architecture	Wall	Lightweight Bricks	0.08%	1	25	100-(25) = 75		
		Plastering	0.08%	1	25	100-(25) = 75		
		Asian	0.04%	0	0	100-(25) = 100		
	Doors and Windows	Leaf doors	Leaf doors	0.63%	1	25	100-(25) = 75	
			Shutters	0%	0	0	100-(0) = 100	
		Jamb	Jamb	8.15%	1	25	100-(25) = 75	
			Hinge	0.10%	0	25	100-(25) = 100	
			Lock and Handle	0.31%	0	25	100-(25) = 100	
		Floor Cover	Wind Hook	0%	0	0	100-(0) = 100	
			Ceramic/granite floor	0.36%	1	25	100-(25) = 75	
	Palate	Vinyl Floor	0%	0	0	100-(0) = 100		
		Ceiling Frame	1.10%	1	25	100-(25) = 75		
	Finishing (Paint)	Ceiling	1.51%	1	25	100-(25) = 75		
		Structural Paint	Structural Paint	0.00%	1	25	100-(25) = 75	
			Wall paint	2.40%	1	25	100-(25) = 75	
		Ceiling Paint	1.49 %	1	25	100-(25) = 75		
		Door and Wood Paint	0%	1	0	100-(25) = 100		
Utilities	Air Conditioning Installation	Air Conditioning (AC)	8.93%	1	25	100-(25) = 75		
		Negative Pressure	1.9%	1	25	100-(50) = 75		
	Water Installation	Clean Water	4.6%	1	25	100-(25) = 75		
		Dirty Water and Wastewater Installation	1.6%	1	25	100-(25) = 75		
	Sanitary Equipment	toilet	1.0%	1	25	100-(0) = 75		
		Sink	2.2%	1	25	100-(25) = 75		
		Floor Drain	0.9%	1	25	100-(25) = 75		
		faucet	28.0%	1	50	100-(50) = 50		

Source: Data Analysis (2022)

Based on **Table 1.**, it can be seen that the lowest IKE value is on the faucet element, which is faucet (50) or bad condition. The IKE value of all the parts of the structural component is 100 consisting of the Upper Structure and Bottom Structure, or are in very good condition. Still, the IKE values of the parts of the architectural component vary from 75 to 100, consisting of Walls, Doors and Windows, Floor Cover, Palate, Finishing (Paint), or good condition.

### 3.1.2 Calculation of the Sub-Component Condition Index (IKSK)

Calculating the Sub Component Condition Index (IKSK) for the Bali Mandara Hospital building is carried out after obtaining the IKE of each element. Examples of ceiling IKSK calculations are as follows;

$$IKSK = (IKE_1 \times BE_1) + (IKE_2 \times BE_2) + \dots + (IKE_r \times BE_r)$$

$$IKSK_{Palate} = (IKE_{Ceiling\ Frame} \times Bobot_{Ceiling\ Frame}) + (IKE_{Ceiling} \times Bobot_{Ceiling})$$

$$IKSK_{Palate} = (75 \times 0,5) + (75 \times 0,5)$$

$$IKSK_{Palate} = 75$$

IKSK calculations for other sub-components are carried out in the same way. The IKSK value of each sub-component of the Bali Mandara hospital building can be seen in **Table 2**.

**Table 2.** IKSK Bali Mandara Hospital Building

Component	Sub Component	Element	Condition Index (IKE)	Element weight	RISK	
Structure	Upper Structure	Roof truss	100	0.500	100	
		Roof Cover	100	0.500		
	Upper Structure	Plate	100	0.333	100	
		Column	100	0.333		
		Beam	100	0.333		
	Bottom Structure	Foundation	100	0.500	100	
Sloof		100	0.500			
Architecture	Wall	Lightweight Bricks	75	0.333	83	
		Plastering	75	0.333		
		Asian	100	0.333		
	Doors and Windows		Leaf doors	75	0.262	88
			Shutters	100	0.196	
			Jamb	75	0.199	
			Hinge	100	0.140	
			Lock and Handle	100	0.140	
			Wind Hook	100	0.062	
	Floor Cover		Ceramic/granite	75	0.500	88
			Vinyl Floor	100	0.500	
	Palate		Ceiling Frame	75	0.500	75
			Ceiling	75	0.500	
	Finishing (Paint)		Structural Paint	75	0.485	79
			Wall paint	75	0.221	
			Ceiling Paint	75	0.132	
			Door and Wood Paint	100	0.162	
Utilities	Air Conditioning Installation	Air Conditioning	75	0.500	75	
		Negative Pressure	75	0.500		
	Water Installation		Clean Water Installation	75	0.500	75
			Dirty Water and Wastewater Installation	75	0.500	
			Sanitary Equipment	toilet	75	
			Sink	75	0.250	69
			Floor Drain	75	0.250	
			faucet	50	0.250	

Source: Data Analysis (2022)

Based on **Table 2.**, it can be seen that the IKSK value for the lowest risk sub-component is found in the faucet element, namely 69 or bad condition. The IKSK value for all structural components is 100 or is in very good condition, but the IKSK value for architectural parts varies from 75 to 88 or good condition.

### 3.1.3 Calculation of Component Condition Index (IKK)

Calculating the Component Condition Index (IKK) is carried out after obtaining the IKSK of each sub-component. An example of the calculation of the Architectural IKK is as follows;

$$\begin{aligned}
 IKK &= (IKSK_1 \times BSK_1) + (IKSK_2 \times BSK_2) + \dots + (IKSK_r \times BSK_r) \\
 IKK_{Architecture} &= (83 \times 0,332) + (88 \times 0,087) + (88 \times 0,218) + (75 \times 0,282) + (79 \times 0,081) \\
 IKK_{Architecture} &= 81.96
 \end{aligned}$$

The IKK calculation for the other components is carried out the same way. The IKK value of each element of the Bali Mandara hospital building can be seen in **Table 3.**

**Table 3.** IKK Bali Mandara Hospital Building

Component	Sub Component	Element	Sub Component Weight	IKSK	IKK
Structure	Upper Structure	Roof truss	0.333	100	100
		Roof Cover Plate			
	Upper Structure	Column Beam	0.333	100	
	Bottom Structure	Foundation Sloof	0.333	100	
Architecture	Wall	Lightweight Bricks	0.332	83	81.96
		Plastering Asian			
	Doors and Windows	Leaf doors and Shutters	0.087	88	
		Jamb Hinge			
		Lock and Handle Wind Hook			
	Floor Cover	Ceramic/granite Vinyl Floor	0.218	88	
	Palate	Ceiling Frame Ceiling	0.282	75	
Finishing (Paint)	Structural Paint	0.081	79		
	Wall paint Ceiling Paint Door and Wood Paint				
Utilities	Air Conditioning Installation	Air Conditioning (AC)	0.333	75	73
		Negative Pressure			
	Water Installation	Clean Water Installation Dirty Water and Wastewater Installation	0.333	75	
	Sanitary Equipment	Toilet Sink Floor Drain faucet	0.333	69	



Source: *Data Analysis* (2022)

The results of the IKK analysis from **Table 3.** show that overall structural sub-components have a weight of 100% or are in very good condition, architectural sub-components have a weight of 75%–88% or good condition, and utility sub-components have a weight of 75% or good condition for installation sub-components.

### 3.1.4 Calculation of Building Condition Index (IKB)

The Building Condition Index (IKB) calculation is carried out after obtaining the IKK of each component. An example of the calculation of the Architectural IKB is as follows;

$$IKB = (IKK_1 \times BKK_1) + (IKK_2 \times BKK_2) + \dots + (IKK_r \times BKK_r)$$

$$IKB = (100 \times 0.465) + (81.96 \times 0.446) + (0.089 \times 73)$$

$$IKB = 89,492$$

Based on the calculation results above, the index value of the condition of the infrastructure of the Bali Mandara Hospital building is 89.492 with perfect condition criteria and is in zone I. By knowing the level of damage according to the area; it can be determined the handling action.

## 3.2 Priority Scale for Maintenance

Determination of the priority scale for maintenance and maintenance of the Bali Mandara Hospital building infrastructure using the condition index value, service life, and cost. The results of the priority weighting using Expert Choice V.11 are shown in **Table 4.**

**Table 4.** Priority Scale of Bali Mandara Hospital Building Elements

Element	Mark	Priority	Element	Mark	Priority
Faucet	1,000	1	Ceiling Frame	0.205	11
Air Conditioning	0.659	2	Toilet	0.119	12
Jamb	0.550	3	Floor Drain	0.080	13
Clean Water Installation	0.456	4	Ceramic/granite floor	0.073	14
Dirty Water and Wastewater Installation	0.456	5	Leaf doors	0.072	15
Wall paint	0.433	6	Lock and Handle	0.071	16
Sink	0.351	7	Hinge	0.062	17
Negative Pressure	0.269	8	Lightweight Bricks	0.052	18
Ceiling	0.227	9	Plastering	0.050	19
Ceiling Paint	0.219	10	Acian	0.050	20

Source: *Data Analysis* (2022)

Based on **Table 4.**, the priority scale of maintenance and maintenance activities for the building infrastructure of the Bali Mandara Hospital using the index value of the condition, service life, and cost, where the highest priority is on the faucet element, which is 1,000, and the lowest priority is the acian element of 0.050.

### 3.3 Analysis of Maintenance Management with the SWOT Method

Each identification number stated in the SWOT column, it should indicate the priority scale or level of urgency.

**Table 5.** Maintenance Management SWOT Analysis

	<u>Strength (S)</u>	<u>Weakness s s /Weaknesses (W)</u>
Internal factors	<ol style="list-style-type: none"> <li>1. Availability of type B hospital infrastructure</li> <li>2. Availability of human resources (related to supporting the management of Bali Mandara Hospital Maintenance)</li> <li>3. Availability of SOPs in the Implementation of Building Maintenance</li> <li>4. Routine maintenance costs already exist</li> <li>5. Maintenance Installation is available, namely IPSRS</li> </ol>	<ol style="list-style-type: none"> <li>1. The building database is not complete</li> <li>2. There is no scheduled maintenance planning for both incidental and long-term work (short term) and long-term.</li> <li>3. There is no method to analyze the damage (weight &amp; condition assessment)</li> <li>4. The condition monitoring form is not optimal</li> <li>5. Maintenance SOP is not optimal</li> </ol>
External factors		
<u>Opportunity (O)</u>	<u>SO Strategy</u>	<u>WO Strategy</u>
<ol style="list-style-type: none"> <li>1. There are MPW regulations, Permenkes and hospital classification guidelines that regulate the maintenance of building infrastructure.</li> <li>2. Cooperation with Vendors / Partners who have clarification on the maintenance of hospital building infrastructure</li> </ol>	<ol style="list-style-type: none"> <li>1. Optimization of maintenance costs through collaboration with Vendors/Partners who have clarification on the maintenance of hospital building infrastructure</li> <li>2. Carry out maintenance management of building infrastructure by the Minister of Public Works Regulation, Permenkes and hospital classification guidelines by optimizing all available resources</li> </ol>	<ol style="list-style-type: none"> <li>1. Completing the building infrastructure database</li> <li>2. Make a scheduled maintenance plan for both incidental and long-term work (short term) and long-term.</li> <li>3. Develop maintenance programs/activities in detail</li> <li>4. Optimization of monitoring from Infrastructure condition</li> <li>5. Optimization of existing maintenance SOPs</li> </ol>
<u>Threats (T)</u>	<u>ST strategy</u>	<u>WT Strategy</u>
<ol style="list-style-type: none"> <li>1. Buildings that are not cared for and maintained properly will reduce their function and age of the building.</li> <li>2. Damage to building components can disrupt services at the Bali Mandara Hospital.</li> </ol>	<ol style="list-style-type: none"> <li>1. Infrastructure Buildings must be maintained according to standards</li> <li>2. Optimization of existing resources to facilitate service activities at the Bali Mandara Hospital</li> </ol>	<ol style="list-style-type: none"> <li>1. Designing infrastructure maintenance and maintenance programs that can maintain the function and life of the building</li> <li>2. SOPs and scheduled monitoring of the condition of building components can facilitate services at the Bali Mandara Hospital.</li> </ol>

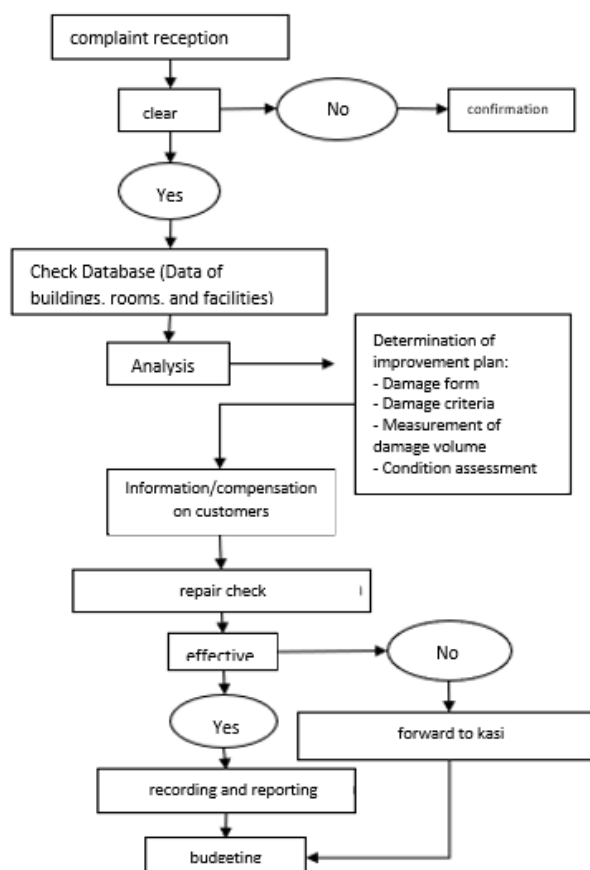
Source: Data Analysis (2022)

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Based on the results of the SWOT analysis above, the things that are recommended are optimizing maintenance costs through collaboration with vendors/partners who have clarification regarding hospital building infrastructure maintenance; implementing building infrastructure maintenance management according to the Regulation of the Minister of Public Works No. 24 of 2008, Permenkes No. 24 of 2016, and the classification guidelines for class B hospitals by optimizing all available resources; making scheduled maintenance plans for both incidental and long-term (short-term) and long-term work; and developing detailed maintenance programs/activities, complete with weighting and condition assessment methods; optimizing existing maintenance SOPs; and optimizing infrastructure condition monitoring forms. From the recommendations above, a special *Standard Operating Procedure (SOP)* was made for the maintenance of building infrastructure as follows:



Source: Data Analysis (2022)

**Figure 3.** Recommended SOP or Maintenance Activity Flow

#### 4. Conclusion

The index value of the infrastructure condition of the Bali Mandara Hospital building is 89.492, with perfect condition criteria, and is in zone I. The priority scale for maintenance and management of the Bali Mandara Hospital building infrastructure uses the index value conditions, service life, and cost. The highest priority is on the faucet element, which is 1,000, and the lowest is on the installment element, which is 0.050. The priority scale can be used in planning *Standard Operating Procedures (SOP)* and efficient maintenance management.

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