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Infrastructure Management of the Smart and Green Learning Center Building Using the Analytical Hierarchy Process (AHP)

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ABSTRACT

Building infrastructure management is a key element in maintaining and improving the efficiency, sustainability, and quality of a building. The Smart and Green Learning Center (SGLC) building at Gadjah Mada University is a modern building that functions as both an administrative office and a lecture hall. The building boasts a modern design featuring extensive use of glass and stands 11 stories tall. It embodies the concept of a green and smart building. Hence, it requires serious attention in terms of effective maintenance and proper maintenance to ensure the building can function properly. Analytical Hierarchy Process (AHP) method was used to obtain weighting values for room components/elements. This weighting value is then used to calculate the SGLC building component condition index, which can provide information of whether the component is damaged or not. The weighting values are obtained by distributing questionnaires, while the condition index is determined through observation. The components observed include structural, architectural, and utility components. The results show that weighting values for structure, architecture and utilities were 46.3%, 33.9% and 19.8%, respectively. In the structural components, it is found that the column, beam, and plate weighting values are 48.3%, 42.7% and 8.9%, respectively. In the architectural components, the weighting values for ceilings, walls, floors & ceramics, doors & windows are 11.7%, 36.6%, 8.8%, 42.9% respectively. In the utility components, the weighting values for electricity, electronics, elevators, building sensor systems, and plumbing are 30%, 22.3%, 4.9%, 19.1%, and 23.7%, respectively. After searching floors 1 to 11, it was seen that the structural components were still in exceptionally good condition. There is only minor damage to utility and architectural components that require maintenance such as repair or replacement of components that are no longer suitable for use.

1. Introduction

Building infrastructures, including commercial buildings, factories, educational buildings, hospitals, and other public facilities, are valuable assets that play important roles in our daily lives. The Smart and Green Learning Center (SGLC) building at Gadjah Mada University is a new building that serves a dual purpose as administrative offices and lecture rooms. The building boasts a modern design featuring extensive use of glass and stands 11 stories tall. It embodies the concept of a green and smart building. Therefore, it needs to receive serious attention in terms of effective maintenance and care. The need for effective maintenance is widely recognized because it can provide a satisfactory level of service by ensuring the desired condition of the building [1]. Effective maintenance can save maintenance costs [2][3][4].

Neglecting maintenance, repairs, and thorough inspections will cause the building's performance to decline more rapidly as time goes on. Therefore, negligence or imprecision in maintenance activities may potentially result in significant failures of maintenance process, consequently posing risks to human safety, loss of revenue, or operational disruptions [5].

Research on the implementation of the Multi-Criteria Decision Making (MCDM) method with an objective approach in the context of maintenance planning for concrete structures vulnerable to corrosion has been

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conducted [6]. The outcome of this research is the determination of the best maintenance alternatives based on the global priority vector derived from a paired comparison matrix. Consequently, it can be concluded that the newly developed dynamic decision model has proven to be highly valuable in the decision-making process related to the planning of structural maintenance. Research aimed at developing a decision support tool for healthcare facility asset management and prioritization has been conducted [7]. This research utilized Neutrosophic logic, Analytic Network Process (ANP), and Multi-Attribute Utility Theory (MAUT) to mitigate subjectivity in assessing the criticality, levels, and performance deficiencies of hospital building assets. The outcome of this study is the development of a consistent and objective scheme for prioritizing hospital asset renewal. The assessment tool for sustainable buildings has been developed by considering the triple bottom line aspects [8]. This research reviews ten existing sustainable assessment tools and applies the Analytical Hierarchy Process (AHP) technique to assign weights and prioritize assessment categories and criteria. The research findings indicate that assessment priorities encompass material and resource aspects, sustainable location and ecology, energy efficiency, indoor environmental quality, economic aspects, management, water efficiency, as well as location and transportation.

In SGLC building maintenance planning, the AHP method will be used. Through AHP, we can determine the weighting of elements/components in each room, which impact the condition index of the main components of the building. This allows monitoring the condition of components in each room and implementing appropriate measures for care and maintenance.

2. Theoretical Basis

2.1 Analytical Hierarchy Process (AHP)

AHP can solve complex multicriteria problems into a hierarchy. Organizing problems in a hierarchical form helps improve understanding of the existing problem, the decisions that need to be made, the criteria to be used, and the alternatives to be evaluated. Experts' participation at this stage is important because they ensure that all criteria and alternatives are considered comprehensively.

The AHP method is used to calculate the relative weighting of building components [9]. The assessment of the weighting of building components is carried out by applying a pairwise comparison matrix referring to Table 1.

The AHP method has its limitations, such as high computational requirements, subjective nature, reliance on emotions in numerical assessments, and the need for more time and effort in pairwise comparisons. Additionally, this method is also vulnerable to fluctuations in criteria values over space and time. Despite these limitations, AHP can still be a powerful tool if used appropriately [11]. On the other hand, the advantage of AHP is that it is exceptionally good at handling situations that involve many criteria or factors that must be considered in decision-making, so it can break down big problems into smaller, more manageable parts.

In using AHP to model a problem, a hierarchical or network structure is needed to represent a problem, as well as a pairwise comparison matrix to build relationships within that structure. A pairwise comparison matrix can be seen in Equation (1)

$$\begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \dots & \dots & \dots & \dots\dots\dots. \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} \tag{1}$$

Table 1. The pairwise comparison scale in AHP [9].

Scale	The level of importance	Explanation
1	Equal level	The two components contribute equally to the goal
3	Moderate level	The assessment slightly favors one component over another
5	Strong level	Assessment strongly favors one component over another
7	Extraordinarily strong level	A component is highly preferred over other components
9	Extreme importance level	One component is important compared to other components is the strongest evidence
2,4,6,8	Values in between	If unsure in choosing a scale.
Reciprocal	If the comparison of element 1 to element 2 is on a scale of 7, then the comparison of element 2 to element 1 is 1/7	A reasonable assumption.

A pairwise comparison matrix is created from the lowest level to the highest level, in the order namely sub-elements, elements, sub-components, and components.

2.2 Weighting factors

The weighting calculation is carried out from the lowest level to the highest level, namely the weighting of sub-element *c*, weighting of element *j*, weighting of sub-component *z*, weighting of component *W*. In general, the weight calculation is carried out with the following steps:
(a) Calculation of the multiplication of pairwise comparison matrix elements in one row and root to the power of n, see Equation 2.

$$x_i = \sqrt[n]{a_{11}a_{12}\ x \ldots \ldots a_{1n}} \tag{2}$$

where *n* is the number of sub-element or element or subcomponent or component.
(b) Weighting calculation using Equation 3.

$$w_i = \frac{x_i}{\sum x_i} \tag{3}$$

The elements in the Pairwise comparison matrix is filled in by conducting interviews with respondents. The data obtained needs to be analyzed to determine the reliability of the data by calculating the *CR* consistency ratio value. The *CR* value is obtained using Equation (4) to Equation (6). *CR* value must be less than 0.1. However, if the *CR* value exceeds 0.1, the Interview must be repeated [12].

$$CR = \frac{CI}{RI} < 0.1 \tag{4}$$

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{5}$$

$$\lambda_{max} = \sum_{aij} w_i \tag{6}$$

CI is the consistency index, λ_{max} is the largest eigenvalue, *n* is the number of component that compiler the matrix, *RI* is the random index value, which depends on the size of the matrix as shown in Table 2.

Table 2. Average random consistency index (RI).

Matrix size	Random index	Matrix size	Random index
1.2	0.00	9	1.45
3	0.58	10	1.49
4	0.90	11	1.51
5	1.12	12	1.48
6	1.24	13	1.56
7	1.32	14	1.57
8	1.41	15	1.59

2.3 Component Condition Assessment

To assess the condition of a building, the building condition index can be determined by combining two or more component condition indices. The combined condition index is formulated as Equation 7 up to Equation 11 [12].

$$b = 100 - \sum_{i=1}^{P} \sum_{j=1}^{m} a\ (D_{ij}) \times T_j \times S_j \tag{7}$$

$$i = b_1\, c_1 + b_2\, c_2 + \cdots + \ b_n\, c_n \tag{8}$$

$$y = i_1\, j_1 + i_2\, j_2 + \cdots + \ i_n\, j_n \tag{9}$$

$$C = y_1\, z_1 + y_2\, z_2 + \cdots + \ y_n\, z_n \tag{10}$$

$$CCI = W^1\ x\ C^1 + W^2\ x\ C^2 + \cdots + W_n x\ C_n \tag{11}$$

Where *CCI* is the combined condition index, *W* is the component factor weight, *C* is the component condition index, *y* is the sub-component condition index, *z* is the sub-component weight, *i* is the element condition index and *j* is the sub-element weight, *b* is the condition index of the sub element, *c* is the weighting of the sub element, a is the reduction value, D_{ij} is the ratio of the number of damaged components subcomponents elements or sub elements to the total number of observed components or sub components or elements or sub elements for the certain type of damage illustrated in Table 10, *P* is the number of types of damage to the sub element being considered, and *m* is the number of damage levels for type of damage. As explained in Equation 11, *a* is the D_{ij} function which is determined as No damage (D_{ij} = 0%), with *a* = 0; Light damage (D_{ij} =>0% - <15%), with *a* = 25; Medium damage (D_{ij} =>15% - 35%), with *a* = 50; Severe damage (D_{ij} =>35% - 65%), with *a* = 75; Improper fuctional damage (D_{ij} =>65%), with *a* = 100.

If no damage occurs (0%), then *a* = 0 which indicates the condition of the building elements/components is in good condition, while providing a condition index scale value of 100. However, the *a* value will increase as the level of damage increases. *a* value = 100 when inappropriate functional damage occurs. The T_j value depends on the total type of damage from the sub-elements being reviewed. If a sub-element experiences only one of three damage types, the T_j value is calculated as 1/3 of the total damage types. The S_j value is determined based on Table 3. The higher the level of danger of damage, the closer the S_j value to 1.

Table 3. Level of damage.

Level of damage	Value	Explanation
1	1	Total damage
2	0.8	Considerable damage
3	0.6	Medium damage
4	0.4	Moderate damage
5	0.2	Minor damage

3. Research Methods

3.1. Location of research

The location used in this study is the Smart Green Learning Center of the Faculty of Engineering, Gadjah Mada University, located at Grafika Street No. 2, Sleman, Yogyakarta. The questionnaire form that has been prepared consists of structural components (columns, beams, floor slabs), architectural (walls, ceilings, floors & ceramics, and doors & windows), and utilities (electrical, electronic, lift, plumbing, building sensor system (BSS), which consider aspects of comfort, safety, aesthetics, security, and support user activities. In more detail, the observation values for structural, architectural and utility components can be seen in Table 4 up to Table 6.

3.2. Types of Data

In this study, data collection is divided into 2 types. Primary data is obtained through direct surveys and questionnaire distribution to determine the weighting of each component. Four questionnaires were distributed to four respondents. Secondary data is obtained from relevant literature, component determination, related regulations, building addresses, and other supporting data.

3.3. Data Collection Technique

Interviews with the manager and three infrastructure staff of Engineering Faculty Head Office were considered an appropriate method for collecting data. This method allows experts to participate in the process by answering questions and sharing ideas based on their knowledge. In this case, a survey questionnaire format is used that includes open-ended questions. Questionnaire questions were created by considering the criteria used in compiling the pairwise comparison matrix. The complete criteria for each component or sub-component or element can be seen in Table 7. Examples of interview results for SGLC building structural components can be seen in Table 4.

3.4. Data Analysis

This research uses a quantitative approach with a questionnaire containing the Analytical Hierarchy Process (AHP) method as the main instrument. The data obtained from the respondents are used to determine the performance assessment weights of each building component, starting from the structural component, utilities, and architectural.

Pairwise comparison matrix. After the data was obtained from interviews, a pairwise comparison matrix was then prepared. An example of the results of preparing a pairwise comparison matrix of structural components for the criteria of strength, supporting building shape and durability can be seen in Equation 12 to Equation 14.

Strength:

$$\begin{array}{c} \\ \text{Column} \\ \text{Beam} \\ \text{Plate} \end{array} \begin{array}{c} \begin{array}{ccc} \text{Column} & \text{Beam} & \text{Plate} \end{array} \\ \begin{pmatrix} 1 & 1 & 4.75 \\ 1 & 1 & 3.75 \\ 0.21 & 0.27 & 1 \end{pmatrix} \end{array} \tag{12}$$

Support the shape of the building:

$$\begin{array}{c} \\ \text{Column} \\ \text{Beam} \\ \text{Plate} \end{array} \begin{array}{c} \begin{array}{ccc} \text{Column} & \text{Beam} & \text{Plate} \end{array} \\ \begin{pmatrix} 1 & 1 & 7.75 \\ 1 & 1 & 4 \\ 0.13 & 0.25 & 1 \end{pmatrix} \end{array} \tag{13}$$

Durability:

$$\begin{array}{c} \\ \text{Column} \\ \text{Beam} \\ \text{Plate} \end{array} \begin{array}{c} \begin{array}{ccc} \text{Column} & \text{Beam} & \text{Plate} \end{array} \\ \begin{pmatrix} 1 & 1 & 4.75 \\ 1 & 1 & 3.75 \\ 0.21 & 0.27 & 1 \end{pmatrix} \end{array} \tag{14}$$

Deriving relative weighting/relative priority (normalization). Relative weighting evaluation is required for each category and selected criteria. The normalization process involves calculating the urgency of each criterion based on its contribution to the expected goal. The results of this normalization produce a normalized pairwise comparison matrix [13].

The weighting calculation of structural components based on strength criteria can be seen in Equation 15.

$$\begin{array}{ccc} \text{Comparison matrix} & \text{Weighting} & \text{Eigen} \\ \begin{pmatrix} 1 & 1 & 4.75 \\ 1 & 1 & 3.75 \\ 0.21 & 0.27 & 1 \end{pmatrix} & \begin{pmatrix} 0.46 \\ 0.43 \\ 0.11 \end{pmatrix} & \begin{pmatrix} 1.40 \\ 1.29 \\ 0.32 \end{pmatrix} \end{array} \tag{15}$$

The comparison matrix written in Equation 15 is obtained from the matrix written from Equation 12. After the comparison matrix is prepared, each element in row i of the comparison matrix is then calculated using Equation 2, which is as follows:

Line I : $x_1 = (1.00 \text{ x } 1.00 \text{ x } 4.75)^{1/3} = 1.68$
Line II : $x_2 = (1.00 \text{ x } 1.00 \text{ x } 3.75)^{1/3} = 1.55$
Line III : $x_3 = (0.21 \text{ x } 0.27 \text{ x } 1.00)^{1/3} = 0.38$
so that $\sum_{x_i} = 3.62$

The calculation of the weighting of each component by using Equation 3 result the weighting of column, beam, plate component, for the strength criteria as follows :

– weighting of column component,
$w_1 = 1.68/3.62 = 0.46$
– weighting of beam component,
$w_2 = 1.55/3.62 = 0.43$
– weighting of plate component,
$w_3 = 0.38/3.62 = 0.11$

The weighting calculation of structural components based on supporting the shape of the building criteria can be seen in Equation 16.

$$\begin{array}{ccc} \text{Comparison matrix} & \text{Weighting} & \text{Eigen} \\ \begin{pmatrix} 1 & 1 & 7.75 \\ 1 & 1 & 4 \\ 0.13 & 0.25 & 1 \end{pmatrix} & \begin{pmatrix} 0.51 \\ 0.41 \\ 0.08 \end{pmatrix} & \begin{pmatrix} 1.55 \\ 1.25 \\ 0.25 \end{pmatrix} \end{array} \quad (16)$$

The calculations conducted by using Equation 2 are described as follows:

Line I : $x_1 = (1.00 \text{ x } 1.00 \text{ x } 7.75)^{1/3} = 1.98$
Line II: $x_2 = (1.00 \text{ x } 1.00 \text{ x } 4.00)^{1/3} = 1.59$
Line III: $x_3 = (0.13 \text{ x } 0.25 \text{ x } 1.00)^{1/3} = 0.32$
so that $\sum_{x_i} = 3.88$

The calculation of the weighting of each component by using Equation 3 result the weighting of column, beam, plate component for supports the shape of the building, as follows:

– weighting of column component,
$w_1 = 1.98/3.88 = 0.51$
– weighting of beam component,
$w_2 = 1.59/3.88 = 0.41$
– weighting of plate component,
$w_3 = 0.32/3.88 = 0.08$

The weighting calculation of structural components based on durability criteria can be seen in Equation (17).

$$\begin{array}{ccc} \text{Comparison matrix} & \text{Weighting} & \text{Eigen} \\ \begin{pmatrix} 1 & 1 & 6.50 \\ 1 & 1 & 4.75 \\ 0.15 & 0.21 & 1 \end{pmatrix} & \begin{pmatrix} 0.48 \\ 0.43 \\ 0.08 \end{pmatrix} & \begin{pmatrix} 1.45 \\ 1.31 \\ 0.25 \end{pmatrix} \end{array} \quad (17)$$

The calculations conducted by using Equation 2 are described as follows:

Line I : $x_1 = (1.00 \text{ x } 1.00 \text{ x } 6.50)^{1/3} = 1.87$
Line II: $x_2 = (1.00 \text{ x } 1.00 \text{ x } 4.75)^{1/3} = 1.68$
Line III: $x_3 = (0.15 \text{ x } 0.21 \text{ x } 1.00)^{1/3} = 0.32$
so that $\sum_{x_i} = 3.87$

The calculation of the weighting of each component by using Equation (3) result the weighting of column, beam, plate component, for the durability criteria as follows :

– weighting of column component,
$w_1 = 1.87/3.87 = 0.48$
– weighting of beam component,
$w_2 = 1.68/3.87 = 0.43$
– weighting of plate component,
$w_3 = 0.32/3.87 = 0.08$

In the same way, the weight of the structural criteria is then calculated. Data obtained from the results of the questionnaire. As previously explained, structural components have three criteria, *i.e.*, the strength, supporting the shape of the building, and durability. The results of the structural criteria comparison matrix and weighting calculations can be seen in Equation (18).

$$\begin{array}{ccc} \text{Comparison matrix} & \text{Weighting} & \text{Eigen} \\ \begin{pmatrix} 1 & 1.25 & 0.67 \\ 0.8 & 1 & 0.44 \\ 1.5 & 2.25 & 1 \end{pmatrix} & \begin{pmatrix} 0.30 \\ 0.22 \\ 0.48 \end{pmatrix} & \begin{pmatrix} 0.90 \\ 1.68 \\ 1.43 \end{pmatrix} \end{array} \quad (18)$$

The calculations conducted by using Equation 2 are described as follows:

Line I: x1 $= (1.00 \text{ x } 1.25 \text{ x } 0.67)^{1/3} = 0{,}94$
Line II: x2 $= (0.80 \text{ x } 1.00 \text{ x } 0.44)^{1/3} = 0.71$
Line III: x3 $= (1.50 \text{ x } 2.25 \text{ x } 1.00)^{1/3} = 1.50$
so that $\sum_{x_i} = 3.15$

The calculation of the weighting of each component by using Equation 3 result the weighting of structural criteria, as follows:

– weighting of strength criteria,
$w_1 = 0.94/3.15 = 0.30$
– weighting supports the building,
$w_2 = 0.71/3.15 = 0.22$
– weighting of durability criteria,
$w_3 = 1.50/3.15 = 0.48$

After calculating the weighting, the last step is to calculate the global weighting of the structural components. This calculation is done by compiling a comparison matrix as shown in Equation 19.

$$\underset{\text{Comparison matrix}}{\begin{pmatrix} 0.46 & 0.51 & 0.48 \\ 0.43 & 0.41 & 0.43 \\ 0.11 & 0.08 & 0.08 \end{pmatrix}} \underset{\text{Weighting}}{\begin{pmatrix} 0.30 \\ 0.22 \\ 0.48 \end{pmatrix}} \underset{\text{Eigen}}{\begin{pmatrix} 0.483 \\ 0.427 \\ 0.089 \end{pmatrix}} \qquad (19)$$

The first column of the comparison matrix written in Equation 19 is the result of the strength criteria weighting calculation for each structural component (weighting matrix column described in Equation 15). The second column of the comparison matrix written in Equation 19 is the result of the support building form criteria calculation for each structural component (weighting matrix column described in Equation 16). The third column of the comparison matrix written in Equation 19 is the result of the durability criteria calculation for each structural component (weighting matrix column described in Equation 17).

The weighting value of column matrix written in Equation 19 is obtained from the results of the structural criteria weighting calculation described in Equation 18. Then, the column, beam, and plate weighting can be obtained by multiplying the comparison matrix with the weighting column matrix as illustrated in Equation 19. The weighting of column, beam, and plate are 0.483, 0.427 and 0.089, respectively. In the same way, the weighting for all the building components considered can be calculated. The results of weighting calculations for all these components can be seen in Table 4 to Table 6.

3.5. Determining the Consistency Ratio (CR)

As explained, in preparing the comparison matrix for each component, it is necessary to calculate the consistency ratio value. Analysis will continue if the *CR* value is less than 0.1. However, if the *CR* value exceeds 0.1 then the interview process will be repeated. As a result, the preparation of the comparison matrix was also repeated.

Examples of calculating *CR* values for weighting structural components related to strength criteria are explained in this paragraph. Based on Equation 6, the λ_{max} value in Equation 15 is obtained at 3.01. The *aij* element in Equation 6 is an element in the comparison matrix column in Equation 15, while x_i is an element in the weighting matrix column in Equation 15.

The CR calculation of structural elements based on strength criteria is to carry out consistency testing by calculating the CI value using Equation 5.

Based on Equation 5, *CI* calculations are calculated as Equation 20.

$$CI = \frac{3.01-3}{3-1} = 0.003 \qquad (20)$$

The *RI* value is obtained from Table 2. Because the matrix size is 3, the *RI* value is taken as 0.58. Next, the *CR* value is calculated based on Equation 4, as explained in Equation 21.

$$CR = \frac{0.003}{0.58} = 0.01 \qquad (21)$$

The *CR* value obtained is less than 0.1, so that the weighting calculation results for the strength criteria can be accepted without the need to repeat the interview. The results of calculating the weighting values shown in Table 4 to Table 6 have gone through the *CR* value checking process.

3.6 Calculation of Building Condition Index

Building condition index calculations were carried out for each room from the 1st floor to the 11th floor of the SGLC building. The function of the room on each floor of the SGLC building can be seen in Table 9. The building condition index calculation is carried out for each building hierarchy starting from the lowest hierarchy to the component hierarchy (see Table 4 to Table 6). The expected output is the condition index of sub-elements, elements, sub-components, and components for each room and each floor. The index condition value for each floor is taken from the average index condition value for all rooms on each floor. The condition index value is calculated using Equation 7 to Equation 11.

By using Equation 7 up to Equation 11, the first step that must be taken is to determine the type of damage to each component, sub-component, element, and sub-element being reviewed. The types of damage considered for components/subcomponents/elements/sub-elements in this study are available in Table 10. After the type of damage is determined, the next step is to determine the level of damage. The level of damage is described in Table 3. Then, the volume of damage is determined by investigating the building condition.

The following explanation will cover the calculation of the condition index for the electrical outlet element.

According to Table 6, the electrical outlet is categorized as an element of the electricity subcomponent, which is a part of the utility component. An example of calculating the index condition of an electrical outlet element is explained which focuses on the case of Meeting Room 2, 3rd floor.

In Meeting Room 2 on the 3rd floor, there are 18 electrical outlet units. It was found, from the results of the investigation, that one of the electrical outlets was damaged, as shown in Figure 1. Referring to Table 10, the type of damage shown in Figure 1 is categorized as a loose electrical outlet. Referring to Table 3, electrical outlet damage is considered at level 2 (considerable damage), so the S_j value is 0.8. Because the number of damaged electric outlets in Meeting Room 2 is 1 out of 18 electric outlets, the value of D_{ij} is 5.56% so the value of a=25. The T_j value for the case of loose electric outlets damage is 1/3. A value of 1/3 indicates that the type of damage being reviewed (loose) is 1 of a total of 3 types of damage that may occur (loose, broken, disconnected), as described in Table 10.

In a survey of damage to the electrical outlet in Meeting Room 2, only a loose electrical outlet was found. There was no broken electrical outlet, and no electrical current was found. Therefore, the b value of the electrical outlet can be calculated using Equation 7, which is as follow:

$$b = 100 - \sum_{i=1}^{p=3} \sum_{j=1}^{m=5} a\,(D_{ij}) \times T_j \times S_j \tag{22}$$

$$b = 100 - 25\ \times \tfrac{1}{3} \times 0.8) = 93.33$$

The same calculation process is applied to the switch and light elements (see Table 6). Since the observation results indicate that there is no damage to the switch and light elements, the condition index of both elements is 100 (see Table 6). After obtaining the condition index for all elements in the electricity subcomponent, the next step is to calculate the condition index value for the electricity subcomponent using Equation 8. As a result, the condition index for the electricity subcomponent is 96.46. By using the same principle as Equation 8, we can obtain a utility condition index of 98.94.

The condition index of all sub-elements, elements, subcomponents, and components in Meeting Room 2 on the 3rd floor is calculated by using the same calculation principle as explained in the paragraph above. The results of the condition index calculations can be seen in Table 4 to Table 6.

By repeating the steps described above for the other rooms, a condition index for each room on the 3rd floor can be obtained. The condition index for certain components or subcomponents or elements, or sub elements on the entire 3rd floor can be obtained by averaging the component or subcomponent or elements or sub elements condition indexes. The same method also applies to other floors.

Figure 1. Photo of damage to the utility component of the electrical outlet.

Table 4. Weighting value of structural components

Components	Sub-components	Elements	Sub -elements
Structural (0.463; 100)	Column (0.483; 100)		
	Beam (0.427; 100)		
	Plates (0.089; 100)		

Table 5. Weighting value architectural components.

Components	Subcomponents	Elements	Sub elements
Architectural (0.339; 100)	Wall (0.366; 100)	Wall paint (0.137; 100)	
		Plastering (0.374; 100)	
		Brick making (0.500; 100)	
	Ceiling (0.117; 100)	Ceiling paint (0.141; 100)	
		Ceiling frame (0.523; 100)	
		Close the ceiling (0.336; 100)	
	Door & window (0.429; 100)	Doors (0.472; 100)	Door leave (0.391; 100)
			Sill (0.301; 100)
			Handling (0.083; 100)
			Paint of the door (0.068; 100)
			Hinge (0.158; 100)
			Glass (0.371; 100)
		Windows (0.528; 100)	Window frame (0.229; 100)
			Handling (0.111; 100)
			Hinge (0.078; 100)
			Window paint (0.211; 100)
	Floor and ceramic (0.088; 100)		

Table 6. Weighting value utility components.

Components	Subcomponents	Elements	Sub elements
Utility (0.198; 98.94)	Electricity (0.300; 96.46)	Switch (0.198; 100)	
		Electrical outlet (0.531; 93.33)	
		Light (0.270; 100)	
	Electronic (0.223; 100)	LCD projector (0.284; 100)	
		LED TV (0.214; 100)	
		Smart board (0.229; 100)	
		Sound system (0.096; 100)	
		Access point (0.084; 100)	
		CCTV (0.029; 100)	
		Fan (0.062; 100)	
	Lift (0.049; 100)	Drive cables (0.449; 100)	
		Control buttons (0.279; 100)	
		Ventilation (0.138; 100)	
		Lighting (0.134; 100)	
	Plumbing (0.237; 100)	Dirty water (0.212; 100)	Sewage flushing water (0.292; 100)
			Clean out & distributions pipe (0.286; 100)
			Control tank (0.222; 100)
			Waste management tubs/ absorption Wells (0.200; 100)
		Sprinkler (0.195; 100)	
		Box hydrant (0.209; 100)	
		Clean water (0.384; 100)	Storage tank (0.346; 100)
			Water distribution (0.333; 100)
			Booster pump (0.321; 100)
	Building Sensor System (BSS) (0.191; 100)	Light dependent resistor (0.237; 100)	
		Accelerometer (0.032; 100)	
		Wind speed sensor (0.032; 100)	
		Smoke detector (0.031; 100)	
		Hygrometer (0.125; 100)	
		AC (0.263; 100)	Blower (0.507; 100)
			Temperature controller (0.493; 100)
		Motion sensor (0.166; 100)	
		CO_2 sensor (0.115; 100)	

Table 7. The criteria of components/subcomponents/elements.

Components/subcomponents/element/sub element	Criteria
SGLC building	Comfort, safety, and health.
Structural	Strength, support for the building shape and durability
Architectural	Safety, comfort, and providing aesthetic value.
Utility	Supporting user activities, supporting health, supporting safety in emergency conditions
Electrical	Supports occupant activities and supports comfort
Electronic	Supports comfort and supports activities
Plumbing	Supports security and supports comfort
Lift	Safety & security and comfort
Buiding sensor system	Supports comfort in activities and supports security/evacuation
Dirty water	Comfort, supporting the availability of clean water, and safety
Clean water	Comfort and safety
AC	Conditioning and air circulation regulation
Wall	Provides aesthetic value, comfort, security
Ceiling	Supports comfort, supports aesthetic value
Doors & windows	Supports security, adds aesthetic value, comfort

Table 8. Arithmetic mean of structural components

Comparison of criteria/alternatives	Respondents				Arithmetic mean
	1	2	3	4	
Strength					
Column-beam	1	1	1	1	1
Column-plate	2	5	7	5	4.75
Beam-plate	2	3	5	5	3.75
Supports the shape of the building					
Column-beam	1	1	1	1	1
Column-plate	9	7	7	8	7.75
Beam-plate	3	3	5	5	4
Durability					
Column-beam	1	1	1	1	1
Column-plate	7	7	7	5	6.50
Beam-plate	4	5	5	5	4.75

Table 9. The function of SGLC building rooms.

Floor	Room function
1st first	Medical center and coworking space
2nd second	Administration room
3rd third	Meeting room
4th fourth	Classroom and coworking space
5th fifth	Classroom and coworking space
6th sixth	Classroom and coworking space
7th seventh	Classroom and coworking space
8th eighth	Classroom and coworking space
9th ninth	Classroom and coworking space
10th tenth	Classroom and coworking space
11th eleventh	Classroom and coworking space

Table 10. Type of damage of building components.

Component/subcomponent/element/sub element	Type of damage
Column, plate	Porous, cracked, bent
Beam	Broken, cracked, bent
Switches, electrical outlet, light	Loose, broken, disconnected
LCD projektor, smart board, LED TV, CCTV, fan, access point, sound system	Turns on but doesn't work, turns off
Drive cables, control buttons, ventilation, lighting	Not working, off
Sprinkler, dirty water, clean water, box hydrant	Leaking, stuck
Light dependent resistor, accelerometer, wind speed sensor, smoke detector, hygrometer,sensor CO_2, AC, motion sensor	Not working, missing
Ceramic floor	Loose, cracked, broken
Paint the walls, paint the walls, paint the doors, paint the windows	Peeling, color faded
Brick plastering	Cracked, peeling
Brick masonry, window glass	Crack, break
Ceiling frame, ceiling cover	Soft, weathered, loose
Hinge	Loose, stuck
Handle/lock, window frame	Broken, rotten

4. Results

4.1 The weighting of component, subcomponent, element, or sub-element.

Based on Table 4 to Table 6, it can be determined that the weighting of the structural, architectural, and utility components is 0.463; 0.427; and 0.089, respectively. The resulting weighting values are reasonable considering the columns are elements that support loads acting on plates and beams.

Based on Table 5, the weighting of the wall, ceiling, door & window, floor & ceramic sub-components are 0.366; 0.117; 0.429; and 0.088, respectively. This can provide an overview of maintenance priorities if there is damage to the four sub-components of architectural components. The greater the weighting means the higher the maintenance priority. Furthermore, the weighting of elements and sub-elements of architectural components can be seen in Table 5.

Table 6 shows the weighting values of utility components divided into electrical, electronic, elevator, plumbing and BSS sub-components of utility component, each of which is 0.300; 0.223; 0.049; 0.237; and 0.191, respectively. Electricity has the highest level of importance with a weighting of 0.300, followed by electronics with a weighting of 0.223. Both are important sub-components of the utility component in supporting operational academic activities at SGLC. Plumbing ranks third after electricity and electronics. This may be because plumbing is closely related to the use of clean water and disposal of dirty water. If problems occur with the plumbing, it will affect the comfort and health of users during their activities at SGLC building. Based on Table 6, the Building Sensor System (BSS) and lift occupy the two lowest positions of the utility components. The BSS has a weighting of 0.191 and the lift has a weighting of 0.049. The BSS system in the SGLC building has the function to monitor the use of electrical energy and water while the elevator has a vertical access function. The elevator weighting is the lowest due to stairs as an alternative vertical access in SGLC building. Furthermore, the weighting of elements and sub-elements of utility component can be seen in Table 6.

4.2 Condition Index of component or subcomponent or element or Sub element

The average condition index calculation results for structural, architectural, and utility components from the 1st to the 11th floor can be found in Figure 2 up to Figure 4 respectively. Based on Figure 2, the structural components are still in excellent condition, as evidenced by the condition index value of 100 for all structural components on each floor.

Based on Figure 3, there is one floor with a condition index value for architectural components less than 100, which is the 5th floor with a condition index value of 99.86. The results of the architectural component observations on the 5th floor for each room can be seen in Figure 5. The observations revealed damage to the architectural components in Classroom 5A2, as indicated by the condition index value of 99.16 for the architectural components of Classroom 5A2. Figure 6 shows damage to architectural components in classroom 5A2, where the damage occurred at the door with a condition index value of 98.05.

Figure 4 indicates that there are five floors out of a total of eleven floors with utility component condition index values less than 100, *i.e.*, on the 3rd, 4th, 6th, 9th, and 11th floors. In brief, the utility component condition index values contributing to the failure to achieve a condition index of 100 on these five floors can be seen in Figure 7. Damage to utility components is found in Meeting Room MR2 on the 3rd floor, Classroom CR 4B2 on the 4th floor, Classroom 6B3 on the 6th floor, Classroom 9B2 on the 9th floor, and the toilet on the 11th floor.

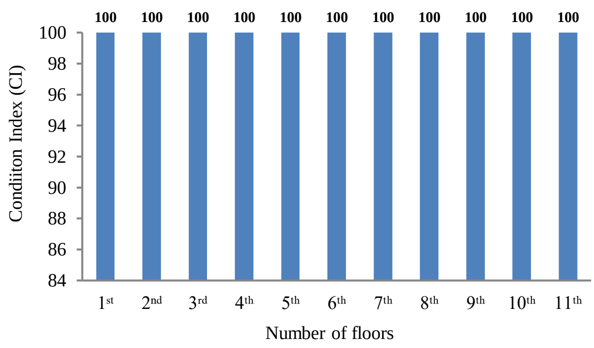


Figure 2. Diagram of the average condition index values for structural components on floors 1st up to 11th.

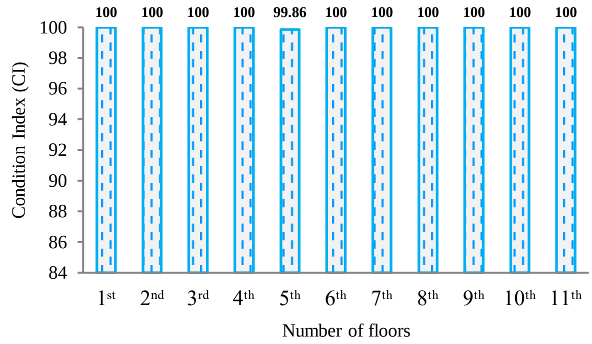


Figure 3. Diagram of the average condition index values for architectural components on floors 1st up to 11th.

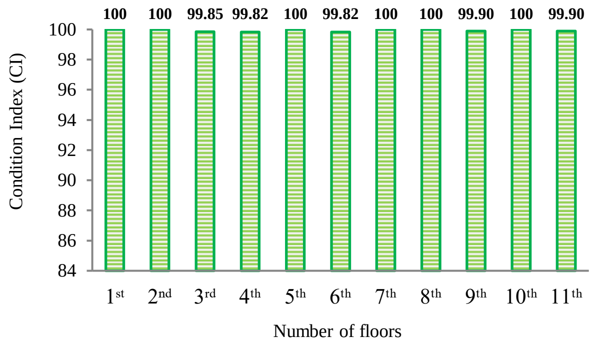


Figure 4. Diagram of the average condition index values for 11th utility components on floors 1st up to 11th.

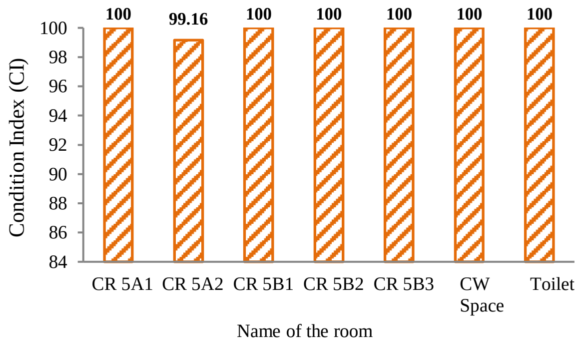


Figure 5. Diagram of the condition index values for architectural components in the room on the 5th floor.

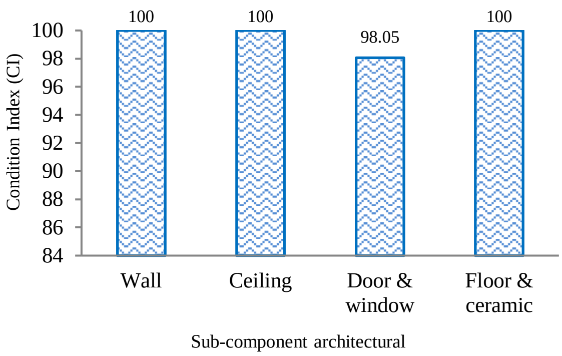
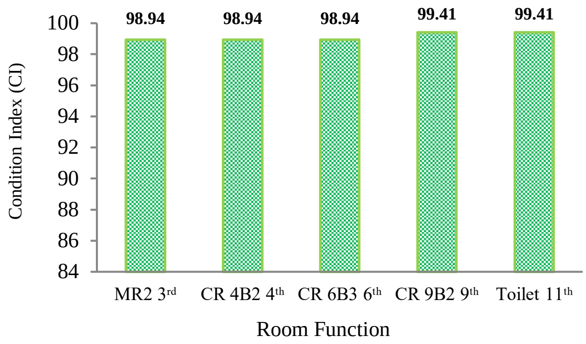


Figure 6. Diagram of the condition index values for architectural sub-components



MR: meeting room; CR: class room

Figure 7. Diagram of the condition index values of utility components.

5. Conclussion

The research results using AHP method reveal that the weighting factors of structural, architectural, and utility are 46.3%, 33.9%, and 19.8%. Below the structural level the weighting factors of columns, beams, and plates are as follows 48.3%, 42.7%, and 8.9%. Below the architecture level the weighting factors of ceilings, walls, floors, & ceramics, doors & windows are 11.7%, 36.6%, 8.8%, and 42.9%. Below the utility level the weighting factors of electrical, electronic, lift, building sensor system, and plumbing are 30%, 22.3%, 4.9%, 19.1%, and 23.7%.

Overall, the condition of structural components is good. The condition index value of structural components for all floors is 100. Overall, the condition of architectural components is good. Damage to architectural components is only found in one room on the 1st floor, namely classroom 5A2 on the 5th floor, with a condition index value of 99.16.

Damage to utility components is more common than structural and architectural components. There are five floors that have a condition index of less than 100 due to damage to utility components in several rooms on these floors, namely meeting room 2 on the 3rd floor (CI = 99.80), classroom 6B3 on the 6th floor (CI = 99.80), classroom 4B2 on the 4th floor (CI = 99.80), classroom 9B2 on the 9th floor (CI = 99.41), classroom 5A2 on the 5th floor (CI = 99.16), and toilets on the 11th floor (CI = 99.61).

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