Life Cycle Cost Analysis in Construction of Green Building Concept, A Case Study

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Abstract. Based on data from the Green Building Council of Indonesia, more than one-third of CO\textsubscript{2} gas emissions worldwide are generated by buildings, it has an impact on the environment such as global warming, ozone layer depletion, and accumulation of waste. The concept of Green Building is considered very necessary to overcome global warming and improve energy and resource efficiency. In the process of building a building that is Green Building requires a relatively high cost when compared to conventional buildings. Therefore, the Life Cycle Cost (LCC) method is used to determine the total cost needed, the optimal cost of the building, the economic age of the building, the number of crew maintenance and the level of energy efficiency. The analysis using the Life Cycle Cost method requires several related costs such as Initial Costs, Maintenance Costs, Energy Costs, Replacement Costs, and Utility Costs. The analysis was conducted using the Present Worth method within a period of 8 years from the start of building construction. Based on data processing using the Life Cycle Cost method, the optimal cost of a green building concept building is IDR 232,296,615,337 with the economic life of the building being 8 years, the optimal number of maintenance crews is 1 person and the level of energy consumption intensity is very efficient.

Keywords: Green Building, Life Cycle Cost, Economical Age, Present Worth Analysis, Energy Efficiency, Global Warming.

1. Introduction
The state of the world is currently facing major problems related to the environment such as global warming, ozone depletion, waste buildup and others. In recent years studies have shown that the global climate is changing very rapidly. Based on data from the Green Building Council of Indonesia, all CO\textsubscript{2} gas produced by buildings is around 30-40\% and therefore buildings have an important role in consuming energy throughout the world [1]. From these problems to minimize the impact that occurs by applying the concept of environmentally friendly buildings or the concept of green building. Building construction with the concept of Green Building is one of the government's efforts in energy efficiency and resource issues that affect the costs required in the Green Building construction process [2]. Indonesia's achievement in implementing development with the Green Building concept can save energy by 853,914 MWh / year, as well as cost savings of $ 68,313,105 / year and CO2 reduction of 605,425 Metric Tons / year. This achievement is expected to increase as development is carried out, especially...
in Jakarta, Indonesia. The process of building a Green Building requires a relatively high cost when compared to conventional buildings, but in its application that focuses on energy efficiency and resources will be an advantage that affects operational costs, maintenance costs and replacement costs [3]. Therefore, Life Cycle Cost is a tool to optimize buildings with a long-term perspective and to exploit sustainable economic principles [4] and also see how much the total costs are removed from the construction stage up to the economic age of the building and the optimal number of maintenance crews.

2. Method

2.1. Maintenance Management
According to the journal [5] Maintenance is defined as an activity so that damaged components/systems will be returned/repaid under a certain condition in a certain period. Maintenance Management is an activity that is carried out repeatedly with the aim that the equipment is in the same condition as the initial state.

2.2. Life Cycle Cost
Based on journal [6] Life Cycle Costs (LCC) are the sum of estimated costs over the entire life cycle from initiation to completion, both equipment and projects. LCC components can be broadly classified into design and development costs, acquisition costs, operating costs and disposal costs. Life Cycle Cost approach emphasizes the consideration of total cost for the operation of the equipment from the initial cost [7].

![Figure 1. Life Cycle Cost Classification](image)

Life Cycle Cost is classified into several parts, there are Sustaining Cost and Acquisition Cost [7]. Sustaining cost is the sum of annual energy or operational costs, annual maintenance costs, and annual replacement costs and for the Acquisition Cost is the sum of annual initial costs including construction costs, initial costs of green building features and administrative costs. In this method, the formula according to [5]:

$$LCC = SC + AC$$  \hspace{1cm} (2.1)

Where:
LCC: Life Cycle Cost
SC: Sustaining Cost
AC: Acquisition Cost

2.3. LCC Calculation Procedure
Steps in calculating life cycle cost based on [8], there are :
- Collecting data and categories of costs required
- Input the data of Energy Cost, Operational & Maintenance Cost and Replacement Cost in a year
- Calculate the total cost of energy cost (multiplies the cost of each usage and total usage)
- Calculate the total cost of operational and maintenance cost
• Calculate the total cost of replacement cost (multiplies the cost of each replacement unit and total unit)
• Calculate Sustaining Cost = Total Energy Cost + Total Operational & Maintenance Cost + Total Replacement Cost
• Calculate annual cost of the sustaining cost (using single-payment present worth analysis)
• Single-payment present worth analysis (P= F(P/F,i,n)
• Input the data of Construction Cost, Initial Cost for Feature Green Building, Administrative Cost, and Population Cost
• Calculate the total cost of construction cost
• Calculate the total cost of initial cost (multiplies the cost of each unit and total unit)
• Calculate the total cost of administrative cost (multiplies the construction cost and precentage)
• Calculate Acquisition Cost = Total Construction Cost + Total Initial Cost + Total Administrative Cost + Population Cost
• Calculate annual costs from the acquisition cost category (using single-payment present worth analysis)
• Single-payment present worth analysis (P= F(P/F,i,n)
• Life Cycle Cost = Annual Sustaining Cost + Annual Acquisition Cost

2.4. Green Building
According to DKI Jakarta Provincial Governor Regulation number 38, 2012 that Green Buildings is a building that is responsible for the environment and efficient resources from the planning, implementation of construction, utilization, maintenance, until deconstruction.
The requirements and criteria for developing a Green Building concept that has been determined by the government are:
1. Building Types and Extents, for example, the type of building that is a business, in the field of trade, must have a limit of the entire building floor area of more than 50,000 m² (fifty thousand square meters), while for the type of building in the health service sector, it must have a floor area of more than 20,000 m², etc.
2. Building Technical, Technical requirements for green buildings for new buildings include Energy Efficiency, Water efficiency; Indoor air quality, land and waste management; and Implementation of construction activities.

2.5. Life Cycle Cost on Green Building
LCC has a long history in Denmark with sustainable building construction and emphasizes energy saving as a major driver of life cycle costs [9]. Another strong driver of the LCC in Denmark is the construction of buildings with certificates from DGNB for sustainable buildings and urban areas. Strongly supported by industry, the Danish Green Building Council (DK-GBC) was established to manage the DGNB scheme and promote sustainable development more generally. DGNB assesses buildings based on six groups of criteria include (i) Environmental Quality; (ii) Economic Quality; (iii) Social, Cultural and Functional Quality; (iv) Technical Quality; (v) Process Quality; (vi) Site Quality.
Based on research [1] that has been used for environmental evaluations of buildings and related industrial buildings (including construction products, construction systems, buildings, and civil engineering construction) through highly scattered, summarized and regulated literature. The journal also explains that energy use in a building can change to go up or down depending on the consumption of a building at the total cost of construction, material costs, energy costs for materials, operational energy costs, for example, Buildings built with most materials can be used again as a component of new materials and buildings where all materials and components are new. The results show that about 55% of energy can be saved with the material being reused as a new component.
Based on others journal [8] the construction of green building cost a relatively higher cost compared to the cost of conventional building construction. The building with the concept of green building is only
focused on energy efficiency throughout the project life cycle will be a sustainable advantage in its operational costs. From the results of Life Cycle Cost analysis with cost categories consisting of Initial Costs, Energy Costs, Operational Costs, Maintenance, and Replacement Costs, the total cost of the Malaysian Diamond Building cycle is IDR 759,290,649,000. If you include the Remaining Value in the Life Cycle Cost category, the total cost of living for the Diamond Building will be IDR 559,940,649,000.

3. Result and Discussion

3.1 Sustaining Cost Calculation

There are breakdown of the energy cost, operational and maintenance cost and replacement cost estimate which are components in the sustaining cost;

| Description                        | Usage       | Cost/usage | Total Cost |
|------------------------------------|-------------|------------|------------|
| Day-Lighting Cost                  | 25.005 kWh  | IDR 1,115  | IDR 27,881 |
| Garden Lamp ø45 PLC-1x18 W         | 0.072 kWh   | IDR 1,115  | IDR 80     |
| Hanging Lamp REF 23 W              | 0.391 kWh   | IDR 1,115  | IDR 436    |
| Halogen Lamp 50 W                  | 1.25 kWh    | IDR 1,115  | IDR 1,394  |
| Hanging Lamp (Decorative)          | 0.092 kWh   | IDR 1,115  | IDR 103    |
| Water Usage Cost/month             | 7.57 m²     | IDR 20,000 | IDR 151,400|
| **Total Energy Cost**              |             |            | IDR 181,293|
| **Total Energy Cost/year**         |             |            | IDR 2,175,517.80|

Seen from the Table 1 Energy costs are focused on electricity and water use costs, electricity usage costs in the alerts from PLN are IDR 1,115 per kWh multiplied by total usage per month, while for water use costs are IDR 20,000 per m² in electricity and water usage utilizing energy-saving lamps and water-saving sanitation technology.

| Description                                      | Period | Cost/Period | Total Cost |
|--------------------------------------------------|--------|-------------|------------|
| Building Maintenance Cost :                      |        |             |            |
| Cleaning Cost                                    | 12     | IDR 35,000  | IDR 420,000|
| Security and Safety Cost                         | 2      | IDR 245,000 | IDR 490,000|
| Environmental Control Costs                      | 1      | IDR 155,000 | IDR 155,000|
| Building and Infrastructure Maintenance Costs     | 12     | IDR 20,000  | IDR 240,000|
| Maintenance Feature Green Building Cost :        |        |             |            |
| Garden Maintenance Costs (Green Area)            | 8      | IDR 25,000  | IDR 200,000|
| Rainwater Harvesting Maintenance Costs            | 8      | IDR 25,000  | IDR 200,000|
| Maintenance Crew Salary                          | 1      | IDR 4,267,349 | IDR 4,267,349|
| **Total Maintenance**                             |        |             | IDR 22,327,349|
| **Total Maintenance/year**                       |        |             | IDR 267,928,188|

Based on Table 2, Maintenance costs is performed every month on a regular basis and the maintenance costs for each component are different with different maintenance times as well, while the operational costs calculated are maintenance crew salaries obtained from the Jakarta regional minimum of IDR 4,267,349 for one crew member.
Table 3 Replacement Cost Estimates for Green Building

| Description                              | Year | Total Cost  |
|------------------------------------------|------|-------------|
| Replacement Cost                         |      |             |
| Daylighting Replacement Cost             | 8    | IDR 14,811,800 |
| Building Facility Replacement Cost       | 5    | IDR 18,500,000 |
| Rainwater Harvesting Replacement Cost    |      |             |
| Pump Replacement                         | 8    | IDR 450,000  |
| Water Storage Tank                       | 8    | IDR 2,125,000 |
| Water filtration                         | 5    | IDR 705,000   |
| Total Replacement Cost                   |      | IDR 34,466,800 |
| Total Sustaining Cost                    |      | IDR 301,570,506 |

On the Table 3, Replacement costs are only done to replace some components that cannot be reused or have been completely damaged and replacement of components is often done about 5 years or more after the age of the component, each component has a different replacement costs with different ages as well.

From all the calculations that have been done, the total obtained from the sustaining cost which is the sum of energy costs, operational & maintenance costs, and replacement costs, the total sustaining cost is IDR 301,570,506.

3.2 Acquisition Cost Calculation

There are breakdown of the construction cost, initial feature green building cost, administrative cost and population cost estimate which are components in the acquisition cost;

Table 4 Construction Cost Estimates for Green Building

| Description               | Volume  | Cost/Volume | Total Cost    |
|---------------------------|---------|-------------|---------------|
| Construction Cost         |         |             |               |
| a. Land Cost              | 25,677 m² | IDR 5,000,000 | IDR 128,385,000 |
| b. Building Cost          |         | IDR 14,916,325,790 | IDR 14,916,325,790 |
| c. Cost of Used Equipment | 36.41%  | IDR 14,916,325,790 | IDR 5,431,034,220 |
| Total Construction Cost   |         | IDR         | IDR 148,732,360,010 |

Based on Table 4 Estimated construction costs consist of the process of purchasing land, building construction and the cost of consumable equipment. The assumption from the purchase of land in South Jakarta is IDR 5,000,000 for 1 m², for the cost of green building construction costs is IDR 14,916,325,790 while for the cost of consumable equipment is 36.41% of the construction costs.

Table 5 Initial Cost Feature Green Building Estimates

| Description               | Unit  | Cost/Unit | Total Cost |
|---------------------------|-------|-----------|------------|
| Feature Green Building Initial Cost : |       |           |            |
| Daylighting               |       |           |            |
| a. Lamp TL-5-2x28 W      | 78    | IDR 27,000 | IDR 2,106,000 |
| b. Downlight PLC-2x26 W   | 46    | IDR 29,800 | IDR 1,370,800 |
| c. Downlight PLC-2x18 W   | 118   | IDR 27,000 | IDR 3,186,000 |
Table 5 Initial Cost Feature Green Building Estimates

| Description                  | Unit | Cost/Unit | Total Cost |
|------------------------------|------|-----------|------------|
| d. Downlight PLC-1x18 W      | 33   | IDR 27,000| IDR 891,000|
| e. Downlight PLC-1x13 W      | 191  | IDR 38,000| IDR 7,258,000|
| Air Conditioning :           |      |           |            |
| a. AC Split Duct 1 PK        | 3    | IDR 3,300,000| IDR 9,900,000|
| b. AC Split Duct 1.5 PK      | 15   | IDR 4,100,000| IDR 61,500,000|
| c. AC Split Duct 2 PK        | 24   | IDR 5,450,000| IDR 130,800,000|
| d. AC Split Duct 2.5 PK      | 48   | IDR 7,500,000| IDR 360,000,000|
| Rainwater Harvesting :       |      |           |            |
| a. Recycle Tank              | 3    | IDR 3,200,000| IDR 9,600,000|
| b. Flush Plants /Lanscape    | 3    | IDR 2,500,000| IDR 7,500,000|
| Total Initial Feature Green Building Cost |      | | IDR 604,011,800 |

As we seen on Table 5 Initial Cost Feature Green Building is the cost of each component or material used to save energy expended, for example, the use of electricity using energy saving TL-5 LED lamps with several models and types as well as the use of AC Split Duct saving electricity on each floor of the building with some species also save water by utilizing rainwater harvesting. The price of each component is obtained from e-commerce from various lights and air conditioners.

Table 6 Administrative Cost and others

| Description           | Percentage | Construction Cost | Total Cost    |
|-----------------------|------------|-------------------|---------------|
| Administrative Cost   | 5%         | IDR 148,732,360,010| IDR 7,436,618,000.51 |
| Others Cost           | 10%        | IDR 148,732,360,010| IDR 14,873,236,001.01 |
| Total                 |            | IDR               | IDR 171,646,225,812.00 |

On Table 6 Administrative costs in construction are required such as the cost of verifying documents, taxes and other government costs, as well as unexpected costs in building construction. Administrative costs and others are assumed to be 5% and 10% of the construction costs for each administration fee and unexpected costs.

From all the calculation, the total of Acquisition Cost is IDR 171,646,225,812.00 before adding up the salvage cost and book value. The total Acquisition Cost will be added to the salvage cost and book value when calculating using present worth analysis.

Table 7 Population Cost Estimate for Green Building

| Year | Salvage Cost | Construction Cost | Book Value |
|------|--------------|-------------------|------------|
| 1    | IDR 130,884,476,809 | IDR 148,732,360,010 | IDR 16,360,559,601 |
| 2    | IDR 115,178,339,592  | IDR 148,732,360,010 | IDR 14,397,292,449 |
| 3    | IDR 101,356,938,841  | IDR 148,732,360,010 | IDR 12,669,617,355 |
| 4    | IDR 89,194,106,180   | IDR 148,732,360,010 | IDR 11,149,263,272 |
| 5    | IDR 78,490,813,438   | IDR 148,732,360,010 | IDR 9,811,351,680 |
| 6    | IDR 69,071,915,826   | IDR 148,732,360,010 | IDR 8,633,989,478 |
| 7    | IDR 60,783,285,927   | IDR 148,732,360,010 | IDR 7,597,910,741 |
| 8    | IDR 53,489,291,615   | IDR 148,732,360,010 | IDR 6,686,161,452 |
Population cost calculation consists of book value and salvage costs with a fixed cost construction cost of IDR 148,732,360,010 so that there is a calculation of the remaining cost of a building by multiplying the construction cost and assuming the depreciation 12% per year while for book value calculation is a reduction in construction costs and the remaining costs already divided by the age of the building, the results of salvage cost and book value can be seen from the Table 7.

3.3 Life Cycle Cost Calculation
Life Cycle Cost is the sum of annual sustaining costs and annual acquisition costs that previously used a single-payment present analysis or present worth analysis assuming if there were 1 to 8 maintenance crew and the age of the building since it was built 8 years ago, so that the results obtained are age the economic cost of the building (vertical column year in Table 8), the number of maintenance crew (horizontal column in Table 8) and the optimal total cost of the green building concept, the results of the Life Cycle calculation are as follows:

Table 8 Life Cycle Cost Calculation

| Maintenance Crew | Year 1 | Year 2 | Year 3 | Year 4 |
|------------------|-------|-------|-------|-------|
| IDR 289,717,867,781 | IDR 289,760,305,725 | IDR 289,802,743,669 | IDR 289,845,181,613 |
| IDR 275,923,724,425 | IDR 275,967,316,681 | IDR 276,010,908,937 | IDR 276,054,501,193 |
| IDR 264,355,316,693 | IDR 264,400,094,658 | IDR 264,444,872,624 | IDR 264,489,650,589 |
| IDR 254,761,072,235 | IDR 254,807,068,161 | IDR 254,853,064,087 | IDR 254,899,060,013 |
| IDR 246,920,029,417 | IDR 246,967,276,432 | IDR 247,014,523,447 | IDR 247,061,770,462 |
| IDR 240,638,175,511 | IDR 240,686,707,645 | IDR 240,735,239,793 | IDR 240,783,771,913 |
| IDR 235,745,224,625 | IDR 235,795,076,832 | IDR 235,844,929,040 | IDR 235,894,781,248 |
| IDR 232,091,782,585 | IDR 232,142,990,773 | IDR 232,194,198,961 | IDR 232,245,407,149 |

Based on Table 8 the output from the Lifecycle Cost method with an estimated maintenance crew of 1 to 8 people and an estimated building of around 8 years due to construction starting in 2013 is IDR 232,296,615,337 for an optimal Lifecycle Cost with 1 maintenance crew and an economic age of 8 years.

3.4 Efficiency Energy Calculation

Table 9 Emission CO2 Calculation

| Maintenance Crew | Year 5 | Year 6 | Year 7 | Year 8 |
|------------------|-------|-------|-------|-------|
| IDR 289,887,619,556 | IDR 289,930,057,500 | IDR 289,972,495,444 | IDR 290,014,933,388 |
| IDR 276,098,093,449 | IDR 276,141,685,705 | IDR 276,185,277,961 | IDR 276,228,870,216 |
| IDR 264,534,428,554 | IDR 264,579,206,519 | IDR 264,623,984,485 | IDR 264,668,762,450 |
| IDR 254,945,055,939 | IDR 254,991,051,865 | IDR 255,037,047,791 | IDR 255,083,043,717 |
| IDR 247,109,017,477 | IDR 247,156,264,492 | IDR 247,203,511,507 | IDR 247,250,758,522 |
| IDR 240,832,304,047 | IDR 240,880,836,181 | IDR 240,929,368,315 | IDR 240,977,990,449 |
| IDR 235,944,633,456 | IDR 235,994,485,664 | IDR 236,044,337,872 | IDR 236,094,190,080 |
| IDR 232,296,615,337 | IDR 232,347,823,525 | IDR 232,399,031,713 | IDR 232,450,239,901 |

Table 9 Emission CO2 Calculation

| Emission CO2 | Total Energy Consumption | Emission CO2 |
|--------------|--------------------------|--------------|
| Baseline     | 827,337.92 kWh           | 737,158.17 kg |
| Design       | 659,022.56 kWh           | 587,189.10 kg |
| Deviation    | 168,315.36 kWh           | 149,969.07 kg |
From Table 9 Carbon dioxide emissions per kWh of annual energy consumption are 0.891 kg. The reduction of carbon dioxide emissions is calculated from the difference in energy consumption between the baseline building and the design multiplied by the annual energy consumption of 0.891 kg so that the reduction of carbon dioxide emissions is 149,968.99 kg.

### Table 10 Energy Consumption Intensity

| No | Floor        | Total Area | Total Watt |
|----|--------------|------------|------------|
| 1  | Basement Floor | 779.68 m²  | 5990 kWh   |
| 2  | 1st Floor    | 779.68 m²  | 5284 kWh   |
| 3  | 3rd Floor    | 889.98 m²  | 5239 kWh   |
| 4  | 4th Floor    | 890.04 m²  | 7436 kWh   |
| 5  | 5th Floor    | 689.07 m²  | 2961 kWh   |
|    | Total        | 4028.45 m² | 26910 kWh  |

Seen from Table 10 that the intensity of energy consumption is said to be very efficient if the intensity value of 4.17-7.92 kWh/m² so that the result of the division between Total Watts and Total Area is 6.68 then, the intensity of energy consumption in the Green Building is very efficient.

### 4. Conclusion

Based on the analysis and discussion in the previous chapter, the cost categories contained in the Green Building, consist of Initial Costs, Energy Costs, Maintenance Costs, and Replacement Costs, using the Life Cycle Cost method, the optimal cost of a Green Building concept is IDR 232,296,615,337 with the economic life of the building is 8 years because the construction process starts in 2013, so that the economic age is still followed and the optimal maintenance crew is 1 maintenance crew. The intensity of energy consumption in the Green Building case study is 6.68 kWh/m², which can be said that the intensity of energy consumption in the green building concept is very efficient than conventional buildings. For future research, it is expected to be able to compare costs used in buildings that are Green Building concepts and conventional buildings, and calculate overall energy efficiency and compare between Green Buildings and conventional buildings.

### 5. References

[1] L. F. Cabeza, L. Rincón, V. Vilariño, G. Pérez, and A. Castell 2014 Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review. *Renew. Sustain. Energy Rev.* **29**, pp. 394–416.

[2] F. Salvado, N. M. de Almeida, and A. Vale e Azevedo 2018 Toward improved LCC-informed decisions in building management. *Built Environ. Proj. Asset Manag.* **8**(2), pp. 114–133.

[3] H. Islam, M. Jollands, and S. Setunge 2015 Life cycle assessment and life cycle cost implication of residential buildings - A review. *Renewable and Sustainable Energy Reviews*.

[4] A. Pelzeter 2007 Building optimisation with life cycle costs – the influence of calculation methods. *J. Facil. Manag.* **5**(2), pp. 115–128.

[5] A. R. Eliyus and J. Alhilman 2014 Estimasi Biaya Maintenance Yang Optimal Dengan (Studi Kasus: Pt Toa Galva). *J. Rekayasa Sist. Ind.*, pp. 48–54.

[6] C. Ghosh, J. Maiti, M. Shafiee, and K. G. Kumaraswamy 2018 Reduction of life cycle costs for a contemporary helicopter through improvement of reliability and maintainability parameters. *Int. J. Qual. Reliab. Manag.* **35**(2), pp. 545–567.

[7] A. Anggriawan and A. Kurniawati 2015 Biaya Maintenance Dengan (Studi Kasus: PT Telkomsel Indonesia). *J. Rekayasa Sist. Ind.* **2**(3), pp. 33–38.

[8] T. Firsani and C. Utomo 2012 Analisa Life Cycle Cost pada Green Building Diamond Building Malaysia. *Tek. ITS* I(September), pp. D34–D38.

[9] K. Haugbølle and L. M. Raffnsste 2019 Rethinking life cycle cost drivers for sustainable office buildings in Denmark. *Facilities* **37**(9–10), pp. 624–638.