Evaluation of Green Warehouse Performance Indicators Using Analytical Hierarchy Process and Objective Matrix (Case Study: PLN Cilegon)

Yelita Anggiane Iskandar[1], Mega Rizkah Sudiar[2]

{yelita.ai@universitaspertamina.ac.id[1], 102417016@student.universitaspertamina.ac.id[2]}

Logistics Engineering Pertamina University, Jl. Teuku Nyak Arief, Simprug, Kebayoran Lama, Kota Jakarta Selatan, Daerah Khusus Ibukota Jakarta 12220, Indonesia[1,2]

Abstract. State electricity enterprise (PLN) as a state-owned enterprise in Indonesia is had and committed to support government's efforts to reduce greenhouse gas (GHG) emissions and to implement Sustainable Development Goals (SDGs) by managing all environmental aspects. To achieve PLN's strategy in continuously providing the green-based energy and showing the evidence of compliance to the rules, it is necessary to evaluate its operational activities, including in the warehouse area by measuring the success of its green concept implementation. The evaluation was carried out by identifying the performance indicators currently implemented, determining the weight using the Analytical Hierarchy Process (AHP), assessing the productivity using the Objective Matrix (OMAX), and classifying the accomplishment with the Traffic Light System (TLS). Based on the data processing and analysis, there are 8 performance indicators found regarding the green warehouse concept: 2 good, 3 moderate, and 3 poor, they are related to waste, environmental management, emission control, building, materials, lighting energy consumption, handling equipment, and fuel use.

Keywords: Performance Indicators, Green Warehouse, Analytical Hierarchy Process, Objective Matrix, Traffic Light System.

1 Introduction

Observing the phenomenon of climate change on earth in recent years, many parties feel concerned about the current environmental conditions and worried about the sustainability of the environment in the future. One of the main factors for this phenomenon is the increase in greenhouse gas (GHG) emissions. Given the importance of efforts to reduce the GHG emissions, various parties are increasingly concerning for the environmentally and friendly movements and campaigns in the community. Many companies are starting to realize the importance of maintaining environmental sustainability and implementing the concept of sustainability as one of the key performance indicators of the company's success. The governments in various

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countries also play a role by determining strict policies related to reducing GHG emissions and urging companies to comply with these policies. In an effort to reduce GHG emissions, the Indonesian government followed up on the agreement of the UN Climate Change Conference which discussed phenomena related to world climate change through Law No. 16 of 2016 on 24 October 2016 ratifying the Paris Agreement to the United Nations Framework Convention on Climate Change (1). In order to achieve the target in the Paris Agreement, the Government of Indonesia involves companies in Indonesia to participate in reducing GHG emissions.

State electricity enterprise (PLN) as a State-Owned Enterprise engaged in the electricity sector realizes that every operational activity carried out by the company has a direct impact on environmental sustainability. PLN is committed to supporting the government's efforts to reduce GHG emissions and to implement Sustainable Development Goals (SDGs) related to reducing GHG emissions by managing environmental aspects in every operational activity carried out as well as in products and services provided in a sustainable manner (2). In 2020, PLN has implemented a strategic initiative program called "#Transformasi PLN" with the tagline "Power Beyond Generations". The program has four strategic targets, i.e., green, innovative, customer-focused, and lean. One of the four strategic targets is in accordance with the sustainability principle, called "green" with the main focus on making PLN a company that is able to provide environmentally friendly energy. In order to achieve this goal, PLN continues to evaluate and develop its operational activities that have the potential to contribute to a negative impact on the environment (3).

Operational activities carried out by PLN include administrative activities, electricity development activities, and electricity production and distribution. Activities that have the potential to contribute negatively to the environment and generate emissions are electricity development activities (warehousing and transportation of materials) as well as electricity production and distribution activities. PLN has various types of warehouses which are classified based on the type of material stored. In general, warehouses owned by PLN are divided into warehouses for new materials and used materials, as well as warehouses for unused materials. The warehouse that is used as the object of this research is the warehouse of unused material. The unused material warehouse is used to store Non-operating Fixed Assets called ATTB. ATTB are fixed assets that are no longer used or it can be said that these assets have been discontinued from operational activities, and the economic value of these assets has also experienced depreciation (4).

The sustainability concept implemented from strategic initiatives that have been launched by PLN is also implemented in all operational activities of the company, including warehousing activities. According to the reference, warehousing activities account for 11% of the total emissions of logistics activities, so they can be taken into consideration for implementing the concept of sustainability (5). PLN itself has implemented the green warehouse concept in several warehouses in certain regional areas. Based on the references, the green warehouse concept refers to a managerial concept that integrates and implements environmentally friendly operations intending to minimize energy consumption, energy costs, and GHG emissions from a warehouse. The application of a managerial concept that integrates and implements environmentally friendly practices in business is important because it can resolve the impacts of climate change and other environmental problems, it is also a long-term strategy for a company to become sustainable for both current and future generations (6). Primarily, the green warehouse concept has a goal to minimize negative impacts on ecosystems and the environment

(7). Some of the benefits that may be obtained by the company if implementing the green warehouse concept in addition to complying with the laws and regulations that have been set by the government are being able to preserve the environment and being able to cut costs that must be incurred from warehousing activities effectively (8). Thus, the optimization of the green warehouse concept might be seen to improve the efficiency as well as the competitiveness of the company (9).

The manifestation of human awareness of sustainability takes various forms, not only related to personal life but also to a wider area. The industrial sector and the supply chain that surrounds it are also increasingly aware of the effects of business activities on the environment. The warehouse as one of the actors in the supply chain is also inseparable from the obligation to protect the environment. As research conducted by Waaly et al. (10), the application of green performance is measured based on the supply chain operations reference (SCOR framework), taking the observation object of a leather tanning company in Indonesia. From their experiments, it is known that the "percentage of the number of suppliers with EMS or ISO 14001 certification" is the key performance indicator (KPI) with the highest weight.

As mentioned by Fichtinger et al. (11) & Bajec et al. (12), to this day there has been considerable research on the environmental impact of supply chains but most of them focused on the transportation while warehousing there were relatively few except under the context of distribution networks, as also stated by Chandra (13). More often found in the literature, topics related to warehouse performance are those in general, meaning that it does not specifically pay attention to environmental and sustainability factors. Their study is an example which takes a case study at a common warehouse of PT GMS in Jakarta. The research was conducted by applying the balanced scorecard (BSC) with the results that 3 aspects: financial, customer, and internal processes were good and needed to be maintained while 1 other aspect, learning, and growth still needed to be improved.

The study of green warehousing can be found in several references as shown by Agyabeng-Mensah et al. (14), which stated that green warehousing along with logistics optimization negatively affects economic performance but increase economic performance through the implementation of supply chain sustainability. Their research was taken in Ghana involving 200 managers of manufacturing companies. They used partial least square structural equation modeling (PLS-SEM) under the concept of the resource dependency theory (RDT). A study by Torabizadeh et al. (15), used a similar approach using structural equation modeling (SEM) to identify and weight indicators to assess sustainability in a warehouse management system and produced 33 key performance indicators which can be applied across industry. Another literature by Ghani et al. (16), developed a theoretical framework to later measure the effectiveness and responsiveness of the general warehouse covering an aspect of operation extending toward green eco-friendly considerations. They identified gap analysis between prior and after a full standard system implemented through extensive literature review with no quantifiable performance score provided. Incorporation of green elements in measuring warehouse performance was also conducted by Ali et al. (17). They proposed the concept of fuzzy Delphi and Best Worst Method to rank the sustainability performance improvement in a warehouse. With object observation of warehouses of frozen food supply chains in Saudi Arabia, it was confirmed that green operations for energy and resource conservations encouraged sustainability performance outcomes. Another similar study was proposed by Kamarulzaman et al. (18), considering warehouses in Malaysian food-based industry. They measure the adoption level of the manufacturers' performance towards green initiatives in warehousing and found that it was well applied.

Research on fixed asset warehouses (ATTB) is very rare, one of them conducted by Indracahya (19), which takes PT Bio Farma in Indonesia as the observation object whose description is similar to the observation of this study. The difference is that this Bio Farma warehouse was still in the planning stage where it was necessary to prepare its needs therefore the performance of green warehouse is not the focus of discussion.

Previous research on evaluating performance indicators are using several methods, research conducted by Waaly et al. (10), used Green Supply Chain Management (GSCM) to integrate and implement environmental and supply chain aspects, Supply Chain Operation Reference (SCOR) to evaluate supply chain performance, and Analytical Hierarchy Process (AHP) to determine the highest weight of key performance indicator in the leather industry by focusing on environmental aspects. Their research obtained 18 key performance indicators that can be used in measuring the performance of green procurement. A study by Bidarti et al. (20), used AHP to determine the performance indicator weight, Objective Matrix (OMAX) to calculate the scoring system, and Traffic Light System (TLS) to find out whether the performance indicator of supplier network phase rice supply chain management in South Sumatra needs improvement or not. Their results show that the overall performance of supplier network phase rice supply chain management is in the yellow category, which means that the performance has not achieved the expected performance in terms of rice supply chain even though the result is close to the pre-determined target.

This research focuses on evaluating green warehouse performance indicators that have been implemented in PLN's Cilegon ATTB warehouse. The warehouse has implemented several practices related to the green warehouse. From the interview results with the company, the problem that can be identified is that the company wants to improve its performance by evaluating performance indicators related to the green warehouse concept, but the company does not yet have a perfect design related to the assessment of performance indicators which are categorized based on their performance results. The main objective of this research is to identify and evaluate the green warehouse performance indicators currently implemented by PLN's Cilegon ATTB warehouse. The evaluation was carried out by identifying the performance indicators currently implemented, first by determining the weight using the AHP which is a very well-known method in realizing the relative importance between items, here are the green warehouse indicators. The AHP is not sufficient to assess the indicators scoring with various value scale therefore we use the OMAX to measure the overall performance. The final step would be the classification the accomplishments with the TLS. The use of TLS is required to better visualize the evaluation results of performance indicators.

The remaining sections of this research are organized as follows: section 2 presents the research methodology or framework of this research. Section 3 presents the related studies between the previous research and this research. Section 4 presents the results obtained and discussion. Then, section 5 provides the conclusion of this research.

2 Research methodology

The method used to find the best solution to the problems in this research is quantitative and qualitative methods. The quantitative method was chosen to determine the weight and score of the company's performance indicators, so that quantitative results were obtained. While the selection of qualitative methods is done to make it easier to describe the performance indicators based on their performance classifications. The steps that need to be carried out in this research are shown in the form of a flow chart as can be seen in Figure 1.

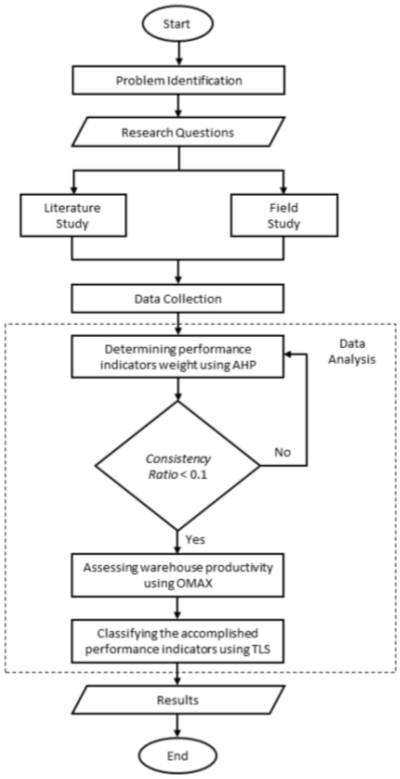

Fig. 1. Research methodology flow chart.

3 Basic theory

3.1 Green warehouse

Green warehouse can be defined as a managerial concept that integrates and implements environmentally friendly operations to minimize energy consumption, energy costs, and GHG emissions from a warehouse (7). The green warehouse concept refers to the concept of 'go green' or environmentally friendly practices that focus on efforts to use alternative fuels, use natural resources wisely, and make decisions regarding cost-effective spending (18). The application of the green warehouse concept is able to help maintain the condition of the environmental ecosystem ethically and be able to reduce operating costs in the long term (9). The existence of environmentally friendly practices in warehousing activities can help reduce the carbon footprint in the air while reducing operational costs and increasing a company's social responsibility (21). On the other hand, the company also uses the green warehouse concept as a form of participation in the trend of preserving the environment that can attract public attention, so that the company gains a competitive advantage when compared to other companies (22).

Based on general topics or themes, green warehouse is divided into 3 (three) aspects or assessment criteria, i.e., green warehouse management, warehouse building features, and energy consumption. Green warehouse management focuses on warehouse managerial practices that apply the green warehouse concept through certification, policies, guidelines, and regulations related to more environmentally friendly warehousing activities. Warehouse building features focus on the use of warehouse building supporting features that are able to optimize the use of natural resources around the warehouse building. Energy consumption focuses on the use of supporting equipment for warehouse activities that are more energy-efficient and use energy sources that are more environmentally friendly. The example of the application of each of the green warehouse assessment criteria can be seen in Table 1.

Table 1. Green warehouse criteria.

Criteria	Indicators	Reference
Green warehouse management	Environment certification	[23]
	Application of Triple Bottom Line (TBL) concept	[21]
	Cap-and-trade emission policy	[22], [24]
	Sustainability guidelines	[25]
Warehouse building features	Use of eco-friendly material	[26]
	Use of air ventilation	[27]
	Use of natural lighting	[27]
Energy consumption	Use of manual handling	[7]
	Use of alternative fuels	[7]
	Energy consumption from material handling equipment	[7]
	Energy consumption from lighting equipment	[21]

3.2 Slovin‘s formula

Before distributing the questionnaire, it is necessary to calculate the number of respondents who will fill out the questionnaire with a simple statistical test. These calculations need to be done to ensure that the results obtained represent the existing population. One of the formulas that can be used to calculate the number of respondents is the Slovin formula. Slovin’s formula is generally used to determine the proper number of samples in a population. Slovin’s formula was first formulated in 1960 by Slovin (28). The sample size is calculated using Slovin’s formula as shown in the following equation:

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

Where n is the sample size, N is the population size, and e is the significance level (α). The higher the value of e is determined, the higher the level of accuracy or it can be said that the existing data is believed to represent the entire population (29).

3.3 Analytical hierarchy process

Analytical Hierarchy Process (AHP) was first proposed by Thomas L. Saaty in 1971 – 1975 as a general theory of measurement. The theory is used to calculate the ratio scale of pairwise comparisons. This comparison can be made using actual measurements or can use a basic scale capable of reflecting the relative strength of a preference. AHP is very concerned about consistency, measurement, and the relationship between several elements contained in the hierarchical structure. AHP is generally applied for the purposes of multi-criteria decision making, planning, resource allocation, and solving other problems (30). The AHP method was first created to solve complex problems with minimal availability of data and statistical information. AHP is a method that can be used to solve Multi-Criteria Decision Making (MCDM) problems (31). The advantage of the AHP method is that it is able to translate evaluations in qualitative form into quantitative results that can be measured. In AHP, decision-makers select various criteria in a hierarchical structure. The validity of the selected criteria will be calculated by measuring the consistency of the assessment (32). The AHP method has several basic principles, i.e., decomposition, comparative judgment, synthesis of priority, and logical consistency. The AHP assessment is carried out using a predetermined importance scale, as shown in Table 2 (33).

Table 2. Importance scale.

Intensity of importance scale	Definition
1	Two indicators are equally important
3	One indicator is moderate important over another
5	One indicator is strong important over another
7	One indicator is very strong important over another
9	One indicator is absolutely important over another
2, 4, 6, 8	Values between the two adjacent considerations
Reciprocals (1/3, 1/5, etc.)	If indicator *i* has one of the above values when compared with indicator *j*, then indicator *j* has the reciprocal value when compared with indicator *i*.

Before getting the weighting results for each element in the hierarchy, it is necessary to do five steps to solve the problem using the AHP method (34):

Step 1. Identify the problem and determine the goal or desired solution to the problem and then arrange a hierarchical structure starting from level 1: goals, then level 2: several criteria, and level 3: several sub-criteria or alternatives.

Step 2. Determine the priority of elements by compiling a pairwise comparison matrix that describes the relationship or relative influence between elements in the hierarchical structure. A comparison of elements is carried out based on an assessment of the level of importance between two elements made by the respondent.

Step 3. Synthesize the pairwise comparison matrix to get the overall priority.

Step 4. Measure the consistency of all assessment results using the Consistency Ratio (CR). Before calculating the CR, it is necessary to calculate the Consistency Index (CI). CI is calculated using the following equation:

$$CI = \frac{(\lambda_{max} - n)}{n - 1} \quad (2)$$

Where CI is the consistency index, λ_{max} is the largest eigenvalue of the pairwise comparison matrix, and n is the number of element or the size of the matrix. CR can be found using the following equation:

$$CR = \frac{CI}{RI} \quad (3)$$

Where CR is the consistency ratio and RI is the random index. The RI value is drawn based on the size of the matrix. The RI value is shown in Table 3.

Step 5. Perform hierarchy consistency checks. The assessment results must have a value of CR ≤ 10% or CR ≤ 0.1 so that the assessment results can be considered correct or consistent. If the results of the assessment have a CR ≥ 0.1, then the assessment results are considered less consistent.

Table 3. Random Index (IR).

Order of matrix	IR	Order of matrix	IR
1	0.00	9	1.45
2	0.00	10	1.49
3	0.58	11	1.51
4	0.90	12	1.48
5	1.12	13	1.56
6	1.24	14	1.57
7	1.32	15	1.59
8	1.41		

3.4 Objective matrix

Objective Matrix (OMAX) was first developed in the 1980s in the United States by a professor of the Department of Industrial Engineering at Oregon State University, i.e., James L. Riggs (35). OMAX can be said as a system to measure company productivity with productivity criteria or targets as determined by the company objectively. OMAX is a method that can be used to calculate performance indicator scores. This method has a measurement concept by combining several criteria or performance indicators into a matrix form. Each of these performance indicators has a weight that is in accordance with the goal of increasing company productivity (36). The scoring scheme using the OMAX method is divided into three blocks, i.e., defining block, quantification block, and weight and value block. The defining block consists of the performance indicators to be assessed and the performance scores or scores that have been achieved by the company for each performance indicator. Quantification block is a division of levels based on the achievement of performance indicators from the lowest level to the highest level. The weight and value block consists of the results of levels, weights, and performance values for each performance indicator (37). OMAX involves five main steps:

Step 1. Determine the performance indicators.

Step 2. Determine the weight of each performance indicator by the company. The weight value is obtained from the calculation results using the AHP method. Then the company determines the optimistic value (level 10), the target value (level 3), and the pessimistic value (level 0).

Step 3. Determine short-term targets and then fill in the matrix with a score scale based on the following equation:

$$\Delta X_{LH} = \frac{Y_H - Y_L}{X_H - X_L} \quad (4)$$

Where ΔX_{LH} is the interval value between higher level and lower level, X_H is the higher level, X_L is the lower level, Y_H is the higher-level value, Y_L and is the lower-level value.

Step 4. Fill in the numbers on the scoring scheme matrix. Calculations to determine the value at each level can be done using the following equation:

$$Y_X = Y_{X+1} - \Delta X_{LH} \quad (5)$$

Where Y_X is the value of level X and Y_{X+1} is the value of level X+1.

Step 5. Calculate the performance value using the following equation:

$$Value = Level \times Weight \quad (6)$$

Where value is the performance score, level is the class achievement score, and weight is the priority weight.

3.5 Traffic light system

Traffic Light System (TLS) is a method commonly used to make it easier to read and understand the results of the OMAX method. TLS can serve as a marker of the assessment results using color indicators. The color indicators used consist of green, yellow, and red. Each color indicator has a different description. The green indicator indicates that the realization score has reached or above the target set by the company (good). The yellow indicator indicates that the realization score is below the target but within the tolerance limit set by the company (moderate). The red indicator indicates that the realization score is below the target and outside the tolerance limit set by the company (poor) (38).

4 Results and discussion

4.1 Data collection

The data collected is primary data and secondary data. Primary data was obtained through discussions with the company and the questionnaire results. From the discussion results, the data obtained is the performance indicator data of PLN's Cilegon ATTB warehouse related to green warehouse and the performance indicator data assessment criteria. Meanwhile, the data obtained from the questionnaire results are weighting data for each performance indicator. In addition, the secondary data obtained is historical data on the assessment of PLN's Cilegon ATTB warehouse performance indicators related to green warehouse concept in 2020.

Performance indicators data. Identification of green warehouse performance indicators is carried out to determine the performance indicators currently applied by PLN's Cilegon ATTB warehouse in accordance with the green warehouse concept. The identification of PLN's Cilegon ATTB warehouse performance indicators will be adjusted based on three green warehouse criteria, i.e., green warehouse management, warehouse building features, and energy consumption. Based on the interview results with the company, the identification results of green warehouse performance indicators can be seen in Figure 2.

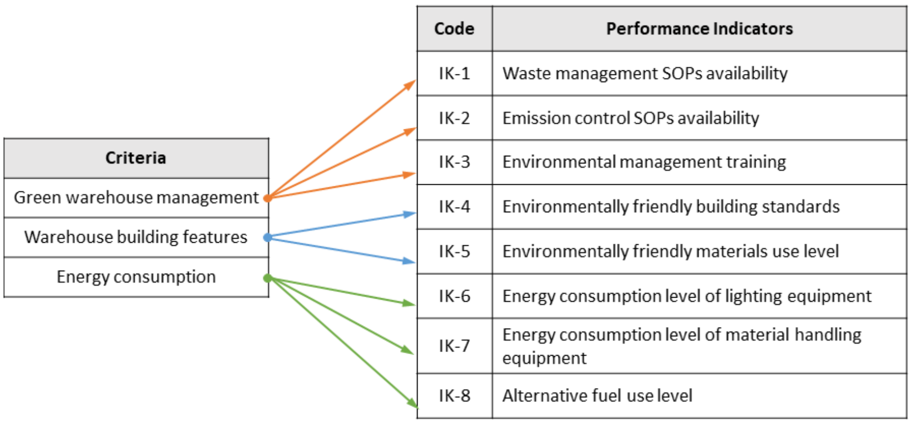

Fig. 2. Grouping performance indicators based on green warehouse criteria.

Table 4. Performance indicator assessment criteria.

Code	Performance Indicators	Criteria
IK-1	Waste management SOPs availability	Higher is better
IK-2	Emission control SOPs availability	Higher is better
IK-3	Environmental management training	Higher is better
IK-4	Environmentally friendly building standards	Higher is better

Code	Performance Indicators	Criteria
IK-5	Environmentally friendly materials use level	Higher is better
IK-6	Energy consumption level of lighting equipment	Lower is better
IK-7	Energy consumption level of material handling equipment	Lower is better
IK-8	Alternative fuel use level	Higher is better

The general assessment for each performance indicator is divided into three categories, i.e., zero/one, lower is better, and higher is better. Zero/one means that the assessment only consists of two achievements, i.e., success with a value of 100% or failure with a value of 0%. Lower is better means that the lower the assessment, the better the achievement, while higher is better means that the higher the assessment, the better the achievement [39]. Based on the interview results with the company, a summary of the assessment criteria for each performance indicator can be seen in Table 4.

Performance indicator assessment historical data. This data is a secondary data obtained from the results of a field study and documentation analysis at the company. The indicators related to green warehouse concept have been previously set by the company based on government's regulation. The historical data related to the assessment of eight green warehouse performance indicators from the PLN Cilegon ATTB warehouse in 2020 can be seen in Table 5.

Table 5. Green warehouse performance indicators assessment data in 2020.

Code	Performance Indicators	Target value (%)	Yield value (%)	Max. target value (%)	Min. target value (%)
IK-1	Waste management SOPs availability	98	100	100	90
IK-2	Emission control SOPs availability	95	96	100	80
IK-3	Environmental management training	95	99	100	80
IK-4	Environmentally friendly building standards	75	78	80	50
IK-5	Environmentally friendly materials use level	70	72	75	50
IK-6	Energy consumption level of lighting equipment	5	10	0	30
IK-7	Energy consumption level of material handling equipment	30	37	25	60
IK-8	Alternative fuel use level	60	40	65	30

Sample size calculation. The weighting questionnaire will be filled out by several respondents who are employees from PLN Cilegon with fields of work related to managing warehousing activities in the PLN Cilegon ATTB warehouse. There are eleven employees at the Cilegon ATTB warehouse, which are divided into permanent employees and outsourced employees. Permanent employees are people who work permanently or are officially registered as employees at PLN Cilegon. Permanent employees consist of two employees from the Logistics division, one employee from the Environmental division, one employee from the OHS and Security division, and one employee from the Menes Substation. Outsourced employees are people who are contracted by PLN Cilegon from a labor service provider company. Outsourced employees consist of one material handling equipment operator and five manual handling laborers. Considering the difficulty of accessing communication with outsourced workers, the respondents in this study only came from permanent workers at PLN Cilegon. The total population of respondents is five respondents who are permanent employees of PLN Cilegon, with a confidence level determined by the company of 98% or an error tolerance value of 0.02. From the calculation results using equation (1), the number of respondents who will fill out the weighting questionnaire is five respondents from PLN Cilegon.

4.2 Results of AHP method

The data from the weighting questionnaire that has been filled in by the respondents is then processed using Expert Choice software. The Expert Choice software displays pairwise comparisons between elements at different levels based on the hierarchical structure of the AHP method. Pairwise comparisons fall into three distinct levels in the hierarchy. The first level is the goal, which is to improve the performance of the green warehouse at PLN Cilegon ATTB warehouse. The second level is the criteria, i.e., green warehouse management, warehouse building features, and energy consumption. The third level is the sub-criteria consisting of eight performance indicators. The use of Expert Choice software is required to carry out weighting by assigning a scale of importance to each criterion and sub-criteria. After processing the data from the questionnaire results using the Expert Choice software, then the local weight values data for each criterion and sub-criteria were obtained as shown in Table 6.

The AHP method not only measures the weighted results but also checks for the consistency ratio (CR) in the assessment results. The maximum tolerance limit for CR in the assessment is 10% or 0.1. If the assessment results have a value of $CR \geq 0.1$, then the assessment results are considered inconsistent and need to be corrected. In the assessment results for each level, the largest CR value (inconsistency) found is 0.02. Based on the CR value obtained, the assessment is accepted or considered consistent because it meets the requirements for the CR value ≤ 0.1.

Table 6. Local weight value of each criterion and sub-criteria.

Criteria	Weight	Performance Indicators	Weight
Green warehouse management	0.352	IK-1 Waste management SOPs availability	0.185
		IK-2 Emission control SOPs availability	0.454
		IK-3 Environmental management training	0.361
Total			1.000

Criteria	Weight	Performance Indicators	Weight
Warehouse building features	0.077	IK-4 Environmentally friendly building standards	0.672
		IK-5 Environmentally friendly materials use level	0.328
Total			1.000
Energy consumption	0.570	IK-6 Energy consumption level of lighting equipment	0.077
		IK-7 Energy consumption level of material handling equipment	0.592
		IK-8 Alternative fuel use level	0.332
Total	1.000		1.000

Furthermore, the global weight value calculation for each performance indicator is carried out by synthesizing between local weight values. The calculation is done by multiplying the weight of the performance indicator (level 2) against the weight of the green warehouse criteria (level 1), then the global weight value for each performance indicator is as shown in Table 7.

Table 7. Global weight value of each performance indicators.

Code	Performance Indicators	Weight
IK-1	Waste management SOPs availability	0.065
IK-2	Emission control SOPs availability	0.160
IK-3	Environmental management training	0.127
IK-4	Environmentally friendly building standards	0.052
IK-5	Environmentally friendly materials use level	0.025
IK-6	Energy consumption level of lighting equipment	0.044
IK-7	Energy consumption level of material handling equipment	0.337
IK-8	Alternative fuel use level	0.189
Total		1.000

4.3 Results of OMAX method

After getting the weight value for each performance indicator, it is continued by calculating the score from the performance indicator using the OMAX method. Before making an assessment scheme, it is necessary to first determine data related to performance scores, target values, optimistic values, and pessimistic values for each performance indicator based on the secondary data obtained. In the scoring scheme table, there are 11 levels consisting of level 0 to level 10. These levels are the performance indicator scores that will be filled in based on historical data and calculation results. The performance section will be filled with performance score data (yield value), level 10 is filled with optimistic value data (maximum target value), level 3 is filled with target value data (target value), and level 0 is filled with pessimistic value data (minimum target value) based on historical data as shown in Table 5. Levels 1, 2, 4, 5, 6, 7, 8, and 9 will be filled in based on the results of calculations using equations (4) and (5). Then to determine the final level of each performance indicator, it can be determined by finding the closest value to the number at levels 0 to 10 with performance. Value for each performance indicator will be calculated based on the multiplication of the level results with the weights using equation (6). The calculation results of the assessment scheme using the OMAX method as shown in Table 8.

Table 8. Performance indicators score calculation results.

KPI No.		IK-1	IK-2	IK-3	IK-4	IK-5	IK-6	IK-7	IK-8
Performance		100.000	96.000	99.000	78.000	72.000	10.000	37.000	40.000
	10	100.000	100.000	100.000	80.000	75.000	0.000	25.000	65.000
	9	99.714	99.286	99.286	79.286	74.286	0.714	25.714	64.286
	8	99.429	98.571	98.571	78.571	73.571	1.429	26.429	63.571
L	7	99.143	97.857	97.857	77.857	72.857	2.143	27.143	62.857
E	6	98.857	97.143	97.143	77.143	72.143	2.857	27.857	62.143
V	5	98.571	96.429	96.429	76.429	71.429	3.571	28.571	61.429
E	4	98.286	95.714	95.714	75.714	70.714	4.286	29.286	60.714
L	3	98.000	95.000	95.000	75.000	70.000	5.000	30.000	60.000
	2	95.333	90.000	90.000	66.667	63.333	13.333	40.000	50.000
	1	92.667	85.000	85.000	58.333	56.667	21.667	50.000	40.000
	0	90.000	80.000	80.000	50.000	50.000	30.000	60.000	30.000
Level		10	4	8	7	5	2	2	1
Weight		0.065	0.160	0.127	0.052	0.025	0.044	0.337	0.189
Value		0.651	0.639	1.017	0.362	0.126	0.088	0.675	0.189

4.4 Results of TLS method

After knowing the score calculation results with the OMAX method, to make it easier to see the calculation results, the TLS method is used. The TLS method is applied by adding color indicators to the OMAX scoring schemes. At levels 0-2 a red indicator will be given, at levels 3-7 a yellow indicator will be given, and at levels 8-10 a green indicator will be given. The color classification of performance indicators using the TLS method is shown in Table 9. To make it easier to understand the performance score results, a simple form of the performance indicators classification results using the TLS method ranked by score results is shown in Table 10.

Table 9. Performance indicators color classification.

KPI No.		IK-1	IK-2	IK-3	IK-4	IK-5	IK-6	IK-7	IK-8
Performance		100.000	96.000	99.000	78.000	72.000	10.000	37.000	40.000
	10	100.000	100.000	100.000	80.000	75.000	0.000	25.000	65.000
	9	99.714	99.286	99.286	79.286	74.286	0.714	25.714	64.286
	8	99.429	98.571	98.571	78.571	73.571	1.429	26.429	63.571
L	7	99.143	97.857	97.857	77.857	72.857	2.143	27.143	62.857
E	6	98.857	97.143	97.143	77.143	72.143	2.857	27.857	62.143
V	5	98.571	96.429	96.429	76.429	71.429	3.571	28.571	61.429
E	4	98.286	95.714	95.714	75.714	70.714	4.286	29.286	60.714
L	3	98.000	95.000	95.000	75.000	70.000	5.000	30.000	60.000
	2	95.333	90.000	90.000	66.667	63.333	13.333	40.000	50.000
	1	92.667	85.000	85.000	58.333	56.667	21.667	50.000	40.000
	0	90.000	80.000	80.000	50.000	50.000	30.000	60.000	30.000
Level		10	4	8	7	5	2	2	1
Weight		0.065	0.160	0.127	0.052	0.025	0.044	0.337	0.189
Value		0.651	0.639	1.017	0.362	0.126	0.088	0.675	0.189

Table 10. Performance indicators ranking based on score results.

Code	Performance Indicators	Level	Performance
IK-1	Waste management SOPs availability	10	Good
IK-3	Environmental management training	8	Good
IK-4	Environmentally friendly building standards	7	Moderate
IK-5	Environmentally friendly materials use level	5	Moderate
IK-2	Emission control SOPs availability	4	Moderate
IK-6	Energy consumption level of lighting equipment	2	Poor
IK-7	Energy consumption level of material handling equipment	2	Poor
IK-8	Alternative fuel use level	1	Poor

Based on the data processing results, the final result of the performance value for each green warehouse performance indicator at the PLN Cilegon ATTB warehouse is shown in Table 11.

Table 11. Summary of performance indicators score results.

Code	Performance Indicators	Weight	Value	Performance
IK-1	Waste management SOPs availability	0.065	0.651	Good
IK-3	Environmental management training	0.127	1.017	Good
IK-4	Environmentally friendly building standards	0.052	0.362	Moderate
IK-5	Environmentally friendly materials use level	0.025	0.126	Moderate
IK-2	Emission control SOPs availability	0.160	0.639	Moderate
IK-6	Energy consumption level of lighting equipment	0.044	0.088	Poor
IK-7	Energy consumption level of material handling equipment	0.337	0.675	Poor
IK-8	Alternative fuel use level	0.189	0.189	Poor

4.5 Discussion

As shown in Table 11, it is known that there are eight green warehouse performance indicators at the PLN's Cilegon ATTB warehouse that can be identified. If viewed based on the weight value, the performance indicator that has the highest weight is IK-7: Energy consumption level of material handling equipment with a weight value of 0.337. According to the respondents' assessment results, the IK-7 performance indicator is considered the most important when compared to other indicators. While the performance indicator that has the lowest weight is IK-5: Environmentally friendly materials use level with a weight value of 0.025. If viewed based on its value, the performance indicator with the highest value is IK-3: Environmental management training with a value of 1.017. According to the calculation results using the OMAX method, the IK-3 performance indicator is an indicator with a fairly good performance value and has a fairly high weight value, resulting in the highest value. Meanwhile, the performance indicator with the lowest value is IK-6: Energy consumption level of lighting equipment with a value of 0.088.

Performance indicators that have good performance and have reached the target (marked with a green color indicator) are IK-1: Waste management SOPs availability and IK-3: Environmental management training. Performance indicators that have been marked with green indicators need to maintain and improve their performance in the next period. Then performance indicators that have moderate performance but have not reached the specified target (marked with a yellow color indicator) are IK-2: Emission control SOPs availability, IK-4: Environmentally friendly building standards, and IK-5: Environmentally friendly materials use level. Performance indicators are marked with a yellow indicator, need to improve performance in the next period in order to be able to achieve the predetermined target. Then the performance indicators that have poor performance or performance values below the average and far from achieving the target (marked with a red color indicator) are IK-6: Energy consumption level of lighting equipment, IK-7: Energy consumption level of material handling equipment, and IK-8: Alternative fuel use level. Performance indicators marked with a red indicator are highly recommended to conduct an in-depth performance evaluation in order to be able to find out the root cause that causes the low performance measurement results. After knowing the root cause, the company can find alternative solutions that can improve its performance in the next period.

5 Conclusion

In this research, green warehouse performance indicators currently implemented by PLN's Cilegon ATTB warehouse have been evaluated using the AHP, OMAX, and TLS methods. From the identification results, there are 8 green warehouse performance indicators found regarding the green warehouse concept, they are related to waste, environmental management, emission control, building, materials, lighting energy consumption, handling equipment, and fuel use. The AHP method was used to determine the weight of each performance indicator. The OMAX method was used to assess the productivity of the performance indicators by calculating the performance score. The TLS method was used to classify the performance indicators with colors based on the score results. From the final results obtained, there are 8 performance indicators found regarding the green warehouse concept: 2 good, 3 moderate, and 3 poor. Performance indicators with good performance are IK-1: Waste management SOPs availability and IK-3: Environmental management training. Performance indicators with moderate performance are IK-2: Emission control SOPs availability, IK-4: Environmentally friendly building standards, and IK-5: Environmentally friendly materials use level. Performance indicators with poor performance are IK-6: Energy consumption level of lighting equipment, IK-7: Energy consumption level of material handling equipment, and IK-8: Alternative fuel use level. We can conclude that to this far, of the 8 performance indicators, there are 2 that best explain PLN compliance with regulations, 3 others are quite representative while the remaining 2 still need improvement.

This research has several key limitations. For instance, the respondents in this research are limited due to difficulties in communicating with the wider range of respondents. Therefore, in the future research, it is necessary to consider using a larger sample to ensure that the results obtained better represent the actual situations. Another limitation is that this research only used AHP method for MCDM problems. Nevertheless, it is also necessary to use other methods for MCDM problems to compare the results and find the best solution.

References

[1] Kementerian Lingkungan Hidup dan Kehutanan. Laporan inventarisasi gas rumah kaca (GRK) dan monitoring, pelaporan, verifikasi (MPV) tahun 2019. Jakarta: Kementerian Lingkungan Hidup dan Kehutanan, Direktorat Jenderal Pengendalian Perubahan Iklim, Direktorat Inventarisasi GRK dan MPV; 2020.
[2] PLN. Laporan keberlanjutan PT PLN (Persero). Jakarta: PT PLN (Persero); 2019.
[3] PLN. Laporan keberlanjutan PT PLN (Persero). Jakarta: PT PLN (Persero); 2020.
[4] Supriyatin F, Yusuf R, Islami MR. Sistem informasi aktiva tetap dan aktiva tetap tidak beroperasi pada PT PLN (Persero) Distribusi Lampung Area Metro berbasis web. Journal Computer Science and Information System (J-Cosys). 2021:1(1).
[5] Doherty S, Hoyle S. Supply chain decarbonization: The role of logistics and transport in reducing supply chain carbon emissions. Geneva: World Economic Forum; 2009.
[6] Loknath Y, Azeem BA. Green management – concept and strategies. India: National Conference on Marketing and Sustainable Development; 2017.
[7] Bartolini M, Bottani E, Grosse EH. Green warehousing: Systematic literature review and bibliometric analysis. Journal of Cleaner Production. 2019:226;242-258.
[8] Luu M. Developing the implementation of green warehousing at IKEA Finland. Helsinki: Haaga - Helia University of Applied Sciences; 2016.
[9] Laari S, Töyli J, Ojala L, Supply chain perspective on competitive strategies and green supply chain management strategies. Journal of Cleaner Production. 2017:141;1303-1315
[10] Waaly AN, Ridwan AY, Akbar MD. Supply chain operation reference (SCOR) model dan analytical hierarchy process (AHP) untuk mendukung green procurement pada industri penyamakan kulit. Journal Industrial Servicess. 2018:4(1);1-6.
[11] Fichtinger J, Ries JM, Grosse EH, Peter B. Assessing the environmental impact of integrated inventory and warehouse management. International Journal of Production Economics. 2015:170(Part C);717-729.
[12] Bajec P, Tuljak-Suban D, Bajor I. A warehouse social and environmental performance metrics framework. Promet - Traffic & Transportation. 2020:32(4);513-526.
[13] Chandra A. pengukuran kinerja gudang dengan menggunakan metode balanced scorecard - Studi kasus pada PT GMS – Jakarta. Jurnal Metris. 2014:15;105-110.
[14] Agyabeng-Mensah Y, Ahenkorah E, Afum E, Dacosta E, Tian Z. Green warehousing, logistics optimization, social values and ethics and economic performance: The role of supply chain sustainability. The International Journal of Logistics Management. 2020:31(3);549-574.
[15] Torabizadeh M, Yusof NM, Ma'aram A, Shaharoun AM. Identifying sustainable warehouse management system indicators and proposing new weighting method. Journal of Cleaner Production. 2020:248;1-11.
[16] Ghani ZA, Abdullah MA, Hajemi A, Hassan SS, I. Ibrahim I, Baharun N. Performance elements of green eco-friendly warehouse towards supply chain management effeciency. International Journal of Latest Research in Humanities and Social Science. 2020:3(1);11-19.
[17] Ali SS, Kaur R, Khan S. Evaluating sustainability initiatives in warehouse for measuring sustainability performance: an emerging economy perspective. Annals of Operations Research. 2022;1-40. DOI: 10.1007/s10479-021-04454-w.
[18] Kamarulzaman NH, Hussin H, Abdullah AM, AbdRahman A. Green warehousing initiatives towards environmental sustainability: adoption and performance in the Malaysia food-based industry. International Conference on Agribusiness Marketing Proceedings. 2018.

[19] Indracahya MR. Perencanaan kebutuhan gudang aset tetap tidak produktif (ATTP) PT Bio Farma (Persero). Bandung: Politeknik Negeri Bandung; 2018.
[20] Bidarti A, Darwanto DH, Hartono S, Jamhari. Supplier structure and performance evaluation of supplier network phase rice supply chain management in South Sumatra. AGRARIS: Journal of Agribusiness and Rural Development Research. 2019:5(1);7-20.
[21] Amjed TW, Harrison NJ. A model for sustainable warehousing: From theory to best practices. International Decision Sciences Institute and Asia Pasific Decision Sciences Institute Conference Proceedings. 2013.
[22] Chen YS, Chang CH, Wu FS. Origins of green innovations: The differences between proactive and reactive green innovations. Management Decision. 2012:50(3);368-398
[23] Żuchowski W. Division of environmentally sustainable solutions in warehouse management and example methods of their evaluation. Scientific Journal of Logistics. 2015:11(2);171-182.
[24] Trivellas P, Malindretos G, Reklitis P. Implications of green logistics management on sustainable business and supply chain performance: Evidence from a survey in the Greek agri-food sector. Sustainability. 2020:12;1-29.
[25] Tan KS, Ahmed D, Sundaram D. Sustainable enterprise modelling and simulation in a warehousing context. Business Process Management Journal. 2010:16(5);871-886
[26] Indrasiri R, Rathnayake W. Analysis of green warehouse practices in Sri Lanka. Proceedings of 8th International Research Conference. 2015.
[27] Pudleiner D, Colton J. Using sensitivity analysis to improve the efficiency of a Net-Zero Energy vaccine warehouse design. Building and Environment. 2015:87;302-314.
[28] Altares P, Copo A, Gabuyo Y, Laddaran A, Mejia L, Policarpio I, et al. Elementary statistics: A modern approach. 1st edition. Manila: REX Book Store; 2003.
[29] Glen S. Slovin's formula: What is it and when do i use it? [Online]. Available from: https://www.statisticshowto.com/probability-and-statistics/how-to-use-slovins-formula/.
[30] Saaty RW. The analytic hierarchy process - what it is and how it is used. Mathematical modelling. 1987:9(3-5);161-176.
[31] Saaty TL. The analytic hierarchy process: Planning, priority setting, resource allocation. 2nd ed. Pennsylvania: RWS; 1990.
[32] Syafnidawati. Kelebiihan dan kekurangan metode AHP (analytic hierarchy process) [Onine]. Raharja.ac.id:; 2020. Available from: https://raharja.ac.id/2020/04/01/kelebihan-dan-kekurangan-metode-ahp-analytic-hierarchy-process/.
[33] Mulyono S. Riset operasi. Jakarta: Fakultas Ekonomi Universitas Indonesia; 2004.
[34] Saaty TL. The analytic hierarchy process. New York: McGraw Hill International; 1980.
[35] Yulifiyanto, Sarjono H. Objective matrix (OMAX). Binus.ac.id; 2017. Available from: https://bbs.binus.ac.id/management/2017/08/objective-matrix-omax/.
[36] Riggs JL. Production systems: Planning, analysis, and control. New York: Wiley; 1970.
[37] Riggs JL, Felix GH. Productivity by objectives. New Jersey: Prentice-Hall; 1983.
[38] Kardi T. Penggunaan metode AHP dalam menganalisa faktor-faktor yang mempengaruhi pemilihan moda ke kampus (studi kasus: Universitas Kristen Petra). Jurnal Teknik Sipil Universitas Kristen Petra. 1999:1;11-17.
[39] Sinaga KRG. Perancangan indikator kinerja rantai pasok farmasi menggunakan pendekatan supply chain operational reference. Jakarta: Universitas Pertamina; 2021.
[40] Mohammedehsan T, Yusof NM, Ma'aram A, Shaharoun AM. Identifying sustainable warehouse management system indicators and proposing new weighting method. Journal of Cleaner Production. 2020:248;1-11.