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Article

Evaluating green supply chain management performance in the Indonesian mechanical assembly industry

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Abstract: This study aims to evaluate the efficiency and performance of implementing green supply chain management in a specialized mechanical assembly company. The research focuses on a company that produces plastic-molded components and mechanical assemblies for medical, industrial, automotive, and transport sector clients, representing a significant segment of the Indonesian mechanical assembly industry. Utilizing the Supply Chain Operations Reference (SCOR) model and the Analytical Hierarchy Process (AHP), the study assesses green supply chain performance across five domains: planning, sourcing, production, delivery, and returns. The results indicate a green supply chain performance score of 80.1, categorized as good, suggesting effective implementation of environmentally friendly practices. Based on these findings, it is recommended that the company continue to refine its green supply chain strategies, particularly in areas that scored lower, to further enhance overall performance. Future studies could expand this research by including a larger sample of companies within the Indonesian mechanical assembly industry, enabling broader generalizations and identification of industry-wide trends in green supply chain management implementation.

Keywords: green supply chain management; supply chain operations reference; analytical hierarchy process; key performance indicators

1. Introduction

Researchers have conducted comprehensive analyses of the environment in light of the recent publication of the report on global warming patterns. Both governmental and non-governmental organizations have implemented various efforts and programs to promote environmental awareness. As a result, both consumers and companies have shown an increasing interest in this matter. Corporations bear the responsibility for their supply chains, which compels them to conduct and evaluate research on environmental aspects of their supply chain activities [1]. Suppliers, manufacturers, and retailers are required to use sustainable practices throughout all aspects of their operations, with particular emphasis on actions within the supply chain that have a direct impact on the product, in order to acquire ecologically sustainable materials. Implementing Green Supply Chain Management (GSCM) can increase organizational productivity, both financially and efficiently; and improve environmental performance [2]. While the importance of GSCM is well-established, there is a notable gap in research specifically addressing its implementation and effectiveness in the Indonesian mechanical assembly industry. This study aims to address this gap by evaluating the eco-friendly supply chain in this sector, considering its unique challenges and opportunities.

The green supply chain management techniques of many businesses have garnered significant interest due to their potential environmental and economic benefits. The aim of these strategies is to mitigate the negative impacts of supply chain activities on the environment while simultaneously improving overall performance. Evaluating the effectiveness of the eco-friendly supply chain poses unique challenges in the mechanical assembly industry. The strategic implementation of green supply chain management will help manufacturing enterprises enjoy cost and efficiency benefits [3]. These challenges involve the complex features of mechanical assembly, which include multiple components and techniques. Moreover, it is crucial to integrate environmental sustainability into supply chain management strategies in this industry in order to achieve long-term performance and competitiveness [4]. In order to evaluate the effectiveness of the eco-friendly supply chain in the mechanical assembly industry, it is essential to consider specific attributes that are relevant to this field.

1.1. Background

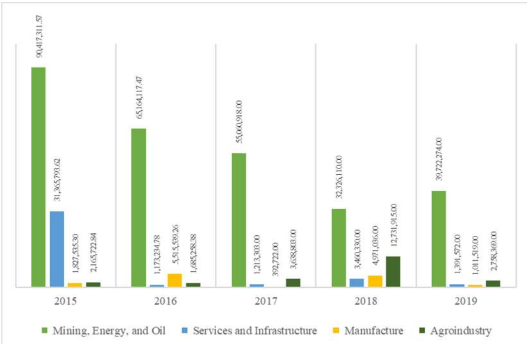

Figure 1. Amount of hazardous waste managed (Tons).

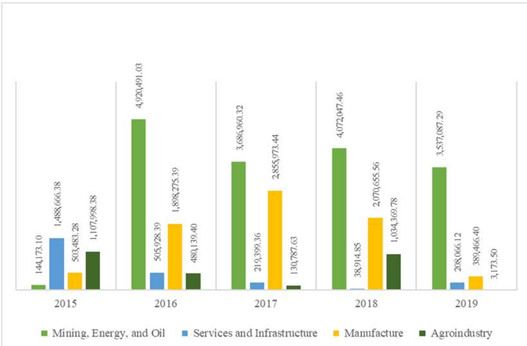

Figure 2. Amount of hazardous waste utilized (Tons).

Based on statistical data provided by the Ministry of Environment and Forestry of the Republic of Indonesia, the monitored industry generates a total of 60,309,198.23 tons of hazardous waste. This encompasses the waste produced by institutions tasked with the management of hazardous waste, which can be handled either by outsourcing it to third-party entities or by managing it internally. However, the supervision of hazardous industrial waste management and utilization in the manufacturing industry is insufficiently monitored in comparison to other industrial sectors, as evidenced by **Figures 1** and **2**. This is despite the Ministry of Environment and Forestry of the Republic of Indonesia overseeing multiple industrial units within the manufacturing industry between 2015 and 2019. Moreover, the supply chain operations in certain industries significantly contribute to various types of pollution and waste caused by the movement of the industrial supply chain in Indonesia [5].

Implementing green supply chain efforts is an essential approach for firms seeking to improve sustainability and remain competitive in today's environmentally aware market. These initiatives involve various practices, such as green purchasing (obtaining materials from environmentally responsible suppliers), eco-design (developing products with minimal environmental impact throughout their lifespan), and reverse logistics (handling the return and recycling of products and materials) [6]. Multiple factors motivate the adoption of such practices, including the need to comply with increasingly stringent government regulations, the desire to improve customer relations and public perception, and the potential for financial benefits through cost reduction and improved effectiveness [7]. Strategic green supply chain management is of utmost importance in rising economies such as India, where the rapid growth of industry sometimes clashes with environmental considerations. Businesses can address growing environmental concerns and meet the changing expectations of environmentally conscious consumers. Nevertheless, the distinct factors and obstacles associated with implementing environmentally-friendly supply chain activities in these emerging nations may vary compared to those in more advanced countries. This emphasizes the need for additional investigation in order to comprehend the distinct aspects that influence the adoption of green supply chains in various economic settings. Such research could provide valuable insights for developing more efficient ways to apply sustainable practices in global supply chains [8].

PT CP, an upscale producer of accurate plastic-molded components and mechanical assemblies for medical, industrial, and automotive customers, runs a facility in Batam, Indonesia. This site offers assembly services, tool design and fabrication, plastic injection molding, vertically integrated secondary processes, and advanced spray paint process technologies in collaboration with the manufacturing industry in Singapore. The company primarily produces mechanical products, requiring an environmentally sensitive supply chain management system to align with its business operations. For three months, PT CP temporarily keeps its hazardous and toxic waste at a designated site. After this time, a third party is responsible for transporting and managing the garbage. The total amount of hazardous and toxic waste produced in the previous six months was 1.71 tons. PT CP generated more than 3 metric tons of hazardous and toxic waste within a span of one year. The Batam City Environmental Impact Handling Agency has issued the firm a permit to handle hazardous waste, specifically for temporary storage activities. Every quarter, the corporation consistently notifies the government of the periodic containment of dangerous waste. PT CP has obtained ISO 14001:2014 accreditation, which is a globally acknowledged standard for environmental management. The certification was revised in 2018. These activities exemplify the company's dedication to fostering a sustainable industry.

Therefore, the evaluation of performance will be carried out utilizing performance indicators specific to green supply chain management. These indicators will help the company improve its reputation, customer loyalty, sales, profits, and competitiveness [9]. The validation of these indicators will be conducted according to the firm's business processes. Afterwards, work indicators that need improvement will be identified based on recommendations that are in line with the company's ability to make adjustments. This study employs an approach by combining the Green Supply Chain Operation Reference (Green SCOR) model with the Analytical Hierarchy Process (AHP). The results of this study will be classified using the Traffic Light System (TLS) in order to identify the Key Performance Indicators (KPIs) that require improvement. This company's process of designing performance metrics includes combining performance indicators with environmental issues. These features are directly associated with the steps of planning, sourcing, manufacturing, delivering, and returning.

1.2. Research objectives

The objective of this research is to evaluate the efficiency and performance of Green Supply Chain Management (GSCM) implementation in a company specializing in producing plastic-molded components and mechanical assemblies. By focusing on key areas such as planning, sourcing, production, delivery, and returns, the study aims to assess how well the company incorporates environmentally friendly practices throughout its supply chain operations. Using the Supply Chain Operations Reference (SCOR) model and the Analytical Hierarchy Process (AHP), the research seeks to measure the effectiveness of GSCM and identify areas that require improvement to enhance both environmental and operational performance. The study also explores which aspects of the supply chain need refinement to further boost the company's environmental sustainability.

2. Literature review

2.1. Green supply chain management

Studies have shown that the adoption of Green Supply Chain Management (GSCM) strategies can provide competitive advantages, reduce operational costs, and improve overall business efficiency [10]. Among these programs, eco-design is typically the most widely adopted, followed by green purchasing, while reverse logistics tends to have the lowest level of acceptability [11]. Participating in environmentally-focused organizations and having a larger number of suppliers (more than 10) are factors that positively influence the adoption of Green Supply Chain Management (GSCM) strategies [11].

Various factors, measured as a second-order construct, influence the implementation of a company's environmentally friendly supply chain initiatives in developing countries [8]. While implementing Green Supply Chain Management (GSCM) may have challenges, such as those related to waste management, it is critical to prioritize the pursuit of financial, social, and environmental benefits through these initiatives in order to achieve sustainability [8]. As environmental concerns become more important, companies are realizing the relevance of Green Supply Chain Management (GSCM) in creating their reputation as socially responsible and environmentally sustainable [10].

2.2. Measurement of Performance

A range of studies have delved into the complex task of evaluating the performance of Green Supply Chain Management (GSCM). There is a critical need for a comprehensive measurement system that takes into account the entire supply chain, including its green aspects [12]. This holistic approach is essential for accurately assessing the environmental impact and effectiveness of GSCM practices across all stages of the supply chain. Previous research [13,14] has proposed innovative methodologies for GSCM performance measurement. Both scholars advocate for the use of a modified balanced scorecard in combination with the analytic hierarchy process (AHP), specifically focusing on integrating AHP with the balanced scorecard to create a more robust evaluation framework.

2.3. Green supply chain operation reference

The Green Supply Chain Operation Reference (Green SCOR) model has emerged as a valuable tool for evaluating and improving the environmental performance of supply chains across various industries. This is evident from studies conducted in different sectors, including rubber processing, steel manufacturing, and green tea production. For instance, researchers applied the Green SCOR method to assess a rubber processing factory's green supply chain performance, yielding a score of 72.03%, which was considered good [15]. Similarly, other research evaluated a steel company's green supply chain performance using Green SCOR, resulting in an average score of 67.73 [16]. These studies demonstrate the versatility of the Green SCOR model in quantifying and benchmarking environmental performance across diverse industrial contexts.

The use of Green SCOR not only provides an overall performance score, but also identifies specific areas for improvement within supply chains. For example, Pulansari and Putri [16] found that water usage was a critical area needing improvement in the steel company they studied. In the case of green tea production, Suharno et al. [17] used Green SCOR to highlight both strengths (such as clean energy use and zero waste disposal) and areas for improvement (including water usage optimization and supplier screening). These findings underscore the importance of Green SCOR as a diagnostic tool that can guide targeted interventions to enhance the environmental sustainability of supply chains. Moreover, the evolution of Green SCOR from its inception, as described by Cash et al. [18], to its current applications demonstrates its growing relevance in integrating sustainability and environmental considerations into supply chain management practices.

2.4. The analytical hierarchy process (AHP)

Thomas Saaty developed the Analytic Hierarchy Process (AHP), a powerful decision-making methodology that combines mathematical rigor with psychological intuition. It is designed to handle complex multi-criteria decisions by breaking them down into hierarchical structures and using pairwise comparisons to derive priority scales [19]. At its core, AHP is based on the fundamental human capability to make pairwise comparisons, which allows decision-makers to cope with a constantly changing world where fixed standards may not exist [19]. The process utilizes a psychophysical scale of 1-9 for making these comparisons.

AHP's strength lies in its ability to synthesize individual judgments into a cardinal group decision through a mathematically justifiable method [20]. Priority scales are determined by pairwise comparisons using expert judgments for both tangible and intangible factors [21]. These derived priority scales are then synthesized by multiplying them by the priority of their parent nodes and adding for all such nodes [21]. This approach allows AHP to address multiple objectives simultaneously, making it particularly useful for decisions involving benefits, costs, opportunities, and risks [19]. However, there are some potential flaws in AHP, suggesting that its rankings can be arbitrary due to the principle of hierarchic composition. It was proposed to synthesize AHP with concepts from multi-attribute utility theory to address this issue [22].

The process involves calculating the consistency ratio to ensure the reliability of expert opinions. This is done by comparing the Consistency Index (CI) with a predetermined Random Index (RI). The CI is calculated using the following formula:

$$CI = \frac{Lmax - n}{n - 1}$$

Description:

CI = Consistency Index;

Lmax = Eigen value max;

N = Number compared/matrix order

The Consistency Ratio (CR) is then determined by dividing (Consistency Index) CI by Random Index (RI). If the CR value is less than or equal to 0.10, the comparisons are considered consistent and acceptable. However, if the CR exceeds 0.10, decision-makers are required to review their assessments. This systematic approach allows for a structured evaluation of complex decisions, incorporating both objective data and subjective expert judgments [21,23].

Performance assessment can be conducted using many methods, and the achievement of performance is assessed by standardizing performance indicators. The process of normalization is referred to as Snorm De Boer normalization [24]. The Snorm De Boer normalization formula [25] facilitates the normalizing process in the following manner:

$$\text{Snorm (Score)} = \frac{(\text{Smax} - \text{Si})}{(\text{Smax} - \text{Smin})} \times 100\%$$

$$\text{Snorm (Score)} = \frac{(\text{Si} - \text{Smin})}{(\text{Smax} - \text{Smin})} \times 100\%$$

2.5. ISO 14000/14001

Organizations embark on the varied and challenging process of implementing ISO 14001, an Environmental Management System (EMS), to enhance their environmental performance. This system encounters multiple impediments and is influenced by different factors that can affect its successful implementation and efficacy. Typical obstacles include a lack of government encouragement to embrace these systems, the significant financial commitment needed for implementation, and a dearth of support or interest from customers and stakeholders [26,27]. Notwithstanding these obstacles, firms that effectively apply ISO 14001 frequently enjoy substantial advantages. The benefits encompass increased environmental performance through the methodical handling of environmental factors, decreased operating expenses resulting from enhanced efficiency and resource management, and enhanced adherence to environmental laws and regulations [28]. Studies have demonstrated that ISO 14001 can be highly efficient in reducing environmental effects, particularly when it is coordinated with and enhances existing environmental standards [29]. The system offers a systematic framework for firms to establish environmental goals, track their progress, and consistently enhance their environmental management practices, ultimately leading to more sustainable company operations and potentially enhancing corporate reputation.

3. Research methods

This study is an evaluative research project that utilizes a qualitative approach, whose conceptual framework can be observed in **Figure 3**. Evaluative research is a methodical and systematic investigation to assess an object, program, practice, activity, or system. Its purpose is to provide decision-makers with valuable information for making informed decisions [30]. Primary data refers to data or information collected directly from the subject of study. The sample size in this study consisted of six experts directly involved in supply chain activities. The sample size in this study consisted of six experts directly involved in supply chain activities. While this sample size is limited, it represents key decision-makers across various functions within the company, providing a comprehensive view of the GSCM practices. These experts were carefully selected based on their extensive experience and their direct involvement in shaping the company's GSCM strategies. These experts include PPIC Managers, Purchasing Assistant Managers, Quality Managers, Engineering Managers, Operational Directors, and HSE personnel.

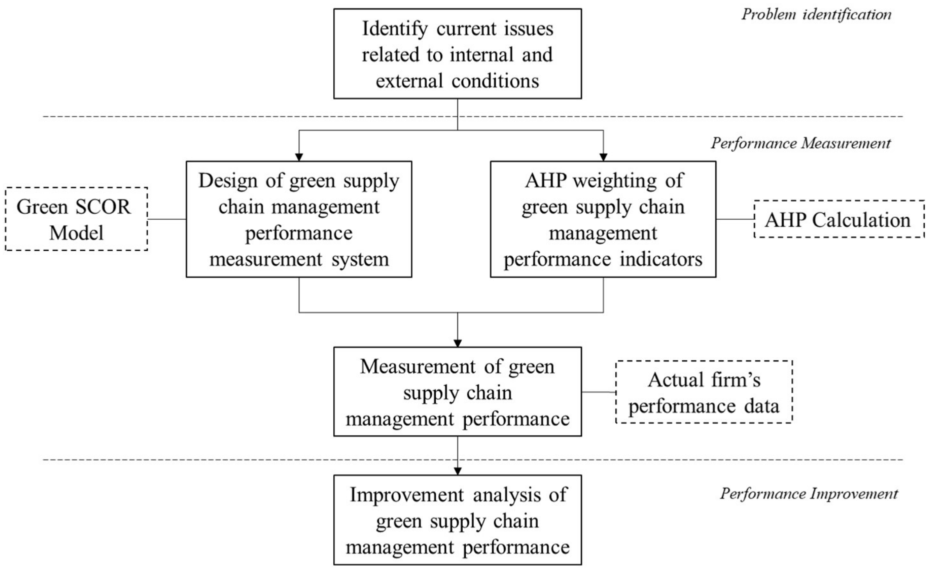

Figure 3. Conceptual framework.

The sampling strategy employed in this study is purposive sampling, conducting non-probability sampling. Purposive sampling is a method of selecting data sources based on specific considerations [31]. The criteria for expert selection were as follows: (1) a minimum of 5 years of experience in supply chain management, (2) direct involvement in the company's GSCM initiatives, (3) decision-making authority in their respective departments, and (4) a comprehensive understanding of the company's overall business strategy. This rigorous selection process ensures that despite the limited number of experts, the insights gathered are highly relevant and authoritative.

Table 1. Process, attributes, and indicators.

Process	**Process definition**	**Attribute**	**Indicator**	**Indicator definition**
Plan	Plan activities include all forms of production planning, through good planning it will be followed by a good production process. Production process is both effective and efficient.	Reliability	Forecast Accuracy	Accuracy of forecasting demand with actual demand
		Reliability	Raw Material Planning Accuracy	Total forecasting actual compared with actual needs
Source	Activities in the source process include the procurement of raw materials needed during the production process. The source process starts from purchasing raw materials to checking for defective raw materials.	Reliability	% Order Received Damaged Free	Percentage of rejected or defected raw materials
		Reliability	% Of Feasible Package	Percentage of damaged packaging
		Reliability	% Hazardous Material in Inventory	Percentage of hazardous materials
		Reliability	% Supplier with → an EMS → or ISO 14000 Certification	Percentage of suppliers that have an environmental management system or are ISO 14000 certified
		Responsiveness	Source Cycle Time	The total time required by the supplier from ordering until the goods are received in the warehouse, often referred to as lead time, with lead time.
Make	Make activities include production activities from raw materials to finished goods.	Reliability	Energy Used	Total electrical energy used for production.
		Reliability	Water used	Total water used for production.
		Reliability	Liquid Waste	Total liquid waste generated during the production process.
		Reliability	Solid Waste	Total solid waste generated during the production process.
		Responsiveness	Make Cycle Time	Total time required for manufacturing the finished product.
Deliver	Deliver activities include activities related to the delivery of products to customers.	Reliability	Shipping Document Accuracy	Total complete and correct shipping documents.
		Reliability	Delivery Quantity Accuracy	The total quantity of products delivered by the company in accordance with demand
		Responsiveness	Delivery Cycle Time	The total time taken is from when the product is packed until it is picked up by the delivery service.
Return	The activity of returning products for various reasons or not in accordance with the request	Reliability	% of Error Free Return Shipped	Percentage of products returned by customers.
		Reliability	Defective Product: Recyclable	Number of products returned as damaged or defective and recyclable

The study commences with the development of indicators for Green Supply Chain Management (GSCM). The Key Performance Indicators (KPIs) selected by researchers as variables and sub-variables are developed from a thorough assessment of literature studies, as can be seen in **Table 1**. These KPIs will then be validated by the company.

Subsequently, it is important to authenticate the GSCM performance indicators. The significance of this phase lies in its ability to identify the company's performance indicators for subsequent measurement. During this phase, a validation questionnaire was distributed to assess the existing state of the company's supply chain in relation to environmental factors. The stage involves evaluating the performance indicator information collected from the literature review and verifying it with company experts. The validation of KPI performance indicators will be distributed to PPIC Managers, Purchasing Assistant Managers, Quality Managers, Engineering Managers, Operational Directors, and HSE. These individuals have been selected due to their experience and knowledge of the company's supply chain process, which makes them well-suited to determine the company's GSCM performance measurement indicators. **Figure 4** below shows the indicators hierarchy based on the expert validation process.

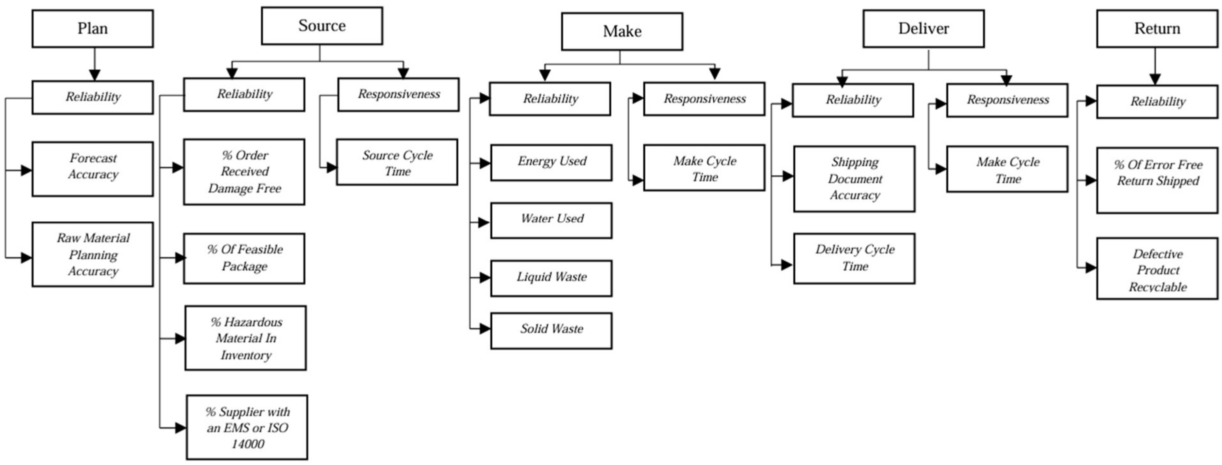

Figure 4. Indicators hierarchy.

Once the performance indicators have been validated, valid and feasible indicators will be acquired to measure the company's performance. Moreover, the significance of each job indicator is assessed using the Analytic Hierarchy Process (AHP) method. The AHP approach is employed as a weighting tool due of its ability to address both quantitative and judgmental difficulties. The limitation of the AHP weighting process in this research is that it only applies to the criteria and does not consider alternatives. The criteria are divided into three levels: at level one, the weighting is done between green SCOR processes; at level two, the weighting is done between attributes; and finally, at level three, the weighting is done between performance indicators.

Once the weight of the process, attributes, and performance indicators of GSCM has been determined using the AHP method, the next step will involve measuring GSCM performance. This will be done by collecting data on the company's green supply chain management performance from July to December 2021. The data will be obtained through document studies focusing on each performance indicator process. Normalization is performed on each value of the performance indicators based on the data received from the corporate document research. Sumiati [24] defines the level of performance fulfillment as the normalization of these performance indicators. This is done due to the fact that each Key Performance Indicator (KPI) carries a distinct weight, which corresponds to a unique scale of measurement. To address this issue, it is necessary to implement a parameter equalization procedure, specifically through the process of normalization.

The Snorm De Boer normalization method considers zero (0) as the lowest value and one hundred (100) as the highest value for each performance indicator, representing the worst and best parameter, respectively. To clarify and facilitate understanding of performance measurement results, it is essential to use the Traffic Light System (TLS) method. This method categorizes performance values into three color categories: red, yellow, and green. The purpose of this categorization is to indicate whether the KPI score requires improvement or not. The red hue indicates that the indicator is below 60, signifying that the company's performance is unsatisfactory. Similarly, the yellow color indicates that the performance score is below 80, again indicating unsatisfactory performance. A performance score between 60 and 80 indicates that the company's performance is marginal. A performance score above 80, shown by the green hue, signifies good performance.

4. Result and discussion

4.1. AHP weighting performance indicators

The purpose of pairwise comparisons is to assess the significance of each indicator and assign weights to the three criteria levels. Performance indicators are assigned varied weights based on their respective levels of importance. The weighting mechanism assists in assigning priority to specific indications during the assessment of overall performance [32]. The first level consists of weighting criteria between processes, followed by weighting criteria between attributes at the second level, and finally weighting criteria between performance indicators at the third level.

Six corporate experts who comprehensively understood the organization's supply chain management completed the pairwise comparison questionnaire. For each expert, a separate pairwise comparison was conducted, where they scored the priority of each Key Performance Indicator (KPI) on a scale of 1 to 9. To consolidate these individual assessments into a single, representative pairwise comparison matrix, the geometric mean of the experts' scores for each comparison was calculated. This approach allows for the integration of diverse expert opinions while mitigating the impact of extreme values. The resulting consolidated pairwise comparison matrix was then input into the Expert Choice program as the result can be seen in **Table 2**.

Table 2. AHP weighting performance indicators.

Process	Level 1	Attribute	Level 2	KPI	Level 3
Plan	0.197	Reliability	1	Forecast Accuracy	0.24
				Raw Material Planning Accuracy	0.76
Source	0.344	Reliability	0.471	% Order Received Damage Free	0.24
				% Of Feasible Package	0.17
				% Hazardous Material in Inventory	0.23
				% Supplier with an EMS or ISO 14000	0.36
		Responsiveness	0.529	Source Cycle Time	1
Make	0.186	Reliability	0.774	Energy Used	0.65
				Waste	0.35
		Responsiveness	0.226	Make Cycle Time	1
Deliver	0.194	Reliability	0.317	Shipping Document Accuracy	0.601
				Delivery Quantity Accuracy	0.399
		Responsiveness	0.683	Delivery Cycle Time	1
Return	0.079	Reliability	1	% Of Error Free Return Shipped	1

4.2. Evaluating key performance indicator (KPI)

The subsequent task involves calculating the company's Key Performance Indicator (KPI) data, which includes all relevant information about the Key Performance Indicator (KPI) summarized for the period of July to December 2021. **Table 3** below is an illustration of the calculation process for forecast accuracy indicator:

Table 3. Forecast accuracy.

Month	Forecast Demand	Actual Demand	Forecast Accuracy
July	7,067,397	8,166,837	86.54
August	9,140,812	7,499,746	78.12
September	9,212,925	6,959,503	66.00
October	6,973,523	6,536,629	93.32
November	6,384,949	6,514,759	98.01
December	5,674,338	5,788,311	98.03

The data will undergo processing utilizing the Green SCOR methodology for each Key Performance Indicator (KPI). The data that has been handled before will be normalized by using the Snorm de Boer method. Here is an illustration of a calculation for the forecast accuracy indicator.

$$Forecast\ Accuracy = \left(\frac{87-66}{98-66}\right) \times 100 = 66$$

4.3. Performance score

After processing the data using the Green SCOR method for each KPI, the previously processed data will be normalized using the Snorm de Boer method. The results in **Table 4** show that the final value of the company's performance is "80.1". This figure indicates that the company's current performance falls into the satisfactory category.

Table 1. Calculation of the final performance score.

KPI	Snorm	Final Weight	Norm × Weight	Final Score
Forecast Accuracy	66	0.05	3.1	80.1
Raw Material Planning Accuracy	77	0.15	11.6	
% Order Received Damage Free	80	0.04	3.1	
% Of Feasible Package	100	0.03	2.8	
% Hazardous Material in Inventory	99	0.04	3.8	
% Supplier with an EMS or ISO 14000	47	0.06	2.7	
Source Cycle Time	89	0.18	16.3	
Energy Used	36	0.09	3.4	
Waste	100	0.05	5	
Make Cycle Time	80	0.04	3.4	
Shipping Document Accuracy	100	0.04	3.7	
Delivery Quantity Accuracy	58	0.02	1.4	
Delivery Cycle Time	91	0.13	12.1	
% Of Error Free Return Shipped	100	0.08	7.9	

Table 5. Traffic light system.

KPI	Actual	Min	Max	Snorm
Forecast Accuracy	87	66	98	66
Raw Material Planning Accuracy	90	80	93	77
% Order Received Damage Free	98	94	99	80
% Of Feasible Package	100	98	100	100
% Hazardous Material in Inventory	0.0183	0.0004	0.0266	99
% Supplier with an EMS or ISO 14000	47	0	101	47
Source Cycle Time	352	350	369	89
Energy Used	691.355	571.751	760.069	36
Waste	1.2	1.0	1.5	100
Make Cycle Time	7.4	6.5	11.0	80
Shipping Document Accuracy	100	0	100	100
Delivery Quantity Accuracy	58	52	62	58
Delivery Cycle Time	62	61	73	91
% Of Error Free Return Shipped	100	99	100	100

The Traffic Light System is utilized to identify the specific areas of the company's GSCM performance that require improvement, depending on the essential criteria, as shown in **Table 5**. The Traffic Light System utilizes red, yellow, and green indicators. When the SNORM value falls below 60, it indicates subpar performance and activates the red indicator. If the SNORM score falls between 60 and 80, the yellow indicator indicates marginal performance. The green indicator is employed when the SNORM number reaches 80, signifying commendable performance on the criterion.

4.4. Plan process

Two essential Key Performance Indicators (KPIs) are pivotal in the planning process: forecast accuracy and raw material planning accuracy. The color yellow represents the current forecast accuracy indicator, which has a score of 66. The previous research also experienced a similar scenario, with forecast accuracy hitting the yellow mark [33]. The score indicates the difficulties the business faces in effectively forecasting demand, primarily because there are several projects with uncertain requirements. The yellow level signifies that although the forecast accuracy is not dangerously poor, there is substantial potential for enhancement. Several factors influence forecast accuracy, including production-related factors, information-related factors, the human factor, and technology and tools [34]. To realize the benefits of improved forecast accuracy, companies must implement techniques to improve forecast accuracy and integrate the more accurate forecasts into their planning and management activities [35].

The second key performance indicator (KPI), which measures accuracy of raw material planning, is also indicated by a yellow color, but with a higher score of 77. The score can be deemed satisfactory, indicating that the firm is adequately addressing its raw material requirements in its planning process. The yellow status indicates that the current performance is satisfactory, but there are still possibilities for improving and optimizing the raw material planning process. Factors such as supplier reliability, inventory management techniques, and the precision of production plans are likely to impact this Key Performance Indicator (KPI). Active management of raw material sourcing can add value to supply chains through strategies like direct supply to suppliers or facilitating supplier cooperation, in contrast to a hands-off approach [36]. To mitigate risks in raw material planning such as supply continuity, delivery delays, knowledge gaps, and quality issues, it is recommended enhancing buyer-supplier coordination and information sharing, as well as implementing Supplier Relationship Management (SRM) systems [37].

4.5. Source process

The source process consists of five essential Key Performance Indicators (KPIs) that offer significant insights into the effectiveness and durability of the supply chain. The Key Performance Indicators (KPIs) consist of several metrics. These include "percentage of order received damage-free," which measures the quality of received shipments; "percentage of feasible packages," which assesses the practicality of packaging solutions; "percentage of hazardous material inventory," which tracks the management of dangerous substances; "percentage of suppliers with an EMS or ISO 14000," which evaluates the environmental management standards of suppliers; and "source cycle time," which gauges the overall speed of the sourcing process. Out of these five Key Performance Indicators (KPIs), four show adequate performance, as shown by their green color markers. These KPIs are "percentage of order received damage-free," "percentage of feasible package," "percentage of hazardous material inventory," and "source cycle time." This indicates that the organization is proficiently overseeing the majority of its sourcing process.

Nevertheless, the Key Performance Indicator (KPI) "percentage of suppliers with an Environmental Management System (EMS) or ISO 14000 certification" is particularly worrisome, as it is highlighted in red and has a score of only 46. These findings suggest that a considerable proportion of suppliers, specifically 101 vendors who provide raw materials directly, have not achieved ISO 14000 certification, which is an essential benchmark for environmental management systems. In order to resolve this matter and establish a consistent certification process throughout the supply chain, it is recommended that the organization enforce a policy mandating all 47 vendors who currently do not possess ISO 14000 certification to acquire it. Suppliers who adopted the EMS and ISO 14001 standards have a greater impact on performance and a positive influence on innovation and commitment to the environment related to company targets than those firms that did not apply them [38]. Moreover, companies implementing formal environmental management systems (EMS), especially certified ones like ISO 14001, experience benefits beyond pollution reduction, including improved overall operating performance and a tendency to make more environmentally friendly choices over time [39].

4.6. Make process

The Make process measures three distinct Key Performance Indicators (KPIs): Energy Utilization, Waste Generation, and Make Cycle Time. Out of these metrics, the Energy Used measure is particularly noteworthy due to its alarming red warning and a score of 36. The operational requirements of the company's production units primarily drive its high energy consumption, contributing to its low score. The increased energy consumption not only has an influence on the company's environmental impact, but also has a substantial effect on operational expenses and overall efficiency.

In order to tackle this crucial matter, the organization should adopt a complete approach focused on energy management and sustainability. Evaluating end-energy uses and implementing measures to reduce energy consumption can improve energy efficiency in the industrial sector [40]. An exhaustive examination of the overtime schedule is also essential, with the goal of reducing excessive energy usage during off-peak hours. Moreover, it is highly recommended to gradually shift from traditional energy sources to more environmentally friendly alternatives. An explicit suggestion is to substitute fossil fuel-powered machinery with environmentally friendly alternatives, such as hydrogen-powered fuel cell forklifts. Better monitoring and control of energy consumption and performance indicators are important for improved energy efficiency performance in manufacturing for current and future enterprises [41]. Performance-based indicators are one way to enable companies to set energy efficiency targets for manufacturing facilities [42].

4.7. Deliver process

The delivery process is an essential element of supply chain management, which includes three vital key performance indicators (KPIs): Shipping Document Accuracy, Delivery Quantity Accuracy, and Delivery Cycle Time. Although two of these key performance indicators (KPIs) are showing positive results, as evidenced by their green status, the Delivery Quantity Accuracy metric is currently in a critical state with a score of 57, indicated by the red zone. The main reason for this underperformance is the disparity between the production volume and the quantity of products delivered to clients. This is a result of the company's strategic decision to keep a stock of products for consumers rather than send all manufactured items directly to customers.

Although this inventory management approach may lead to a disparity in the Delivery Quantity Accuracy Key Performance Indicator (KPI), it plays a crucial role in the company's broader supply chain strategy. Management initiatives to improve delivery performance are best focused on informational flows within the supply chain and leveraging new process technologies that offer flexibility to respond to uncertainty [43]. Through the use of buffer stock, the company guarantees its capacity to constantly fulfil consumer demand and reduce the likelihood of stock shortages. This proactive technique aims to improve customer satisfaction and provide a dependable supply chain, even if it leads to a temporary discrepancy between production and delivery numbers. Meanwhile, the positive status of the Shipping Document Accuracy and Delivery Cycle Time KPIs indicates that the organization is operating well in these areas, demonstrating effective documentation processes and punctual deliveries.

4.8. Return process

Returns management is the supply chain management process by which activities associated with returns, reverse logistics, gatekeeping, and avoidance are managed within the firm and across key members of the supply chain [44]. A single Key Performance Indicator (KPI) is used within the return process: the percentage of errors. Return at no cost. The product received a score of 100 and is indicated as "green," indicating satisfactory performance for the Key Performance Indicator (KPI). This is due to the minimal number of customer returns. Additionally, returned products are destroyed, and the final product is sold, generating economic value from the returned item. This process demonstrates a highly efficient return system that not only minimizes errors but also maximizes customer satisfaction through a no-cost return policy. The "green" score reflects the company's success in maintaining product quality and meeting customer expectations, resulting in few returns. Furthermore, the company has implemented a sustainable approach to handling returned items by destroying them and selling the final product, thereby recouping some of the costs associated with returns and reducing waste. This comprehensive strategy showcases the company's commitment to customer service, quality control, and environmental responsibility, all while maintaining a positive economic impact.

5. Conclusions

According to the Green SCOR approach, the company's measurement findings indicate a positive performance, with a score of 80.1 out of 100, placing it in the Good category. This score reflects the company's overall commitment to sustainable supply chain practices. However, the evaluation also highlighted areas for improvement, as three out of the 14 Key Performance Indicators (KPIs) were classified as red, signaling the need for targeted enhancements.

To address these areas of concern, several improvements have been suggested for PT CP. First, the company should require all direct and indirect material suppliers to obtain ISO 14000 certification. This aligns with ISO 14001:2015 clause 8.1, which emphasizes the importance of communicating environmental standards to external providers, including contractors. By implementing this requirement, PT CP can ensure a standardized approach to environmental management across its supply chain.

Secondly, the company is advised to implement measures to regulate energy use and evaluate overtime patterns. This recommendation aims to reduce the company's reliance on electrical energy, potentially lowering costs and environmental impact. Additionally, there is a strong emphasis on exploring alternative energy sources, such as adopting fuel cell forklifts that use hydrogen instead of fossil fuels. This initiative demonstrates a commitment to innovation and sustainability in the company's operations.

Lastly, effective inventory management is highlighted as a crucial area for improvement. This recommendation is in line with clause 8.1 of ISO 14001:2015, which stresses the importance of monitoring and measuring operations to ensure desired outcomes. By implementing strategic inventory management practices for both consumer materials and products, PT CP can avoid excess stock, reduce waste, and optimize its supply chain efficiency. This approach not only supports environmental sustainability but also has the potential to improve the company's overall operational performance and cost-effectiveness.

5.1. Limitation

While this study provides valuable insights into PT CP's green supply chain management performance, it is important to acknowledge certain limitations. The small sample size of six experts, though representative of key decision-makers within the company, limits the generalizability of the findings to broader contexts or other organizations. The cross-sectional nature of this study provides only a snapshot of the company's GSCM performance at a single point in time, rather than capturing changes over an extended period. Additionally, data collection challenges, such as potential bias in expert opinions or limitations in accessing certain types of data, should be considered when interpreting the results.

5.2. Future Research

Future research should utilize the fuzzy AHP approach as a weighting criterion. This approach is expected to produce more complex and subtle outcomes, improving the thorough analysis in evaluating green supply chain management. Companies aiming to enhance their green supply chain performance and obtain more precise measures should consider exploring options that enable more nuanced assessments. Utilizing sophisticated approaches and measuring tools can help gain a thorough comprehension of the company's environmental sustainability practices, assisting in pinpointing areas that can be improved.

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