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Supply chain performance measurement incorporating green factors using the supply chain operations reference on a fertilizer company

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A B S T R A C T

The fertilizer industry plays a crucial role in assuring the food security of a nation, but it also faces significant environmental obstacles. These problems often contribute to decreased supply chain efficiency and overall industrial productivity. The industry's focus on profit maximization hinders adopting green supply chain strategies. This paper examines company q's adoption of green supply chain management (GSCM) practices. This study evaluates its performance using the green supply chain operations reference (Green SCOR) model, scoring 73.54 out of 100, classifying it as 'good.' However, there is room for improvement, especially concerning key performance indicators (KPIs). This paper identifies six KPIs that fall below satisfactory levels and offers specific recommendations for improvement. This study significantly contributes to the fertilizer industry by providing actionable insights for practitioners and advancing theoretical understanding by highlighting key overlooked indicators. Furthermore, this research also emphasizes the crucial role of government policies in stimulating the implementation of sustainable supply chain practices.

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1. INTRODUCTION

The fertilizer industry receives significant attention from the government due to its strategic role in supporting national food security [1]. However, the agricultural sector encounters significant environmental obstacles. Contemporary farming systems potentially have environmental consequences, such as agrochemical pollutants and overconsumption of energy and water resources [2].

The intensification of business competition has potentially led to environmental issues within the supply chain management (SCM). Therefore, environmentally friendly SCM has become an inevitable trend [3]. It is necessary to establish an SCM that considers both the environmental aspect and the organization's objectives to achieve ecological sustainability [4].

The term SCM, which incorporates environmental aspects, is called green supply chain management (GSCM) [5]. Implementing GSCM has successfully mitigated environmental impacts while enhancing the organization's competitive advantage [6]. The objective of GSCM is to provide continuous improvement [7], encompassing initiatives aimed at reducing environmental impacts [8]

and incorporating the strategic and operational plans of the organization [9]. Therefore, the industry must consider and insist that environmental factors are considered within the GSCM practice [10], knowing the resulting performance [7] and determining its suitability to the GSCM concept [11].

On the other hand, performance measurement is critical for maintaining and improving an organization's competitiveness [12]. In the context of SCM, performance measurement aims to enhance stakeholder coordination and improve performance and efficiency [13]. Significant performance improvements in SCM have been made to ensure information flow increases transparency [14]. Supply chain performance is crucial for optimizing opportunities and minimizing losses [15] across processes within the supply chain [16]. The more complex an organization is, the more important SCM is in the organization [17]. It is necessary to utilize a supply chain measurement tool performance, such as the supply chain operations reference (SCOR), To assess the supply chain performance [18].

SCOR provides a comprehensive [19] and systematic framework [20] for assessing SCM performance. SCOR is designed for the entire supply chain process, such as planning, procurement, production, and distribution [19]. In addition, SCOR provides a systematic step consisting of identifying indicators for assessment criteria [21], converting the assessment processes into key performance indicators (KPIs) applied to the supply chain subsystem [22], and weighting the performance indicator using the analytical hierarchy process (AHP) approach [23].

SCOR also provides a tool called Green SCOR to measure the performance of the green supply chain. The Green SCOR is a relevant tool due to its complete criteria and alignment with the context of the supply chains. It considers many environmental concerns [10]. To successfully fulfill customer demands, it is essential to harmonize and coordinate inter-organizational procedures and the execution of strategies across the whole supply chain [24].

As mentioned before, considering environmental aspects in SCM can provide a sustainable system and minimize the negative environmental impacts [25]. However, adopting green supply chain strategies within the fertilizer industry remains infrequent due to the focus on profit generation. Therefore, this research aims to measure the performance of green supply chains in the fertilizer industry.

There is an opportunity to incorporate GSCM practices at *Company Q*. The company has not yet measured SCM with an environmentally friendly approach. Therefore, this study aims to provide insights and recommendations regarding ecological aspects within the company's supply chain. By understanding the company's business process and supply chain, this study is expected to offer a deeper understanding of sustainable solutions on supply chain practices that consider environmental aspects.

This research was conducted at *Company Q*, located in East Java, and serves as a central hub for the agricultural industry in Indonesia. With more than 50,000 m^2, the company possesses extensive infrastructure, significantly contributing to Indonesia's agricultural sector. *Company Q's* primary focus on producing high-quality fertilizers represents the company's commitment to supporting the productivity of Indonesia's agriculture.

The study of GSCM in the fertilizer industry becomes crucial considering the limitations of previous research, which were predominantly descriptive or theoretical. Empirical studies are expected to provide a deeper understanding of environmentally friendly supply chain practices. In addition, empirical research would validate theories and concepts proposed in the existing literature. With its direct impact on the agricultural sector and food security, the fertilizer industry must better understand how environmentally friendly supply chain practices can be effectively applied. Through empirical evidence, this research is also anticipated to drive changes in corporate behavior by motivating the adoption of sustainable practices in supply chain management. Consequently, this empirical study is expected to significantly contribute to advancing the sustainability of the fertilizer industry.

Singh *et al*. [26], [27] conducted a study to find key drivers of green supply chain adoption in the fertilizer industry in India. The study indicates that the government regulatory system is a critical driver in adopting the green supply chain in the fertilizer industry. However, after searching the same database and time frame, there has been no empirical research on measuring green supply chains in fertilizer companies. Therefore, this research addresses the empirical gap in measuring the green supply chain performance in the fertilizer industry.

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This paper fills a gap in GSCM literature by addressing empirical research on the fertilizer industry. This study introduces 14 key performance indicators (KPIs) and proposes improvements for *Company Q's* GSCM using the Green SCOR framework. By offering practical recommendations for GSCM efficiency and advocating consistent performance measurement, this paper contributes practical insights and theoretical advancements to environmentally friendly supply chain practices.

2. RESEARCH METHODS

This research comprises five stages: (1) identification of key performance indicators (KPIs) for the three levels of the Green SCOR metric, (2) application of the analytic hierarchy process (AHP) to determine the weightage of each level of the Green SCOR metric, (3) normalization of indicators using Snorm De Boer method, (4) computation of green supply chain performance, and (5) development of proposed recommendations. This stage has likewise been conducted by other previous studies [21], [28], [29]. Study Munawir *et al*. [21] evaluated the green supply chain performance in the batik industry, study Hapsari *et al*. [30] assessed the green supply chain in shoe manufacturing, and study Qurtubi *et al*. [29] evaluated the green supply chain practices in garment industries. In addition, the five steps are also relevant to the SCOR framework from APICS (association for supply chain management).

2.1. Key performance indicator

KPI is used as an indicator in the three levels of the Green SCOR metric. This study's KPIs were derived from literature reviews and brainstorming with the company and experts. In this study, the weighting aims to determine the importance of the identified KPI [30].

This study elaborated on KPIs by referring to SCOR 11.0, the current company's KPI, and previous studies such as Yongan & Menghan [8] and Hwang *et al*. [20]. This study utilized historical data and discussions with company experts, such as operations planners, production divisions, warehouse divisions, and hse divisions, to obtain the proposed KPI. Three months of historical data were then used to measure the performance of each KPI. Identified KPIs were further categorized according to the Green SCOR levels: level 1 (process), level 2 (performance attributes), and level 3 (key performance indicator). Table 1 displays a detailed description of KPIs across three levels.

2.2. Analytical hierarchy process

AHP was utilized to determine the weights for the three green SCOR levels. This method aligns with the study by Qianhan *et al.* [6]. The AHP was assessed using a scale of 1 to 9 to weigh the verified KPIs [31]. This scale assigns values to indicate the importance of one element over another. Each scale is described in Table 2.

Table 1. KPIs grouping

Process	Performance attribut	KPI	Source
Plan	Reliability	Energy usage	Company KPIs
		MPS - Commitment monthly order	Company KPIs
	Responsiveness	Cycle time in supplier selection and negotiation	[32]
Source	Reliability	% of suppliers with an EMS or ISO 14000 certification	[8]
		Percentage quality accuracy by supplier	Company KPIs
		Percentage quantity accuracy by supplier	Company KPIs
Make	Reliability	Yield (material efficiency)	[33]
		Number of trouble machines	[34]
		% of recyclable/reusable materials	[32]
		Percentage of solid waste recycling	[34]
		% hazardous waste from total waste	[34]
Deliver	Reliability	Deliver quantity accuracy	[20]
		Shipping document accuracy	[20]
Return	Reliability	% of Error – free return shipped	[34]

Table 2. AHP rating scale

Scale of Importance	Description
1	Both elements are equally important
3	One element is slightly more important than the other.
5	One element is more important than the other.
7	One element is more important than the other.
9	One element is more important than the other.
2, 4, 6, 8	Is a value between two adjacent consideration values

2.3. Snorm de boer

Storm de boer aims to standardize each indicator, considering the varying parameters and weights assigned to each indicator. Snorm de boer is utilized to equalize the values utilized as measured indicators. The normalization process using Snorm de boer was implemented using the following equation (1) and equation (2):

Larger is better

$$Snorm = \frac{(SI-Smin)}{Smax-Smin} x\ 100 \quad (1)$$

Smaller is better

$$Snorm = \frac{(Smax-SI)}{Smax-Smin} x\ 100 \quad (2)$$

Where SI: actual indicator value that can be achieved; Smax: best performance value achieved, and Smin: worst performance value achieved

The overall green supply chain performance was calculated by multiplying the final value obtained from the normalization step by the corresponding weight. Proposed improvements were provided to indicators classified in red and yellow or with a final performance score under 80.

3. RESULTS AND DISCUSSION

Based on 14 identified KPIs, *Company Q's* GSCM performance was evaluated. The Level 1, 2, and 3 weights were defined using AHP in the first step. During this stage, the Consistency Ratio (CR) is calculated and found to be 0.0089. This number is derived from the Consistency Index (CI) 0.01 and the Index Random (IR) 1.12. The result demonstrates that the pairwise comparisons exhibit consistency, with a consistency ratio (CR) of less than or equal to 0.1. Therefore, the weighting results of the procedure can be utilized for further steps.

Furthermore, historical data and expert review from Company Q were used to generate each KPI's Si, Min, and Max values. The Snorm was then measured using Eq. 1 and Eq. 2. Level 1, 2, and 3 weights were then multiplied to determine the total weight for each KPI. After that, the Snorm and the final weight were multiplied to normalize the parameter. The aggregate normalization of KPI was then calculated to determine the final performance of Company Q's GSCM. Table 3 depicts the performance evaluation of Company Q's GSC.

The total score of the green supply chain of Company Q is 73.54. This value indicates that the GSCM of Company Q was on a "good" scale. However, some KPIs still require improvements to improve GSCM performance. Furthermore, the traffic light system was implemented to identify KPIs that need to be improved. The three color indicators of the traffic light system used were red, yellow, and green. When the SNORM value is ≤50, it signifies unsatisfactory or poor performance; when it is 50 <70, it indicates performance in the marginal or average category; and when it is ≥70, it means satisfactory or good performance.

Based on the assessment of 14 KPIs, three fall under the red category, indicating areas of concern, while three fall under the yellow category, suggesting areas that require attention. Table 4 thoroughly reviews suggested improvements for *Company Q's* operational efficiency and overall performance. Recommendations were formulated through interviews with Company Q experts, such as operations planners, production divisions, warehouse divisions, and HSE divisions.

Proposed improvements are given to 6 Indicators: "MPS- commitment monthly order," "% of suppliers with an EMS or ISO 14000 certification", "percentage quality accuracy by supplier," "Yield (material efficiency)," "Number of trouble machines," and "% of recyclable/reusable materials." Table 4 shows the potential causes and proposed improvements for the six indicators. In the existing condition, the indicator "% of suppliers with an EMS or ISO 14000 certification" has a Snorm value of 0 because no suppliers have an environmental management certificate. It is recommended that

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Table 3. The assessment of green supply chain performance

Business Process	Weight Level 1	Attribute	Weight Level 2	KPI	Weight Level 3	Actual (Si)	Min	Max	Snorm	Final weight	Normalizes	Final score
Plan	0.38	Reliability	0.67	1	0.75	0.008	0	0.1	92	0.19	17.50	
				2	0.25	124.23	95	14.8	62.46	0.06	3.94	
		Responsi-veness	0.33	3	1	2	2	4	100	0.12	12.54	
Source	0.21	Reliability	1	4	0.6	0	0	100	0	0.13	0	
				5	0.2	82	50	100	64	0.04	2.68	
				6	0.2	94	50	100	88	0.04	3.69	
Make	0.22	Reliability	1	7	0.63	101	90	108	61.11	0.14	8.47	73.54
				8	0.03	29	0	45	35.56	0.006	0.23	
				9	0.08	30	0	100	30	0.02	0.53	
				10	0.13	90	0	100	90	0.03	2.57	
				11	0.13	0.005	0	10	99.95	0.03	2.86	
Deliver	0.12	Reliability	1	12	0.5	96	50	100	92	0.06	5.52	
				13	0.5	100	50	100	100	0.06	6	
Return	0.07	Reliability	1	14	1	0.003	0	100	99.99	0.07	6.99	

Table 4. Proposed improvements for Company Q to improve GSCM performance

No	Indicator	Potential cause	Proposed improvement
1	MPS – Commitment Monthly Order	Inappropriate production planning and target setting	Pay more attention to controlling inventory and understanding the company's production capacity.
2	% of suppliers with an EMS or ISO 14000 certification	None of the suppliers have an environmental management system certificate or ISO 14001.	Consider ownership of environmental management system certificate in supplier selection.
3	Percentage quality accuracy by supplier	The supplier failed to deliver materials that met the specifications.	We need to be more selective in supplier selection. Suppliers can send material samples in advance. Need to follow up on goods that do not meet specifications by complaining or asking for a return.
4	Yield (Material efficiency)	Some materials were not processed correctly. The efficiency of materials was compromised due to the dispersion of some materials outside the machine.	Conduct routine machine maintenance and implement technological advancements. Provide sufficient understanding for employees related to effective and efficient work.
5	Number of trouble machines	Machines operate frequently but lack maintenance.	Perform planned maintenance to improve machine performance. Consider adding new machines to increase productivity.
6	% of recyclable/reusable materials	Scrab or waste of materials cannot be directly processed; only a small portion can be utilized for the production mix.	Special handling and processing of residual materials must be utilized more effectively and efficiently.

Company Q incorporate the possession of environmental certificates as a criterion in their supplier selection process. This strategy can be achieved by initially familiarizing existing suppliers with the concept of supplier certificates as a criterion for selection

In addition, Alqudah *et al*. [35] provides a comprehensive overview of an extensive environmentally friendly purchasing approach within the supply chain. This approach emphasizes the integration of suppliers with environmentally friendly manufacturing processes and utilizing environmentally sustainable raw materials. The strategy implies a meticulous partner or supplier selection process based on specific criteria determining when products or components should be procured from environmentally friendly suppliers. The established criteria obligate suppliers to adhere to environmental quality standards, comply with hazardous substances and achieve green certifications such as ISO 14001, OHSAS 18000, and/or the RoHS directive from international organizations like the international organization for standardization (ISO).

The indicator with the second lowest value is "% of recyclable / reusable materials," which has a value of 30. According to the insights gathered through discussion with the management of Company Q, it has been determined that the current situation can be attributed to the limited utilization of scrap or waste materials in production. Furthermore, before its utilization in the production mixture, scrab/waste undergoes initial treatment.

The indicator ranked third in terms of its Snorm value is "Number of trouble machines," which obtained a score of 35.56. The present circumstance can be attributed to the machine's uninterrupted operation for 24 hours and the absence of a comprehensive maintenance protocol inside the company. One potential enhancement is introducing scheduled maintenance practices and undertaking extensive research to facilitate the successful integration of novel technologies. Furthermore, it is possible to offer training programs for operators to enhance their effectiveness and efficiency in their work.

Adopting green supply chain solutions within the fertilizer business is not commonly observed, primarily due to enterprises prioritizing profit development. Meanwhile, as previously described, the fertilizer industry pollutes the environment in its supply chain. Therefore, the primary objective of this study is to fill the existing empirical void regarding the measurement of the green supply chain within the fertilizer business.

The study yielded a set of 14 indicators for measuring the success of green supply chains, specifically applicable to the fertilizer industry. In the application submitted to *Company Q*, three indicators fell within the red category, while three were in the yellow category. The three indicators that fall into the red category are: "% of suppliers with an EMS or ISO 14000 certification", "number of trouble machines," and "% of recyclable/reusable materials." Two of the three indicators classified as red category indicators are included as indicators within the green supply chain factor. Therefore, fertilizer companies should prioritize two key indicators: selecting suppliers with environmental management certifications and implementing recycling or reusable material programs. Furthermore, as indicated by Singh's research, government policy plays a crucial role in promoting the adoption of green supply chains [27]. Therefore, it is recommended that the Indonesian government formulate policies that mainly target the two indicators above to support the implementation of green supply chains.

This study fills the empirical research gap because, in the last ten years, a search in the Scopus database obtained one article with the keyword "green supply chain AND fertilizer." Singh [27] did a research study to identify the factors that drive the adoption of green supply chain practices within the fertilizer business in India. The study's findings suggest that the regulatory structure implemented by the government has a significant role in facilitating the adoption of green supply chain practices within the fertilizer industry.

In contrast to Singh's research, the present study aims to discover green supply chain indicators within the fertilizer industry and subsequently apply them to assess the performance of a specific fertilizer company, referred to as Company Q. The findings of this study have identified two green supply chain indicators that the fertilizer industry has overlooked. The findings in question are choosing suppliers who have environmental management certification and implement recycling programs or materials that can be reused. Combined with Singh's research findings, these indicators can serve as valuable

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input for the Indonesian government in formulating regulations encouraging fertilizer companies to incorporate environmental management policies into their supply chain operations. As mentioned before, government policy plays a crucial role in promoting the adoption of green supply chains [27].

Moreover, the research enriches the current literature on GSCM by delving into implementing the AHP for assessing green supply chain performance. Its theoretical contribution involves integrating AHP as a crucial evaluation tool, providing specific insights into factors influencing GSCM. AHP simplifies the complexity of strategic decision-making, especially in evaluating sustainability-related KPIs. Furthermore, using weighting through the fuzzy-AHP method can be beneficial in reflecting the subjective evaluations of experts in the decision-making process [36]. The study's identification and assessment of these factors outline an applicable approach for enhancing green supply chain performance. Moreover, by offering recommendations based on expert interviews, the research provides practical insights for GSCM practitioners and decision-makers, extending its theoretical contribution to practical applications

4. CONCLUSION

Company Q's green supply chain performance assessment yielded a score of 73.54 out of 100, indicating that the company's performance falls within the "good" category. A total of 14 KPIs were measured, resulting in three KPIs being red and three being *yellow* categories. This paper presents suggested improvements for six KPIs below satisfaction levels to enhance the supply chain performance. Furthermore, conducting continuous assessments of the GSC's performance measurement is imperative for *Company Q* to maintain and increase its performance level.

This paper proposed and measured KPIs related to green supply chain practices in a fertilizer company, focusing on implementing concrete strategies to increase efficiency and responsiveness. In terms of empirical studies, this research aims to contribute to the existing body of research on measuring the green supply chain in the fertilizer industry. Future research might be conducted by examining existing regulations in Indonesia, especially on practices that still receive low scores, such as % suppliers with EMS certification and % of reusable materials. Furthermore, using weighting through the Fuzzy-AHP method can be beneficial in reflecting the subjective evaluations of experts in the decision-making process.

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