



Evaluating the impact of green SCOR and ISO 14001: Based practices on sustainability in palm oil supply chains

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ABSTRACT

This study aims to assess the effectiveness of environmentally conscious practices in the palm oil industry's supply chain by integrating the Green SCOR model with ISO 14001-based environmental indicators. A case study was conducted in a government-owned palm oil refinery in Central Kalimantan, Indonesia. The research employs a mixed-method approach involving surveys, interviews, and the Analytical Hierarchy Process (AHP) using Expert Choice software to weight and prioritize 24 Key Performance Indicators (KPIs). The results indicate that environmental management performance reached a satisfactory level of 83.51%, with the most critical indicators being related to waste quality monitoring and hazardous waste (B3) disposal. These findings underscore the importance of aligning supply chain operations with environmental management standards to ensure regulatory compliance and sustainability. The integration of ISO 14001 and Green SCOR enhances the accuracy and comprehensiveness of environmental performance assessments. The study concludes that periodic re-evaluation and the inclusion of broader environmental metrics are essential to maintain long-term sustainability in industrial operations. Future research should explore stakeholder involvement and dynamic data integration for more adaptive environmental strategies.

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1. INTRODUCTION

The advancement of the industrial sector significantly influences various aspects of human life. Industrial growth contributes to societal development by improving education standards, welfare, and per capita income. However, the negative externalities of industrialization, particularly in terms of waste generation, present serious environmental challenges. Improperly managed waste can adversely affect public health and environmental quality, with growing concerns over the increasing volume and diversity of waste produced (Mor & Ravindra, 2023).

Waste management has thus emerged as a critical issue that demands collective attention from governments, industries, and communities alike. Effective waste management involves several interconnected stages, including storage, collection, transfer, transportation, processing, and final disposal (Hoang et al., 2022). A coordinated approach that integrates environmentally friendly industrial practices with a comprehensive and structured waste management system is essential. Such synergy can mitigate environmental degradation while supporting sustainable industrialization and promoting the growth of small-scale and home-based enterprises.

Emphasizing environmentally sustainable industrial development requires a thorough assessment of the environmental risks associated with industrial waste to identify and minimize potential hazards (Awewomom et al., 2024).

This research focuses on the palm oil refining industry, which plays a central role in the industrial landscape. The supply chain process in this sector begins with fruit harvesting on plantations, followed by transportation to processing facilities where the fruit is sorted and processed into crude palm oil (CPO). The company involved collaborates with downstream processing industries, forming a supply chain network that includes plantations, palm oil mills (POMs), and final processing facilities. Each stage of this supply chain contributes to environmental pollution, including air, water, and soil contamination (Lee & Bateman, 2023).

Palm oil mills are particularly known for generating significant environmental waste in the form of solid, liquid, gaseous, and hazardous materials (Merrylin et al., 2023). Approximately 42.5% of solid waste and 50% of liquid waste result from the palm fruit processing cycle. Without effective waste treatment strategies, this byproduct can cause severe ecological harm (Rani et al., 2023). Therefore, implementing a robust waste management system is essential for industrial facilities. One method to enhance waste management is through the adoption of an Environmental Management System (EMS), such as that outlined in the ISO 14001 standard (Bhateria, 2024).

ISO 14001 provides a structured framework for implementing environmental management practices and helps organizations fulfill regulatory obligations while reducing environmental risks. However, despite its global recognition, ISO 14001 implementation in the palm-oil mill context often remains superficial largely focused on obtaining certification rather than embedding environmental criteria into routine operational decisions. Zimon et al. (2022) note persistent gaps between documented EMS procedures and actual field practices, highlighting a need to investigate real-world alignment of ISO indicators with supply-chain activities. To overcome these limitations, companies are encouraged to incorporate environmental performance evaluation tools into their management practices

Green Supply Chain Management (GSCM) offers a strategic approach that integrates environmental considerations into all stages of the supply chain. GSCM aims to optimize the flow of materials from upstream to downstream processes while minimizing environmental impact (Chairia et al., 2024; Salifu et al., 2025). It focuses on converting waste materials into marketable products, thus enhancing both environmental and economic performance. The GSCM framework can address various waste-related challenges in industries that deal with chemical, solid, and liquid waste streams (Khoshsepehr et al., 2023). To evaluate GSCM performance, this study employs the Supply Chain Operations Reference (SCOR) model and the Analytic Hierarchy Process (AHP) (Putra et al., 2022). The SCOR model provides a standardized framework for mapping and analyzing supply chain processes planning, sourcing, making, delivering, and returning while AHP is used to assign weights and priorities to performance indicators (Ayyildiz & Taskin Gumus, 2021; Nguyen, 2024). The combination of SCOR and AHP enables comprehensive environmental performance assessment based on key performance indicators (KPIs).

Unlike previous research that treats GSCM and ISO 14001 as separate frameworks, this study uniquely integrates both into a singular evaluative model. The novelty of this approach lies in its use of ISO 14001 standards as a foundation for identifying key environmental performance indicators, which are then evaluated through the SCOR model within a palm oil supply chain context. Moreover, the incorporation of AHP introduces a dynamic weighting system that reflects stakeholder priorities, thus enhancing the decision-making process for sustainability interventions.

This research distinguishes itself by using ISO 14001 certification as a benchmark for identifying environmental KPIs within the palm oil supply chain and evaluates their alignment with green supply chain strategies. Through this approach, the study aims to provide insights into the integration of environmental management systems within industrial operations to promote sustainability and regulatory compliance.

2. RESEARCH METHOD

Data collection for this study involved the distribution of questionnaires and the conduct of interviews. The research was conducted in a government owned palm oil refinery plant in Central

Kalimantan Province, Indonesia. The data analyzed pertains to the adoption of ISO 14001 certification in 2018. The primary data consisted of environmental management indicators derived from ISO 1400 certification. Meanwhile, the secondary data collected included ISO 14001 certification data from 2018 and data on the company's refusal to process data. The data collection strategy employed in this study was purposive sampling, which involves selecting participants based on specific objectives and considerations (Robinson, 2024). Researchers were mandated to gather ten samples from individuals with corporate environmental management expertise. The software utilized in this study encompassed SPSS and expert selection software.

The questionnaire instrument was developed based on the 24 environmental management indicators derived from ISO 14001 clauses, as detailed in Table 2. Each item was measured using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), allowing a structured quantitative evaluation of indicator implementation. Prior to full deployment, the questionnaire was pilot-tested with three internal experts to evaluate item clarity, relevance, and formulation. Feedback from the pilot phase informed minor revisions to improve the instrument's validity. Indicator validity was confirmed through a Pearson correlation test, where each item demonstrated an *r*-value exceeding the critical threshold of 0.631. Additionally, the instrument's reliability was verified through Cronbach's Alpha, which returned a score of 0.957, signifying high internal consistency across the questionnaire items.

To further validate and triangulate the results, semi-structured interviews were conducted with the same group of experts. These interviews provided qualitative insight into the relevance, accuracy, and applicability of each environmental indicator within real-world palm oil supply chain operations. For the Analytical Hierarchy Process (AHP), data were processed using Expert Choice software version 11. Pairwise comparisons were conducted among the indicators, and weight prioritization was derived. The calculated Consistency Ratio (CR) was 0.02, below the acceptable threshold of 0.1, indicating coherence in expert judgment and eliminating the need for further review or redesign of the comparison matrix.

3. RESULTS AND DISCUSSIONS

The company's business process has three entities: plantations, producers (or palm oil mills), and customers (or final processing businesses). The Green SCOR model includes processes that explain each business process involving an entity. The procedures above encompass planning, sourcing, production, delivery, and returns. Next, we will delineate the business research process and its constituent elements. Each entity plays a critical role in shaping the environmental impact of the overall supply chain. The Green SCOR model helps identify and evaluate key performance indicators (KPIs) at each stage, allowing for targeted improvements in sustainability. This structured approach ensures that environmental performance is assessed not only holistically but also in detail across all operational levels.

Table 1. Data processing stages

Description	Stages
Identification of Company Business Process	The objective is to identify the entities and business processes involved in building Green SCOR mapping to calculate the company's environmental management indicators. The classification is derived from the five Green SCOR processes: Plan, Source, Make, Deliver, and Return.
Determination of environmental management indicators in supply chain strategy	The indicators included in this study are derived from many sources, encompassing ISO 14001 certification and several prior studies on GSCM that have been tailored to align with the company's operational procedures. Validity and reliability assessments are conducted after the acquisition of the indicators.
Identification of environmental management performance measurement matrix	The Green SCOR matrix has three levels of matrices, with level 1 denoted by the green SCOR process. This process encompasses planning, procurement, manufacture, delivery, and return. The level 2 matrix in the SCOR model is a component of the green SCOR process. The dimensions include reliability, responsiveness, flexibility, cost, and assets. The Key Performance Indicators that were previously gathered are in the form of a level 3 matrix.
Weighting (AHP)	The utilization of the Analytical Hierarchy Process (AHP) methodology in constructing the matrix is deemed satisfactory, provided that the consistency ratio does not exceed 0.1. In this work, the AHP method is computed using software that experts chose.
Calculation of	This study creates indicators with diverse values and measuring scales. Normalization is

Description	Stages
normalization value	employed to guarantee that performance-measuring parameters are standardized. Furthermore, this inquiry incorporates the implementation of Dr. De Boer's Snorm normalization.
Calculating environmental management performance value	The environmental management performance value is produced by computing the Snorm De Boer normalization score using the entire weight of the indicator.

The SCOR process in plantation businesses commences with the planning phase, which encompasses procurement planning (plan source), production planning (plan make), delivery planning (plan delivery), and delivery planning (Sarjono et al., 2022). Submit a request for a return (return plan). This plantation employs various materials, such as seeds, fertilizers, and pesticides, to cultivate oil palm fruit silk. The origin of the items stored to maximize oil palm fruit output includes the resources owned by the plantation. The make to stock system is utilized in the creation phase of the plantation, whereas the delivery phase of the plantation employs a stocked product distribution system. The gathered harvest will be transferred to the Palm Kernel Station (PKS).

The plantation undergoes two distinct return processes: source return, which occurs when the fruit fails to satisfy quality standards and return delivery, which involves fruit return due to delays and delivery issues. The SCOR process in the PKS entity commences with the planning process (plan), encompassing the activities of sourcing, manufacturing, delivering, and returning. In addition, the PKS utilizes a product procurement system integrated into the procurement process (sourcing). This system prioritizes the collection of fruit before production. PKS employs a make-to-stock approach in its production process since the processed fruit, or CPO is held in a container before shipment. The PKS shipping procedure delivers stocked products while the stored CPO is transferred to the processing industry. The PKS return process consists of two distinct stages.

The first process involves returning the CPO due to its failure to satisfy quality standards. The second process involves re-shipping the product due to delays or shipping limitations. The SCOR process in industrial processing entities commences with the planning phase (plan), which consists of gathering planning sources and formulating and submitting plans. Furthermore, the procurement process in the processing industry employs a source inventory product system, wherein CPO is initially collected before production. The processing business utilizes a make-to-stock system in its manufacturing process, as it involves converting the existing CPO into several items stored before shipment. The shipping process uses a standardized product shipping system, storing the processed products before being dispatched.

Table 2. Environmental management indicators (key performance indicators) based on ISO 14001

No.	Indicator Description	Source (ISO 14001 Clause)	Adapted to Supply Chain Process
1	Percentage of emergency equipment available in required places	Clause 8	Yes
2	Percentage of available B3 (hazardous material) documents	Clause 7	Yes
3	Environmental policy-making planning	Clause 5	Yes
4	Identifying and evaluating hazardous areas	Clause 6	Yes
5	Conducting regular supplier evaluations regarding environmental requirements	Clause 8	Yes
6	Updating regulations related to environmental compliance	Clause 9	Yes
7	Minimizing energy use in operations	Clause 8	Yes
8	Packaging and labeling B3 materials as required	Clause 8	Yes
9	Percentage of suppliers committed to environmental principles	Clause 8	Yes
10	Percentage of hazardous goods stored properly	Clause 8	Yes
11	Conducting periodic inspections of goods conditions	Clause 9	Yes
12	Percentage of products damaged during storage	Clause 8	Yes
13	Conducting measurements and controls on waste quality	Clause 9	Yes
14	Percentage of trained workers on environmental practices	Clause 7	Yes
15	Percentage of liquid waste produced	Clause 6	Yes

16	Percentage of solid waste produced	Clause 6	Yes
17	Increasing consistency of product and environmental quality	Clause 8	Yes
18	Total water consumed for production	Clause 6	Yes
19	Percentage of complete shipping documents	Clause 8	Yes
20	Conducting B3 waste disposal according to requirements	Clause 8	Yes
21	Percentage of B3 waste distributors committed to environmental practices	Clause 8	Yes
22	Percentage of consumer complaints regarding the quality of CPO produced	Clause 9	Yes
23	Percentage of environmental violations based on applicable regulations	Clause 9	Yes
24	Percentage of solid and liquid waste that can be utilized	Clause 6	Yes

To assess environmental performance within the company's supply chain strategy, this study identifies and evaluates a set of environmental management indicators. These indicators, derived from the ISO 14001 certification framework, serve as Key Performance Indicators (KPIs) tailored to the organization's operational context. The environmental management indicators or Key Performance Indicators (KPIs) used in this study are obtained from ISO 14001 certification and are specified in Table 2. The collected indicators have been modified to match the company's supply chain and business procedures. Nevertheless, the commercial world does not consistently utilize and execute these indicators. Indicator verification assesses the company's accurate implementation and utilization of the received indicators. The survey was disseminated to ten environmental management specialists within the organization to validate the indicators. An assessment was conducted to determine the accuracy and consistency of the questionnaires completed by the participants.

All indicators or Key Performance Indicators (KPIs) were valid during the validity test. The first indicator, the proportion of emergency equipment availability when needed, has a calculated correlation coefficient (*r*-value) of 0.774, which exceeds the critical value (*r*-table value) of 0.631. The reliability of the disseminated questionnaire is confirmed by Cronbach's Alpha score of 0.957, which surpasses the established threshold of 0.7 obtained by the reliability test. This indicates that the questionnaire has demonstrated exceptional dependability.

To further enhance the evaluation process, expert interviews were conducted to establish a structured hierarchy for measuring environmental management performance. This hierarchical approach facilitates the classification of each Key Performance Indicator (KPI) based on specific processes and environmental dimensions, ensuring that the assessment yields accurate, consistent, and relevant results. Interviews with professionals in corporate environmental management successfully established a robust ranking system for KPIs, allowing each indicator to be aligned with appropriate operational processes and environmental aspects. This structured classification enables a more systematic evaluation framework, enhancing the clarity and precision of performance assessments (Karasan et al., 2023; Mio et al., 2022).

To quantify the relative importance of each environmental performance indicator, calculations were performed using Expert Choice software version 11. This software supports multi-criteria decision-making by generating weight values and the Consistency Ratio (CR) for the environmental performance measurement matrix developed by Jasim. The software output provides a clear prioritization of each KPI, revealing that KPI M101, which assesses and influences waste quality, holds the highest weight at 0.088. Conversely, KPI R102, which ensures compliance with environmental regulations, holds the lowest weight at 0.014. The CR value is calculated at 0.02, which is within the acceptable threshold of ≤ 0.1 , indicating that the expert judgments are consistent and that no further evaluation of the questionnaire design or respondent selection is necessary (Gavalas et al., 2022; Grošelj et al., 2024; Pinheiro & de Mello Sant'Ana, 2025).

Table 3. Calculation of environmental management performance values

No	Environmental Management Indicators	Weighted	Score	Score x Weight
1	Percentage of emergency equipment available in required places	0,069	66,67	4,60
2	Percentage of available B3 documents	0,039	100,00	3,90

No	Environmental Management Indicators	Weighted	Score	Score x Weight
3	Environmental policy-making planning	0,049	100,00	4,90
4	Identifying and evaluating hazardous areas	0,062	68,00	4,22
5	Conducting regular supplier evaluations regarding environmental requirements	0,024	75,00	1,80
6	Updating regulations	0,058	90,00	5,22
7	Minimizing energy use	0,039	93,10	3,63
8	Packaging and labelling B3 symbols and labels according to requirements	0,031	80,00	2,48
9	Percentage of suppliers who are committed to the environment	0,066	60,00	3,96
10	Percentage of hazardous goods in storage	0,019	80,00	1,52
11	Conducting periodic inspections of goods conditions	0,055	75,00	4,13
12	Percentage of products damaged during storage	0,042	75,00	3,15
13	Conducting measurements and controls on waste quality	0,088	93,10	8,19
14	Percentage of trained workers	0,023	70,00	1,61
15	Percentage of liquid waste produced	0,049	66,67	3,27
16	Percentage of solid waste produced	0,03	66,67	2,00
17	Increasing consistency of product quality and the environment	0,035	95,00	3,33
18	Total water consumed for production	0,029	80,00	2,32
19	Percentage of complete shipping documents	0,039	66,67	2,60
20	Conducting B3 waste disposal according to requirements	0,088	95,00	8,36
21	Percentage of B3 waste distributors who are committed to the environment	0,025	80,00	2,00
22	Percentage of consumer complaints about the quality of CPO produced	0,021	93,10	1,96
23	Percentage of environmental violations based on applicable regulations	0,014	80,00	1,12
24	Percentage of solid and liquid waste that can be utilized	0,035	93,10	3,26
Total				83,51

A total of 24 key performance indicators (KPIs) are derived from measurements of environmental management performance. The company employs 24 performance measuring indicators to accomplish its purpose at each stage of the Green SCOR process, namely planning, sourcing, production, delivery, and returns. The source process consists of 5 key performance indicators (KPIs), the making process consists of 6 KPIs, the delivery process consists of 3, and the return process consists of 3. There are seven key performance indicators (KPIs) in the planning process. According to the research results, the company's environmental management performance is considered "good", with a performance value of 82.41%. The ideal range for achieving best performance is between 71% and 90% (Petruzzelli & Badia, 2024).

A closer analysis of the weighting results shows that KPI, which focuses on conducting measurements and controls on waste quality, received the highest weight (0.088) and performance score (93.10). This finding underscores the critical role of B3 (hazardous waste) monitoring in achieving environmental compliance and mitigating environmental risk. The prioritization of this indicator by experts reflects its potential impact on both operational safety and legal exposure. In practice, continuous monitoring of B3 waste ensures that companies can identify harmful outputs early, reduce contamination risks, and avoid costly penalties or regulatory sanctions.

Conversely, KPI, which relates to compliance with environmental regulations, was assigned the lowest weight (0.014). This may suggest that compliance is viewed as a baseline requirement, externally audited, and less influenced by internal innovation. However, deprioritizing this area may increase the company's vulnerability to regulatory lapses if attention is not maintained. Thus, even low-weight indicators require routine internal review to ensure proactive compliance.

These findings are consistent with previous studies which emphasize that the integration of environmental indicators across supply chain stages enhances performance evaluation and sustainability outcomes. The use of the Green SCOR model and KPIs derived from ISO 14001

significantly improves environmental monitoring and control in the palm oil industry (Rosyidah et al., 2022). Strategic environmental indicators, when aligned with operational processes, contribute to improved environmental performance and firm competitiveness (Habib et al., 2021). Green supply chain management practices including the application of environmental KPIs positively influence both operational and environmental dimensions of business performance (Khan et al., 2022).

Despite the generally high performance score, specific operational gaps still exist and can be improved with targeted interventions. For instance, the KPI concerning the percentage of trained workers on environmental practices has a relatively low performance score of 70.00, although training is essential for fostering a proactive environmental culture. This suggests the need for systematic, recurring training programs tailored to different organizational levels. Companies should institutionalize mandatory induction training for new employees, refresher sessions for existing staff, and integrate environmental modules into regular performance evaluations.

Furthermore, the KPI on supplier commitment to environmental practices (score: 60.00) indicates a disconnect between internal sustainability objectives and external supply chain partners. To address this, the company should revise procurement policies to include environmental clauses, perform supplier assessments periodically, and consider green supplier development programs. These operational improvements can help close the gap between policy and execution, thus enhancing end-to-end environmental sustainability in the supply chain.

While the organization has successfully adopted an efficient environmental management system, there is no assurance that its future environmental management performance will be equally effective. To uphold and enhance the existing performance, it is imperative to regularly assess environmental management performance utilizing the specified Key Performance Indicators (KPIs). The methodology employed to examine an organization's environmental management performance can thoroughly evaluate its present environmental management status. The research findings suggest that the company's management performance value is delighted, mainly when the organization successfully implements an efficient environmental management system. The support from previous studies further reinforces the necessity of continuously aligning environmental performance metrics with evolving sustainability standards and operational realities.

4. CONCLUSION

This study demonstrates that the environmental management performance of the analyzed palm oil company is considered highly satisfactory, with an overall performance value of 83.51%. The integration of ISO 14001-based indicators with the Green Supply Chain Management (GSCM) framework particularly through the Green SCOR model and the Analytical Hierarchy Process (AHP) provides a structured and effective method for evaluating environmental performance. Among the 24 identified Key Performance Indicators (KPIs), the most influential were related to waste quality monitoring and B3 waste disposal, highlighting the importance of regulatory compliance and environmental safety in industrial operations. The findings confirm that the company's efforts to align its supply chain practices with environmental sustainability goals are both measurable and impactful, especially in waste control and resource management.

Despite the positive outcomes, maintaining consistent environmental performance requires continuous improvement and periodic reassessment. The study recommends that organizations not only rely on the ISO 14001 framework but also expand the set of environmental indicators to better reflect dynamic operational conditions. Future research should explore the integration of additional sustainability standards and examine long-term trends in KPI effectiveness across different entities within the supply chain. Furthermore, incorporating external stakeholder perspectives and real-time environmental data could enhance the precision and relevance of performance evaluations. These steps will ensure that environmental management practices remain proactive, adaptive, and aligned with broader goals of sustainable industrial development.

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