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Performance Analysis of the Biosolar Supply Chain in Mining Industries using AHP and SCOR Models

Is Anin Nazura[1*], Sawarni Hasibuan[2]
[1]Industrial Engineering Department, Universitas Mercu Buana, West Jakarta, Indonesia
[2]Industrial Engineering Department, Universitas Mercu Buana, West Jakarta, Indonesia

*Corresponding author email: isaninnazur4@gmail.com

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ABSTRACT

The shift towards renewable alternative energy has become a critical agenda for countries worldwide, including Indonesia. The Indonesian government has set a goal to reduce CO_2 emissions by 358 million tons, or 12.5% of the national emission reduction target by 2030. This study aims to design an efficient system for measuring the performance of the biodiesel supply chain in mining companies. The research methods used are the Analytical Hierarchy Process (AHP) and Supply Chain Operations Reference (SCOR) model. The SCOR model is used to create a process-based supply chain performance evaluation system, enabling companies to evaluate their supply chain activities comprehensively for monitoring, control, and communication of business goals to related functions and the supply chain. The SCOR model focuses on five dimensions: reliability, responsiveness, agility, cost, and asset management. As a structured process hierarchy, this model facilitates supply chain management and provides metrics to assess specific performance aspects in these SCOR dimensions. Initially, relevant Key Performance Indicators (KPIs) were validated using the SCOR framework, and the weighting of selected KPIs was carried out using the AHP method. Of the 42 initial indicators, 23 were selected. The results of the performance measurement for the biodiesel supply chain in mining companies showed that the highest SCOR values were for responsiveness and cost (1.00), followed by reliability (0.95), agility (0.88), and asset management (0.82).

Keywords: KPI, AHP, SCOR, Biodiesel, Mining Companies.

Introduction

Modern bioenergy is currently the largest source of renewable energy in the world, representing 55% of total renewable energy and over 6% of the global energy supply. The Net Zero Emissions by 2050 (NZE) scenario predicts a swift rise in bioenergy usage to substitute fossil fuels. Between 2010 and 2022, the adoption of modern bioenergy has grown at an average annual rate of approximately 3% and continues to trend upward [1].

Greater efforts are necessary to speed up the adoption of modern bioenergy to align with the NZE scenario, which calls for an annual increase of 8% between 2022 and 2030, while also ensuring that bioenergy production does not lead to adverse social and environmental impacts [2]. The progress of Indonesia B30 biodiesel initiative is also influenced by the realization of the B30 biodiesel program [3].

A study conducted by indicates that biodiesel is an alternative fuel that offers several advantages over conventional diesel. One key benefit is its high combustion efficiency, which enhances overall engine performance. Additionally, biodiesel has low levels of sulfur

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and aromatic compounds, making it a suitable option for diesel vehicles. The adoption of biodiesel blends has gained popularity in the mining sector, providing a viable solution that positively affects the performance of heavy equipment in the field. Biodiesel blends, particularly those with higher concentrations, show improved attributes such as increased cetane numbers, enhanced lubricating properties, and lower emissions.

In Indonesia, the mining sector has been steadily increasing the proportion of biodiesel in fuel blends, particularly up to 30% biodiesel by volume (B30), since early 2020 [3]. The primary objective of recent advancements in engine technology is to minimize carbon emissions. This review aims to contribute to achieving the NZE 2050 target through the utilization of Biodiesel B30. Previous research has largely concentrated on specific locations, with few studies analyzing the performance of the biodiesel supply chain across various industries, including mining [4]. The use of biodiesel in the mining sector is not only linked to efforts for operational sustainability but also reflects the company's commitment to environmental stewardship. With the growing demand to reduce carbon emissions and enhance energy efficiency, the management of the biodiesel supply chain is becoming increasingly vital [5].

Nonetheless, the biodiesel supply chain's complexity ranging from procurement and distribution to field utilization often poses significant challenges, particularly in ensuring that each stage operates optimally and efficiently [6]. The Analytical Hierarchy Process (AHP) and Supply Chain Operations Reference (SCOR) are two methodologies that can be employed to create a comprehensive and adaptable performance measurement system. AHP enables performance evaluations to be conducted while accounting for existing uncertainties and variabilities, whereas SCOR offers a structured framework for mapping and managing the entire supply chain process [7].

The SCOR model is utilized to create a process-based evaluation system for supply chain performance, allowing companies to thoroughly assess their supply chain activities for monitoring and control. Additionally, it facilitates the communication of organizational goals to relevant business functions and supply chains [8].

Methods

This research employe a quantitative methodology. Quantitative methods will be applied to develop a framework for evaluating supply chain performance using the SCOR and AHP approaches. Data collection for this study involves questionnaires distributed to 13 expert respondents from mining companies. The research design focuses on identifying the requirements of the biodiesel supply chain, with weighting conducted through AHP. [9] The research is carried out within a mining company. Previous studies have not identified any research findings concerning relevant KPIs for assessing the performance success of the biodiesel renewable energy supply chain, particularly in mining companies [10]. By utilizing the SCOR model, the evaluation of supply chain performance emphasizes supply chain management functions from an operational process perspective, encompassing customer interactions, physical transactions, and biodiesel transactions [11].

Analytical Hierarchy Process (AHP) Process

The AHP method involves three in the decision-making process, including the structure (decompose) of the model; the comparison of the criteria and alternatives and calculation of the weight; and the synthesis of priorities [12]. Thomas L. Saaty created a standard rating scale as see as in Table 1.

Table 1. The Saaty scale

Intensity of Interest	Definition
1	Both elements hold the same level of importance.
3	One element is slightly more significant than the other elements.
5	One element is more significant than the other elements.
7	One element is distinctly more important than the other elements.
9	One element is unequivocally more important than the other elements.

2,4,6,8	The values of the two considerations are relatively close to each other.

AHP can be utilized to analyze data from a single expert, but it can also incorporate insights from multiple experts across different disciplines [13]. Consequently, the judgments made by these experts must be individually assessed for consistency. The consistent opinions are then aggregated using geometric averages [14].

$$XG = \sqrt[n]{\prod_{i=1}^{n} X_i}$$

N Number of specialists

Xi Assessment by the first expert

Calculating priorities and weighting consistency [15]. The following steps outline the process for calculating priorities and assessing weighting consistency:

Sum the values in each column's elements.

1. Divide each element in the column by the corresponding column total.
2. Calculate priorities by summing the results for each row and then divide by the number of elements. The consistency calculation process involves:
   - Multiplying the matrices by the corresponding priorities.
   - Adding the results of these multiplications.
   - Dividing each row total by the relevant priority and then summing the results.
   - Dividing the final result by the number of elements to obtain the value of λ max.
   - Calculate the Consistency Index using the appropriate formula.

$$(CI) = (\lambda \max - n) / n-1 \quad (2)$$

   - Calculating CR Value. Consistency Ratio.

$$(CR) = CI / RI \quad (3)$$

If the consistency ratio value is less than 0.1, there is no need to revise the input values in the matrix. The Random Index (RI) represents the average value of indices generated randomly from Thomas L. Saaty's experiments (1988), which utilized matrices of order ranging from 1 to 7 [16].

The critical Score of Each Medical Device: The initial step in determining the critical score of a medical device involves identifying the grade to which the device belongs [17]. Each intensity value associated with the grade will be multiplied by the weight of the corresponding sub-criteria or criteria. Subsequently, all the weighted sub-criteria and criteria, which have been multiplied by the appropriate grade, are summed to yield the total value, which represents the critical score of the medical device [18].

Supply Chain Operations Reference (SCOR) Framework

As stated by SCOR integrates elements of business process engineering, metrics, benchmarking, best practices, and human capabilities into a single framework [19]. SCOR defines supply chain management as a cohesive process encompassing Planning, Sourcing, Making, Delivering, and Returning from suppliers to customer [20]. Each component of the SCOR process is represented in Fig. 2.

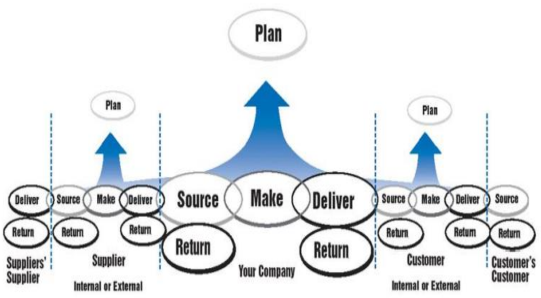

Figure 2. Five Fundamental Supply Chain Processes in

Supply chain management systems involve a series of approaches aimed at efficiently integrating suppliers, manufacturers, warehouses, and retailers to ensure that products are produced and distributed in the correct quantities, to the right locations, and at the right time . This minimizes overall system costs while meeting required service levels. The SCOR model helps map the components of the supply chain by breaking it down into

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five key processes: plan, source, production (make) deliver and return [21].

The term "supply chain management" was first introduced by Oliver and Weber in 1982. It represents a comprehensive business process, starting from raw material acquisition from suppliers, continuing through manufacturing, and ending with distribution to consumers[22]. Measuring supply chain management (SCM) performance is crucial for reducing costs, meeting customer satisfaction, improving company profits, and determining the success of the company's supply chain. Supply chain performance refers to how well the supply chain meets the needs of consumers and stakeholders based on key performance indicators at various stages [23].

The purpose of performance measurement is to support goal achievement, evaluate current performance, and shape future strategies, tactics, and actions. Supply chain integration is essential for managing and controlling processes within the production or service systems. In the operational process, companies aim to achieve specific goals regarding quality, speed, flexibility, and cost-efficiency. Supply chain performance measurement plays a key role here by comparing current performance against established standards [24].

In Supply Chain Management, the sequence of activities from suppliers to end consumers is viewed as a unified entity without major divisions, and the flow of information between components is transparent. A key principle is the sharing of material and information flow across the supply chain [25].

Every activity or process within a supply chain requires resources as inputs, which are then transformed to add value, resulting in outputs that meet customer expectations [26]. Thus, each activity incurs costs as it consumes resources and creates value. A process-based approach in designing a supply chain performance measurement system enables problem identification early on, allowing for corrective actions before issues become widespread [27].

The SCOR model outlines five dimensions: reliability, responsiveness, agility, cost, and asset management [28]. As a structured hierarchy of processes, it aids in supply chain management and provides metrics to evaluate specific performance elements within the SCOR framework.

1) Supply Chain Reliability pertains to the dependability of the supply chain.
2) Supply Chain Responsiveness concerns the speed of response to changes.
3) Supply Chain Agility involves the flexible to adapt to changes.
4) Supply Chain Cost relates to expenses incurred within the supply chain.
5) Supply Chain Asset Management focuses on the value of goods.

Results and Discussions

Selection of Key Performance Indicators (KPIs)

Table 3 presents the outcomes of the KPI selection process, resulting in 23 indicators out of a total of 42 indicators.

Table 3. Selected and Unselected KPIs in the Biodiesel Supply Chain

No	Notation	Indicators	Selected/ Unselected
1	A1	Reliability	Selected
2	A11	Percent of order delivery in full	Selected
3	A113	Inventory Accuracy	Selected
4	A13	Perfect Condition	Selected
5	A131	Percent order received defect free	Selected
6	A14	Documentation document	Selected
7	A141	Shipping document accuracy	Selected
8	A111	Deliver quantity accuracy	Unselected
9	A112	Percent of stock out	Unselected
10	A12	Delivery performance to customer commit day	Unselected
11	A121	Delivery location accuracy	Unselected
12	A122	Deliver cycle time	Unselected
13	A132	Percent faultless invoices	Unselected
14	A133	Warranty and return	Unselected
15	A142	Compliance document accuracy	Unselected
16	A143	Payment document accuracy	Unselected
17	B1	Responsiveness	Selected
18	B11	Source cycle time	Selected
19	B111	Receive product cycle time	Selected
20	B12	Deliver cycle time	Selected
21	B121	Fill rate by line item	Unselected
22	C1	Agility	Selected
23	C12	Supply chain delivery flexibility and adaptability.	Selected
24	C121	Delivery volume	Selected
25	C13	Supply chain deliver return flexibility and adaptability	Selected
26	C131	Deliver return volume	Selected
27	C11	Supply chain source flexibility and adaptability	Unselected
28	C111	Current and hand inventory	Unselected
29	C112	Capacity utilization	Unselected

No	Notation	Indicators	Selected/ Unselected
30	C113	Forecast accuracy	Unselected
31	C14	Supply chain source return flexibility and adaptability	Unselected
32	C141	Source return volume	Unselected
33	D1	Cost	Selected
34	D11	Cost to plan	Selected
35	D12	Cost to make	Selected
36	D13	Cost to deliver	Selected
37	D14	Cost to source	Unselected
38	D15	Cost to return	Unselected
39	E1	Asset management	Selected
40	E11	Days payable outstanding	Selected
41	E111	Days payable	Selected
42	E12	Death stock	Non-Selected

Table 4. Summary of The Selected Indicators Matrix

Level 1	Level 2	Level 3
A1	A11	A113
	A13	A131
	A14	A141
B1	B11	B111
	B12	
C1	C12	C121
	C13	C131
D1	D11	
	D12	
	D13	
E1	E11	E111

Upon completing all calculations, the following is a summary of the Consistency Ratio (CR) test results for the relationships between criteria and sub-criteria at KPI levels 1, 2, and 3.

Table 5. Summary Of All Consistency Ratio (CR) Test Results

Comparison of Pairwise Criteria and Sub-Criteria	λ (max)	CI	IR	CR	Hasil
Level 1 Criteria	5.38	0.10	1.12	0.08	Consistent
Level 2 Sub-Criteria: Reliability	3.10	0.05	0.58	0.08	Consistent
Level 2 Sub-Criteria: Responsiveness	2.00	0.00	0.00	0.00	Consistent
Level 2 Sub-Criteria: Agility	2.00	0.00	0.00	0.00	Consistent
Level 2 Sub-Criteria: Cost	3.06	0.03	0.58	0.05	Consistent
Level 3 Sub-Criteria: Reliability	3.08	0.04	0.58	0.07	Consistent
Level 3 Sub-Criteria: Agility	2.00	0.00	0.00	0.00	Consistent

Weighting of KPIs

Based on the processed data results, the following is a summary of the KPI Level 1-3 weight values derived from the priority vector outcomes.

Table 6. Summary of Key Performance Indicators (KPI)

Level 1	Bobot	Level 2	Pairwise Comparison Weight	Level 3	Pairwise Comparison Weight	Global Weight
A1	0,17	A11	0.31	A113	0.28	0.06
		A13	0.34	A131	0.39	0.07
		A14	0.35	A141	0.33	0.07
B1	0,19	B11	0.45	B111	1.00	0.09
		B12	0.55			0.11
C1	0,17	C12	0.36	C121	0.31	0.07
		C13	0.64	C131	0.69	0.13
D1	0,25	D11	0.32			0.06
		D12	0.40			0.08
		D13	0.28			0.06
E1	0,23	E11	1.00	E111	1.00	0.20
		Amount				1.00

Outcomes of the Biodiesel Supply Chain Performance Assessment

To establish the final score for the performance assessment of the biodiesel supply chain within the Mining Company, the weighting results for each level 1-3 matrix are required. The primary data calculations using the AHP method for levels 1, 2, and 3 matrices were conducted, leading to the development of the Mining Company performance measurement framework. Figure 4 illustrates the hierarchical framework of criteria and sub-criteria of the AHP model within the SCOR performance measurement framework for the Mining Company.

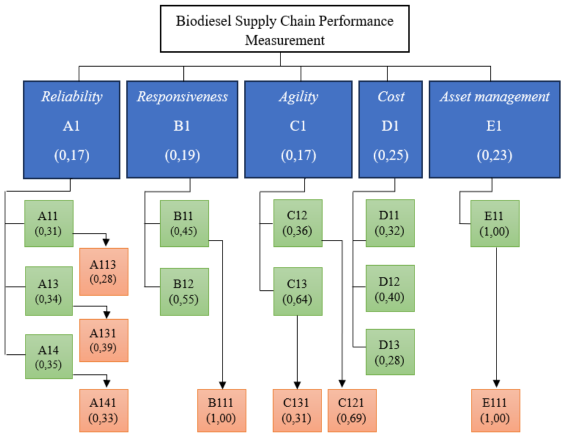

Figure 4 Hierarchical framework of criteria and sub-criteria in the AHP model within the SCOR performance measurement framework.

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Performance Measurement of the SCOR Biosolar in Mining Companies

In measuring the performance of the supply chain for mining companies, the framework SCOR was developed based on previous calculations using the selected indicators. According to the metric classification, the gap is calculated for each measurement metric.

Table 7. Validation of Performance Indicators for The Biodiesel Supply Chain Utilizing the SCOR Model

Aspect	SCOR
Reliability	0.95
Responsiveness	1.00
Agility	0.88
Cost	1.00
Asset Management	0.82

Conclusions

Based on the research conducted, the conclusions from this study are as follows:

1. The study utilized the following criteria to assess the performance of the biodiesel supply chain in mining companies: reliability, responsiveness, agility, cost, and asset management. According to the SCOR method, the criteria with the highest SCOR values are responsiveness and cost, both at 1.00, followed by reliability at 0.95, agility at 0.88, and asset management at 0.82.
2. Improving reliability in the flow from suppliers to mining companies should also be a focus area for refining the supply chain activities. Until now, mining companies have not specifically evaluated the performance of their suppliers. Conducting performance assessments and fostering cooperation based on trust and long-term relationships can enhance supply chain performance. Suppliers, as the first link in the supply chain, play a critical role in providing input to mining companies.

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