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A Sustainability-Based KPI Framework for Distribution Performance Assessment and Supply Chain Improvement in Soybean Processing SMEs

Khoerun Nisa Safitri[1*], Nurul 'Aini[2], Khairunnisa Sulistiawati[3], Nayla Uriatul Ulfa[4]
[1234]Department of Logistics Engineering, Universitas Ibnu Sina, Indonesia

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*Corresponding Author

Khoerun Nisa Safitri
E-mail: khoerunnisas@uis.ac.id

ABSTRACT

The sustainability of distribution activities has become increasingly important for improving supply chain performance in soybean-processing SMEs. However, many SMEs still lack a structured performance measurement system that integrates economic, environmental, and social aspects. This study aimed to develop a sustainability-based Key Performance Indicator (KPI) framework to assess distribution performance and improve supply chains for soybean-processing SMEs in Batam City, Indonesia. A quantitative case study approach was employed, using the Triple Bottom Line (TBL) concept, the Delphi method, and the Analytic Hierarchy Process (AHP). The results identified and validated 18 KPIs, comprising 6 economic, 6 environmental, and 6 social indicators. AHP analysis revealed that the Economic dimension received the highest weight (0.52), followed by the Environmental (0.29) and Social (0.19) dimensions. At the indicator level, Order Fulfillment Rate (0.109) and Delivery Reliability (0.109) achieved the highest global weights, followed by On-Time Delivery (0.104) and Carbon Emission (0.087). The consistency test yielded a CR value of 0.062, indicating reliable expert judgments. The proposed framework provides a practical tool for evaluating distribution performance, identifying improvement priorities, and supporting sustainable supply chain development in soybean-processing SMEs.

INTRODUCTION

Small and Medium Enterprises (SMEs) are a major driver of Indonesia's economy, with approximately 30.18 million registered SMEs employing 45.26 million workers in 2024 [1]. The soybean-processing sector, particularly tofu and tempeh producers, plays a strategic role in supporting national food security and providing affordable protein sources for the population [2]. Indonesia's soybean consumption continues to increase, reaching an estimated 2.86 million tons in 2024–2025, while domestic production remains only around 360,000 tons, creating substantial dependence on imported soybeans [3], [4]. Consequently, distribution performance has become a critical factor affecting product availability, logistics efficiency, operational costs, and customer satisfaction throughout the soybean supply chain [5], [6].

Despite its importance, the soybean supply chain faces significant distribution challenges. Indonesia imported approximately 2.68 million tons of soybeans in 2024, representing a 17.67% increase compared to 2023, indicating persistent dependence on foreign suppliers [3], [4]. This condition exposes SMEs to raw-material price volatility, supply uncertainty, and logistics disruptions [7], [8]. In addition, most soybean-processing SMEs still lack structured Key Performance Indicators (KPIs), causing performance evaluation to rely on subjective judgment rather than data-driven decision-making [5], [9]. Therefore, this study proposes a sustainability-based KPI framework integrating Triple Bottom Line dimensions. The Delphi method is employed to obtain expert consensus on indicator selection, while Analytical Hierarchy Process (AHP) is utilized to determine indicator priorities objectively [10], [11].

The research focuses on soybean-processing SMEs in Batam City, one of the major soybean-processing centers in the Riau Islands Province. According to local industry data, Batam requires nearly 1,000 tons of soybeans monthly to support tofu and tempeh production, involving approximately 133 entrepreneurs consisting of 67 tofu producers and 66 tempeh producers [3]. However, the sector remains highly vulnerable to imported soybean price fluctuations [4]. Reports indicate that soybean prices in Batam increased by almost 100% within two years, significantly affecting production costs and profitability [2]. These challenges highlight the importance of developing a sustainable distribution performance measurement system capable of improving operational resilience and competitiveness among local SMEs [7], [8], [12].

Numerous studies have demonstrated the effectiveness of Delphi and AHP methods in developing performance measurement systems [13], [14]. Delphi has been widely adopted to establish consensus among experts regarding relevant performance indicators, while AHP provides a systematic approach for prioritizing indicators through pairwise comparison analysis [15]. Delphi and AHP were successfully integrated in developing TQM 4.0 performance indicators [15], [16], whereas applied both methods to construct an environmental quality assessment framework [17]. Similarly, supply chain studies have emphasized that combining expert validation and hierarchical weighting improves KPI reliability, objectivity, and practical applicability for organizational performance evaluation [18], [19].

Although KPI development and supply chain performance measurement have been extensively discussed in previous studies, most frameworks primarily focus on operational efficiency, cost reduction, and delivery performance [20], [21], [22]. Sustainability aspects are often addressed only conceptually and rarely translated into measurable indicators suitable for SMEs [2], [6]. Furthermore, existing studies generally examine supply chain performance at a broad organizational level rather than specifically focusing on distribution activities, which directly influence competitiveness and customer satisfaction [5], [6], [23]. The novelty of this study lies in developing a sustainability-based distribution KPI framework that integrates economic, environmental, and social dimensions using the Triple Bottom Line approach while combining Delphi validation and AHP weighting specifically for soybean-processing SMEs in Batam [13], [20].

This study aims to develop a sustainability-based KPI framework for assessing distribution performance and improving supply chain effectiveness in soybean-processing SMEs in Batam City. The proposed framework integrates economic, environmental, and social indicators through the Triple Bottom Line perspective and employs Delphi and AHP methods to ensure indicator validity and prioritization [19], [24], [25]. The resulting framework is expected to provide a practical decision-support tool for SME managers in monitoring distribution performance, enhancing logistics efficiency, reducing operational risks, and strengthening competitiveness. Academically, the study contributes to the advancement of sustainable supply chain performance measurement literature, particularly within food-processing SMEs operating in import-dependent environments.

RESEARCH METHODS

This study employed a quantitative case-study approach to develop a sustainability-based Key

Performance Indicator (KPI) framework for assessing distribution performance in soybean-processing SMEs in Batam City, Indonesia. The proposed framework integrates the Triple Bottom Line (TBL) dimensions, namely economic, environmental, and social sustainability. Data were collected through literature reviews, field observations, semi-structured interviews, and expert judgments involving academics, supply chain practitioners, and SME owners. The research procedure consisted of KPI identification, Delphi-based validation, AHP weighting, and development of the final sustainability KPI framework.

1. KPI Identification and Delphi Validation

The initial KPI candidates were identified through literature reviews and field observations of soybean-processing SMEs. The indicators were classified into economic, environmental, and social dimensions based on the Triple Bottom Line concept. Subsequently, the Delphi method was employed to obtain consensus among experts regarding the relevance and applicability of each indicator. Several Delphi rounds were conducted until agreement was achieved among panel members. The Content Validity Ratio (CVR) was used to evaluate indicator validity:

$$CVR = \frac{n_e - \frac{N}{2}}{\frac{N}{2}} \tag{1}$$

where $n_e$represents the number of experts rating an indicator as essential and Ndenotes the total number of experts. Indicators meeting the required validity threshold were retained for further analysis.

2. KPI Weighting Using Analytical Hierarchy Process (AHP)

The validated indicators were prioritized using the Analytic Hierarchy Process (AHP). A hierarchical structure was established consisting of the research objective, sustainability dimensions, and KPI indicators. Experts performed pairwise comparisons using Saaty's scale to determine the relative importance of each indicator. The priority weights were calculated via matrix normalization, and consistency was assessed using the Consistency Ratio (CR).

Priority weights were calculated as follows:

$$w_i = \frac{\sum_{j=1}^{n} \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}}{n} \tag{2}$$

Consistency was assessed using:

$$CR = \frac{CI}{RI} \tag{3}$$

where $CI$is the Consistency Index and $RI$is the Random Index. The comparison matrix was considered acceptable when $CR < 0.10$.

3. Development of Sustainability-Based KPI Framework

The final stage involved integrating the validated and weighted indicators into a sustainability-based KPI framework for soybean-processing SMEs. The framework was designed as a practical tool for evaluating distribution performance across economic, environmental, and social dimensions. The overall sustainability performance score was determined using the weighted KPI values:

$$SPI = \sum_{i=1}^{n} (W_i \times S_i) \tag{4}$$

where SPI denotes the Sustainability Performance Index, W_i represents the weight of KPI i, and S_i is the performance score of KPI i. The resulting framework enables SMEs to identify performance gaps, prioritize improvement initiatives, and enhance sustainable supply chain performance.

RESULTS AND DISCUSSION

This section presents the results of sustainability-based KPI development for distribution performance assessment. The analysis includes KPI identification, Delphi validation, AHP weighting, and framework formulation to support sustainable supply chain performance improvement in soybean-processing SMEs.

1. Identification of Sustainability-Based Distribution KPIs

This stage aimed to identify sustainability-based distribution Key Performance Indicators (KPIs) relevant to soybean-processing SMEs in Batam City. KPI identification was conducted through a comprehensive literature review and field observations, considering the economic, environmental, and social dimensions of the Triple Bottom Line (TBL) framework. The identified indicators represent critical factors influencing distribution performance and sustainable supply chain improvement.

Table 1. Sustainability-Based Distribution KPI Indicators

Dimension	Code	KPI Indicator	Description
Economic	E1	Distribution Cost	Total distribution expenditure
	E2	Transportation Cost Efficiency	Efficiency of transportation expenses
	E3	Inventory Turnover	Inventory utilization efficiency
	E4	Order Fulfillment Rate	Percentage of fulfilled orders
	E5	Delivery Reliability	Consistency of delivery performance
	E6	On-Time Delivery	Percentage of deliveries completed on schedule
Environmental	EN1	Fuel Consumption	Fuel usage in distribution activities
	EN2	Carbon Emission	Emissions generated during transportation
	EN3	Energy Consumption	Total energy used in logistics operations
	EN4	Packaging Waste	Amount of waste generated from packaging
	EN5	Recyclable Packaging Usage	Utilization of recyclable packaging materials
	EN6	Waste Reduction Rate	Effectiveness of waste minimization efforts
Social	S1	Employee Safety	Occupational health and safety performance
	S2	Employee Training	Frequency of training and skill development
	S3	Customer Satisfaction	Customer perception of distribution services
	S4	Complaint Resolution Rate	Effectiveness in handling customer complaints
	S5	Community Engagement	Participation in local community activities
	S6	Employee Welfare	Employee well-being and work satisfaction

Table 1 presents 18 sustainability-based distribution KPIs grouped into Economic (E1–E6), Environmental (EN1–EN6), and Social (S1–S6) dimensions. Economic indicators measure efficiency and reliability, environmental indicators assess resource use and emissions, while social indicators evaluate employee and customer-related aspects. Together, they support comprehensive distribution performance assessment in soybean-processing SMEs.

2. Delphi Validation Results

This stage aimed to validate the relevance and applicability of the identified sustainability-based distribution KPIs. The Delphi method was conducted with a panel of experts to achieve consensus and ensure that the selected indicators accurately reflect the distribution performance requirements of soybean-processing SMEs [15], [16].

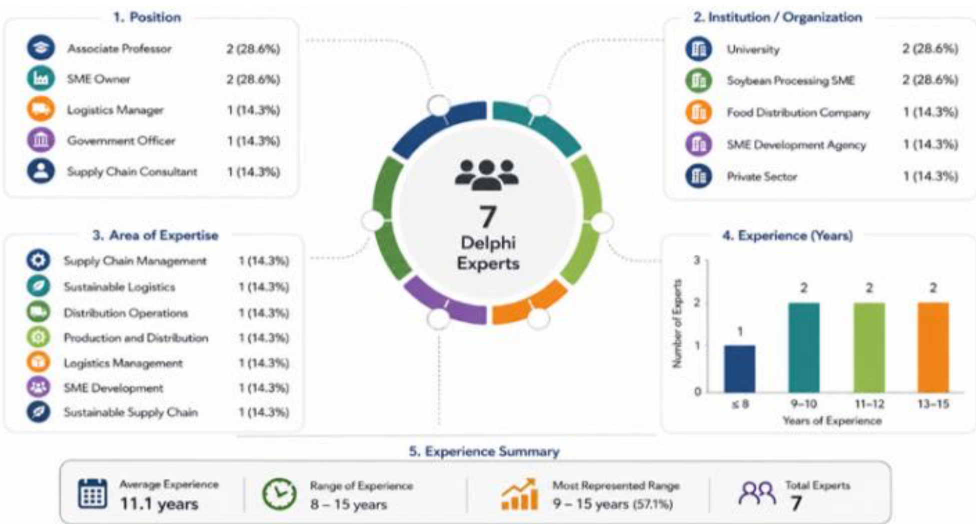

Fig.1. Characteristics of Delphi Experts

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Figure 1 shows that the Delphi panel consisted of seven experts with professional experience ranging from 8 to 15 years in supply chain management, logistics, sustainability, and SME development. The panel included two academics (28.6%), two soybean-processing SME owners (28.6%), one logistics practitioner (14.3%), one government representative (14.3%), and one supply chain consultant (14.3%). This diverse composition ensured a balanced evaluation by integrating theoretical knowledge, practical industry experience, and policy perspectives, thereby enhancing the reliability and validity of the KPI validation process. Based on the Delphi evaluation, all proposed indicators achieved the minimum consensus threshold and were retained for further analysis [13]. The Content Validity Ratio (CVR) values ranged from 0.71 to 1.00, indicating strong expert agreement regarding the relevance of each KPI.

Table 2. Delphi Validation Results of Sustainability-Based Distribution KPIs

Code	KPI Indicator	CVR Value	Decision
E1	Distribution Cost	1.00	Accepted
E2	Transportation Cost Efficiency	0.86	Accepted
E3	Inventory Turnover	0.86	Accepted
E4	Order Fulfillment Rate	1.00	Accepted
E5	Delivery Reliability	1.00	Accepted
E6	On-Time Delivery	1.00	Accepted
EN1	Fuel Consumption	0.86	Accepted
EN2	Carbon Emission	1.00	Accepted
EN3	Energy Consumption	0.86	Accepted
EN4	Packaging Waste	0.71	Accepted
EN5	Recyclable Packaging Usage	0.86	Accepted
EN6	Waste Reduction Rate	0.86	Accepted
S1	Employee Safety	1.00	Accepted
S2	Employee Training	0.86	Accepted
S3	Customer Satisfaction	1.00	Accepted
S4	Complaint Resolution Rate	0.86	Accepted
S5	Community Engagement	0.71	Accepted
S6	Employee Welfare	0.86	Accepted

Table 2 indicates that all 18 proposed KPIs achieved the minimum Delphi consensus threshold and were accepted for further analysis. Among these indicators, six KPIs achieved the highest CVR value of 1.00: E1, E4, E5, E6, S1, and S3, indicating unanimous agreement among the seven experts. Meanwhile, ten indicators achieved a CVR of 0.86, and two indicators (EN4 and S5) obtained a CVR of 0.71. These results suggest strong expert consensus regarding the relevance and applicability of the sustainability-based KPI framework for evaluating distribution performance in soybean-processing SMEs [17], [20].

3. KPI Prioritization Using AHP

This stage aimed to determine the relative importance of sustainability dimensions and KPI indicators using the AHP. Pairwise comparison matrices were developed from expert judgments, followed by weighting and consistency analysis to ensure reliable prioritization.

Pairwise comparison analysis was conducted to evaluate the relative importance of the Economic, Environmental, and Social dimensions in improving distribution performance within soybean-processing SMEs. The judgments were aggregated from seven Delphi experts and converted into a reciprocal comparison matrix.

Table 3. Pairwise Comparison Matrix of Sustainability Dimensions

Criteria	Economic	Environmental	Social
Economic	1.00	2.00	3.00
Environmental	0.50	1.00	2.00
Social	0.33	0.50	1.00

Table 3 shows that the Economic dimension was considered more important than the Environmental and Social dimensions, with comparison values of 2.00 and 3.00, respectively.

Environmental performance was judged to be twice as important as Social performance. These findings reflect the operational characteristics of soybean-processing SMEs, in which distribution cost efficiency, service reliability, and profitability remain primary concerns, while sustainability continues to gain strategic attention.

To obtain detailed priorities, pairwise comparisons were also performed among individual KPI indicators within each sustainability dimension.

Table 4. Pairwise Comparison Matrix of Sustainability KPI Indicators

KPI	E1	E2	E3	E4	E5	E6
E1	1.00	1.00	2.00	0.50	0.50	0.50
E2	1.00	1.00	2.00	0.50	0.50	0.50
E3	0.50	0.50	1.00	0.33	0.33	0.33
E4	2.00	2.00	3.00	1.00	1.00	1.00
E5	2.00	2.00	3.00	1.00	1.00	1.00
E6	2.00	2.00	3.00	1.00	1.00	1.00
KPI	EN1	EN2	EN3	EN4	EN5	EN6
EN1	1.00	0.50	1.00	2.00	2.00	2.00
EN2	2.00	1.00	2.00	3.00	3.00	3.00
EN3	1.00	0.50	1.00	2.00	2.00	2.00
EN4	0.50	0.33	0.50	1.00	1.00	1.00
EN5	0.50	0.33	0.50	1.00	1.00	1.00
EN6	0.50	0.33	0.50	1.00	1.00	1.00
KPI	S1	S2	S3	S4	S5	S6
S1	1.00	2.00	1.00	2.00	3.00	2.00
S2	0.50	1.00	0.50	1.00	2.00	1.00
S3	1.00	2.00	1.00	2.00	3.00	2.00
S4	0.50	1.00	0.50	1.00	2.00	1.00
S5	0.33	0.50	0.33	0.50	1.00	0.50
S6	0.50	1.00	0.50	1.00	2.00	1.00

Table 4 presents the pairwise comparison results for the sustainability KPI indicators based on expert judgments. Within the Economic dimension, Order Fulfillment Rate (E4), Delivery Reliability (E5), and On-Time Delivery (E6) received the highest relative importance values of 3.00 when compared with Inventory Turnover (E3). In the Environmental dimension, Carbon Emission (EN2) had the highest preference value of 3.00 among EN2–EN6. Similarly, Employee Safety (S1) and Customer Satisfaction (S3) emerged as the most influential Social indicators, each obtaining comparison values up to 3.00. These findings indicate that service reliability, environmental impact reduction, and stakeholder satisfaction are the primary priorities for sustainable distribution performance improvement in soybean-processing SMEs [14], [15], [16].

Following pairwise comparison analysis, priority weights were calculated for each sustainability dimension. Consistency testing was performed to ensure the reliability of expert judgments and compliance with AHP requirements.

Table 5. Sustainability Dimension Weights and Consistency Test Results

Dimension	Weight	Rank	Parameter	Value
Economic	0.52	1	λmax	3.054
Environmental	0.29	2	CI	0.027
Social	0.19	3	CR	0.047

Table 5 indicates that the Economic dimension achieved the highest priority weight (0.52), followed by the Environmental dimension (0.29) and the Social dimension (0.19). These findings suggest that soybean-processing SMEs place greater emphasis on improving distribution efficiency, cost effectiveness, and operational reliability to enhance supply chain performance. Nevertheless, environmental and social considerations also received substantial attention, reflecting the growing importance of sustainability practices. Furthermore, the consistency test yielded $\lambda max = 3.054$, $CI = 0.027$, and $CR = 0.047$, which is well below the acceptable threshold of 0.10. This result confirms that the expert judgments were highly consistent, ensuring the validity and reliability of the AHP-based prioritization process.

Table 6. Sustainability KPI Weights and Consistency Test Results

Code	Local Weight	Global Weight
E1	0.15	0.078
E2	0.15	0.078
E3	0.08	0.042
E4	0.21	0.109
E5	0.21	0.109
E6	0.20	0.104
EN1	0.17	0.049
EN2	0.30	0.087
EN3	0.17	0.049
EN4	0.12	0.035
EN5	0.12	0.035
EN6	0.12	0.035
S1	0.25	0.048
S2	0.15	0.029
S3	0.25	0.048
S4	0.15	0.029
S5	0.08	0.015
S6	0.12	0.023

Table 9 indicates that Order Fulfillment Rate (E4) and Delivery Reliability (E5) achieved the highest global weights of 0.109, followed by On-Time Delivery (E6) with 0.104 and Carbon Emission (EN2) with 0.087. These results demonstrate that delivery performance and environmental sustainability are the most critical factors in improving distribution performance. Furthermore, the consistency test yielded λmax = 18.624, CI = 0.037, and CR = 0.062, which are below the acceptable threshold of 0.10, confirming the validity and reliability of the AHP weighting results [10], [11], [13], [15].

4. Development of Sustainability-Based KPI Framework

This stage developed a sustainability-based KPI framework for soybean-processing SMEs by integrating validated and weighted indicators across Economic, Environmental, and Social dimensions. The framework provides a practical tool for evaluating distribution performance, identifying improvement opportunities, and supporting sustainable supply chain management.

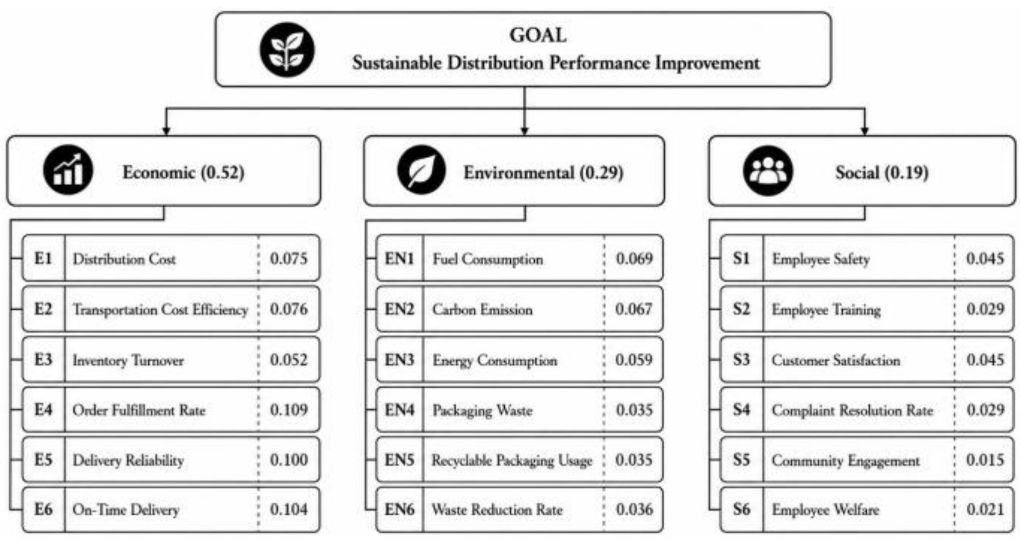

Fig.2. Sustainability-Based KPI Framework for Distribution Performance Assessment

Figure 2 presents the Sustainability-Based KPI Framework for distribution performance assessment, integrating Economic, Environmental, and Social dimensions. The Economic dimension

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received the highest weight (0.52), with Order Fulfillment Rate (E4) and Delivery Reliability (E5) identified as the most important indicators (global weight = 0.109), followed by On-Time Delivery (E6) (0.104). The Environmental dimension (0.29) was led by Carbon Emission (EN2) (0.087), while the Social dimension (0.19) emphasized Employee Safety (S1) and Customer Satisfaction (S3) (0.048 each). These results indicate that sustainable distribution performance in soybean-processing SMEs is primarily driven by reliable delivery performance, environmental responsibility, and stakeholder well-being, supporting long-term competitiveness and supply chain sustainability.

The global weights derived from the AHP analysis were used to calculate the Sustainability Performance Index (SPI). This index provides a comprehensive measure of distribution performance by integrating all validated sustainability-based KPIs. The SPI calculation framework is presented in Table 7.

Table 7. Sustainability Performance Index (SPI) Calculation Framework

Code	Global Weight (Wi)	Performance Score (Si)	Wi × Si
E1	0.078	Si_1	$0.078 \times Si_1$
E2	0.078	Si_2	$0.078 \times Si_2$
E3	0.042	Si_3	$0.042 \times Si_3$
E4	0.109	Si_4	$0.109 \times Si_4$
E5	0.109	Si_5	$0.109 \times Si_5$
E6	0.104	Si_6	$0.104 \times Si_6$
EN1	0.049	Si_7	$0.049 \times Si_7$
EN2	0.087	Si_8	$0.087 \times Si_8$
EN3	0.049	Si_9	$0.049 \times Si_9$
EN4	0.035	Si_{10}	$0.035 \times Si_{10}$
EN5	0.035	Si_{11}	$0.035 \times Si_{11}$
EN6	0.035	Si_{12}	$0.035 \times Si_{12}$
S1	0.048	Si_{13}	$0.048 \times Si_{13}$
S2	0.029	Si_{14}	$0.029 \times Si_{14}$
S3	0.048	Si_{15}	$0.048 \times Si_{15}$
S4	0.029	Si_{16}	$0.029 \times Si_{16}$
S5	0.015	Si_{17}	$0.015 \times Si_{17}$
S6	0.023	Si_{18}	$0.023 \times Si_{18}$
Total SPI	1.000		Σ(Wi × Si)

Table 7 presents the Sustainability Performance Index (SPI) calculation framework developed from the validated and weighted KPI indicators. The framework integrates 18 sustainability-based KPIs across Economic, Environmental, and Social dimensions. Each KPI is assigned a global weight obtained from the AHP analysis, where Order Fulfillment Rate (E4) and Delivery Reliability (E5) received the highest weights (0.109), followed by On-Time Delivery (E6) (0.104) and Carbon Emission (EN2) (0.087). The overall SPI score is calculated by multiplying each KPI weight by its corresponding performance score and summing the results. This approach enables soybean-processing SMEs to assess distribution performance comprehensively while identifying priority areas for sustainable supply chain improvement. Based on the final KPI weights, Equation (4) can be expanded as:

$$SPI = (0.078S_1) + (0.078S_2) + (0.042S_3) + (0.109S_4) + (0.109S_5) + (0.104S_6) + (0.049S_7) + (0.087S_8) + (0.049S_9) + (0.035S_{10}) + (0.035S_{11}) + (0.035S_{12}) + (0.048S_{13}) + (0.029S_{14}) + (0.048S_{15}) + (0.029S_{16}) + (0.015S_{17}) + (0.023S_{18} \quad (6)$$

A higher SPI score reflects superior distribution performance and a greater degree of sustainability integration across economic, environmental, and social dimensions. Consequently, soybean-processing SMEs with higher SPI values are considered to exhibit more effective and sustainable supply chain distribution practices.

5. Managerial Implications for Supply Chain Improvement

The proposed sustainability-based KPI framework provides a practical tool for soybean-processing SMEs to systematically monitor and improve distribution performance. The results indicate that Order Fulfillment Rate (E4), Delivery Reliability (E5), and On-Time Delivery (E6) are the most important indicators, with global weights of 0.109, 0.109, and 0.104, respectively. These findings suggest that managers should prioritize delivery accuracy, responsiveness, and service reliability to improve customer satisfaction and strengthen supply chain performance [6], [8], [17], [20].

In addition, Carbon Emission (EN2) achieved the highest environmental weight (0.087), while Employee Safety (S1) and Customer Satisfaction (S3) obtained the highest social weights (0.048 each). These results highlight the importance of balancing economic performance with environmental responsibility and social well-being [2], [5], [6], [19]. Therefore, soybean-processing SMEs should implement continuous performance monitoring, optimize logistics operations, improve workplace safety, and adopt environmentally friendly distribution practices to enhance competitiveness and support sustainable supply chain development.

CONCLUSION

This study developed a sustainability-based Key Performance Indicator (KPI) framework for assessing distribution performance and improving supply chain management in soybean-processing SMEs in Batam City. Through literature review, field observations, Delphi validation, and Analytical Hierarchy Process (AHP) analysis, a total of 18 KPIs were identified and validated across three sustainability dimensions: Economic (6 indicators), Environmental (6 indicators), and Social (6 indicators). The AHP results revealed that the Economic dimension received the highest priority weight (0.52), followed by the Environmental (0.29) and Social (0.19) dimensions. At the indicator level, Order Fulfillment Rate (E4) and Delivery Reliability (E5) achieved the highest global weights (0.109), followed by On-Time Delivery (E6) (0.104) and Carbon Emission (EN2) (0.087). Furthermore, the consistency test yielded a CR value of 0.062, confirming the reliability and validity of the expert judgments. These findings demonstrate that distribution reliability, service performance, and environmental responsibility are the key drivers of sustainable supply chain improvement. The proposed KPI framework provides a practical and systematic tool to support performance evaluation, continuous improvement, and the long-term sustainability of soybean-processing SMEs, while enhancing their competitiveness in increasingly dynamic market conditions.

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