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Integrating Material Circularity and Green Logistics Indicators in Supply Chain Performance Measurement Using the Green SCOR Model

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ABSTRACT

Integrating environmental considerations into supply chain performance measurement has become increasingly critical, growing sustainability and corporate responsibility. In the textile industry, particularly the non-woven sector, complex activities and mounting environmental pressures underscore the need for sustainability-oriented evaluation. The company lacks a supply chain performance measurement system that considers environmental aspects, creating a research gap that this study addresses. This study evaluates supply chain performance by embedding environmental dimensions into the measurement framework. The research was conducted in four stages: (1) identifying indicators through the Content Validity Index; (2) weighting indicators using the Analytic Hierarchy Process; (3) assessing performance with the Objective Matrix; and (4) classifying priorities through the Traffic Light System. A total of 22 validated indicators were applied, including three green indicators: Recycled Material Usage, Reusable Material, and Truck Load Optimization Rate. Recycled Material Usage was introduced as a novel indicator and validated as contextually significant for industrial supply chains. Results show a 2024 performance score of 5.678, classified as yellow under the Traffic Light System with five indicators as critical priorities for improvement. This study provides a regular monitoring tool that enables managers to establish a sustainable supply chain.

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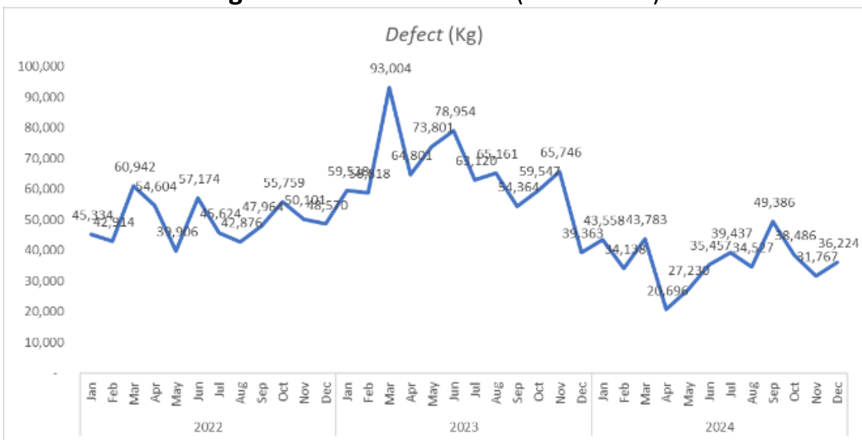
INTRODUCTION

The non-woven textile industry plays a strategic role in global and national value chains. To remain competitive, companies in this sector are required to maintain efficient and responsive supply chains that ensure both reliability and adaptability. However, many performance measurement models, particularly those based on the conventional SCOR framework, still focus heavily on cost, quality, and delivery while overlooking environmental aspects. For instance, Gonzalez-Pascual et al. [1] applied SCOR in the transportation sector to improve logistics efficiency but did not consider emissions or fuel consumption, while Sipho et al. [2] reported SCOR-based improvements in the jeans industry without addressing waste management or carbon footprint.

Circular Economy (CE) provides a relevant theoretical foundation for addressing these sustainability challenges. CE emphasizes keeping materials in use, designing out waste, and optimizing resource flows. These principles directly align with the company's existing sustainability practices, such as achieving an 85% material reuse rate and improving distribution efficiency through truck load optimization. Although these CE-oriented practices are already implemented operationally, they are not yet integrated into the company's formal supply chain performance measurement system. Embedding CE principles ensures that performance evaluation captures not only environmental impacts but also the circularity of material flows, which is increasingly critical for resource-intensive industries such as non-woven textiles.

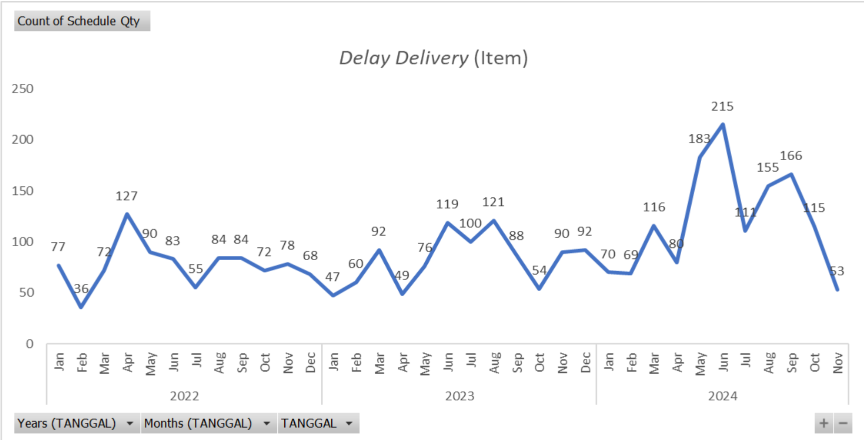
Despite its importance, the non-woven textile sector faces persistent supply chain challenges at the company level. The company has experienced recurring inefficiencies, including fluctuating defect rates, delivery delays, and increasing product returns. For example, defects peaked in 2023, while returns rose significantly in mid-2024, highlighting recurring quality issues and mismatches with customer expectations. In addition, reliance on a single supplier has caused raw material delays of up to two weeks, disrupting production flows and further reducing responsiveness. To illustrate these challenges, Figures 1–3 present trends of defect volumes, return rates, and delivery delays during 2022–2024, which together demonstrate systemic inefficiencies that require comprehensive evaluation.

Figure 1. Defect Volumes (2022-2024)



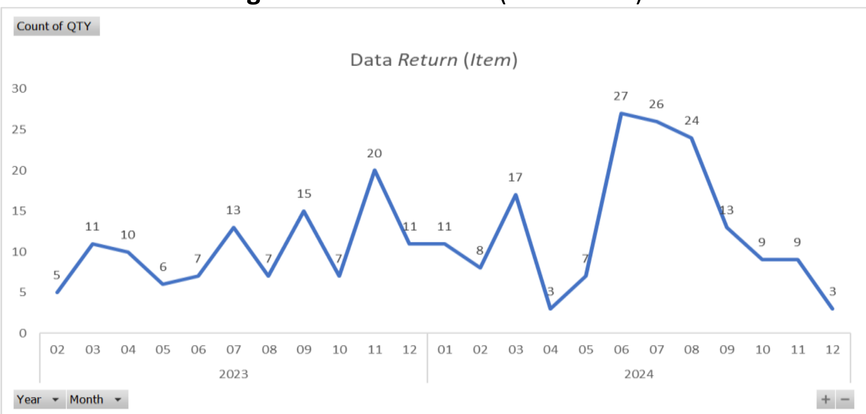
The defect trend fluctuated considerably over the 2022–2024 period in Figure 1, reaching its highest level in early 2023 before showing a general declining tendency toward the end of 2024.

Figure 2. Delivery Delays (2022-2024)



Based on Figure 2, the delay delivery trend exhibited significant fluctuations during the 2022–2024 period, with a substantial increase observed in mid-2024 before declining toward the end of the year.

Figure 3. Return Rates (2023-2024)



Based on Figure 3, the data return trend fluctuated throughout 2023–2024, with the highest number of returns occurring in mid-2024 before gradually declining toward the end of the observation period. These recurring issues reflect the absence of an integrated performance evaluation system. Currently, each division conducts separate performance assessments, producing fragmented insights and partial improvements that fail to address underlying systemic issues.

Alongside these operational challenges, the company has implemented environmentally oriented practices, such as material reuse with a reuse rate of up to 85% and truck load optimization, to achieve near-full capacity utilization in distribution. These practices demonstrate a commitment to sustainability but remain excluded from the company's formal supply chain evaluation system. Instead, environmental indicators are assessed separately from operational ones, limiting their contribution to strategic decision-making. As Chopra and Meindl [3] define, a supply chain consists of all parties involved in fulfilling customer demand, and thus its performance must capture both efficiency and environmental impact.

Similarly, Lee and Billington, as cited in Rahmat Akmal [4], emphasize that systematic performance measurement is crucial to improving overall business outcomes, while Sangwa and Sangwan [5] highlight the necessity of continuous evaluation to sustain competitiveness in global markets.

To address these shortcomings, the Green Supply Chain Operations Reference (Green SCOR) framework provides a structured and sustainability-focused method for evaluating performance across five key processes: Plan, Source, Make, Deliver, and Return [6]. Previous studies illustrate its potential but also its limitations. Flodensa et al. [7] applied Green SCOR in the batik industry and revealed inefficiencies in material use and waste handling, while Putridewi et al. [8] examined garment manufacturing with indicators such as water consumption and distribution emissions. Although these studies demonstrate the adaptability of Green SCOR, they emphasize consumption and emissions, with limited attention to recycling practices.

This creates a clear research gap. Previous Green SCOR applications have not systematically integrated material recycling, even though it is a critical dimension of sustainable manufacturing performance. Addressing this gap, the present study introduces Recycled Material Usage as a novel indicator, validated through the Content Validity Index (CVI) to ensure contextual relevance. Together with Reusable Material and Truck Load Optimization Rate, this indicator reflects actual practices in the observed company while extending Green SCOR beyond conventional environmental metrics.

By embedding these sub-criteria into the SCOR processes (Plan, Source, Make, Deliver, Return), this study contributes both academically and practically. Academically, it advances Green SCOR by expanding its environmental dimensions with validated indicators. In practice, it provides managers with a structured mechanism to align operational efficiency with sustainability objectives, enabling performance evaluation that is both comprehensive and actionable.

This study does not aim to comprehensively measure all environmental impacts. Instead, it focuses on selected environmental indicators directly linked to material circularity and logistics efficiency, which are operationally implemented and consistently recorded at the observed company. Comprehensive supply chain performance evaluation requires integrating operational efficiency, economic value, environmental sustainability, and social responsibility. Several studies have applied the conventional Supply Chain Operations Reference (SCOR) framework to evaluate supply chain performance, particularly in textile, manufacturing, and logistics sectors. Studies such as [9] and [1] demonstrate that SCOR supports performance standardization, improves coordination among supply chain actors, and enhances logistics reliability. Nevertheless, conventional SCOR applications predominantly emphasize operational efficiency and process effectiveness, while environmental and social sustainability dimensions remain limited or absent.

To address these shortcomings, recent studies have extended SCOR into the Green SCOR framework by incorporating environmental indicators. Research applying Green SCOR reports its effectiveness in identifying inefficiencies related to material usage, waste management, energy consumption, and emissions [7], [8]. International applications further confirm the adaptability of SCOR across industries and geographical contexts [1], [2]; however, existing studies generally provide limited emphasis on material recovery, social impacts, and long-term sustainability strategies, despite the growing recognition of green logistics as a strategic component of sustainable supply chain management [10].

These limitations highlight the need for a more integrated and validated sustainability performance measurement framework. In response to these gaps, this study extends the Green SCOR framework by introducing Recycled Material Usage, Reusable Material, and Truck Load Optimization Rate as additional indicators.

Many studies rely on isolated indicators without systematic validation, weighting, or aggregation mechanisms, which limits their analytical robustness. To ensure methodological rigor, the study integrates the Content Validity Index for indicator validation, the AHP for weighting, and the Objective Matrix with Traffic Light System for performance evaluation. This approach provides clearer methodological justification and stronger theoretical grounding for sustainability-oriented supply chain performance measurement. The selected indicators, summarized in Table 1, are derived from previous literature and the contributions of this study and serve as input for expert validation.

Table 1. Supply Chain Performance Indicators from Previous Studies

Supply Chain Indicator	Reference
Raw Material Usage Accuracy	[11]
Forecast Accuracy	[12]
Production Scheduling Time	[6]
Establish Sourcing Plans Cycle Time	[6]
Establish Production Plans Cycle Time	[6]
Time to Revise Production Schedule	[13]
Recycled Material Usage	In-depth interview
Purchase Order Cycle Time	[14]
Supplier Delivery Lead Time	[6]
Minimum Order Quantity (MOQ)	[11]
Machine Efficiency	[15]
Material Efficiency	[7]
Production Defect Rate	[11]
Number of Manpower	[11]
Production Lead Time	[6]
Reusable Material	[7]
Deliver Quantity Accuracy	[15]
Ship Product Cycle Time	[16]
Truck Load Optimization Rate	[17]
Return Rate from Customer	[18]
Refurbish Product Return	[17]
Product Replacement Time	[18]

RESEARCH METHOD

This study was conducted at a primary production facility in West Java from December 2024 to April 2025, with data collection and analysis covering the full year of 2024 to capture seasonal variations and annual trends. A structured approach was used to evaluate supply chain performance based on the Green SCOR framework, which in this study included environmentally oriented indicators such as Recycled Material Usage, Reusable Material, and Truck Load Optimization Rate. These indicators reflect practices already implemented in the company and support reductions in waste, fuel use, and emissions. The initial phase involved site observations, a literature review, and informal discussions with management to identify operational issues, forming the basis of the research problem: the absence of a comprehensive, sustainability-oriented performance measurement system.

Primary data were collected through direct observation, interviews with department heads (Production, Quality Control, PPC, Purchasing, Marketing, and Logistics), and validation questionnaires from eight expert panelists. Secondary data included process maps, production records, procurement schedules, delivery logs, and product return reports. The use of multiple sources enabled triangulation, improving credibility and validity.

The data analysis was conducted in four stages. First, performance indicators were validated using the Content Validity Index (CVI), ensuring that only indicators with strong expert agreement (I-CVI ≥ 0.83) were retained. Second, the Analytic Hierarchy Process (AHP) was applied to assign relative weights to the validated indicators, assisted by Expert Choice software. AHP was selected because it combines qualitative and quantitative factors, is computationally efficient, and can systematically measure the relative importance of hierarchical indicators [19], [20]. To mitigate subjectivity, eight cross-functional experts were involved, and all pairwise comparisons met the Consistency Ratio requirement (CR ≤ 0.10). The involvement of eight experts is methodologically justified, as prior studies on Content Validity Index (CVI) recommend that 6–10 experts are sufficient to ensure adequate content validity while minimizing chance agreement [21], [22]. The selected experts represent cross-functional managerial roles, ensuring diverse operational perspectives. The AHP results were then cross-validated with CVI outcomes and complemented by OMAX scoring, providing an objective, data-driven balance to expert-based weighting.

Third, the Objective Matrix (OMAX) was used to calculate actual performance scores benchmarked against Green SCOR targets (Plan, Source, Make, Deliver, Return). OMAX served as a complementary objective to AHP by converting historical data into numerical values and enabling direct performance comparisons. Finally, the Traffic Light System (TLS) classified performance levels into color-coded categories to identify priority improvement areas.

Although the use of multiple structured tools may appear complex, each serves a distinct and sequential function—CVI for validation, AHP for weighting, OMAX for measurement, and TLS for prioritization—making the framework systematic yet practical. Results are presented in clear numerical and visual outputs that facilitate managerial interpretation. The methodological steps applied in this study are summarized in the research framework shown in Figure 4.

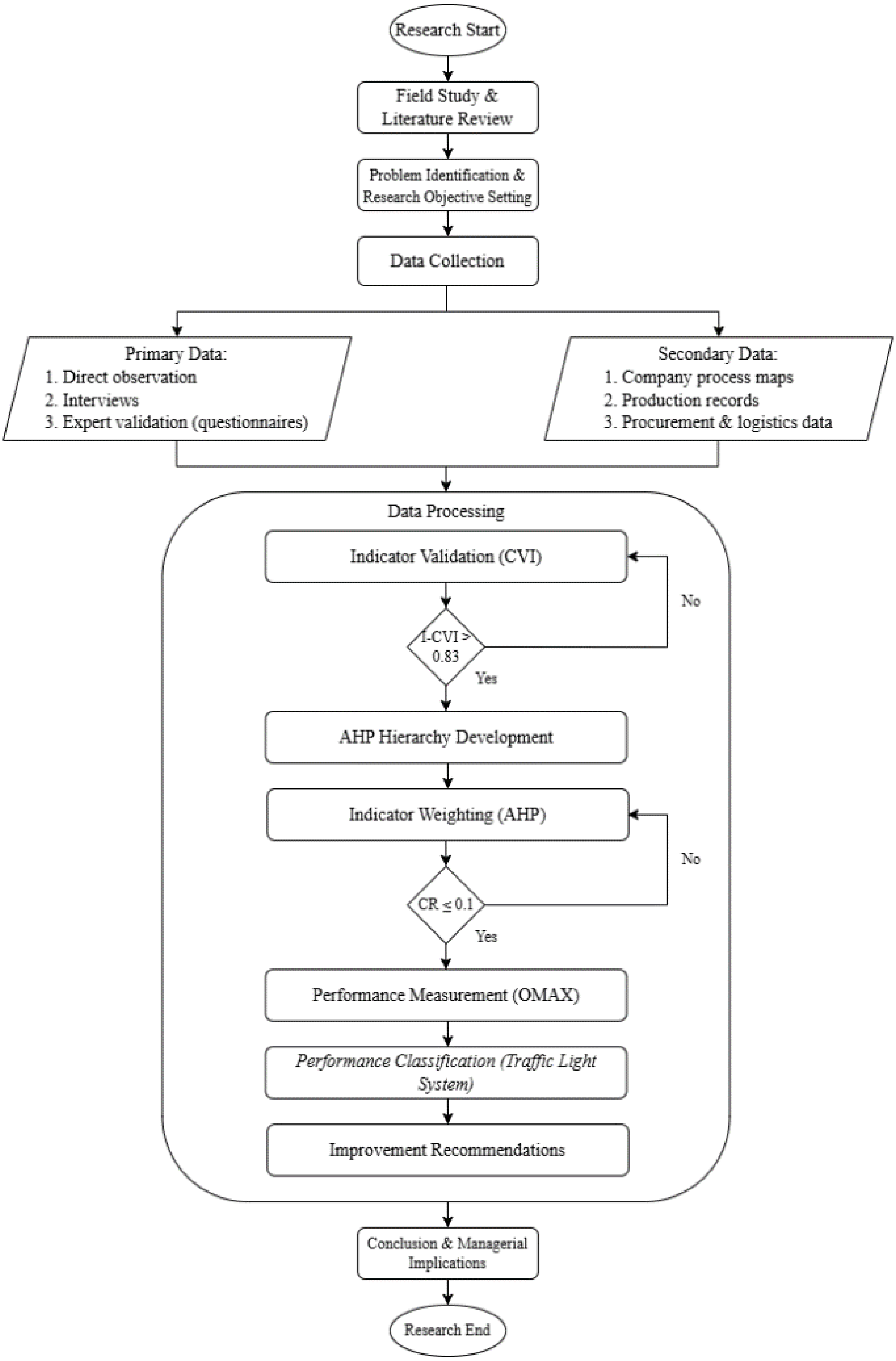


Figure 4. Research Workflow for Supply Chain Performance Evaluation

RESULTS AND DISCUSSION

In this study, the validation of supply chain performance indicators was conducted using the Content Validity Index (CVI) method to ensure that each indicator accurately represents the construct being measured. CVI provides a quantitative assessment of expert consensus, as recommended by Lynn [21] and further developed by Polit and Beck [22].

The assessment involved eight expert panelists drawn from various functional divisions within the observed company, including Production, Purchasing, Logistics, Marketing, PPC, QC & QA, and the General Manager, to capture diverse operational insights and perspectives.

According to the criteria set by Lynn [21], an individual item is considered valid if it achieves an I-CVI score of at least 0.83. Furthermore, Polit and Beck [22] state that an acceptable average scale-level CVI (S-CVI/Ave) should be no less than 0.90. Therefore, indicators scoring below the I-CVI threshold of 0.83 were excluded from the final list. While this exclusion reduced the initial pool of indicators, it did not compromise comprehensiveness. The excluded indicators had low expert agreement, while the remaining 22 cover all SCOR processes and green dimensions, ensuring both operational and environmental aspects are represented. Table 2 presents the validated indicators that met the eligibility requirements and were deemed appropriate for use in the supply chain performance assessment.

Table 2. Final Validation Results of Indicators Based on I-CVI and S-CVI Scores

Item	***Expert***								***Expert in Agree-ments***	**I-CVI**	**UA**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**			
Raw Material Usage Accuracy	1	1	1	1	1	1	1	1	8	1.00	1
Forecast Accuracy	1	1	1	1	1	1	1	1	8	1.00	1
Production Scheduling Time	1	1	1	1	1	1	1	1	8	1.00	1
Establish Sourcing Plans Cycle Time	1	1	1	1	1	1	1	1	8	1.00	1
Establish Production Plans Cycle Time	1	1	1	1	1	1	1	1	8	1.00	1
Time to Revise Production Schedule	1	1	1	1	1	1	1	1	8	1.00	1
Recycled Material Usage	1	1	1	1	1	1	1	0	7	0.88	0
Purchase Order Cycle Time	1	1	1	1	1	1	1	1	8	1.00	1
Supplier Delivery Lead Time	1	1	1	1	1	0	1	1	7	0.88	0
Minimum Order Quantity	1	1	1	0	1	1	1	1	7	0.88	0
Machine Efficiency	1	1	1	1	1	0	1	1	7	0.88	0
Material Efficiency	1	1	1	1	1	1	1	1	8	1.00	1

Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	***Expert in Agree-ments***	**I-CVI**	**UA**
	Expert										
Production Defect Rate	1	1	1	1	1	0	1	1	7	0.88	0
Number of Manpower	1	1	1	1	1	1	1	1	8	1.00	1
Production Lead Time	1	1	1	0	1	1	1	1	7	0.88	0
Reusable Material	1	1	1	0	1	1	1	1	7	0.88	0
Deliver Quantity Accuracy	1	1	1	1	1	1	1	1	8	1.00	1
Ship Product Cycle Time	1	1	0	1	1	1	1	1	7	0.88	0
Truck Load Optimization Rate	1	1	1	1	0	1	1	1	7	0.88	0
Return Rate from Customer	1	1	1	1	1	0	1	1	7	0.88	0
Refurbish Product Return	1	1	1	1	1	0	1	1	7	0.88	0
Product Replacement Time	1	1	1	1	1	0	1	1	7	0.88	0
									S-CVI/Ave	**0.93**	**-**
									S-CVI/UA	**-**	**0.45**

Following the removal of indicators that failed to meet the validity threshold, a recalculated S-CVI/Ave score demonstrated compliance with the minimum acceptable standard, as presented in Table 2. Consequently, 22 indicators were confirmed as valid indicators.

Table 3. KPI Indicator Validation Results

***Level* 1**	***Level* 2**	**Supply Chain Performance Indicator**	**Code**
Plan	*Reliability*	*Raw Material Usage Accuracy*	P.I.1
		Forecast Accuracy	P.I.2
	Responsiveness	*Production Scheduling Time*	P.II.1
		Establish Sourcing Plans Cycle Time	P.II.2
		Establish Production Plans Cycle Time	P.II.3
	Flexibility	*Time to Revise Production Schedule*	P.III.1
Source	*Reliability*	*Recycled Material Usage*	S.I.1
	Responsiveness	*Purchase Order Cycle Time*	S.II.1
		Supplier Delivery Lead Time	S.II.2
	Flexibility	*Minimum Order Quantity*	S.III.1
Make	*Reliability*	*Machine Efficiency*	M.I.1
		Material Efficiency	M.I.2
		Production Defect Rate	M.I.3
		Number of Manpower	M.I.4
	Responsiveness	*Production Lead Time*	M.II.1
		Reusable Material	M.II.2
Deliver	*Reliability*	*Deliver Quantity Accuracy*	D.I.1

***Level* 1**	***Level* 2**	**Supply Chain Performance Indicator**	**Code**
	Responsiveness	*Ship Product Cycle Time*	D.II.1
	Asset	*Truck Load Optimization Rate*	D.IV.1
Return	*Reliability*	*Return Rate from Customer*	R.I.1
		Refurbish Product Return	R.I.2
	Responsiveness	*Product Replacement Time*	R.II.1

Table 3 presented supply chain performance indicators in the observed company. The weighting process was carried out using Expert Choice 11.0 software, based on the results of pairwise comparison questionnaires completed by eight experts from various divisions of the company. This process generated priority weights for each core process and supply chain performance indicator. The consistency of the assessments was tested using the Consistency Ratio (CR), and all results showed a CR value ≤ 0.10, indicating acceptable consistency in accordance with Saaty's (1980) criteria [23].

Table 4. Weighting Results of Supply Chain Performance Indicators

Level 1	**Weight**	**Supply Chain Performance Indicator**	**Indicator Weight**	**Total KPI Weight**
Plan	0.313	*Raw Material Usage Accuracy*	0.265	0.083
		Forecast Accuracy	0.193	0.060
		Production Scheduling Time	0.099	0.031
		Establish Sourcing Plans Cycle Time	0.194	0.061
		Establish Production Plans Cycle Time	0.124	0.039
		Time to Revise Production Schedule	0.125	0.039
Source	0.234	*Recycled Material Usage*	0.183	0.043
		Purchase Order Cycle Time	0.219	0.051
		Supplier Delivery Lead Time	0.287	0.067
		Minimum Order Quantity	0.311	0.073
Make	0.222	*Machine Efficiency*	0.361	0.080
		Material Efficiency	0.176	0.039
		Production Defect Rate	0.111	0.025
		Number of Manpower	0.126	0.028
		Production Lead Time	0.165	0.037
		Reusable Material	0.061	0.014
Deliver	0.139	*Deliver Quantity Accuracy*	0.608	0.085
		Ship Product Cycle Time	0.198	0.028
		Truck Load Optimization Rate	0.194	0.027
Return	0.092	*Return Rate from Customer*	0.500	0.046
		Refurbish Product Return	0.195	0.018
		Product Replacement Time	0.305	0.028

In the company's actual performance measurement, each indicator was characterized by its evaluation type ("Larger is Better" or "Lower is Better") and performance targets (maximum, minimum, or realistic). The evaluation type reflects the desired direction of performance, while the targets were determined through interviews with company representatives. For instance, the indicator "Raw Material Usage Accuracy" is categorized as "Larger is Better," with a maximum target of 100% and a realistic target of 93%. Conversely, the indicator "Production Scheduling Time" is classified as "Lower is Better," with a maximum target of 0 and a realistic target of 2. These characteristics serve as a reference for objectively and systematically assessing the indicator's performance.

Table 5. Evaluation Characteristics for Each Performance Indicator

Code	KPI	Evaluation Type	Minimum Target	Maximum Target	Realistic Target
		PLAN			
P.I.1	*Raw Material Usage Accuracy*	*Larger is Better*	90.00%	100.00%	93.00%
P.I.2	*Forecast Accuracy*	*Larger is Better*	75.00%	100.00%	85.00%
P.II.1	*Production Scheduling Time*	*Lower is Better*	3.00	0.00	2.00
P.II.2	*Establish Sourcing Plans Cycle Time*	*Lower is Better*	5.00	1.00	3.00
P.II.3	*Establish Production Plans Cycle Time*	*Lower is Better*	4.00	0.00	3.00
P.III.1	*Time to Revise Production Schedule*	*Lower is Better*	29.00	16.00	24.00
		SOURCE			
S.I.1	*Recycled Material Usage*	*Larger is Better*	50.00%	75.00%	60.00%
S.II.1	*Purchase Order Cycle Time*	*Lower is Better*	15.00	1.00	11.00
S.II.2	*Supplier Delivery Lead Time*	*Lower is Better*	17.00	2.00	10.00
S.III.1	*Minimum Order Quantity (MOQ)*	*Lower is Better*	10.00	10.00	10.00
		MAKE			
M.I.1	*Machine Efficiency*	*Larger is Better*	90.00%	100.00%	95.00%
M.I.2	*Material Efficiency*	*Larger is Better*	87.00%	91.00%	89.50%
M.I.3	*Production Defect Rate*	*Lower is Better*	10.00%	5.00%	7.00%
M.I.4	*Number of Manpower*	*Larger is Better*	154.00	154.00	154.00
M.II.1	*Production Lead Time*	*Lower is Better*	40.00	17.00	25.00
M.II.2	*Reusable Material*	*Larger is Better*	75.00%	87.00%	80.00%
		DELIVER			
D.I.1	*Deliver Quantity Accuracy*	*Larger is Better*	95.00%	100.00%	97.00%
D.II.1	*Ship Product Cycle Time*	*Lower is Better*	10.00	2.00	4.00
D.IV.1	*Truck Load Optimization Rate*	*Larger is Better*	93.00%	100.00%	95.00%
		RETURN			
R.I.1	*Return Rate from Customer*	*Lower is Better*	27.00	9.00	13.00
R.I.2	*Refurbish Product Return*	*Large is Better*	40.00%	100.00%	50.00%
R.II.1	*Product Replacement Time*	*Lower is Better*	14.00	2.00	8.00

Table 5 presented the supply chain performance measurement using actual data from January to December 2024. The annual average achievement for each indicator for each indicator employed a different unit of measurement (UoM), such as percentage, days, or hours, depending on the characteristics of the respective activities within the Plan process. Despite these differing units, all indicators were quantified into comparable scores using the Objective Matrix (OMAX) method. The evaluation applied a three-level approach: level 0 (pessimistic/minimum target), level 3 (realistic/target achievement), and level 10 (optimistic/maximum target) [24], as defined through interviews and discussions with the company. Actual values were mapped onto this scale using interpolation, resulting in performance scores ranging from 0 to 10, which were then categorized using the Traffic Light System (red, yellow, green). The final value was obtained by multiplying each indicator's performance score by its respective weight.

Table 6. OMAX Matrix for Performance Achievement Measurement of the Plan Process in 2024

Plan Process in 2024							
KPI		P.I.1	P.I.2	P.II.1	P.II.2	P.II.3	P.III.1
UoM		%	%	Day	Day	Day	Hour
Performance		94.98%	86.08%	1.58	2.67	2.00	24.17
Optimistic Value	10	100.0%	100.0%	0.00	1.00	0.00	16,00
	9	99.00%	97.86%	0.29	1.29	0.43	17,14
	8	98.00%	95.71%	0.57	1.57	0.86	18,29
	7	97.00%	93.57%	0.86	1.86	1.29	19,43
	6	96.00%	91.43%	1.14	2.14	1.71	20,57
	5	95.00%	89.29%	1.43	2.43	2.14	21,71
	4	94.00%	87.14%	1.71	2.71	2.57	22,86
Target	3	93.00%	85.00%	2.00	3.00	3.00	24,00
	2	92.00%	81.67%	2.33	3.67	3.33	25,67
Pessimistic	1	91.00%	78.33%	2.67	4.33	3.67	27,33
	0	90.00%	75.00%	3.00	5.00	4.00	29,00
Score		5	4	4	4	5	3
Weighting		0.265	0.193	0.099	0.194	0.124	0.125
Value		1.325	0.772	0.396	0.776	0.620	0.375
Total *Value Plan*							4.264

Based on the Table 6, the performance scores were derived from actual data averaged over the year. For example, indicator P.I.1 had an average achievement of 94.98%, which was then converted to an OMAX score of 5. Indicator P.I.2, with an achievement of 86.08%, was converted to a score of 4. Similarly, other indicators had varying actual values depending on their respective units of measurement (UoM), but all were standardized using the OMAX scale to allow consistent evaluation within a single assessment system.

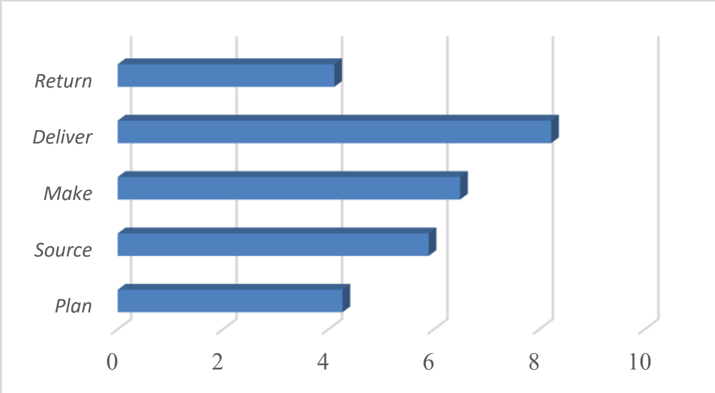
Overall, the Plan process showed performance mostly within the yellow category, with one indicator (P.III.1) falling into the red category. Individual scores ranged from 3 to 5, and the total performance score for the Plan process was 4.264, which falls within the yellow category according to the OMAX scoring system. The same OMAX method and principles were also applied to evaluate the Source, Make, Deliver, and Return processes.

Table 7. OMAX Matrix of Supply Chain Performance Measurement

Core Process Weight (A)	Total Value per Process (B)	Total KPI Value (A x B) (C)	Total Supply Chain Performance Index Value (D)
Plan (0.313)	4.264	1.335	5.678
Source (0.234)	5.898	1.380	
Make (0.222)	6.495	1.442	
Deliver (0.139)	8.222	1.143	
Return (0.092)	4.110	0.378	

Table 7 shows the overall supply chain performance index of the company for 2024. This index was calculated by multiplying the assigned weights of each core process by its corresponding total performance value. The final index score was 5.678, which falls within the yellow zone, indicating a moderate level of performance with identifiable areas for improvement. Among the five core processes, Deliver achieved the highest score at 8.222 (green), followed by Make (6.495, yellow) and Source (5.898, yellow). In contrast, Plan (4.264, yellow) and Return (4.110, yellow) recorded the lowest performance values. To provide a clearer comparison of the company's performance across the five core processes, Figure 5 illustrates the total scores of Plan, Source, Make, Deliver, and Return.

Figure 5. Supply Chain Core Process Performance



The low performance of the Plan and Return processes reflects an imbalance between indicator weights and achieved scores. In the Plan process, Raw Material Usage Accuracy, despite having the highest weight, achieved only a moderate score, while Time to Revise Production Schedule recorded a low performance value. Similarly, the Return process was dominated by Return Rate from Customer, which carried the highest weight but scored poorly, resulting in the lowest overall process performance. These findings align with previous studies by Qurtubi et al. (2022) [3] and Flodensa et al. (2024) [2], which also identified the Return process as the weakest dimension in textile-related supply chains. As shown in Table 8, the Return process consistently emerges as the lowest-performing process across different textile-related industries.

Table 8. Comparison of Green SCOR Applications in Textile-Related Industries

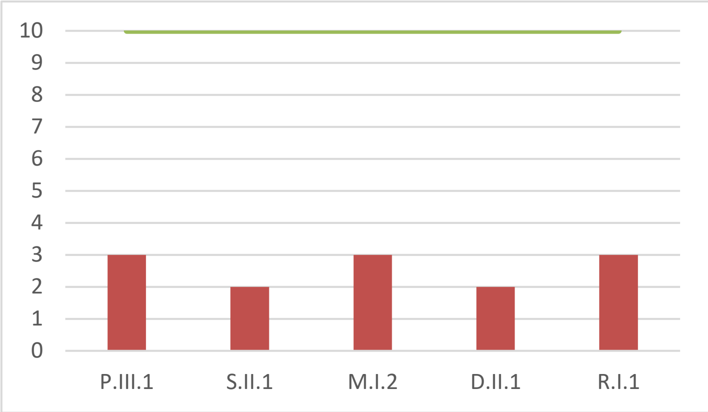
Study	Industry	Environmental Focus	Lowest Performing Process
Flodensa et al. (2024)	Batik	Waste & material efficiency	Return
Qurtubi et al. (2022)	Garment	Not explicitly addressed	Return
This study	Non-woven textile	Recycling & logistics efficiency	Return

As shown in **Table 8**, the Return process consistently emerges as the lowest-performing process across different textile-related industries. This consistency indicates that return management and reverse logistics represent a structural challenge within textile supply chains, reinforcing the relevance of the present findings.

From the 22 KPIs evaluated, five indicators were classified in the red category, indicating critical performance gaps. These indicators include Time to Revise Production Schedule (P.III.1), Purchase Order Cycle Time (S.II.1), Material Efficiency (M.I.2), Ship Product Cycle Time (D.II.1), and Return Rate from Customer (R.I.1).

Figure 6 illustrates the performance scores for these indicators, which remain substantially below the maximum optimistic value, confirming the urgency of targeted improvement actions.

Figure 6. Performance of Red Category Indicators



As shown in Figure 6, the scores of all five indicators remain far below the maximum optimistic value of 10, underscoring significant performance gaps. This condition confirms the urgency for targeted improvements, as the persistence of low scores in these areas can negatively impact overall supply chain efficiency and resilience.

To address these weaknesses, several actionable recommendations are proposed. For Plan, improvements should include implementing integrated planning software [25], establishing cross-functional SOPs [26], and providing on-the-job training to enhance staff capacity [27]. For Return, priority actions involve reinforcing final inspection with standardized checklists [28], enforcing Service Level Agreements with logistics partners [29], adopting ICT for real-time shipment monitoring [30], and developing integrated digital reporting systems for customer returns [27]. These measures are expected to reduce inefficiencies, strengthen responsiveness, and enhance supply chain reliability.

In terms of environmental sustainability metrics, only three out of nine indicators passed the CVI validation stage: Recycled Material Usage, Reusable Material, and Truck Load Optimization Rate. Although these were assigned lower priority weights, their actual performance scores varied considerably (between 5 and 9). This outcome highlights the importance of re-evaluating prioritization strategies and reinforcing sustainability initiatives to ensure that Green Supply Chain Management (Green SCM) principles are more effectively embedded into the company's operational framework.

Beyond internal performance improvements, the validated environmental indicators also offer strategic value in aligning the company with global sustainability policy frameworks. The focus on material reuse, recycling, and logistics efficiency is consistent with the environmental dimension of ESG (Environmental, Social, and Governance) reporting, where transparent disclosure of resource efficiency and waste reduction is increasingly viewed as a marker of strong corporate accountability [31]. These practices also resonate with the objectives of SDG 12 (Responsible Consumption and Production), particularly in promoting circular resource flows and responsible material management.

Collectively, these implications demonstrate that embedding environmental indicators within the supply chain not only enhances operational performance but also positions the company to meet evolving international sustainability expectations, making it more competitive in environmentally regulated and ESG-driven markets.

The selected environmental indicators, Recycled Material Usage and Reusable Material, reflect material circularity by extending resource lifecycles and reducing waste generation. At the same time, the Trucks Load Optimization Rate represents green logistics practices that improve transportation efficiency and indirectly reduce emissions. From a theoretical perspective, these findings confirm that sustainability-oriented operational capabilities function as strategic resources, supporting a resource-based view and highlighting increasing institutional pressures for environmentally accountable supply chain management.

CONCLUSION

The results indicated moderate overall performance, with Deliver performing strongly while Plan and Return emerged as the weakest processes. By integrating environmental aspects into supply chain performance measurement, the framework extends traditional cost, quality, and delivery dimensions toward a sustainability-oriented evaluation. Indicators such as material reuse, recycling practices, and truck load optimization provide a more holistic perspective by linking operational efficiency with environmental performance. For instance, emissions data for the Truck Load Optimization Rate during delivery, or material waste in Recycled Material Usage and Reusable Material indicators during production, can be tracked alongside traditional KPIs, enabling more informed trade-offs between economic and environmental priorities. Compared with prior Green SCOR studies in other industries, this research shows that weak points differ across contexts and highlights material recycling as a critical yet previously overlooked aspect of sustainable supply chain evaluation. While this study provides both academic and practical contributions, several limitations remain. First, the environmental dimension is represented by a limited number of indicators focusing on material circularity and logistics efficiency. It does not include direct measurements of energy consumption, water usage, or carbon emissions. Second, although CVI and AHP rely on expert judgment, potential subjectivity may still exist despite consistency checks and triangulation with objective operational data through OMAX. Third, the discrete scoring nature of the OMAX method may not fully capture minor performance fluctuations. These limitations, however, reflect practical data constraints and do not reduce the applicability of the framework as a structured performance monitoring tool. Future research should refine measurement units and adjust indicators to better reflect specific industry needs. In addition, the framework is adaptable across industries and company scales. Indicator selection can be customized to reflect sector-specific sustainability priorities, such as energy efficiency in heavy manufacturing or water use in food processing. For large enterprises, structured weighting and scoring can support integration into corporate sustainability audits, while for SMEs, the CVI–AHP–OMAX–TLS approach remains feasible as a practical yet resource-efficient tool. This adaptability broadens the framework's relevance beyond the non-woven textile sector and reinforces its potential as a scalable model for sustainable supply chain performance measurement.

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