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ANALYSIS OF SUPPLY CHAIN PERFORMANCE USING GREEN SCOR AND AHP IN A PUBLIC CONSTRUCTION PROJECT IN WEST PAPUA

Nazar Hadiwantoro[1]*, Rosalendro Eddy Nugroho[2]*
[1]Economics and Business Faculty, Universitas Mercu Buana, Indonesia
[2]Business Managemet Post Graduate Program, Universitas Mercu Buana, Indonesia
55123110066@mercubuana.ac.id, rosalendro.eddy@mercubuana.ac.id

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Abstract

This study aims to evaluate and prioritize the supply chain performance of a public construction project in a remote region—namely, the eight-story office building of Bank Indonesia in West Papua. The research adopts a mixed-method approach integrating a quantitative assessment using the Green Supply Chain Operations Reference (Green SCOR) model with a qualitative weighting of indicators through the Analytic Hierarchy Process (AHP). Nineteen key performance indicators (KPIs) were evaluated across five dimensions: reliability, responsiveness, agility, cost, and asset management. Data were collected from 66 stakeholders—including project owners, consultants, contractors, and suppliers—who contributed expert judgment for the AHP analysis. The results indicate that the overall performance level is 58.68%, categorized as average, highlighting the need for optimization. The analysis identifies *Cash-to-Cash Cycle Time* as the most influential KPI, followed by *On-Time Delivery of Materials* and *Total Supply Chain Management Cost*. Due to the average performance level, a Root Cause Analysis (RCA) using the 4M + 1E framework was conducted to explore inefficiencies. The RCA revealed challenges in workforce competence, digital system adoption, material forecasting, supplier dependency, and environmental constraints. Practical implications include integrating digital platforms, AI-based forecasting, supplier diversification, and multimodal logistics strategies. This research contributes to Sustainable Development Goal 9 by promoting resilient, inclusive, and sustainable infrastructure systems in geographically isolated regions.

Keywords: Green SCOR, AHP, Supply Chain Performance, Public Construction, SDG 9

INTRODUCTION

The successful implementation of construction projects, particularly in remote areas, requires efficient and sustainable supply chain management (SCM). In Indonesia, geographical complexity often results in logistical constraints and unreliable material delivery, directly impacting project cost, time, and quality. The eight-story regional office development project of Bank Indonesia in West Papua illustrates these challenges, where limited infrastructure, restricted supplier access, and environmental conditions disrupt execution across the supply chain. Effective coordination among suppliers, contractors, and project owners is thus essential to meet performance targets. SCM has become a critical success factor in construction due to its role in integrating material flow, information, and resources throughout the project lifecycle. As noted by Chopra and Meindl (2018), a well-managed supply chain enhances responsiveness, reduces costs, and improves service levels across all operational nodes. Nevertheless, traditional construction SCM often lacks agility, standardization, and sustainability, particularly in public sector projects constrained by rigid bureaucratic procedures. In this context, Green Supply Chain Management (GSCM) offers added value by embedding environmental considerations into conventional performance models, aligning more closely with Sustainable Development Goals (SDGs) and the increasing demands for sustainable public infrastructure delivery.

This study aims to evaluate the supply chain performance of the BI West Papua office construction using the Green Supply Chain Operations Reference (Green SCOR) model. The Green SCOR model focuses on five performance dimensions—Plan, Source, Make, Deliver, and Return—while integrating environmental considerations such as waste reduction and sustainability compliance (Cigolini et al., 2022). The study further employs the Analytic Hierarchy Process (AHP) to determine the relative weight and priority of 19 key performance indicators (KPIs). A total of 66 respondents from project stakeholders—including owners, consultants, contractors, and suppliers—provided expert assessments through structured questionnaires.

The objectives of this research are threefold: (1) to evaluate the supply chain performance of the BI project based on Green SCOR indicators and AHP, (2) to identify the most influential KPIs using AHP, and (3) to recommend supply chain improvement strategies based on root cause analysis, using the integrated Green SCOR and AHP framework to enhance operational efficiency and effectiveness .

The contribution of this study is both theoretical and practical. Theoretically, it extends the application of Green SCOR and AHP integration in the context of government construction projects in underdeveloped regions. While previous studies often focus on manufacturing or urban construction, this research enriches the literature by addressing supply chain challenges under limited infrastructure conditions. Practically, the study offers a systematic evaluation tool and improvement model that can assist Bank Indonesia and other public institutions in enhancing project delivery performance through evidence-based interventions .

The novelty of this research lies in its contextual application and methodological integration. Unlike previous studies that treat performance evaluation and root cause analysis separately, this study integrates Green SCOR, AHP, and RCA to assess not only what aspects are underperforming but also why they underperform. This combination enables a comprehensive understanding of the operational bottlenecks and sustainability gaps in a remote construction project with national strategic value.

The scope of this study is limited to one government-owned project during the 2023–2024 implementation period. It analyzes supply chain performance from the perspective of internal stakeholders using Green SCOR indicators, without real-time tracking or external benchmarking. However, the integrated methodology offers a practical framework for future evaluation of similar infrastructure projects in other remote Indonesian regions.

LITERATURE REVIEW AND HYPOTHESIS FORMULATION

A project is a temporary effort undertaken to create a unique product, service, or result. According to the Project Management Institute (PMI, 2021), a project is a temporary endeavor with a defined beginning and end, undertaken to meet unique goals and objectives. Projects differ from operational work in that they are non-repetitive and require a tailored approach in planning, execution, and control.

Wysocki (2019) defines a project as a sequence of unique, complex, and connected activities that are goal-oriented and constrained by time, cost, and resources. Projects are also characterized by progressive elaboration, meaning that plans become more detailed as more information becomes available throughout the lifecycle. In the same vein, Kerzner (2017) highlights that a project has specific objectives, requires interdepartmental coordination, and involves performance criteria such as scope, time, quality, and cost.

The implementation of construction projects, especially in remote and underdeveloped regions such as West Papua, adds an additional layer of complexity due to logistical constraints, limited infrastructure, and unpredictable environmental conditions. These constraints demand careful integration of planning, procurement, scheduling, and stakeholder management.

Islam et al. (2024) emphasize that projects in public infrastructure require a strong governance structure, sustainability orientation, and responsiveness to stakeholder interests. These elements are crucial to ensure not only completion but also long-term impact and value generation. Public construction projects must also address transparency, regulatory compliance, and sustainability performance aligned with national policies and the Sustainable Development Goals (SDGs).

In the context of this study, the project in focus—a government office building in West Papua—represents a complex effort with environmental, logistical, and stakeholder challenges that must be managed using structured project management and supply chain frameworks.

Supply Chain Management (SCM) refers to the coordination of planning, sourcing, production, delivery, and return activities across the value chain to optimize resources and meet customer demands (CSCMP, 2023; Heizer, Render, & Munson, 2016). It goes beyond logistics by integrating functions from raw material procurement to product delivery through collaboration among all stakeholders (Wang & Du, 2019).

In construction, SCM takes on unique characteristics. It is project-specific, temporary, and involves multiple contractors and suppliers whose performance affects timelines, budgets, and quality (Bolstorff & Rosenbaum, 2011). Construction supply chains must manage fluctuating demand, fragmented operations, and geographic dispersion—especially in remote regions like West Papua.

According to Zhang and Lu (2022), challenges such as late deliveries, cost inefficiencies, and miscommunication are common in construction supply chains. Effective SCM in this context enhances material availability, schedule reliability, and cost control. The integration of digital tools and sustainability practices further strengthens supply chain performance.

As illustrated in *Figure 1*, construction supply chains connect key actors such as material suppliers, contractors, subcontractors, and clients, all of whom must coordinate to deliver project milestones efficiently.

Gambar 1. Rantai Pasok Konstruksi
Sumber : APPAKSI, 2012

Gambar 2 - GSCM Model

This study emphasizes the importance of SCM in managing the complexity of material flows and decision-making across phases of the 8-story building project in Papua Barat.

Green Supply Chain Management (GSCM) is a strategic approach that integrates environmental considerations into all stages of the supply chain—from planning, sourcing, and manufacturing to distribution and product return (Islam et al., 2024). GSCM aims to minimize environmental impact while maintaining operational efficiency, particularly relevant in industries such as construction that contribute significantly to carbon emissions and waste generation.

In the construction sector, GSCM emphasizes sustainable sourcing of materials, energy-efficient construction practices, and responsible waste management. This is especially critical in projects located in environmentally sensitive or logistically challenging regions like Papua Barat, where improper material flow may lead to cost overruns and ecological harm (Zhang & Lu, 2022).

GSCM is structured around three key dimensions: environmental, economic, and social. The environmental dimension addresses emission reduction, renewable material use, and waste minimization (Islam et al., 2024). The economic dimension focuses on cost efficiency and value creation. The social dimension ensures local employment, health and safety compliance, and stakeholder engagement—particularly vital in underdeveloped regions.

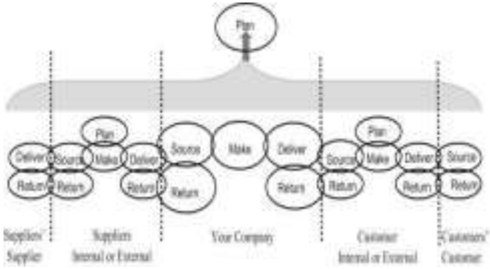
The model illustrated in *Figure 2* shows how GSCM operates across the product life cycle, promoting sustainability in each activity node.

Through the adoption of GSCM, construction projects are better positioned to meet Sustainable Development Goals (SDG 12) while enhancing supply chain responsiveness and resilience.

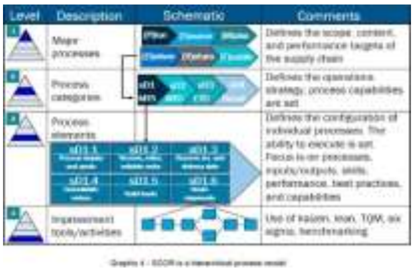
The Supply Chain Operations Reference (SCOR) model, developed by the Supply Chain Council, serves as a standardized framework for assessing, monitoring, and improving supply chain performance. SCOR structures supply chain activities into five main processes: Plan, Source, Make, Deliver, and Return (Stephens, 2001; Bolstorff & Rosenbaum, 2012). Each process includes performance metrics and best practices to enhance visibility and decision-making throughout the supply chain.

In the construction industry, the SCOR model supports complex coordination across multiple actors and sites. For instance, the *Plan* phase involves forecasting and resource allocation; *Source* addresses procurement of critical materials; *Make* focuses on on-site construction activities; *Deliver* encompasses material logistics and scheduling; and *Return* manages defects and surplus materials. These processes are particularly significant in high-risk environments like Papua Barat, where logistics and supplier coordination are critical to success.

To align with sustainability goals, SCOR has evolved into Green SCOR by incorporating environmental criteria—such as carbon emissions, energy use, and waste management—into each core process (Frederiksen et al., 2019). Green SCOR not only optimizes performance but also evaluates environmental impact, allowing construction projects to balance efficiency with sustainability.



Gambar 3 SCOR Model V. 12.0
Sumber : APICS (2017)



Gambar 4 SCOR Model Hirarki Proses
Sumber : APICS (2017)

Key Performance Indicators (KPIs) are central to the Green SCOR framework, serving as quantifiable metrics that reflect the efficiency, responsiveness, reliability, and environmental sustainability of supply chain activities (Bolstorff & Rosenbaum, 2011). In construction supply chains—especially in remote areas such as Papua Barat—KPIs help identify performance bottlenecks and prioritize improvement efforts based on objective data.

Green SCOR KPIs are grouped under six core process dimensions: Plan, Source, Make, Deliver, Return, and Enable, and are extended to include environmental and social impact. These indicators allow stakeholders to track energy usage, waste reduction, carbon footprint, inventory efficiency, supplier reliability, and responsiveness to disruptions (Islam et al., 2024; Zhang & Lu, 2022).

The Analytical Hierarchy Process (AHP), developed by Thomas L. Saaty, is a structured decision-making tool designed to solve complex problems involving multiple criteria and alternatives (Saaty, 1980). AHP breaks down problems into a hierarchy, enabling decision-makers to perform pairwise comparisons and assign relative weights to criteria and sub-criteria based on expert judgment.

Previous studies have demonstrated the practical utility of combining the SCOR model with Analytical Hierarchy Process (AHP) in evaluating supply chain performance, especially in complex or high-risk industries. Internationally, Saleheen and Habib (2023) introduced an Integrated Supply Chain Performance Measurement (ISCPM) model, integrating SCOR, AHP, and Balanced Scorecard (BSC), which successfully captured both operational and strategic metrics in Bangladeshi manufacturing. Adeyemi et al. (2024) applied AHP in SMEs' service supply chains, emphasizing demand management and responsiveness as dominant performance drivers.

Hinkka and Tätilä (2013) employed RFID with SCOR in construction supply chains, improving inventory accuracy and visibility. Frederiksen et al. (2019) explored stakeholder hybridity in construction supply chain management (CSCM), identifying coordination complexity as a critical barrier to performance. Wang and Du (2019) validated SCOR's diagnostic capability in port logistics, underlining the model's cross-industry adaptability.

Domestically, Anindita et al. (2020) found that SCOR-AHP mapping of performance between sugarcane suppliers and processors led to efficiency improvements. Qurtubi et al. (2022) used SCOR in SMEs to assess garment industry supply chains, while Solekha et al. (2024) included green indicators in SCOR to improve environmental accountability in fertilizer companies.

These studies support the current research's method choice, highlighting SCOR-AHP's robustness in evaluating operational and sustainability trade-offs in construction—especially in geographically challenging settings like Papua Barat.

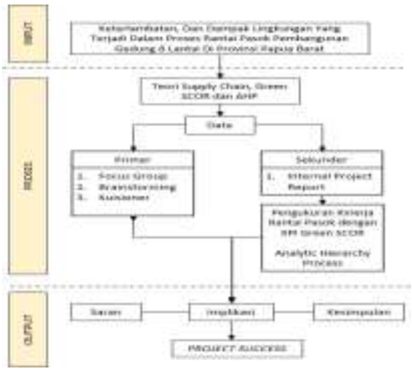
Research on supply chain performance has evolved significantly, particularly with the integration of structured frameworks like SCOR and decision-support methods such as AHP. Most studies have applied this combination in manufacturing sectors (e.g., Saleheen & Habib, 2023; Meena et al., 2023), while a few—such as Hinkka & Tätilä (2013) and Frederiksen et al. (2019)—have begun exploring their relevance in the construction industry. Recent developments include the incorporation of green performance criteria, as demonstrated by Ozbiltekin-Pala et al. (2023) through their Circular-SCOR model and Solekha et al. (2024) in green fertilizer supply chains.

However, these studies are predominantly conducted in industrial and urban contexts. There remains a research gap in applying Green SCOR and AHP methodologies to remote construction projects, where logistical challenges, infrastructure constraints, and environmental sensitivity are amplified. Moreover, while some research integrates environmental performance indicators, few studies holistically measure trade-offs between operational efficiency and ecological impact within construction supply chains. By combining Green SCOR and AHP in the case of an 8-story building construction in Papua Barat, it addresses a contextual and methodological gap in the literature.

The conceptual framework of this study is built upon the integration of the Green Supply Chain Operations Reference (Green SCOR) model and the Analytical Hierarchy Process (AHP) to assess supply chain performance in a construction context. The Green SCOR model provides a structured view of supply chain processes—Plan, Source, Make, Deliver, and Return—while embedding sustainability dimensions such as waste reduction, energy efficiency, and supplier compliance (Frederiksen et al., 2019; Bolstorff & Rosenbaum, 2012).

In parallel, AHP is applied as a multi-criteria decision-making tool to prioritize key performance indicators (KPIs) identified through the Green SCOR framework. By combining these two approaches, the study enables a comprehensive analysis that incorporates both operational and environmental perspectives.

This framework is particularly relevant to remote construction projects, where logistics are constrained, material planning is critical, and sustainability practices are often underdeveloped. In the case of the 8-floor building construction project in Papua Barat, this model will serve to identify priority areas for performance improvement, informed by stakeholder expertise and environmental considerations.



Gambar 5 Kerangka Pemikiran, 2024

Gambar 6 Responden Penelitian

RESEARCH METHODS

This section describes the methodology used in this study, which combines the Green Supply Chain Operations Reference (Green SCOR) model and the Analytical Hierarchy Process (AHP) to evaluate the performance of supply chain activities in an eight-story office building construction project located in West Papua. The methodology covers the research design, population and sampling method, data collection and instrument development, and data analysis techniques.

This research adopts a descriptive quantitative design. The descriptive method is used to systematically present and interpret the characteristics of the construction supply chain, while the quantitative approach allows the analysis of numeric indicators derived from Green SCOR performance metrics. This method is suitable for assessing real-world project execution, especially when measuring complex supply chain flows and sustainability performance without hypothesis testing (Creswell, 2014; Kothari, 2004).

The population consists of all project actors directly involved in the **critical path of the construction project**. These include the project owner, construction management consultant (MK), main contractor, subcontractors, and suppliers who are responsible for material delivery and logistics operations.

Given the limited size and specific focus of the research population, this study uses a **total population sampling** approach to ensure all relevant decision-makers and practitioners are represented in the evaluation. The total number of respondents who participated in data collection activities (questionnaires and AHP assessments) is **66 people**. (Figure 6)

This study uses **mixed-method data collection** combining primary and secondary sources:
Structured Questionnaire: Designed using Green SCOR indicators and AHP dimensions. It consists of three parts: (1) respondent demographics, (2) performance evaluation using Green SCOR processes (Plan, Source, Make, Deliver, Return), and (3) pairwise comparison matrices for AHP prioritization. The structured questionnaire was applied the **Saaty scale (1–9)** for **pairwise comparisons** among performance criteria as required in the AHP method. This dual-format design enabled both intensity-based assessment and criteria prioritization.

Data collection involved structured interviews with key informants—project managers, procurement coordinators, and contractor representatives—to gain qualitative insights into material delays, supplier reliability, and scheduling challenges. This was complemented by a review of secondary data, including procurement records, delivery tracking reports, supplier evaluations, and budget realization documents, which were used to calculate actual values for performance indicators such as cash-to-cash cycle time, logistics cost per ton, and on-time delivery percentage. Instrument development was facilitated through a Focus Group Discussion (FGD) involving the project owner, construction management consultant, main contractor, and key material suppliers, aimed at validating the operational relevance of selected KPIs and establishing a shared understanding of the evaluation criteria used in the AHP process.The analysis was conducted in two stages, corresponding to the dual-framework methodology:

Green SCOR-Based Performance Measurement: Each of the five SCOR categories was linked to specific performance indicators. The actual values of the KPIs were extracted from project documentation and assessed without the use of inferential statistics. Indicators such as on-time delivery, supplier reliability, energy consumption per unit, and percentage of recycled materials were directly calculated using reported figures.

Analytical Hierarchy Process (AHP): Used to prioritize performance dimensions based on stakeholder judgment. The pairwise comparison data from respondents were processed using Expert Choice™ software, which computed eigenvalue-based priority weights and consistency ratios. Only matrices with Consistency Ratio (CR) ≤ 0.1 were accepted to ensure reliability and logical coherence in decision making (Saaty, 1980).

This study adopts the Green SCOR model as the basis for defining supply chain performance indicators. Each KPI is categorized based on performance attributes—reliability, cost, responsiveness, flexibility, asset management, and environmental impact—and is aligned with the relevant SCOR process: Plan, Source, Make, Deliver, Return, and Enable. Furthermore, the indicators are linked to Sustainable Development Goals (SDGs) to ensure alignment with long-term sustainability objectives.

Table 1 presents the operationalization of variables used in this study.

No	Kode KPI	Nama KPI	Satuan KPI	Atribut Performance	Proses	No	Kode KPI	Nama KPI	Satuan KPI	Atribut Performance	Proses
1	AM.1.2	Cash-to-Cash Cycle Time	Waktu (hari)	Asset Management (Efisiensi Aset)	Plan	11	ESG.2.5	Percentage of Recycled Materials Used	Persentase (%)	Reliability (Keandalan)	Make
2	AM.2.1	Inventory Days of Supply	Waktu (hari)	Asset Management (Efisiensi Aset)	Plan	12	CO.2.1	Logistics Cost per Ton of Material	Biaya (Rp/ton)	Cost (Biaya)	Deliver
3	CO.1.1	Total Supply Chain Management Cost	Biaya (Rp)	Cost (Biaya)	Source	13	RL.3.38	On-time Delivery of Materials	Persentase (%)	Reliability (Keandalan)	Deliver
4	AG.2.1	Upside Supply Chain Flexibility	Persentase (%)	Flexibility (Fleksibilitas)	Source	14	RL.3.10	Perfect Order Fulfillment	Persentase (%)	Reliability (Keandalan)	Deliver
5	RL.3.112	Supplier Reliability	Persentase (%)	Reliability (Keandalan)	Source	15	RS.1.1	Order Fulfillment Cycle Time	Waktu (hari)	Responsiveness (Responsivitas)	Deliver
6	RL.1.2	Supplier Sustainability Compliance	Persentase (%)	Reliability (Keandalan)	Source	16	RS.1.4	Order Delivery Lead Time	Waktu (hari)	Responsiveness	Deliver
7	RS.1.2	Lead Time for Critical Materials	Waktu (hari)	Responsiveness (Responsivitas)	Source	17	CO.2.2	Reverse Logistics Cost	Biaya (Rp)	Cost (Biaya)	Return
8	AM.1.1	Return on Supply Chain Fixed Assets	Rasio (%)	Asset Management (Efisiensi Aset)	Source	18	RL.3.41	Return Rate	Persentase (%)	Reliability (Keandalan)	Return
9	ESG.3.3	Energy Consumption per part of Construction	kWh/unit	Reliability (Keandalan)	Make	19	RS.2.3	Complaint Resolution Time	Waktu (hari)	Responsiveness (Responsivitas)	Return
10	ESG.3.2	Waste Reduction in Construction	Persentase (%)	Responsiveness (Responsivitas)	Make						

RESULTS AND DISCUSSION

Performance Measurement Using Green SCOR and AHP

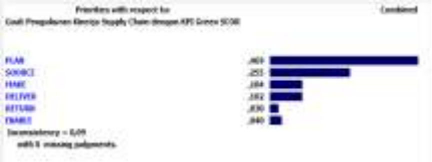
A. AHP-Based Weighting Process Using Expert Choice

The Analytical Hierarchy Process (AHP) was used to prioritize 19 supply chain performance indicators by converting stakeholder judgments into quantifiable weights. Data were collected via structured questionnaires from 66 respondents—comprising project owners, construction management consultants (MK), main contractors, subcontractors, and suppliers—who compared indicators within each SCOR process (Plan, Source, Make, Deliver, Return, Enable) using Saaty's 1–9 scale. Inputs were processed through Expert Choice™, which aggregated responses, validated consistency (all CRs < 0.1), and calculated local and global weights. Final prioritization was derived by synthesizing pairwise comparisons into local weights and multiplying them by their respective SCOR process weights.

The weighting procedure was conducted through several structured stages. First, pairwise comparison matrices were constructed for each SCOR process (e.g., Source), where all relevant KPIs were compared against each other based on their perceived importance toward sustainable performance. For instance, the four KPIs under the Source category were evaluated using Saaty's fundamental scale. Next, Expert Choice™ automatically calculated the Consistency Ratio (CR) for each matrix to ensure logical coherence; all matrices achieved CR values below the 0.1 threshold, confirming acceptable consistency in stakeholder judgments. Finally, the software synthesized the judgments into local priority weights and further computed global weights by multiplying these local weights with the corresponding parent process weights in the overall SCOR hierarchy, resulting in a final ranking of the 19 KPIs.

This approach ensured that all stakeholder inputs were treated equally and transparently, minimizing individual bias and providing a reliable basis for prioritization. By leveraging Expert Choice, the research was able to handle complex judgment data efficiently and uphold methodological rigor through embedded consistency validation and normalization functions.

Ranking of SCOR Processes (Level 1)



Gambar 7 Ranking of SCOR Processes (Level 1)

Gambar 8 Ranking of Atribut Performances (Level 2)

The results of the AHP analysis indicate that Plan (0.469) was the most critical SCOR process, followed by Source (0.255), while Return (0.030) and Enable (0.040) had the lowest priority. This reflects the high importance of strategic planning and procurement preparation in managing construction supply chains, particularly for infrastructure projects in remote areas.

Ranking of Performance Attributes (Level 2)

Each SCOR process was further decomposed into performance attributes such as cost, reliability, responsiveness, asset management, flexibility, and environmental impact. For instance, within the Source process, stakeholders gave the highest weight to Asset Management (0.389), followed by Cost (0.285), whereas Flexibility received only 0.041. This shows that efficient use of inventory and cost control were more heavily emphasized than adaptability.

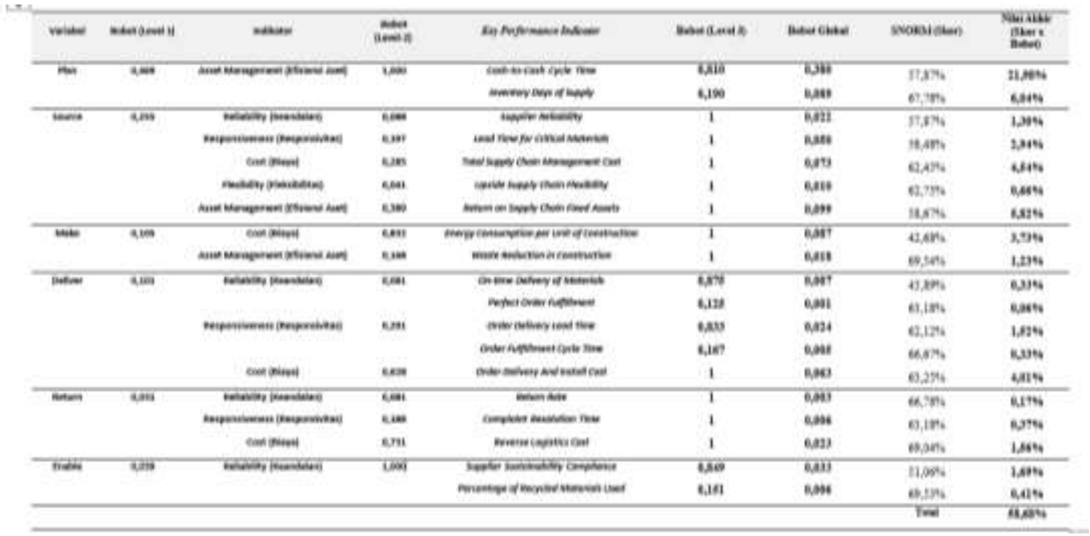
Processes like Plan and Enable, which had only one associated attribute, automatically assigned a full weight (1.000) without pairwise comparisons.

Global Ranking of Key Performance Indicators (Level 3)

The global weights of all 19 KPIs, as derived from Expert Choice™, are presented in Figure above. The top indicators include Cash-to-Cash Cycle Time (0,135), On-Time Delivery (0.076) and Total Supply Chain Cost (0,074). These results highlight a collective preference among stakeholders for indicators related to delivery performance, supplier consistency, and working capital efficiency.

Measurement Results to Answer Research Objective

The ranking results above directly address the first research objective, which is “to measure and prioritize the key performance indicators (KPIs) in the construction supply chain using the Green SCOR model.” By applying AHP to stakeholder assessments, this study successfully identified the most critical KPIs that influence sustainable project delivery.



Variabel	Bobot (Level 1)	Indikator	Bobot (Level 2)	Key Performance Indicator	Bobot (Level 3)	Bobot Global	SNORM (Skor)	Nilai Akhir (Skor x Bobot)
Plan	0,469	Asset Management (Efisiensi Aset)	1,000	Cash-to-Cash Cycle Time	0,810	0,380	57,87%	21,98%
				Inventory Days of Supply	0,190	0,089	67,78%	6,04%
Source	0,255	Reliability (Keandalan)	0,088	Supplier Reliability	1	0,022	57,87%	1,30%
		Responsiveness (Responsivitas)	0,347	Lead Time for Critical Materials	1	0,088	38,48%	3,34%
		Cost (Biaya)	0,285	Total Supply Chain Management Cost	1	0,073	62,43%	4,54%
		Flexibility (Fleksibilitas)	0,041	Upside Supply Chain Flexibility	1	0,010	62,73%	0,66%
		Asset Management (Efisiensi Aset)	0,380	Return on Supply Chain Fixed Assets	1	0,099	58,67%	5,82%
Make	0,105	Cost (Biaya)	0,832	Energy Consumption per Unit of Construction	1	0,087	42,68%	3,73%
		Asset Management (Efisiensi Aset)	0,168	Waste Reduction in Construction	1	0,018	69,54%	1,23%
Deliver	0,103	Reliability (Keandalan)	0,081	On-time Delivery of Materials	0,878	0,007	43,89%	0,33%
				Perfect Order Fulfillment	0,122	0,001	63,18%	0,06%
		Responsiveness (Responsivitas)	0,291	Order Delivery Lead Time	0,833	0,024	62,12%	1,52%
				Order Fulfillment Cycle Time	0,167	0,005	66,67%	0,33%
		Cost (Biaya)	0,628	Order Delivery And Install Cost	1	0,063	63,25%	4,01%
Return	0,031	Reliability (Keandalan)	0,081	Return Rate	1	0,003	66,78%	0,17%
		Responsiveness (Responsivitas)	0,188	Complaint Resolution Time	1	0,006	63,18%	0,37%
		Cost (Biaya)	0,731	Reverse Logistics Cost	1	0,023	69,04%	1,56%
Enable	0,039	Reliability (Keandalan)	1,000	Supplier Sustainability Compliance	0,849	0,033	51,06%	1,69%
				Percentage of Recycled Materials Used	0,151	0,006	69,33%	0,41%
							Total	58,86%

As shown in **Table**, the **final performance score** is derived from the multiplication of each KPI's global weight with its actual performance score (based on project reports). These scores reflect the weighted contribution of each KPI to the total supply chain performance level.

The accumulated result of all 19 indicators yields a total supply chain performance score of **58.86%**. According to the internal benchmarking scale defined in this study (adapted from previous performance evaluation models), this score represents a **average level of performance**. It suggests that while the supply chain system supports the project reasonably well, there is still room for strategic improvement, particularly in areas related to supplier control, delivery accuracy, and logistics responsiveness.

To answer the second research objective, the five most influential indicators are identified based on their final scores. The **Cash-to-Cash Cycle Time** holds the highest weight with a contribution of **21.98%**, making it the most significant factor in supply chain performance. This is followed by **Inventory Days of Supply** (6.04%), **Return on Supply Chain Fixed Assets** (5.82%), **Total Supply Chain Management Cost** (4.54%), and **Order Delivery and Install Cost** (4.01%). Collectively, these five indicators account for over **42%** of the total performance score, highlighting the critical importance of financial efficiency, inventory turnover, capital asset productivity, and logistics cost control in the success of the project's supply chain.

These findings demonstrate the strength of combining Green SCOR and AHP for structured performance evaluation and indicator prioritization. The results provide actionable insights for improving supply chain governance in construction projects with a focus on data-driven sustainability and operational excellence.

Root Cause Analysis (RCA) of Average Performance

The 4M+1E framework revealed five primary root causes affecting supply chain performance: in the **Man** domain, there was a lack of supply chain management (SCM) training and poor team synchronization; under **Material**, issues stemmed from a limited supplier base and inconsistent delivery reliability; the **Machine** aspect highlighted the underutilization of digital systems to support SCM processes; in terms of **Method**, the absence of standardized operating procedures (SOPs) for performance tracking was evident; and under the **Environment** domain, challenges were attributed to limited supporting infrastructure and the geographic isolation of the West Papua project location.

Managerial Implications Based on Root Cause Analysis Using the Integrated Green SCOR and AHP Framework

The third research objective was to recommend strategic improvements for supply chain performance by diagnosing root causes and linking them with performance indicators derived from the Green SCOR-AHP hierarchy. This integration ensures that recommendations are both evidence-based and aligned with measurable operational targets.

Root Cause Analysis (RCA), developed through the 4M+1E Fishbone Diagram (Figure 4.8) and validated via 5W+1H (Table 2), revealed that suboptimal performance stemmed from human, procedural, and technological deficiencies. These root causes were then matched with underperforming KPIs as identified in Table.

Table 2. The implications are structured along Green SCOR performance dimensions as follows:

Aspect (Green SCOR)	Key Root Cause	Managerial Strategy Recommendation
Reliability	Limited supplier network, unclear specs, low delivery consistency	Implement performance-based supplier contracts and integrate RFID-based real-time inventory tracking to ensure material arrival and stock accuracy.
Responsiveness	Delays in procurement & unclear forecasting strategy	Apply AI-driven forecasting tools and digital supply chain dashboards to improve schedule responsiveness and early warning systems.
Flexibility (Agility)	Lack of mitigation scenarios; rigid scheduling	Introduce scenario-based simulation tools and adaptive supply chain policies for risk mitigation under schedule and environmental constraints.
Cost	Inefficient logistics & long procurement chains	Optimize transportation planning through smart logistics routing, bundle procurement strategies, and apply data analytics to reveal hidden cost drivers.
Asset Management	High idle time of tools, misallocation of material	Utilize predictive maintenance, apply digital asset tracking tools, and streamline onsite material distribution through lean supply practices.

Through these integrated recommendations, the supply chain can systematically transition from average to optimal performance, targeting improvements that are directly traceable to their root causes and supported by quantifiable indicators. This evidence-driven approach enhances both operational efficiency and strategic supply chain resilience, particularly in complex infrastructure projects like the eight-story building in West Papua.

CONCLUSION

This study investigated supply chain performance in the construction of an eight-story building in West Papua by integrating the Green SCOR framework, the Analytical Hierarchy Process (AHP), and Root Cause Analysis (RCA). The research involved 66 respondents representing project owners, contractors, construction managers, and suppliers.

The overall supply chain performance was classified as moderate, with a final score of **58.86%** calculated from normalized project data and weighted KPIs. The strongest performance was observed in the **Plan** and **Source** categories, supported by higher stakeholder priority and better execution, while the **Return** and **Enable** processes—particularly those linked to sustainability and reporting—showed the lowest contribution, indicating gaps in environmental alignment and system integration.

To address the second research objective, the five most influential indicators were identified based on their final weighted scores. **Cash-to-Cash Cycle Time** contributed the most at **21.98%**, followed by **Inventory Days of Supply** (6.04%), **Return on Supply Chain Fixed Assets** (5.82%), **Total Supply Chain Management Cost** (4.54%), and **Order Delivery and Install Cost** (4.01%). These five KPIs collectively accounted for more than **42%** of the total score, underscoring the dominant role of **financial efficiency**, **inventory turnover**, **capital asset productivity**, and **logistics cost control** in determining the effectiveness of the supply chain.

Root cause analysis using the **4M+1E fishbone diagram** and the **5W+1H framework** revealed systemic constraints across technical, procedural, and contextual dimensions. Notable issues included weak digital infrastructure, insufficient supplier capability development, limited performance monitoring procedures, and lack of adaptability in logistics operations—especially in remote or constrained locations. These issues directly aligned with underperforming KPIs and provide a clear basis for targeted interventions and future supply chain improvements.

Practical Implications

To enhance performance across critical supply chain dimensions, a multi-pronged strategy is proposed that integrates digital transformation, financial efficiency, sustainability, and institutional coordination. The adoption of IoT, AI, and Big Data technologies should be accelerated to enable real-time tracking of material flows and delivery schedules, while interoperable digital platforms among contractors and suppliers will reduce lead times and enhance decision-making accuracy. Financial performance can be improved by prioritizing key indicators such as Cash-to-Cash Cycle Time and On-Time Delivery through supplier diversification, lean supply chain practices, and proactive risk mapping to ensure continuity. Simultaneously, sustainability must be embedded in procurement and construction workflows by mandating the use of eco-friendly materials, enforcing ISO 14001 compliance, and implementing circular economy practices including recycling, waste monitoring, and low-energy construction methods. Institutional mechanisms such as Early Warning Systems (EWS) powered by machine learning can proactively detect supply disruptions, while BIM-integrated KPI dashboards can visualize schedule impacts. To strengthen coordination, weekly Supply Chain Coordination Meetings (SCCM) should be established to align all stakeholders on logistics performance and production milestones, fostering a responsive, data-driven, and accountable supply chain ecosystem.

Research Limitations

This study was limited to a single construction project and employed a fixed set of 19 KPIs based on the Green SCOR framework, with post-construction data serving as the basis for performance evaluation. These constraints reduce the generalizability of findings and limit real-time applicability. Moreover, the analysis did not explicitly account for external influences such as regulatory policies, political dynamics, or macroeconomic factors. Future research should adopt a multi-project, cross-regional perspective and incorporate broader external variables, including environmental regulations and climate change impacts. The use of advanced analytical tools—such as machine learning, Artificial Neural Networks (ANN), or fuzzy AHP—could improve predictive accuracy and support dynamic, simulation-based decision-making. Additionally, the development of a more holistic KPI model that includes social, regulatory, and stakeholder-driven indicators is recommended to better reflect the complexity and sustainability of modern construction supply chains.

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