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Green Supply Chain Management Performance (Case Study: Green Supply Chain Management Toward SCOR 14.0)

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***Abstract**: The performance measurement of construction supply chains has seen significant evolution. The SCOR 12.0 model, which initially measured supply chain efficiency through five main processes: plan, source, make, deliver, and return, has now evolved. The increasing emphasis on sustainability has led to adopting Green Supply Chain Management (GSCM), which integrates environmental aspects into the supply chain. Two case studies on infrastructure projects demonstrate that SCOR 12.0 and GSCM have significantly enhanced efficiency and productivity, although challenges related to responsiveness and cost remain. This research aims to develop a more comprehensive performance measurement model with SCOR 14.0, which not only evaluates economic aspects but also strongly emphasizes environmental and social performance. The proposed SCOR 14.0 model holds the potential to enhance efficiency and productivity further while also promoting environmental and social responsibility. However, it is crucial to note that further research is urgently needed to validate the integration of SCOR 14.0 into construction supply chains and to understand how this approach can support sustainability and competitiveness in the construction industry.*

Keywords—Supply Chain Management Performance; Green; SCOR 14.0

1. INTRODUCTION

Measuring construction supply chain performance has become a significant concern in recent decades. The concept of value creation, which is the primary basis for this performance evaluation, refers to the benefits generated by the construction supply chain. These benefits, which include cost savings, improved quality, reduced project completion time, and a safer working environment, are generally measured based on cost, quality, time, and health and safety environment [1]. Productivity and efficiency are also important factors contributing to reducing costs, increasing quality, and reducing project completion time [2].

The construction industry has unique characteristics in that it tends to be more complex and unpredictable than other industries [3]. This is because construction is influenced by factors such as project variations, the involvement of many parties, and the nature of construction projects, which are often one-off (unique). The construction supply chain is a network that connects all these elements, from planning to project execution. Supply chain construction plays a vital role in managing this complexity, ensuring the availability of materials on time, of the right quality, and at the right location [4].

In Indonesia, the construction industry faces many obstacles and phenomena, such as project delays, cost overruns, and unsatisfactory building quality. 38% of projects in Indonesia experience delays [5]. This delay results in losses in the form of time and costs, especially for contractors, so that the profits expected by contractors will be reduced, or even no profits at all [5]. Reported on Radarbromo.com shows that some building construction projects are late, ranging from 10-20% of the planning target that should be achieved due to many raw materials whose purchase orders have not been paid or not paid immediately, so the materials do not arrive on time. Figure 1 (a) and Figure 1 (b) show that late projects still occur in Indonesia. The problem is triggered by weak supply chain management. This problem was triggered by weak supply chain management.

(a) **(b)**

Fig 1. *Problems of the Indonesian Construction Industry*
(Source: [6] and [7])

As reported on Prokalimantan.co (2023), the construction of the PKK building and the arrangement of the siring bank park were penalized because the project was late by Rp.400,000 per day according to the contract value. The ISI building project in Denpasar, reported on mcwnews.com (2024), also experienced project delays that were subject to a fine of 1 percent per day. The late fee caused the required budget cost to exceed the allocated one, as shown in Figure 2

(a) and Figure 2 (b). The main problem is that the project delay needs to be corrected to follow the work contract.

(a) **(b)**

Fig 2. *Late Project Cost Overrun Issues*
(Source: [8] and [9])

Research by [10] found that 78.9% of construction projects experienced delays in 2019 due to the pandemic. Then, it was analyzed that the duration of delays showed that most projects, namely 31.85%, experienced delays of between 1 and 3 months, as shown in Figure 3.

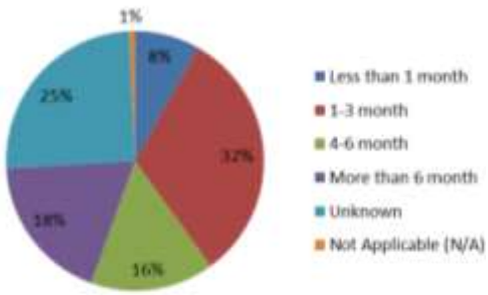

Fig 3. *Duration of Construction Delays in Indonesia*
(Source: [10])

Based on data from the Logistic Performance Index (LPI) in 2023 released by the World Bank, Indonesia is still below the average of other ASEAN countries in terms of logistics efficiency. LPI indicators include customs, infrastructure, logistics quality, and tracking capabilities. According to the World Bank, in 2023, Indonesia experienced a decline and was ranked 61st out of 139 countries. Indonesia's relatively low LPI rating indicates obstacles in the smooth flow of goods and services, including in the construction sector. Apart from LPI, the contribution of the construction sector to the Gross Domestic Product (GDP) can also be an indicator of the performance of this sector. The construction industry is one of the top five pillars of Indonesia's economic growth, where logistics costs will be 14.29% in 2023. Compared to other ASEAN countries, their GDP average logistics costs are 8-10%, whereas Indonesia is still lagging. Although this data varies between countries, the contribution of the construction sector to Indonesia's GDP still has the potential to increase.

Given the complexity and challenges faced, the role of the supply chain in the construction industry is crucial. A good supply chain can help increase efficiency, reduce costs, and improve project quality. Therefore, building a comprehensive supply chain for the construction industry is critical. The first step in building an effective supply chain is to determine the value (value creation) you want to achieve. Value creation creates added value for consumers through the products or services produced. In the construction context, value creation that can be made includes projects that are of high quality (quality), within budget (cost), completed on time (time), and HSE (health, safety, and environment) [1]. High productivity and good efficiency will contribute to reduced costs, increased quality, reduced project completion time, and sustainability [2].

Value creation and supply chain performance have a close relationship. Supply chain performance is reflected in its ability to produce more excellent value for customers, companies, and other stakeholders [11]. By measuring supply chain performance using relevant metrics, companies can identify areas that need improvement to create greater value in the supply chain.

Based on these problems, the condition of construction infrastructure in Indonesia, which is still not optimal, shows that it is essential to measure supply chain performance comprehensively. Through performance measurement, construction companies can identify areas that need improvement, optimize resource use, and increase operational efficiency while minimizing environmental impact. Measuring supply chain performance is currently paying attention to environmental aspects, such as using recycled raw materials, water use, and the contribution of carbon emissions to global warming from the materials and equipment used. Implementing supply chain measurement models with sustainability aspects is a strategic step to improve the performance of construction supply chains in Indonesia and contribute to developing environmentally friendly infrastructure.

2. LITERATURE REVIEW

2.1 Supply Chain Performance Measurement at Project Level

Measuring supply chain performance at the project level is crucial to ensuring the success of construction projects. Previous research shows that supply chain performance at the project level can be measured through various indicators, such as project completion time, project costs, project quality, and customer satisfaction [2]. In addition, sustainability aspects, such as using environmentally friendly materials and waste management, are also important indicators in measuring construction project supply chain performance [12]. At the project level, value creation refers to operational strategy, where value creation focuses on process efficiency, cost reduction, and improving product or service quality. Thus, value creation at the project level is a continuous process and involves all aspects of the supply chain, from planning to delivery of products or services to customers.

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2.2 Supply Chain Performance Measurement with SCOR 12.0

The Supply Chain Operations Reference (SCOR) model is a framework commonly used to measure and improve supply chain performance. SCOR 12.0 identifies five main processes in the supply chain, namely plan, source, make, deliver, and return, presented in Figure 4. Each process has some performance metrics that can be used to evaluate supply chain performance [13]. The SCOR model has a hierarchical structure consisting of four levels to understand supply chain performance comprehensively. Level 1 identifies the core processes of the supply chain, viz Plan, Source, Make, Deliver, and Return [14]. Level 2 breaks down core processes into specific configurations, such as Make-to-Stock or Configure-to-Order. Level 3 defines performance metrics used to measure the efficiency and effectiveness of each activity at level 2 [15]. Level 4 defines areas where the company can make improvements. This hierarchical structure allows a company to conduct a deeper analysis of its supply chain performance and identify areas for improvement. The following is the SCOR hierarchical structure presented in Figure 5.

Fig 4. *SCOR 12.0 process*
(Source: [16])

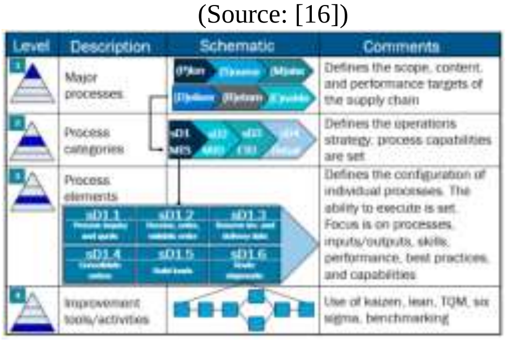

Fig 5. *SCOR 12.0 Hierarchy Process*
(Source: [16])

Applying SCOR 12.0 at the construction project level allows companies to identify obstacles and opportunities for improvement at each project stage. SCOR performance metrics relevant to construction projects include project cycle time, customer satisfaction levels, quality costs, and asset utilization rates. Previous research shows that SCOR 12.0 can help construction companies improve operating efficiency and reduce costs [17].

The SCOR 12.0 model classifies supply chain performance metrics into two main categories: customer and internal-facing [14]. Aspect customer-facing focuses on how customers, including metrics such as reliability, responsiveness, and agility, perceive supply chain performance. On the other hand, the internal facing relates to the company's internal efficiency in meeting customer demand, including metrics such as costs and asset management. This grouping makes it easier for companies to comprehensively evaluate their supply chain performance from a customer and internal company perspective. Thus, SCOR 12.0 provides a valuable framework for identifying areas for improvement and optimizing overall supply chain performance.

2.3 Measuring Supply Chain Performance with Green Supply Chain Management (GSCM)

In the current era of sustainable development, applying Green Supply Chain Management (GSCM) principles in construction projects is becoming increasingly crucial. The project life cycle is constructed from the planning stage to operations and maintenance, providing various opportunities to integrate environmentally friendly practices. By understanding each stage in the project life cycle, you can optimize resource utilization, reduce environmental impacts, and increase building sustainability, as shown in Figure 6 below.

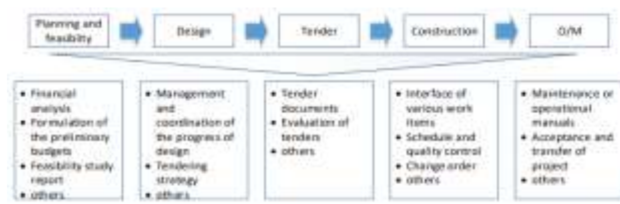

Fig 6. *Project Life Cycle*
(Source:[18])

2.4 Supply Chain Performance Measurement with SCOR 14.0

Model Supply Chain Operations Reference (SCOR) has become a recognized global standard for measuring and improving supply chain performance. The latest version, SCOR 14.0, now includes environmental and social dimensions that previously did not exist in SCOR 12.0. This addition is in line with increasing global awareness of the importance of sustainability. SCOR 14.0 offers a comprehensive framework for evaluating supply chain performance comprehensively, starting from the initiation, design, material management, construction, operation & maintenance stages [19]. This SCOR approach uses customer-facing and internal-facing, where each metric is based on each supply chain process, which contributes to the assessment of supply chain performance, namely plan, source, make, deliver, return, and enabler [13]. Applying SCOR 14.0 at the construction project level can help companies identify opportunities to improve environmental and social performance while maintaining economic performance.

3. RESEARCH METHODOLOGY

This research aims to trace the development of the construction supply chain performance measurement model

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from adopting the SCOR 12.0 model to integrating Green Supply Chain Management (GSCM) principles. By analyzing developments in literature and case studies, this research will identify trends, challenges, and opportunities in adopting the latest SCOR Model, namely SCOR 14.0, as a more comprehensive framework for measuring sustainable construction supply chain performance. It will also explain how the link from GSCM to SCOR 14.0 can be used to measure sustainable supply chain performance.

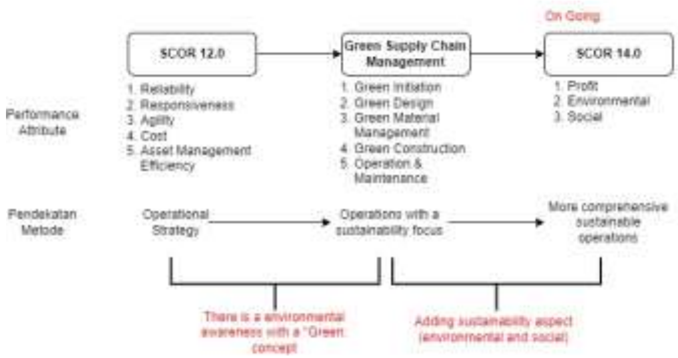

Fig7. *Development of a Supply Chain Performance Measurement Model*

Based on Figure 7., this research adopts a multi-method approach to trace the development of construction supply chain performance measurement from SCOR 12.0 to GSCM and SCOR 14.0. The literature study was conducted comprehensively with a comparative analysis to compare SCOR 12.0, GSCM, and SCOR 14.0 based on main focus, process coverage, performance metrics, and integration of sustainability aspects. Thus, the factors that drive the development of SCOR and GSCM models can be identified. Case studies from previous research regarding construction companies that have implemented SCOR or GSCM will provide an in-depth understanding of the application of the model in practice, including the challenges and opportunities faced. The analytical approach includes qualitative analysis (e.g., content analysis) for text data and quantitative analysis (e.g., descriptive statistics) for numerical data. By comparing performance metrics and identifying construction project performance results, this research will reveal the relevance of model development and provide recommendations for developing performance measurement models that are more relevant to the context of the construction industry. Based on the literature analysis and case studies, a comprehensive framework will be developed to measure construction supply chain performance by integrating SCOR 14.0 principles. Experts in related fields will validate this framework.

4. Discussion and Analysis

4.1 Case Study 1: Supply Chain Performance Measurement with SCOR 12.0

The government-initiated research by [20] on the Semarang - Demak Toll Road Construction Project, worth 4.4 trillion for Section 2 from Sayung to Demak. This research wants to try to measure supply chains at the project level using the SCOR 12.0 approach. It is known from the in-depth interviews conducted that there were problems with procuring precast materials, namely delays in installing Type A 60 cm diameter pile materials due to the trucks delivering the materials not arriving in sequence. This is caused by poor communication between the contractor and the supplier, which causes the supplier's supply chain performance not to meet construction project expectations. This research aims to try to measure supply chain performance. The following is the research position carried out with SCOR 12.0, presented in Figure 8. The hierarchy in SCOR contains four significant processes, namely major processes (general definition of the five core supply chain processes), process categories or configuration level (a configuration description of the five core supply chain processes), process elements level (metrics used in the supply chain), and improvement tools/activities (use of tools and methods to improve supply chain processes). The following is Figure 9, which illustrates the hierarchy in SCOR.

Fig 8. *SCOR 12.0 Research Position*
(Source: [20])

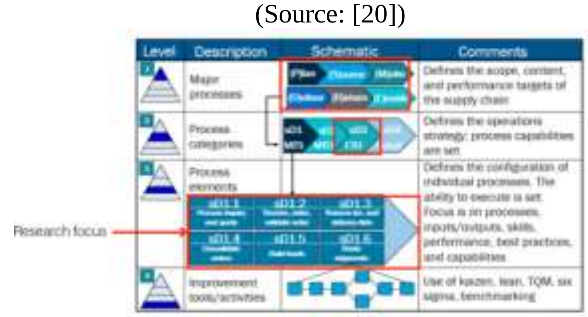

Fig 9. *SCOR Process Hierarchy*
(Source: [20])

This research will model the supply chain framework, adapt SCOR 12.0 performance indicators to the supply chain system, implement the SCOR 12.0 measurement system, evaluate supply chain performance, and provide recommendations for improvement. Based on the validation process, five attributes and six indicators with 19 sub-indicators can be measured, shown in the following calculation table.

Table 1: Comparison Mark Supply Chain Performance

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Attribute	Indicator	Definition	Supply Chain Performances
Reliability	Perfect Order Fulfillment	Percentage of material orders delivered in the correct quantity, with accurate documentation, and without any damage (Nur Sholeh & Suwarto, 2020)	Level 10
Responsiveness	Order Fulfillment Cycle Time	Average cycle time consistently achieved by suppliers in fulfilling contractors' material order requirements (APICS, 2017)	Level 7
Agility	Upside Supply Chain Adaptability	Supplier's ability to respond to an increase in material quantity requested by the contractor within a 30-day period (APICS, 2017)	Level 5
	Overall Value at Risk (VaR)	Number of risk probabilities that can affect the supply chain (APICS, 2017)	
Cost	Total Supply Chain Management Cost	Total cost incurred in the supply chain process (APICS, 2017)	Level 1
	Cost of Goods Sold	Cost incurred in the process of purchasing raw materials and producing finished materials (APICS, 2017)	
Asset Management Efficiency	Return on Working Capital	The relative value of working capital to the revenue generated (APICS, 2017)	Level 8

(Source: [20])

Based on Table 1, the three studies comparing the SCOR 12.0 method and Objective Matrix data processing in several different construction projects and with different materials conclude that the SCOR model can be applied in the construction industry. Three attributes have sufficient and low categories, marked in yellow for the responsiveness and agility attributes and in red for the cost attribute.

As a result, the reliability attribute has level 10, which means 100% of material orders sent are fulfilled according to quantity, quality, and on time. The assets management efficiency attribute is level 8, which means that the potential efficiency of assets and working capital has been utilized by 80%, and it is still possible to increase it by 20%. The reliability and asset management efficiency attributes have a level in the green category, which means they are safe and need to be maintained. Meanwhile, the responsiveness attribute is at level 7, which means that the delivery of materials by the supplier is on time, according to the agreement of 70%. The agility attribute has level 5, which means the ability to meet sudden demand fluctuations of 50% due to limited supplier information regarding exact material needs. The responsiveness and agility attributes are in the yellow category, which means they still need improvement to improve supply chain performance. Then, the cost attribute has level 1, which means the costs required are much more significant than planned. This cost attribute is in the red category, which means immediate improvements are needed to improve supply chain performance.

This assessment shows that the company's customer performance is quite good, especially in terms of reliability. The company will be consistent in the delivery and quality of products or services. However, companies need to increase responsiveness and flexibility to provide faster responses and better suit the needs of dynamic project owners. Recommendations given for customer-facing are creating alternative routes, checking vehicle conditions, risk mitigation analysis, live truck delivery tracking systems, and renewing contracts. Meanwhile, the company has an imbalance in its internal performance for internal facing performance. On the assets side, the company is very good at managing and utilizing its facilities. However, on the cost side, the company's operational costs are still very high. This shows that there are significant inefficiencies in the company's business processes. The recommendations for internal facing are creating alternative routes, a live tracking system for truck deliveries, planning material inventory, maintenance of material production machines, and a material price forecasting system.

4.2 Case Study 2: Supply Chain Performance Measurement With GSCM

Research by [21] on Building Construction Projects by developing a supply chain performance measurement model using the GSCM approach. This research aims to create a Green Supply Chain Management model for building construction projects adapted to the Project Life Cycle. This model was developed with the new importance of environmental aspects in infrastructure development, such as reducing waste and minimizing the negative impact of construction activities on the environment while also increasing productivity in the construction industry, especially building projects. This research produced a model of 5 concepts, 16 dimensions, 61 elements, and 105 indicators. The first concept, Green Initiation, consists of 1 dimension, two elements, and nine indicators. The second concept, Green Design, consists of 5 dimensions, 15 elements, and 35 indicators. The third concept, Green Material Management, consists of 4 dimensions, 11 elements, and 12 indicators. The fourth concept, Green Construction, consists of 4 dimensions, 22 elements, and 33 indicators. The fifth concept, Green Operation and Maintenance, consists of 2 dimensions, 11 elements, and 16 indicators. Then, a trial was carried out on two sample projects.

Table 2: Index Supply Chain Performance

Concept	Index of Project 1	Index of Project 2	Index maximum	% Project 1	% Project 2
Green Initiation	15,432	14,848	21,8	71	68
Green Design	29,089	28,587	40	73	71
Green Material Management	7,029	11,753	17,1	41	69
Green Construction	4,975	7,081	9,8	51	72
Green Operation & Maintenance	7,132	7,025	11,3	63	62
Index GSCM	63,657	69,294	100	60	69

(Source: [21])

Based on Table 2, it is shown that Project 1 (CBT Building and Foreign Language Center, Ministry of Health Polytechnic) obtained a GSCM index of 63,657 with a percentage achievement of 60%. In comparison, the GSCM index was obtained for project 2 (Outpatient Building and Diagnostic Center at Panti Wilasa Citarum Hospital), amounting to 69,224 with a percentage achievement of 69%. Project 1, with an achievement of 60%, was obtained from the average level of implementation of the five GSCM concepts in the project, which was still at the average level. Project 2, with an achievement of 69%, was obtained from the average level of implementation of the five GSCM concepts, which is still at the average level but still superior to Project 1. The GSCM index obtained in projects 1 and 2 is still considered standard because it is in the Average category, so it still needs improvement to realize sustainable construction projects.

4.3 Proposal Development of Performance Measurement with SCOR 14.0 (On-Going)

Supply chain performance measurement has undergone significant evolution in recent decades. Model Supply Chain Operations Reference (SCOR) has become a recognized global standard for measuring and improving supply chain performance. The initial version of SCOR 12.0 provides a comprehensive framework for evaluating overall supply chain performance [22]. However, as awareness of the importance of sustainability increases, the concept of Green Supply Chain Management (GSCM) is starting to be integrated into supply chain management practices (Seuring & Müller, 2008). This encourages developing a more comprehensive SCOR 14.0, emphasizing sustainability and flexibility [22].

	Performance Attributes	Definition
Economic	Reliability (RL)	Perfect Order Fulfillment **(RL.1.1)** Perfect Supplier Order **(RL.1.2)** Perfect Return Order Fulfillment **(RL.1.3)**
	Responsiveness (RS)	Order Fulfillment Cycle Time **(RS.1.1)**
	Agility (AG)	Supply Chain Agility **(AG.1.1)**
Economic	Costs (CO)	Total Supply Chain Management Costs **(CO.1.1)** Cost of Goods Sold (COGS) **(CO.1.2)**
	Profit (PR)	Earnings Before Interest and Taxes (EBIT) as a Percent of Revenue **(PR.1.1)** Effective Tax Rate **(PR.1.2)**
	Assets (AM)	Cash-to-Cash Cycle Time **(AM.1.1)** Return on Fixed Assts **(AM.1.2)** Return on Working Capital **(AM.1.3)**
Sustainability	Environmental (EV)	Materials Used **(EV.1.1)** Energy Consumed **(EV.1.2)** Water Consumed **(EV.1.3)** GHG Emissions **(EV1.4)** Waste Generation **(EV.1.5)**
	Social (SC)	Diversity and Inclusion **(SC.1.1)** Wage Level **(SC.1.2)** Training **(SC.1.3)**

Fig 9. *SCOR 14.0 Performance Attributes*
(Source: [22])

Based on Figure 9., the main difference between SCOR 14.0 and 12.0 lies in adding the sustainability dimension. This shows a paradigm shift in supply chain management, where companies not only focus on economic efficiency but also pay attention to their activities' environmental and social impacts. The SCOR 14.0 model provides more detailed and specific definitions for several performance attributes, especially those related to sustainability. For example, the GHG Emissions metric (EV1.4) is divided into several more particular sub-metrics. The construction industry can build a more sustainable supply chain by using the SCOR 14.0 Model as a supply chain measurement.

5. Conclusion

The importance of developing models for measuring supply chain performance, from the SCOR 12.0 model to Green Supply Chain Management (GSCM) to SCOR 14.0. SCOR 12.0 has provided a solid basis for measuring supply chain performance, focusing on efficiency and productivity through five main processes: plan, source, make, deliver, and return. However, growing sustainability awareness has driven the adoption of GSCM, which integrates environmentally friendly aspects in the construction supply chain. The advent of SCOR 14.0 brings a more comprehensive approach, combining sustainability principles and flexibility in the supply chain process. SCOR 14.0 provides a framework to help companies increase their competitiveness while contributing to sustainable development. Furthermore, it is hoped that the development of a supply chain performance measurement model based on SCOR 14.0 can continue to be refined to face the challenges of the construction industry in this era of globalization.

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