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RESEARCH ARTICLE

A Combined Approach for Green Supply Chain Management Performance Measurement in a Steel Manufacturing Company: An Indonesian Case

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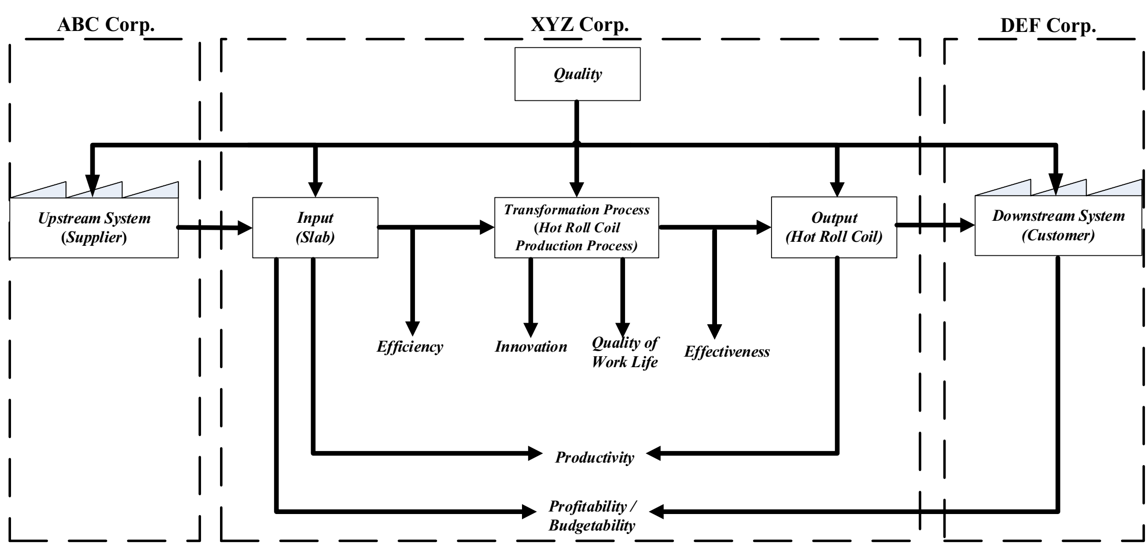
Abstract
The purpose of this research is to provide a complete method for measuring the performance of green supply chain management (GSCM) in the steel manufacturing sector using a combined approach. This study is conducted on an integrated system based on four things: the design of the GSCM performance measurement model based on the Seven Sink Performance Model, weighing performance indicators using the analytical network process, the objective matrix method to measure performance assessment, and the traffic light system method to help identify critical indicators. According to the findings of the study, energy consumption is the most important factor that leads to GSCM application success in an Indonesian steel manufacturing company. The proportion of reusable materials is the smallest and most important performance metric that has to be improved. The suggested methodology may be used by steel company supply chain managers to assess and enhance GSCM performance. The suggested approach is verified by a case analysis at an Indonesian steel manufacturing company.

Graphical Abstract



Keywords Green supply chain management · Performance measurement · Combined approach · Steel industry · Indonesia

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Introduction

Environmental issues nowadays are becoming more and more increasingly aware of by individuals and companies. For example, when buying products, a higher percentage of customers now prefer to select environment-friendly products. Consumers also can affect enterprises or manufacturers through their behaviors when purchasing services and products with minimal ecological or environmental influence [1]. This condition requires companies to apply the concept of environmental concern in their business process, including throughout the entire supply chain. Kurien and Qureshi [2] mentioned that environmental response capabilities are an essential management resource and a key strategic factor for a company's supply chain (SC) performance. Corporate management practices should be integrated with environmental initiatives to improve business performance and enhance firms' credibility with outside parties [3]. Dai et al. [4] stated that environmental management and innovation are essential aspects of competition, and the development of ecological change is critical to the success of today's firms. "Integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers, and end-of-life management of the product after its useful life" is a definition of green supply chain management (GSCM) which is defined by Srivastava [5].

Akkucuk [6] suggested that companies need to take on the road to sustainable practices by applying GSCM. In the long run, GSCM certainly increases a company's profit either directly or indirectly, and the application of this concept will result in a better image for companies that undertake it [7]. According to Yu et al. [8], the company's image and reputation as a green company can attract green-conscious customers and talented workers. Meanwhile, green training applied by the company can directly affect the green supply chain performance [9]. Kirchoff et al. [10] stated that empirical research proves that GSCM practices positively impact firm performance. As a result, companies need to continually monitor and measure GSCM applications' performance to ensure that GSCM does give them competitive advantages.

In the context of GSCM performance measurement activities, as the analysis carried out by de Oliveira et al. [11] for 339 articles published from 2006 to 2016, some theories and frameworks have been used to develop GSCM performance measurement. The fuzzy programming is the most used model applied for decision-making processes in GSCM. ANOVA/Regression analysis and structural equation modeling (SEM) come after. Two other techniques widely used were the analytical hierarchy process (AHP) and the analytical network process (ANP). Gandhi et al. [12] using AHP and DEMATEL for evaluating success factors in the implementation of GSCM in Indian manufacturing industries. For the industrial sectors studied, according to de Oliveira et al. [11], the textile/manufacturing sector is on the top with 23%, and the second is the automotive sector with 20%. However, only 2% of research topics on that GSCM application in the metallurgy sector. Tseng et al. [13] mentioned the opportunities for further research considering each industry's characteristics to give additional insights into GSCM studies.

To our knowledge, no study has been conducted in the setting of Indonesia. To close the gap, GSCM performance measurement in the steel production sector is needed. With a case study from a developing nation like Indonesia, a combined approach model is presented to evaluate GSCM performance in the steel manufacturing sector.

The study proposes a framework to measure GSCM performance based on Sink's Seven Performance model using a combined approach (ANP-OMAX-Traffic Light System) that can provide direct information about which indicators are critical and need to be improved immediately using colors generated by the traffic light system approach. It offers a fresh perspective on existing performance measuring methods.

The purpose of this study is to provide a complete method for measuring GSCM performance in a steel manufacturing business based on Sink's Seven Performance model utilizing a combined approach (ANP-OMAX-Traffic Light System). Sink's Seven Performance model has been chosen because it focuses on the value chain between businesses in the supply chain and takes into account the upstream system, transformation process, and downstream system among supply chain stakeholders, which is appropriate for the goal of this study. Tangen [14] said that Sink's Seven Performance Criteria are still important, despite the fact that the industry has evolved significantly since this model is originally presented. To evaluate the relative importance/priorities of the criteria, sub-criteria, and key performance indicators (KPIs) for GSCM adoption, the ANP was employed. The objective matrix (OMAX) technique is used to assess the performance of the GSCM application's key performance indicators (KPIs). The traffic light system technique is utilized to determine the key indicators of each GSCM application's KPIs that needed to be enhanced. In this research, a combined method is selected since GSCM performance assessment requires a systematic approach as well as an integrated, holistic performance measurement model to handle multi-objective nature, and it is multidisciplinary.

The remainder of this work is structured as follows. Section 2 offers a synopsis of the relevant literature. Section 3 provides a short overview of the suggested model utilized in this paper. Section 4 provides the case study as well as the research's findings. The theoretical and managerial consequences are discussed in Sect. 5. Finally, Sect. 6 discusses the conclusion, limits, and future research prospects.

Literature Review

Over the past decade, many supply chain management, operations, and logistics researchers and practitioners have been researching the GSCM area [15]. According to Tseng et al. [16], GSCM refers to environmental management, including sharing information and knowledge with a mutual willingness among customers, suppliers, and logistics service providers to improve environmental performance.

Chen et al. [17] mentioned that significant performance improvements of firms are influenced not only by the real environmental commitment of companies to internal green management but also by the positive relations of firms with their external cooperative capabilities in environmental relationships with chain partners. As a result, supply chain management operation integrated with environmental factors has become increasingly important for companies to gain and maintain a competitive advantage. Thus, the study of this topic is timely and necessary to better aid organizations in GSCM principles, and appropriate measurement scales are needed to advance the investigation and practice of GSCM in companies [18].

Zhu et al. [19] mentioned that GSCM can be measured using various scales with a goal for its continuous improvements, implementation, and benchmarking. A considerable number of GSCM performance measurement approaches also exist in the literature [20–23]. Bhattacharya et al. [23] used a fuzzy ANP-based balanced scorecard to measure GSCM performance. Facing and Horvath [20] explored life-cycle assessment (LCA) as an analysis method for the environmental evaluation of logistics outsourcing in the automobile industry. Hervani et al. [21] proposed a balanced scorecard as the performance management tool while measuring environmental performance. Lin [22] used fuzzy decision-making trial and evaluation laboratory (DEMATEL) to evaluate the company's green supply chain management practices.

Some researchers have proposed various frameworks to measure GSCM performance [6, 23, 24]. The supply chain council (SCC) proposed the GreenSCOR model as a tool to integrate supply chain company operations with its supply chain's environmental aspects. The GreenSCOR model was extended from the supply chain operations reference (SCOR) model that SCC has developed to guide companies in applying SCM principles [6]. Bhattacharya et al. [23] proposed balanced score card (BSC) as a framework to measure GSCM performance for a UK-based carpet manufacturing company. Sheu et al. [24] set up a framework for systematically managing logistics flows among chain members in a green supply chain with appropriate analytical models.

According to Neely et al. [25], a performance measurement system is the set of metrics used to quantify actions' efficiency and effectiveness. Neely et al. [26] mentioned that the third-generation performance measurement system is needed to guide a business toward its strategic business goals. Third-generation performance measurement systems is a system that can measure progress reliably to gain real value for an organization from measuring both tangible and intangible business performances. In the area of enterprise performance measurement, Rolstadås [27] stated that the Sink and Tuttle model, also known as Sink's Seven Performance model, is one of the best classical approaches for measuring the performance of organizations. In this model, the performance of organizations is measured by seven criteria: effectiveness, efficiency, quality, productivity, quality of work life, innovation, and profitability/budget-ability. De Toni and Tonchia [28] mentioned three typologies of performance measurement system models: vertical, balanced, and horizontal. The vertical model is a model that is characterized by cost and non-cost performances on different levels of aggregation till they ultimately become economic-financial. Models, where several separate performances are considered independently to make a balance condition, are called balanced architectures. At the same time, models focused on the value chain and finding the internal relationship of customer/supplier are defined as horizontal architectures models. Based on this classification, Sink's Seven Performance model belongs to the horizontal architectures model that can handle the complexity of the company supply chain network.

According to Neely et al. [26], the Sink's Seven Performance model is one of the third-generation performance measurement systems needed to develop. Because of that, we utilized the Sink's Seven Performance model as a basic model in this study, and we used a combined approach between ANP, OMAX, and the traffic light system method to get a holistic, integrated, and comprehensive way for measuring the performance of GSCM in the steel manufacturing company. A combined approach using AHP and DEMATEL was also used by Gandhi et al. [12] for evaluating success factors in the implementation of GSCM in Indian manufacturing industries. In this study, we use ANP because ANP is a general framework to deal with decisions without making assumptions about the independence of higher-level elements from lower-level elements and the elements within a level. ANP is a generalized form of the AHP method [29]. The OMAX used in this study is based on Dervitsiotis [30], who stated that OMAX has proven to be a valuable approach in a variety of application areas by providing a common framework for communicating measurable goals and strongly motivating those responsible for making the necessary improvements to achieve them. Balkan [31] mentioned that OMAX is a performance measurement method that evaluates several productivity criteria by weighting a total productivity index. In this recent study, the traffic light system method was used to identify critical indicators that needed improvement so that a company could respond correctly based on the signs of system status. Hargrave [32] used the traffic light method to identify a target, and boundary reference values were proposed to analyze changes where pre-determined thresholds for changes in variables are identified by color categories.

The theoretical contribution of this study is to identify the different dimensions of GSCM application in the steel manufacturing company based on Sink's Seven Performance model through the identification of criteria, sub-criteria, and key performance indicators (KPI). The second contribution is to identify the performance of each dimension of GSCM application in the steel manufacturing company using the OMAX method. The third contribution is to identify the critical indicators of each dimension of the GSCM application that need to be improved by using the traffic light system method.

The Sink's Seven Performance model (also known as the Sink and Tuttle model) claims that the performance of an organizational system is a complex interrelationship between the following seven performance criteria [27]:

(1) Effectiveness, which involves doing the right things with the right quality at the right time. Defining the criteria as a ratio and effectiveness can be defined as the actual output per expected output.
(2) Efficiency, defined as resource expected to be consumed per resource actually consumed.
(3) Quality could be measured at six checkpoints, i.e., upstream systems, inputs, transformation value-adding process, outputs, and downstream systems.
(4) Productivity, which is the ratio of output per input.
(5) Quality of work life, which is an essential contribution to a well-performing system
(6) Innovation, which is a critical element in sustaining and improving performance
(7) Profitability/budget-ability, which represents the ultimate goal for any organization

Proposed Model

This recent study developed a framework for measuring GSCM performance in the steel manufacturing firm based on Sink's Seven Performance model. The study divided the generic Sink's Seven Performance model into three parts of GSCM practices, i.e., upstream, internal processes (focal firms), and downstream activities, as mentioned by Kusi-Sarpong et al. [33].

The key performance indicators (KPI) of GSCM application in the steel manufacturing company were designed based on this framework. The framework of the proposed model is shown in Fig. 1.

The criteria, sub-criteria, and indicators related to GSCM implementation in the steel manufacturing firm had been identified according to the judgment of industrial experts after the critical analysis of the literature. The evaluation criteria and sub-criteria were taken based on Sink's Seven Performance model criteria. The key performance indicators (KPI) for each criterion and sub-criterion are adopted from supply chain operation reference (SCOR) version 10.0 metrics developed by SCC [34] and were also based

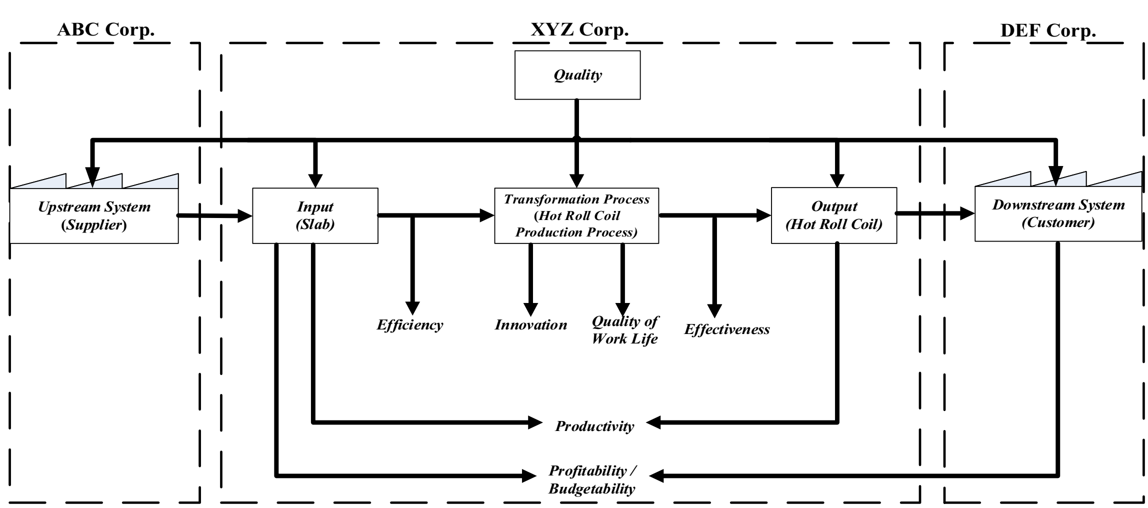

Fig. 1 The framework of GSCM performance measurement in a steel manufacturing company was based on Sink's Seven Performance model

on information and discussion with the industrial experts in the company if the metrics couldn't be found in SCOR version 10.0. The ANP method was used for calculating the local weights of each performance indicator. In the following step, the OMAX method was implemented to know the performance of each KPI from its score, and the last step applied the traffic light system method to identify the critical indicators that need improvement by the company to get more benefit from applying GSCM. Figure 2 illustrates the proposed framework for this research.

This study provided valuable contributions to the challenges of GSCM performance evaluation in the steel manufacturing company by presenting a combined approach, first, by identifying the different dimensions of GSCM application in a steel manufacturing company based on Sink's Seven Performance model , second, by identifying the performance of each dimension of GSCM application in a steel manufacturing company based on Sink's Seven Performance model using the OMAX method, and third, by identifying the critical indicators of each dimension of GSCM application in a steel manufacturing company that needed to be improved using the traffic light system method.

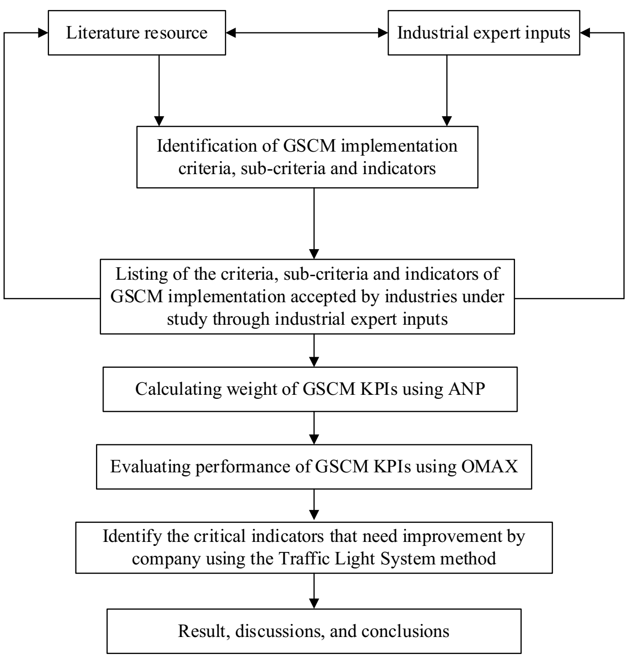

Fig. 2 Research framework

Case Analysis and Results

Supply Chain Scheme in a Steel Manufacturing Firm

In this study, XYZ Company was chosen as a case study. Established in 1970, the company is the first and the most extensive integrated steel manufacturers in Indonesia. XYZ Company is located in Cilegon City, Banten Province, with a production volume of more than 2.4 million tons per year and remains a leader in the Indonesian steel industry. Direct reduction, slab steel, billet steel, hot strip mill, cold rolling mill, and wire rod mill are the six main facilities operated by the XYZ Company. Iron ore, the plant's primary raw material, is obtained from both foreign and domestic sources. The vast majority of goods are developed in response to consumer demands. Among the main customers are automobile component makers, pipe manufacturers, and construction companies. Figure 3 illustrates a schematic representation of this steel manufacturing company's supply chain.

GSCM Performance Measurement

Step 1 Identify and make a list of the GSCM key performance indicators.

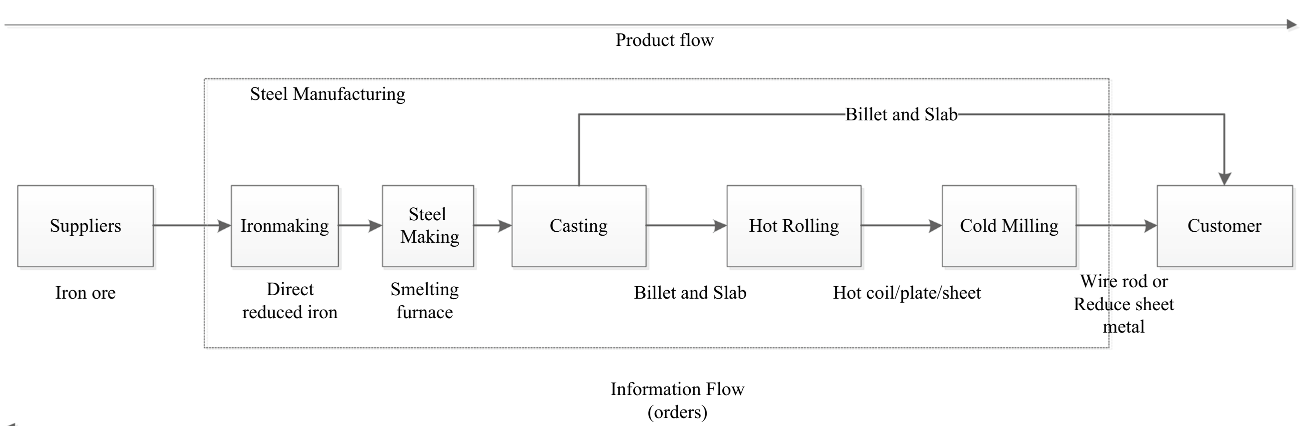

Fig. 3 A schematic diagram of XYZ's supply chain

The identification of GSCM KPIs was carried out in two stages. In the first stage, a review of Sink's Seven Performance model was conducted to list the criteria and sub-criteria used in GSCM performance measurement. The second step involves brainstorming and discussions with business stakeholders to identify the KPIs to be utilized in each criterion and sub-criteria. The KPIs that used in this research for each criterion and sub-criteria were adopted from Supply Chain Operation Reference (SCOR) version 10.0 metrics developed by SCC [34] and were also based on information and discussions with stakeholders in the company if it cannot be found the metrics in SCOR version 10.0. After doing a validation, there were 25 KPIs used in performance measurement, as shown in Table 1. The definition and characteristics of each GSCM KPI are shown in Table 2. All the phases, including inputs and outputs that describe the currently existing process, are illustrated in Fig. 4.

Step 2 Applying the ANP method to determine the GSCM criteria, sub-criteria, and KPIs weight.

The second step was to determine the weighting of each key performance indicator of GSCM using the ANP method. Before applying the ANP method, brainstorming was done by seven managers related to the green programs of XYZ Company to confirm the critical performance indicators for measuring GSCM in the steel manufacturing firm. The application and analysis of the ANP methodology were presented in the following steps.

(1) Construct the model and problem formulation

The first step in the ANP method implementation was to construct the decision structure of determining the weights of criteria, sub-criteria, and indicators used to measure the performance of GSCM in the steel manufacturing company. This model had four levels (see Fig. 5). The first level was the goal of the model to determine the weights of each criterion, sub-criteria, and KPI for GSCM application. The second level consisted of seven criteria clusters taken from Sink's Seven Performance model criteria: effectiveness, efficiency, quality, productivity, quality of work life, innovation, and profitability. From Sink's Seven Performance model criteria, only quality criteria had sub-criteria: upstream, input, process, output, and downstream. These sub-criteria were the third level of the model. The fourth level was the key performance indicators for the criteria and sub-criteria. The KPIs were based on SCOR version 10.0 measures and were developed in discussion with experts in the company. There were 25 criteria under the criteria mentioned above and sub-criteria.

(2) Confirm the GSCM criteria, sub-criteria, and KPIs, perform expanded pairwise comparisons, and obtain relative priorities of the clusters and their elements in the network.

The questionnaire were employed to identify the intensity and dependence relations among the criteria, sub-criteria, and KPIs. Seven managers from different areas were related to the green program in XYZ Company involved in this work. They were logistic manager, production manager, environmental–occupational–safety and health manager, quality control manager of slab steel plant, quality manager of hot strip mill plant, supply chain improvement manager, and production control manager. This study used Saaty's fundamental scales (1–9) to make pairwise comparisons. Each matrix was measured by the inconsistency ratio (CR) and passed the check.

(3) Construct a super-matrix and compute the limiting priorities.

After checking the consistency of each pairwise comparison from the seven managers, this study calculated the geometric mean of individual judgments to specify the group judgments for each pairwise comparison. Next, it inserted the priorities derived from the paired comparisons into the corresponding positions of the unweighted super-matrix. It calculated the weighted super-matrix by multiplying each block in the unweighted super-matrix by the corresponding criteria weight. The results of the ANP weighting calculation are shown in Table 3.

Step 3 Applying the OMAX method to measure the performance of GSCM in the steel manufacturing company.

This study measured GSCM performance in the steel manufacturing firm based on data gathered for each indicator for 12 months. This recent work aimed to know the performance of each GSCM indicator in the firm, as shown in Table 5.

The weights for each indicator obtained from the ANP method in the second step and the definition of the performance measurement scale from the first step results would be measured. The following step was to prioritize the measures by constructing a productivity matrix. It was necessary to collect data from each measure to finalize the matrix. Since the matrix used a scale from 0 to 10 to describe the score for values of different measures, it was necessary to understand the current values for each measure. The summary of the OMAX results is shown in Table 4.

Step 4 Applying Traffic Light System Method.

In this step, the traffic light system method was used as a scoring system. The traffic light system was a measurement model with three colors: green, yellow, and red. Green was a parameter for acceptable, yellow was a parameter for provisionally acceptable (caution required), and red was a parameter for unacceptable [32]. In this study, the traffic

Table 1 Criteria, sub-criteria, and indicators of GSCM implementation in the steel manufacturing firm based on Sink's Seven Performance model

Performance criteria	Sub-criteria	Definition	Key performance indicator	KPI code
1. Effectiveness		Focus on actual output and expected output so that the desired objectives of the company can be achieved	Delivery Performance (SCC [34])	EF1
			Inventory level (SCC [34])	EF2
2. Efficiency		Focus on resource expected to be consumed and resource actually consumed so that the desired objectives of the company can be achieved	Machine efficiency (SCC [34])	ES1
			Energy consumption (SCC [34])	ES2
			Water use efficiency (SCC [34])	ES3
3. Quality	*Upstream*	Increase the quality of raw materials from the supplier	Fe content in iron ore (source: the company)	Q1
			SiO_2 content in iron ore (source: industrial expert)	Q2
			Al_2O_3 content in iron ore (source: industrial expert)	Q3
	Input	Increase the quality of the input product for the transformation process	C (Carbon) content in the slab steel (source: industrial expert)	Q4
			Mn (Manganese) content in the slab steel (source: industrial expert)	Q5
			S (Sulfur) content in the slab steel (source: industrial expert)	Q6
	Transformation Process	Increase the quality of the transformation process of the steel product	The processing or make cycle time (SCC [34])	Q7
	Output	Increase the quality of steel product output	The defect rate (SCC [34])	Q8
	Downstream	Increase customer satisfaction	Return rate (SCC [34])	Q9
4. Productivity		Focus on the ratio of output to input so that productivity will increase	Yield (SCC [34])	P1
5. Quality of work life		An essential contribution to a well-performing system and environment	Air emissions (SCC [34])	QL1
			Liquid waste generated (SCC [34])	QL2
			Noise at the workplace (source: industrial expert)	QL3
			Noise to the surrounding area (source: industrial expert)	QL4
			Waste produced as a percentage of product produced (SCC [34])	QL5
			Recyclable waste as a percentage of total waste (SCC [34])	QL6
			Hazardous waste as a percentage of total waste(SCC [34])	QL7
			Percentage of reusable materials (SCC [34])	QL8
6. Innovation		Focus on improvement of production speed and the quality of product	Percentage of orders delivered in an undamaged state that meet specifications and are accepted by the customer; also called perfect condition (SCC [34])	I1
7. Profitability		There is a balance between financing and income and also rising profits	Cost of goods sold (SCC [34])	PB1

light system method indicated the score of each indicator of GSCM in the steel manufacturing company as a result of the OMAX method. The decision rules used in this study were green if the score was 7–10, which meant the performance of the indicators was acceptable; yellow if the score was 3–6, which means the performance of the indicators was provisional acceptance (caution required); and red if the score was less than 3, which meant the performance of the indicators was unacceptable. Table 5 shows the performance of each GSCM indicator using the traffic light system method.

Table 2 Definition and characteristics of the GSCM performance indicators in the steel manufacturing firm

Performance indicators	Definition	Characteristics
1. Delivery performance	Percentage of consumer orders with correct fulfillment corresponding to product quantity and order time	Larger is better
2. Inventory level	Percentage of actual inventory divided by planned inventory	Smaller is better
3. Machine efficiency	Percentage of actual machine efficiency achieved divided by expected machine efficiency	Larger is better
4. Energy consumption	Energy consumption to produce 1 ton of product	Smaller is better
5. Water use efficiency	Percentage of actual water efficiency divided by planned water efficiency	Nominal is better
6. Fe content in iron ore	Percentage of actual Fe content level divided by the desired Fe content level in iron ore	Optimum value set by the company
7. SiO_2 content in iron ore	Percentage of actual SiO_2 content level divided by desired SiO_2 content level in iron ore	Optimum value set by the company
8. Al_2O_3 content in iron ore	Percentage of actual Al_2O_3 content level divided by desired Al_2O_3 content level in iron ore	Optimum value set by the company
9. C content in the slab steel	Percentage of actual C content level divided by desired C content level in slab steel	Optimum value set by the company
10. Mn content in the slab steel	Percentage of actual Mn content level divided by desired Mn content level in slab steel	Optimum value set by the company
11. S content in the slab steel	Percentage of actual S content level divided by the desired S content level in slab steel	Optimum value set by the company
12. The process/make cycle time	Percentage of the cycle time for issuing sourced or in-process product	Smaller is better
13. Defect rate	Percentage of defective products divided by the total production in the measurement period	Smaller is better
14. Return rate	Percentage of the number of products returned divided by the number of products delivered to the customer	Smaller is better
15. Yield	The ratio of usable output from a process to its input	Larger is better
16. Air emissions	The weight of air pollutants emitted per weight of finished goods produced	Smaller is better
17. Liquid waste generated	Percentage of number of pollutants released into the water to produce one unit of product	Smaller is better
18. Noise at the workplace	The noise level at the workplace	Smaller is better
19. Noise to the surrounding area	Environmental noise level around the company at a certain radius	Smaller is better
20. Waste produced as percentages of product presented	The weight of waste divided by the weight of finished goods produced	Smaller is better
21. Recyclable waste as a percentage of total waste	The percentage of waste generated from production that is recycled internally	Larger is better
22. Hazardous waste as a percentage of total waste	The percentage of waste generated from production that is classified as hazardous material	Smaller is better
23. Percentages of reusable materials	The percentage of product content that is recyclable or reusable	Larger is better
24. Perfect condition	Percentage of orders delivered in an undamaged state that meet specifications	Larger is better
25. Cost of goods sold	The total of direct material costs, direct labor costs, and indirect costs related to making a product	Smaller is better

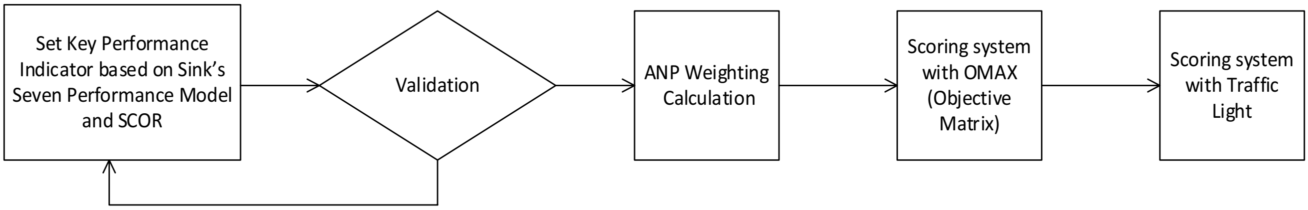

Fig. 4 GSCM performance measurement process in the steel industry

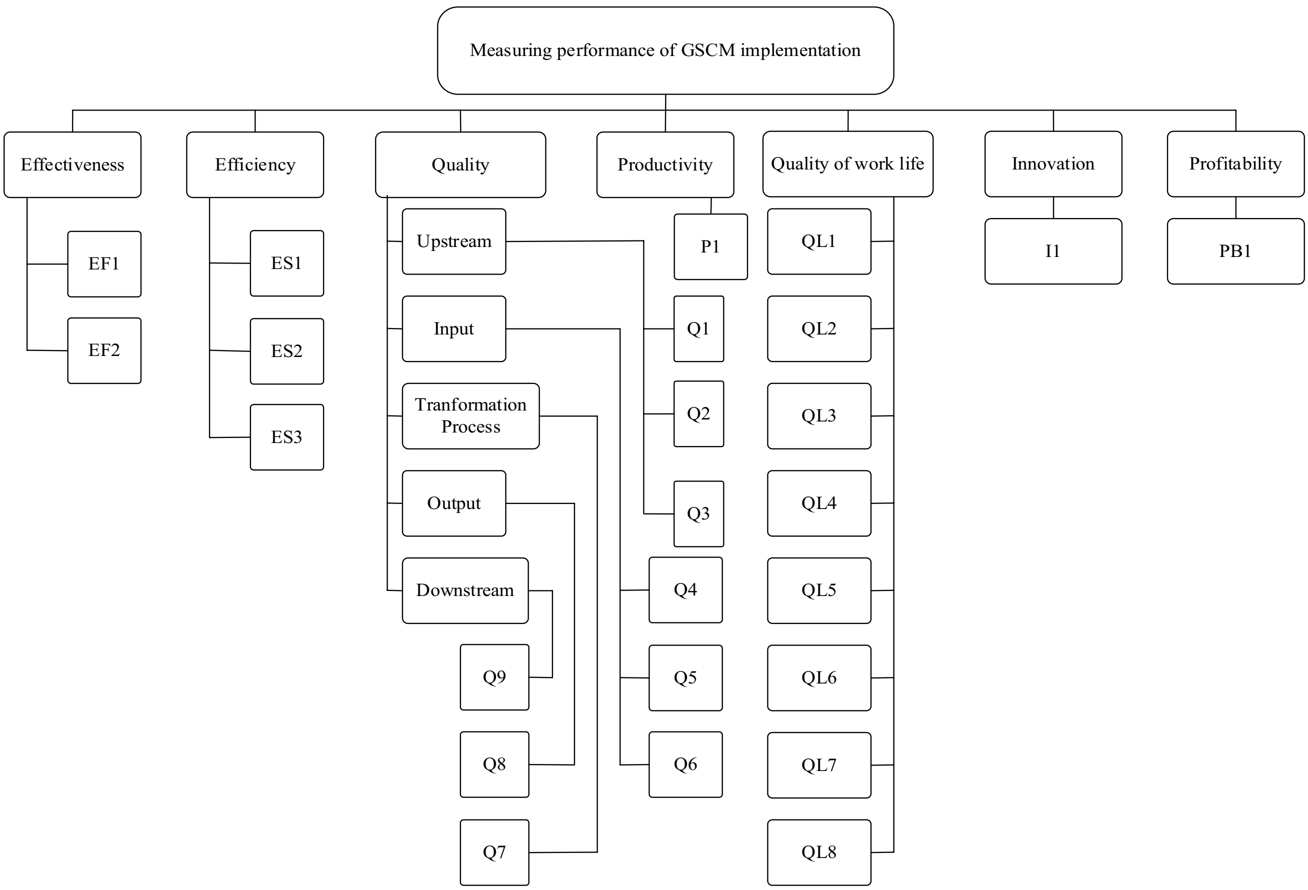

Fig. 5 ANP-based model for GSCM performance measurement

Implications

Theoretical Contributions

This study contributes to the existing literature by presenting a novel measure for evaluating GSCM practice in the steel industry using a combined ANP, OMAX, and traffic light system. In this paper, the ANP method is utilized to analyze and assess the relationships between criteria, sub-criteria, and indicators of GSCM performance in the steel manufacturing industry. Twenty-five performance indicators of GSCM have been evaluated using pairwise comparisons, and some implications are obtained to determine the key performance indicators.

Firstly, the results of the ANP method are taken into consideration as the basis for defining the importance level of the factors. Table 3 shows the rank order of the ANP calculation results for weighting each indicator of GSCM implementation in the steel manufacturing firm. Energy consumption (ES2) is the most crucial factor of GSCM indicators that contribute to sustainability in the steel manufacturing company. The steel industry consumes a lot of energy, like electricity, coal, and natural gas. Therefore, energy consumption is the top factor in making a company sustainable and green. This result is consistent with Kazancoglu et al.

Table 3 The results of ANP weighting calculation

Performance criteria	Performance sub-criteria	KPI code	KPI	Weight	Rank
Effectiveness		EF1	Delivery performance	0.04335	2
		EF2	Inventory level	0.043	3
Efficiency		ES1	Machine efficiency	0.04187	8
		ES2	Energy consumption	0.04511	1
		ES3	Water use efficiency	0.03854	17
Quality	Upstream	Q1	Fe content in iron ore	0.0427	4
		Q2	SiO_2 content in iron ore	0.03864	16
		Q3	Al_2O_3 content in iron ore	0.038006	21
	Input	Q4	C content in the slab steel	0.039302	12
		Q5	Mn content in the slab steel	0.037749	24
		Q6	S content in the slab steel	0.038189	18
	Transformation process	Q7	The process/make cycle time	0.041234	9
	output	Q8	The defect rate	0.042104	6
	Downstream	Q9	Return rate	0.04246	5
Productivity		P1	Yield	0.04196	7
Quality of work life		QL1	Air emissions	0.037928	23
		QL2	Liquid waste generated	0.037532	25
		QL3	Noise at the workplace	0.038998	13
		QL4	Noise to the surrounding area	0.038715	15
		QL5	Waste produced as a percentage of product produced	0.038171	20
		QL6	Recyclable waste as a percentage of total waste	0.038759	14
		QL7	Hazardous waste as a percentage of total waste	0.038176	19
		QL8	Percentage of reusable materials	0.039585	11
Innovation		I1	Perfect Condition	0.037954	22
Profitability		PB1	Cost of goods sold	0.039642	10

[35], who argued that efficiency was the most influencing factor of GSCM application in the cement industry. The steel, petroleum, cement, chemical, and paper industries are energy-intensive and consume most of the industrial energy within the industrial sector. In the energy-intensive sectors, improving energy efficiency can be achieved by technological advancement, process automation, and the application of energy management systems [36].

Delivery performance (EF1) acquires the second-highest priority based on the ANP result, and it is considered a second significant factor in enhancing the performance of GSCM in the steel manufacturing company. Based on SCC [34], delivery is considered perfect if the location, specified customer entity, and delivery time ordered are met upon receipt. This factor is critical to the green practices of steel manufacturing companies because if delivery performance is perfected, transportation costs and energy consumption can be reduced. Similarly, Van et al. [37] proposed delivery performance as one of the sub-criteria to evaluate the performance of green supplier selection. For XYZ Company, to ensure delivery performance meets its target, they use multi-modal transportation to deliver their products to the consumer, e.g., using trucks, trains, and ships.

Inventory level (EF2) is the third priority the company must consider to get high performance in GSCM implementation. SCC [34] defined inventory level as "current finished goods inventory on hand (including safety stock required to sustain current order fulfillment)." A proper inventory level will prevent the company from running out of stock, which can lead to loss of money and time and will support the company's delivery performance. For XYZ Company, to guarantee their inventory level is in a safe condition, they applied a computer-based enterprise resource planning (ERP) system and manufacturing execution system (MES) in their production system. These systems can prevent a human error that can cause out of stock inventory.

Secondly, Table 3 shows that the most influential criteria for the steel company in Indonesia to get high performance in GSCM application are efficiency, effectiveness, and quality. The criteria can be understood because the steel industry is one of the process industries where these three factors play an essential role in improving company performance.

Finally, the OMAX and traffic light system approach were taken into consideration which indicators have the highest and lowest performance under 12 months evaluation of GSCM performance measurement in the steel manufacturing

Table 4 A score of each KPI's of GSCM in the steel manufacturing firm using OMAX method

Month	KPI																								
	EF1	EF2	ES1	ES2	ES3	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	P1	QL1	QL2	QL3	QL4	QL5	QL6	QL7	QL8	I1	PB1
January	3	3	2	10	3	6	7	3	6	3	3	10	3	3	3	3	5	3	7	3	10	10	3	3	3
February	0	0	10	10	3	1	0	1	2	3	0	3	3	3	3	0	3	0	7	3	10	10	0	1	0
March	3	3	2	10	3	5	1	3	10	3	3	8	3	0	3	7	4	3	7	10	10	10	3	3	3
April	3	3	0	0	0	3	3	0	10	4	3	0	3	1	3	0	3	0	2	3	10	10	0	3	3
May	3	6	10	10	3	5	0	1	10	4	10	10	3	0	3	0	3	0	1	8	10	10	0	3	3
June	3	3	10	10	3	3	1	3	0	3	10	4	3	1	3	0	3	0	7	10	10	10	0	3	3
July	3	1	8	10	3	1	5	10	10	3	2	3	10	0	10	3	3	4	10	3	10	10	0	1	2
August	3	3	3	3	4	3	7	3	0	3	10	2	0	1	3	3	3	4	8	3	10	10	0	1	2
September	0	3	10	9	3	5	0	1	2	3	3	8	3	3	3	3	3	4	0	3	10	10	0	0	1
October	3	8	2	2	4	5	3	9	8	3	10	3	7	3	7	3	3	4	0	3	10	10	0	6	2
November	3	4	0	1	3	3	7	0	3	3	10	5	10	3	1	3	3	10	0	4	10	10	0	3	3
December	3	3	1	8	3	3	5	6	10	5	10	5	8	1	9	3	5	3	6	5	10	10	0	3	3

company. The indicators of GSCM with the highest performance have more green colors (score above 6), and the lowest performance have more red colors (score below 3).

The indicators with the highest performance are hazardous waste as a percentage of total waste (QL7) and recyclable waste as a percentage of total waste (QL6). Both of these indicators have the same performance because all waste resulting from the production process of XYZ Company is categorized as hazardous waste, and based on Indonesian government regulation, all hazardous wastes must be neutralized before being discharged into nature. The percentage of reusable materials (QL8) has the lowest performance and is a critical indicator that needs to be improved. The percentage of reusable materials (QL8) has the lowest score because only a few can be reused in the steel manufacturing process, i.e., scale from reheating materials in the reheating machine.

Managerial Implications

The proposed framework for GSCM performance measurement is developed in consultation with practitioners and engineers from the steel manufacturing company. The activities listed under each phase have been framed to lead to the systematic step-by-step procedure to measure the performance of GSCM implementation in this company. Managers can exploit these tools for planning and maintaining green supply chain activities performance in the company.

Conclusion

GSCM is one of the essential strategies to increase company competitiveness and to ensure sustainability in business. From the case study, it is known that Sink's Seven Performance model can be applied as a performance measurement model of GSCM in a steel manufacturing firm and can be integrated with ANP, OMAX, and traffic light system methods. Based on ANP results, there are twenty-five KPIs identified for use in performance measurement, and there are three indicators that denote the most influential indicators that contribute to the performance of the Indonesian steel manufacturing firm. They are energy consumption (ES2), delivery performance (EF1), and inventory level (EF2). Based on OMAX and traffic light system method, the research outcome reveals that the two indicators with high performance are hazardous waste as a percentage of total waste (QL7) and recyclable waste as a percentage of total waste (QL6). In contrast, the lowest and most critical performance indicator that needs to be improved is the percentage of reusable materials (QL8). Finally, the outcomes of this study can help supply chain managers prioritize GSCM implementation and help them develop strategies for efficiently managing GSC in the steel manufacturing industry.

Table 5 Performance for each indicator of GSCM in the steel manufacturing firm using the traffic light system method (Color table online)

KPI / Month	EF1	EF2	ES1	ES2	ES3	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	P1	QL 1	QL 2	QL 3	QL 4	QL 5	QL 6	QL 7	QL 8	I1	PB1
January	3	3	**2**	10	3	6	7	3	6	3	3	10	3	3	3	3	5	3	7	3	10	10	3	3	3
February	**0**	**0**	10	10	3	**1**	**0**	**1**	**2**	3	**0**	3	3	3	3	**0**	3	**0**	7	3	10	10	**0**	**1**	**0**
March	3	3	**2**	10	3	5	**1**	3	10	3	3	8	3	**0**	3	7	4	3	7	10	10	10	3	3	3
April	3	3	**0**	**0**	**0**	3	3	**0**	10	4	3	**0**	3	**1**	3	**0**	3	**0**	**2**	3	10	10	**0**	3	3
May	3	6	10	10	3	5	**0**	**1**	10	4	10	10	3	**0**	3	**0**	3	**0**	**1**	8	10	10	**0**	3	3
June	3	3	10	10	3	3	**1**	3	**0**	3	10	4	3	**1**	3	**0**	3	**0**	7	10	10	10	**0**	3	3
July	3	**1**	8	10	3	**1**	5	10	10	3	**2**	3	10	**0**	10	3	3	4	10	3	10	10	**0**	**1**	**2**
August	3	3	3	3	4	3	7	3	**0**	3	10	**2**	**0**	**1**	3	3	3	4	8	3	10	10	**0**	**1**	**2**
September	**0**	3	10	9	3	5	**0**	**1**	**2**	3	3	8	3	3	3	3	3	4	**0**	3	10	10	**0**	**0**	**1**
October	3	8	**2**	**2**	4	5	3	9	8	3	10	3	7	3	7	3	3	4	**0**	3	10	10	**0**	6	**2**
November	3	4	**0**	**1**	3	3	7	**0**	3	3	10	5	10	3	**1**	3	3	10	**0**	4	10	10	**0**	3	3
December	3	3	**1**	8	3	3	5	6	10	5	10	5	8	**1**	9	3	5	3	6	5	10	10	**0**	3	3

The numbers in red color and bold style indicate that the performance of the indicators was unacceptable (the score is less than 3) and critical to be improved

Limitations and Future Works

The weakness of the proposed model in this work is that it intensely depends on the expert's judgments. Recommendations from the experts were used to finalize the indicators associated with the company's successful GSCM implementation and adoption. This research could be a research instrument construction to measure the performance of GSCM in steel and other industries. In future, the proposed approach in this research can also be applied to other sectors and industries to get different insights. Extensions and integrations with other tools, like interpretive structural modeling (ISM), to evaluate the factors for measuring GSCM performance in a steel manufacturing company can provide avenues for improvement. The decision support system can be developed using the proposed approach to know the results of GSCM assessment in real-time as future works. The models used in this work focus on input and output values, whereas intermittent parameters should also be controlled in the GSCM performance management of steel manufacturing companies. Future work should consider intermittent parameters as KPIs.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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