

Green Supply Chain Performance Measurement using Green SCOR Model in Agriculture Industry: A Case Study

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Abstract: The agriculture industry has proliferated in the last decades, increasing the environmental footprint. Several development concepts include integrating the ecological aspect into the supply chain to reduce environmental degradation. In implementing the idea, companies in the agriculture industry need to evaluate their performance in the environmental area. This measurement uses the Green Supply Chain Operations Reference (GSCOR) Model that provides its entire supply chain aspect. This study demonstrates that the enable parameter criterion, which shows the magnitude of employee management toward environmental requirements, significantly impacts supply chain performance. Other criteria are also critical, such as a plan that considers every entity's usage and a source that considers the supply of the entities. The performance measurement produces a 6.357 value in the yellow color category with an average condition in the company. It produces three key performance indicators (KPI), such as water usage, percentage hazardous materials in inventory, and percentage hazardous waste, with a red classification that should be improved.

Keywords: Agriculture industry, green supply chain, green supply chain operations reference (GSCOR), performance measurement.

Introduction

The agriculture industry has proliferated in the past 50 years to accommodate the demand escalation in the rural area and export sector [1]. This condition shows the importance of improving a company and other parties in the related supply chain [2]. The biggest obstacle faced by the agriculture industry is the challenge of environmental issues [3]. According to Vermeulen *et al.* [4], the agriculture industry is the main contributor to emissions that contribute more than 19% of the global emission of greenhouse gases. The modern agriculture system uses various resources that increase the environmental footprint, such as agrochemicals contamination, fossil fuels, and high energy and water use [5]. Therefore, various concepts have been expertly developed to reduce environmental degradation, such as integrating ecological aspects and, managing the supply chain, producing green supply chain concepts [6].

This solution aims to develop the performance of an organization regarding environmental management, performance, and green initiation [7,8]. However, measuring performance in the green supply chain has been studied across various industries. Saputra *et al.* [9] studied the performance of pulp and paper companies, which resulted in the integration of internal and external stakeholders in their supply chain, such as

supplier requirements and government or regulator requirements, with the limitation of adhering to the SCOR model's systematic approach. Susanty *et al.* [10] used an importance-performance analysis (IPA) to implement a green supply chain practice in small and medium enterprises focused on batik business. They focus more on their performance in using environmentally friendly raw materials rather than other results such as scheduling to minimize energy consumption and maximize production capacity. Suryaningrat *et al.* [11] determined the implementation of a green supply chain by evaluating and measuring the performance of ribbed smoke sheet companies, with minor detail on the measurement of entities between indicator and analysis of each parameter and also limited on determining to enable criteria to develop the performance in managing their strategy implementation. According to previous studies, it is seen that various literature used different combinations in developing performance measurements. To the best of our knowledge, there is no literature from Indonesia on the agriculture sector that focuses on highland vegetables using GSCOR. Therefore, this study can accommodate the combination and development to measure with the GSCOR model.

This study contributes a novel approach to the development of performance measurement by utilizing industrial conditions to improve the green industry as determined by various literature on various criteria, attributes, performance indicators, and models in conjunction with the Analytical Hierarchy Process (AHP), Objective Matrix (OMAX),

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and Traffic Light System (TLS). The new approach provides a priority scale, integrates all parameters with different purposes into one scale, and analyzes easier to classify priority categories for producing performance measurements in the highland vegetable industry. Furthermore, these method combinations are never used to measure the supply chain performance with the GSCOR approach.

This research was carried out in a company specializing in agriculture, specifically highland vegetables, and does seeding, cultivation, processing, and packaging, focusing on export markets such as Japan and Singapore. The company faces several challenges in the expert segment, which must meet requirements such as green businesses and green products. However, to ensure that the company's products and business processes meet the requirements, the organization must examine its operations through an ecological lens.

Methods

This study used the conceptual framework design to examine the company's entire supply chain, including suppliers to the customer. Hence, the concept begins with collecting data, processing the data gradually, and constructing a conclusion.

Data Collection

We collected the data via interviews and questionnaires, which produced qualitative and quantitative data. In the interview, we inquired about the industry's needs. We divided the questionnaires into several steps, such as scoring the importance of each parameter with pairwise comparison.

Systematic of Performance Measurement

Step 1: Designing the Measurement Model

The GSCOR process is used to measure the environmental footprint based on the standards [8]. The first stage is designing the green requirement that considers industry, stakeholders, and literature review. Afterward, the green objectives are developed from the green requirements. The final stage is forming the criteria, attributes, and performance indicators that refer to each stakeholder's green objective using the GSCOR metric.

Step 2: Determining the Weight of Parameter

The Analytical Hierarchy Process (AHP) technique is employed to provide weights and prioritize each criterion, attribute, and performance indicator [12]. Data processing using the AHP method is assisted by Expert Choice Software v.11, which helps to calculate the weighting stage.

Table 1. OMAX categories

| Color | Level of achievement | Category |
|---|----------------------|-----------|
|  | 8 – 10 | Excellent |
|  | 3 – 7 | Average |
|  | 0 – 2 | Poor |

Step 3: Scoring System

Objective Matrix (OMAX) is applied to generate the performance score and the index for each parameter [13]. OMAX connects every criterion on performance into a model [14]. In addition, the systematics of the OMAX method is first determined by setting a minimum level score, which will be the achievement of the minimum target in the performance indicators. After that, optimistic and pessimistic values or scores were assigned to determine a scale of 10 (Optimistic) and 0 (Pessimistic) in the OMAX metric.

We then defined the level of achievement from the current performance. Next, we deduced the score by multiplying the weight that we got from the AHP by the defined achievement level. The results are then identified using Traffic Light System (TLS) [15] (see Tabel 1).

Results and Discussions

This section shows the performance of designing a model for a scoring system. First, the model result was discussed for each stage, consisting of green requirement, green objective, and the GSCOR metrics. Then, the parameters were used to apply the weighting and scoring system to identify performance.

Green Requirements Identification

Forming the green requirement consists of the needs of the industry that consider the environmental aspects. The requirements are determined by considering stakeholders in the supply chain and literature on measuring performance indicators, especially green areas. Defining the stakeholders will lead to the needs and consideration of measuring performance indicators.

Supplier

- (GR1) Environmentally friendly material or substance.
- (GR2) Environmental Management System (EMS) or ISO 14001 certification.

Direct Employee

- (GR3) The employee's understanding of Standard Operation Procedure (SOP) in the assigned task.
- (GR4) Training on environmental aspects and job requirements.

Table 2. Green objective

| No | Green objective | Stakeholder | Realization of green requirement |
|----|---|---|---|
| 1 | Selection of the right supplier according to environmental friendliness | Purchasing | GR13 |
| 2 | Environmentally friendly supplier performance | Supplier, purchasing | GR1, GR15 |
| 3 | Delivery with environmental aspect | Supplier, purchasing, logistic | GR2, GR5, GR8, GR9, GR10, GR14 |
| 4 | Minimize the use of hazardous materials | Supplier, direct employee, production, logistic, purchasing | GR1, GR4, GR5, GR6, GR7, GR8, GR13 |
| 5 | Minimize the use of resources (material, energy, fuel, water, etc) | Supplier, overall unit in the company | GR2, GR3, GR4, GR7, GR9, GR11, GR12, GR14 |
| 6 | Minimization and handling of hazardous waste | Supplier, direct employee, production, logistic | GR2, GR3, GR5, GR6, GR9 |
| 7 | Reuse of resources | Overall unit in the company | GR3, GR4, GR5 |
| 8 | Worker training regarding green business requirements | Direct employee, production, logistic, purchasing | GR3, GR5, GR7, GR9, GR14 |
| 9 | Food safety | Supplier, production, logistic, purchasing | GR1, GR2, GR5, GR6, GR7, GR8, GR13 |

Table 3. GSCOR metrics

| Criteria | Configuration | Attributes | No | Performance indicator | References |
|----------|--------------------------|----------------|----|---|------------|
| Plan | Plan make, deliver | Reliability | 1 | Energy usage | [18, 19] |
| | | | 2 | Water usage | [19, 20] |
| | | | 3 | Fuel consumption | [16,18] |
| | | | 4 | % Synthetic chemical usage | [9, 21] |
| Source | Source stocked product | Reliability | 5 | % Supplier with an EMS or ISO 14001 certification | [10, 22] |
| | | | 6 | % of suppliers meeting environmental metrics/criteria | [22] |
| | | | 7 | % of hazardous material in inventory | [23] |
| Make | Make to stock | Reliability | 8 | % Material efficiency | [9, 11] |
| | | | 9 | % of recycleable product waste/scrap from production | [19, 22] |
| | | | 10 | % Hazardous waste as % of total waste | [9] |
| | | | 11 | % Hazardous waste treatment | [11] |
| Deliver | Deliver stocked product | Reliability | 12 | % of vehicle fuel derived from alternative fuels | [9] |
| | | | 13 | % of product return | [22] |
| Return | Return defective product | Responsiveness | 14 | % of complaints regarding missing environmental requirements from product | [11,20] |
| | | | 15 | % Employee trained on environmental requirements | [9,18,] |

Production

(GR5) Managing Good Agricultural Practices (GAP).
 (GR6) Managing Hazard Analysis Critical Control Point (HACCP).
 (GR7) Availability of technology to support cleaner production (GR7).

Logistic

(GR8) Availability of packaging materials and storage media for delivery by the terms and the required quantity.

(GR9) Cleaner warehouse operation.

(GR10) Complete shipping documentation and reliable information system.

Marketing

(GR11) Legal and environmentally friendly requirements to minimize the number of customer complaints.

(GR12) Convenience administration (Document requirement, Estimate Time Arrival (ETA), etc.).

Purchasing

- (GR13) Purchase of environmentally friendly goods.
- (GR14) Reliable information system to procure goods.
- (GR15) Supplier monitoring.

Green Objectives Identification

The green objective is defined by considering the correlation between the green requirements and the company's goal. The objective is to be achieved at a particular time, which could be different in various industries. For example, the stakeholders who need to purchase environmentally friendly goods set the objective to select the right supplier according to environmental friendliness. Table 2 illustrates the output of completing the green requirements to the green objectives.

Green Supply Chain Operations Reference Formulation Metrics

The criteria, attributes, and performance indicators construction refer to each green objective for each stakeholder by considering the parameters in several previous case studies. One example is the construction of performance indicators of product returns. The product returns should meet the green objectives by ensuring food safety. Companies must also ensure production safety and environmentally friendly products. Additionally, we add the fuel consumption indicators to develop metrics as suggested by some literature (see Table 3). Fuel consumption, particularly fossil fuel consumption, is one of the factors contributing to agricultural emissions [16]. Therefore, reducing fossil fuel consumption will reduce emissions [17]. Finally, we include the enable criteria in the model to accommodate the human resources in the supply chain in the system [8].

The green supply chain model is measured using the following metrics:

- (KPI1) Energy usage is the total electricity used to produce products. Unit: kWh/ton [18,19]
- (KPI2) Water usage is the total use of water to produce products. Unit: m3/ton [19,20]
- (KPI3) Fuel consumption is the total use of fossil fuel, for example, solar, to deliver or produce products. Unit: liter/ton [16,18]
- (KPI4) % Synthetic chemical usage is the percentage of total pesticides or other chemicals in the production system, such as controlling pests and washing products [9,21].
- (KPI5) % Suppliers with an EMS or ISO 14001 are the portion of the overall supply companies with ecological accreditation [10,22].

Table 4. Structuring performance indicator

| No | Green objective | Performance indicator |
|----|---|------------------------------|
| 1 | Selection of the right supplier according to environmental friendliness | KPI5 |
| 2 | Environmentally fiendly supplier performance | KPI6 |
| 3 | Delivery with enviromental aspect | KPI12 |
| 4 | Minimize the use of hazardous materials | KPI7 |
| 5 | Minimize the use of resources (material, energy, fuel, water, etc) | KPI1 KPI2 KPI8 KPI3 |
| 6 | Minimization and handling of hazardous waste | KPI4 KPI10 KPI11 |
| 7 | Reuse of resources | KPI9 KPI13 |
| 8 | Worker training regarding green business requirements | KPI15 |
| 9 | Food safety | KPI14 |

(KPI6) % of suppliers meeting environmental metrics or criteria is the percentage of suppliers with environmentally friendly products or an agreement with the company [22].

(KPI7) %Hazardous materials in inventory is the percentage of materials that are unable to be recycled and causing environmental damage [23].

(KPI8) % Material efficiency is the percentage of raw material used in production [9,11].

(KPI9) % of recyclable product waste or scrap is the percentage of recycled products in production [22]

(KPI10)% Hazardous waste as % of total waste is the percentage of hazardous waste such as chemical and non-recycled material [9].

(KPI11) % Hazardous waste treatment is the percentage of recycled hazardous waste [11].

(KPI12) % of vehicle fuel derived from alternative fuels is the percentage of total vehicles that are environmentally friendly [9]

(KPI13) % of product return is the percentage of returns from the customer [22].

(KPI14) % of complaints regarding missing environmental requirements from the product is the number of customer complaints regarding the environment [11,20]

(KPI15)% employee trained on environmental requirements is the percentage of the number of workers equipped with knowledge of environmental friendliness [18].

Table 4 shows the structuring key performance indicators which fulfilled the green objective.

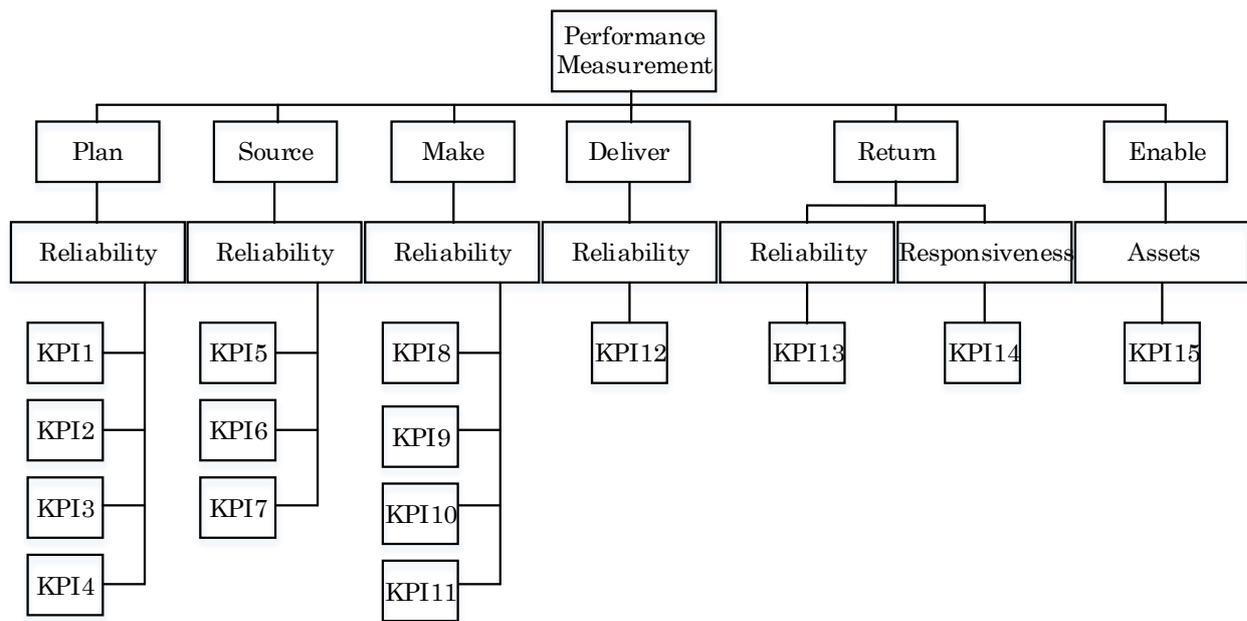


Figure 1. Hierarchy model

Tabel 5. The GSCOR Weight

| Criteria | Weight | Attributes | Weight | Performance indicator | Weight | Total weight |
|----------|--------|----------------|--------|-----------------------|--------|--------------|
| Plan | 0.190 | Reliability | 1 | KPI1 | 0.054 | 0.010 |
| | | | | KPI2 | 0.249 | 0.047 |
| | | | | KPI3 | 0.105 | 0.020 |
| | | | | KPI4 | 0.592 | 0.112 |
| Source | 0.190 | Reliability | 1 | KPI5 | 0.091 | 0.017 |
| | | | | KPI6 | 0.091 | 0.017 |
| | | | | KPI7 | 0.818 | 0.155 |
| Make | 0.105 | Reliability | 1 | KPI8 | 0.278 | 0.029 |
| | | | | KPI9 | 0.043 | 0.005 |
| | | | | KPI10 | 0.251 | 0.026 |
| | | | | KPI11 | 0.428 | 0.045 |
| Deliver | 0.032 | Reliability | 1 | KPI12 | 1 | 0.032 |
| Return | 0.029 | Reliability | 0.833 | KPI13 | 1 | 0.024 |
| | | Responsiveness | 0.167 | KPI14 | 1 | 0.005 |
| Enable | 0.453 | Assets | 1 | KPI15 | 1 | 0.453 |

The GSCOR Metric Parameter Weight

The weight of GSCOR metrics parameter is calculated via AHP (see Figure 1, for the AHP model). Table 5 exhibits the GSCOR metrics parameter weight. The weight shows that realizing governance planning and implementation is crucial in the supply chain process, including understanding each employee with green business and all aspects of the environmental area.

Furthermore, if the employee understands the requirement and implements a green system, it will bring the companies to achieve their objective in the environmental area. Meanwhile, the return criteria are the most overlooked among the other values shown to handle customers.

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Scoring System

The scoring system uses the OMAX and TLS methods to determine the score and value in the green supply chain performance [24]. The score is identified as the level of achievement to determine which parameters

meet the target at every level. The achievement level will be considered an element to be multiplied by the weight of parameters. The assessment weight in the OMAX technique incorporates input from the AHP method and will be calculated with the level of achievement (Score) to show the value of each parameter.

Table 6 presents the overall scoring stages, which were calculated using the OMAX method. Table 7 illustrates the scoring system with each parameter's level of achievement and value. For example, the KPI7 is colored red with a value of 0.233, indicating that the hazardous material in inventory is still at a higher number because it does not meet the minimum target for the created parameter. Another example is the KPI8 shown in yellow, with a value of 0.156 indicating efficiency in raw material usage; the number of the value meets the minimum of the target in the parameters.

Table 6. OMAX method on plan-criteria

| KPI | 1 | 2 | 3 | 4 |
|-------------|--------|--------|--------|--------|
| Performance | 225.13 | 210.00 | 92.91 | 98.82% |
| Scale | 10 | 213.87 | 190.00 | 83.62 |
| | 9 | 215.48 | 191.42 | 84.94 |
| | 8 | 217.08 | 192.85 | 86.27 |
| | 7 | 218.69 | 194.28 | 87.59 |
| | 6 | 220.30 | 195.71 | 88.93 |
| | 5 | 221.91 | 197.14 | 90.25 |
| | 4 | 223.52 | 198.57 | 91.58 |
| | 3 | 225.12 | 200.00 | 92.91 |
| | 2 | 228.88 | 208.33 | 96.00 |
| | 1 | 232.63 | 216.66 | 99.10 |
| 0 | 236.38 | 225.00 | 102.19 | |
| Score | 3 | 1.8 | 3 | 3 |
| Weight | 0.010 | 0.047 | 0.020 | 0.112 |
| Value | 0.031 | 0.085 | 0.060 | 0.337 |

Table 7. Scoring result

| Performance indicator | Value | Level achievement | Color |
|-----------------------|-------|-------------------|--------|
| KPI1 | 0.031 | 3 | Yellow |
| KPI2 | 0.085 | 1.8 | Red |
| KPI3 | 0.060 | 3 | Yellow |
| KPI4 | 0.337 | 3 | Yellow |
| KPI5 | 0.052 | 3 | Yellow |
| KPI6 | 0.173 | 10 | Green |
| KPI7 | 0.233 | 1.497 | Red |
| KPI8 | 0.156 | 5.333 | Yellow |
| KPI9 | 0.045 | 10 | Green |
| KPI10 | 0.035 | 1.333 | Red |
| KPI11 | 0.449 | 10 | Green |
| KPI12 | 0.097 | 3 | Yellow |
| KPI13 | 0.024 | 10 | Green |
| KPI14 | 0.049 | 10 | Green |
| KPI15 | 4.532 | 10 | Green |
| Total | | 6.357 | Yellow |

Table 7 shows the overall score from each performance indicator, gives a value of 6.357, and is categorized as yellow. This result implies that the green supply chain is now in average performance. Of fifteen performance indicators, there are six performance indicators in the excellent or green category, six in the average or yellow category, and three in the poor or red category.

Several indicators need to be improved to achieve the objective (see Table 7). For example, The KPI7 is one of the red categories; it should be improved because of the poor performance of the parameter. Another example is the KPI8 (the indicator is yellow, with a value of 0.156). This value indicates efficiency in raw material usage; it meets the minimum of the target in the parameters. Furthermore, the value of KPI7 is higher than KPI8 because the company's goals are more focused on minimizing hazardous materials rather than considering the cost of material efficiency, and the company is still in the early stages of developing the parameters.

To improve the KPIs, which have red indicators, the company requires specifically handling hazardous material, such as using a material datasheet. The material can be substituted with more environmentally friendly materials such as green oil lubricants [25] and biodegradable natural rubber latex gloves [26]. Additionally, the company also needs to control water waste. The water pinch analysis method can be added to calculate the minimal water requirement (MWR) and minimal effluent treatment (MET) [27].

Conclusion

This study finds that the enable criteria are critical parameters. Those criteria support the governance planning to achieve the green supply chain concept, particularly in the highland vegetable industries. Other criteria, such as plan and source, are also critical in supplementing the current performance measurement. The performance assessment using the GSCOR model is in yellow (average category) with a value of 6.357. It requires improvement on numerous prioritized metrics that will change how business processes in agriculture address environmental challenges. The performance measurement metrics in other similar companies may differ, but this study is intended to serve as a reference for developing performance metrics. The future research will include other standardization indicators such as ISO 14001 or export standardization from specific locations that have prioritized green industries.

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