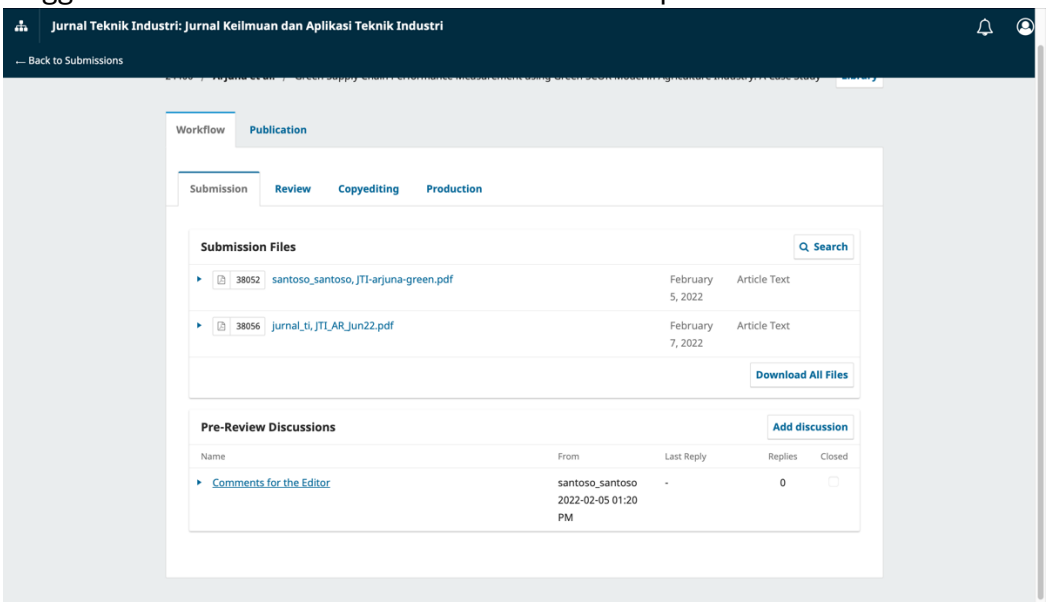
Judul Artikel: Green Supply Chain Performance Measurement using Green SCOR Model in Agriculture Industry: A Case Study

Jurnal: Jurnal Teknik Industri: Jurnal Keilmuan dan Aplikasi Teknik Industri

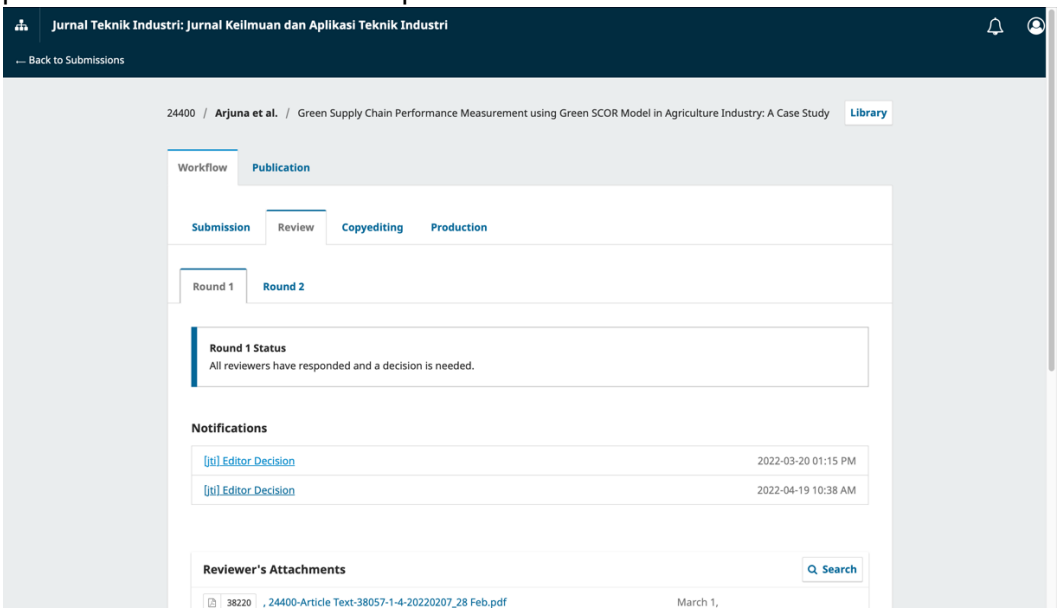
Penulis: Arjuna, Santoso, Rainisa Maini Heryanto

Volume 24 Nomor 1 Tahun 2022

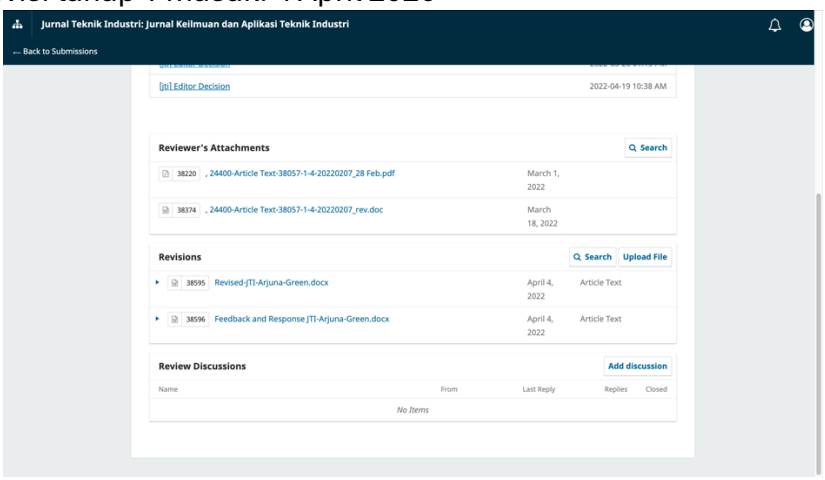
1. Bukti tanggal submit artikel awal: 5 Februari 2022 dan perbaikan 7 Februari 2022



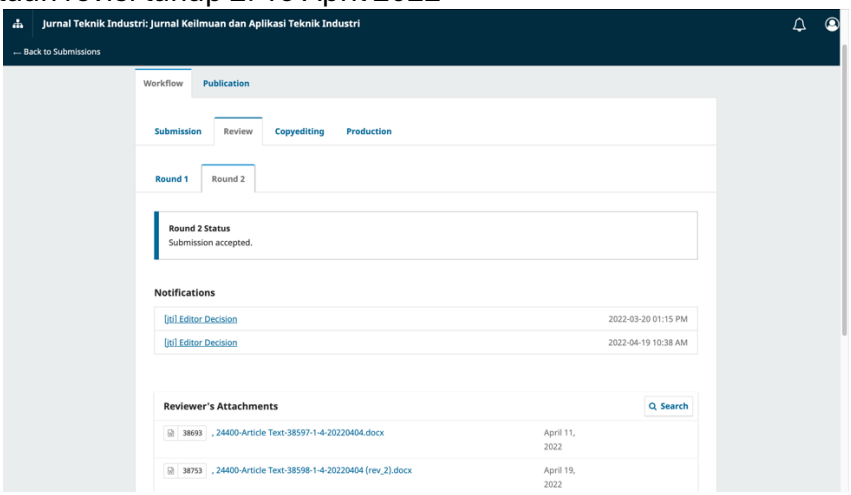

2. Bukti permintaan revisi artikel tahap 1: 20 Maret 2022



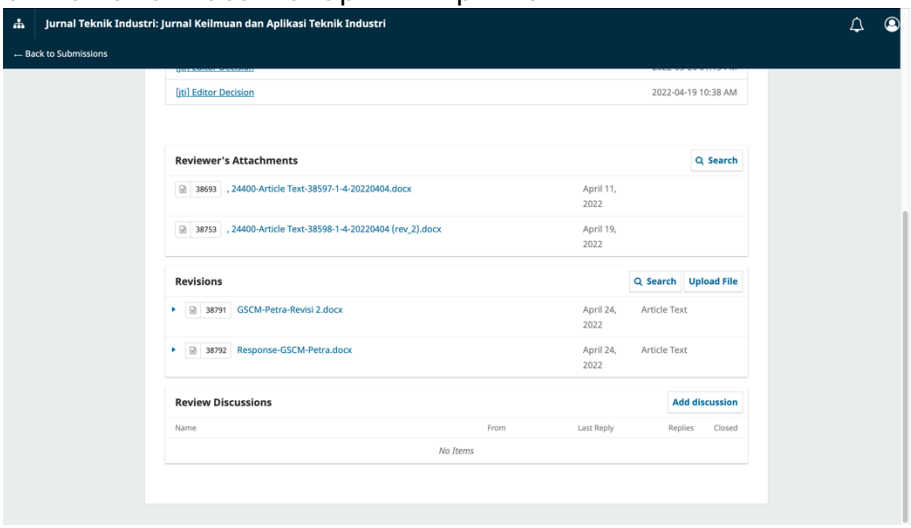
3. Bukti artikel revisi tahap 1 masuk: 4 April 2020



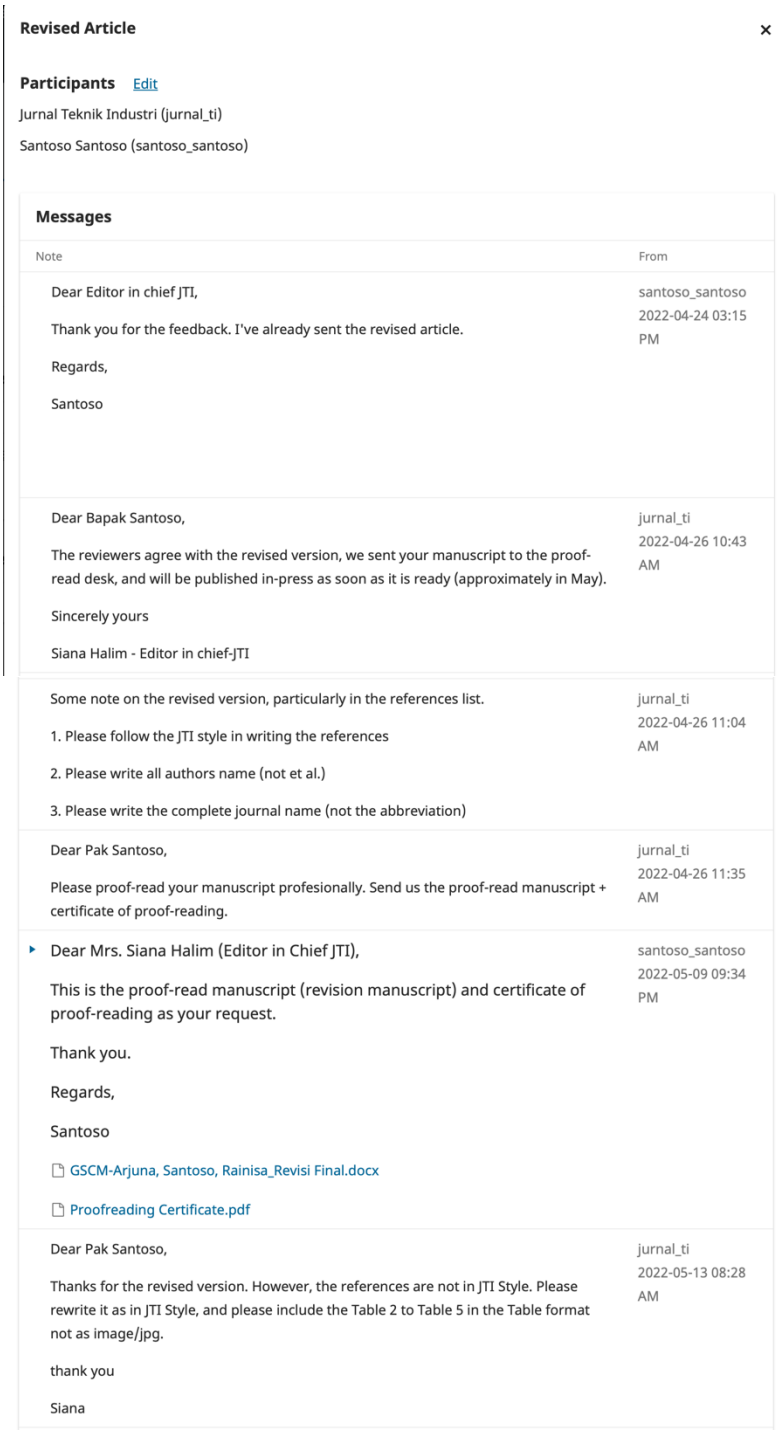

4. Bukti permintaan revisi tahap 2: 19 April 2022




5. Keputusan artikel revisi masuk tahap 2: 24 April 2022



6. Copyediting: 24 April 2022, 26 April 2022, 9 Mei 2022, 13 Mei 2022, 14 Mei 2022, 17 Mei 2022, dan 24 Mei 2022



**Revised Article** ×

**Participants** Edit

Jurnal Teknik Industri (jurnal_ti)

Santoso Santoso (santoso_santoso)

**Messages**

| Note | From |
|---|---|
| Dear Editor in chief JTI,<br>Thank you for the feedback. I've already sent the revised article.<br>Regards,<br>Santoso | santoso_santoso<br>2022-04-24 03:15 PM |
| Dear Bapak Santoso,<br>The reviewers agree with the revised version, we sent your manuscript to the proof-read desk, and will be published in-press as soon as it is ready (approximately in May).<br>Sincerely yours<br>Siana Halim - Editor in chief-JTI | jurnal_ti<br>2022-04-26 10:43 AM |
| Some note on the revised version, particularly in the references list.<br>1. Please follow the JTI style in writing the references<br>2. Please write all authors name (not et al.)<br>3. Please write the complete journal name (not the abbreviation) | jurnal_ti<br>2022-04-26 11:04 AM |
| Dear Pak Santoso,<br>Please proof-read your manuscript profesionally. Send us the proof-read manuscript + certificate of proof-reading. | jurnal_ti<br>2022-04-26 11:35 AM |
| Dear Mrs. Siana Halim (Editor in Chief JTI),<br>This is the proof-read manuscript (revision manuscript) and certificate of proof-reading as your request.<br>Thank you.<br>Regards,<br>Santoso<br>GSCM-Arjuna, Santoso, Rainisa_Revisi Final.docx<br>Proofreading Certificate.pdf | santoso_santoso<br>2022-05-09 09:34 PM |
| Dear Pak Santoso,<br>Thanks for the revised version. However, the references are not in JTI Style. Please rewrite it as in JTI Style, and please include the Table 2 to Table 5 in the Table format not as image/jpg.<br>thank you<br>Siana | jurnal_ti<br>2022-05-13 08:28 AM |

Dear Mrs. Siana Halim,

This is the revision manuscipt (references with JTI Style) and file table. I hope the manuscript in accordance with your request. If there is still something to be revised, please inform me.

Thank you.

GSCOR JTI Petra_Arjuna, Santoso, Rainisa, Revisi Final 140522.docx

Tabel Jurnal Petra.xlsx

santoso_santoso
2022-05-14 08:33 AM

Dear Bapak Santoso,

Attach is your proof-read article. Please rewrite the sentences in reds.

thank you

Siana Halim - Editor in chief

jurnal_ti, 05_JTI_Jun22_Arjuna_Inpress.docx

jurnal_ti
2022-05-17 03:54 PM

Dear Ibu Siana Halim,

Please inform us whether the revised proof read article file that we have sent in this discussion column on May 14, 2022 will readjustments in the sentence structure when presented in articles in press (2 columns)?

We are Sorry because we were confused when there was a request for revision for some sentences that were colored red, after we checked it turned out that there were indeed something different from the revised proof read article that we sent on May 14, 2022 in this discussion column.

We also send an in-press file that is requested to be revised and a revised file of the proof read article that we have sent on May 14, 2022. We have given yellow color for sentences that are different from the results of the revised proof read article.

Please help guide us in revising our articles to fulfill the requirements.

Thank you.

santoso_santoso
2022-05-17 09:04 PM

The files.

santoso_santoso, 24400-Article Text-38990-1-18-20220517.docx

santoso_santoso, GSCOR JTI Petra_Arjuna, Santoso, Rainisa, Revisi Final 140522.docx

santoso_santoso
2022-05-17 09:08 PM

Dear Ibu Siana Halim,

We are sorry for late reply. This is the revision file as your request.

Thank you.

santoso_santoso, 24400-Article Text-38990-1-18-20220517.docx

santoso_santoso
2022-05-24 07:52 AM

Dear Ibu Siana Halim,

This is the revision file as your request with some sentences in Bahasa.

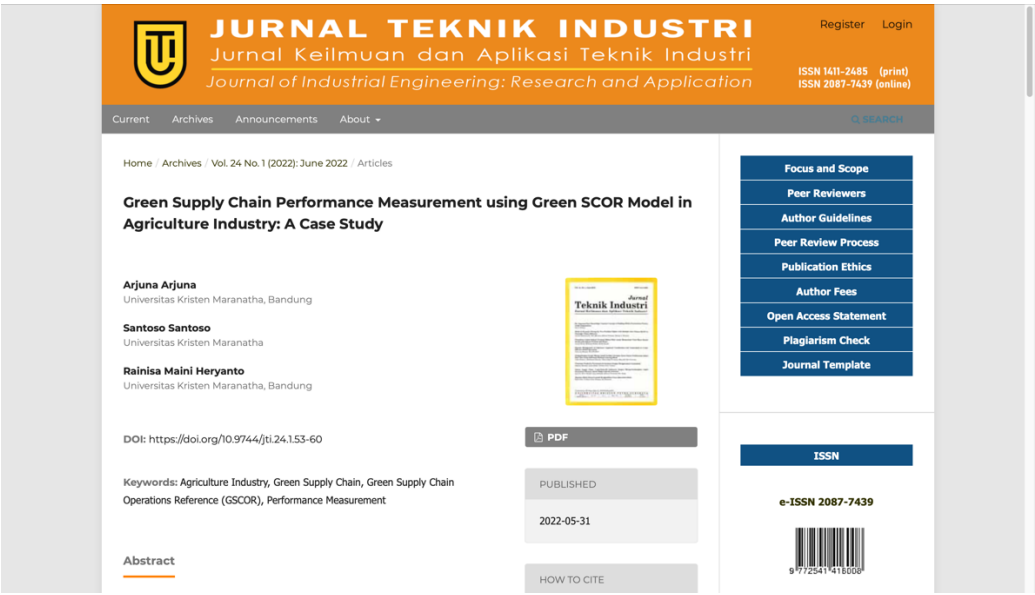
Thank you.

santoso_santoso, 06_JTI_Jun22_Arjuna_Inpress[8].docx

santoso_santoso
2022-05-24 12:34 PM

Add Message

7. Terbit online: 31 Mei 2022



JURNAL TEKNIK INDUSTRI
Jurnal Keilmuan dan Aplikasi Teknik Industri
Journal of Industrial Engineering: Research and Application

Register Login

ISSN 1411-2485 (print)
ISSN 2087-7439 (online)

Current Archives Announcements About SEARCH

Home / Archives / Vol. 24 No. 1 (2022): June 2022 / Articles

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


**Arjuna Arjuna**
Universitas Kristen Maranatha, Bandung

**Santoso Santoso**
Universitas Kristen Maranatha

**Rainisa Maini Heryanto**
Universitas Kristen Maranatha, Bandung



DOI: https://doi.org/10.9744/jti.24.1.53-60

Keywords: Agriculture Industry, Green Supply Chain, Green Supply Chain Operations Reference (GSCOR), Performance Measurement


PDF

PUBLISHED
2022-05-31

HOW TO CITE

Abstract

Focus and Scope
Peer Reviewers
Author Guidelines
Peer Review Process
Publication Ethics
Author Fees
Open Access Statement
Plagiarism Check
Journal Template

ISSN

e-ISSN 2087-7439

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


## ABSTRACT

The agriculture industry has proliferated in the last decades, increasing the environmental footprint. There are several development concepts such as integrating the ecological aspect to 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 showed that the performance measurement produces a 6.357 value in the yellow color category or with the average condition. The result from the performance indicator shows 6 KPI in the green, 6 in the yellow, and 3 with the red classification.



**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]. The biggest obstacle faced by the agriculture industry is the challenge of environmental issues[2]. According to Vermeulen et al.[3], 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[4]. Therefore, various concepts have been expertly developed to reduce environmental degradation, such as integrating ecological aspects and supply chain management, which produce green supply chain management concepts[5].

This solution aims to develop the performance of an organization regarding environmental management, performance supply chain, and green supply chain initiation [6,7]. However, measuring the green supply chain performance has been studied across a wide range of industries. Saputra et al. [8] conducted the performance development of pulp and paper companies, leading to integration between internal and external stakeholders. Susanty et al. [9] implemented a green supply chain that focused on developing performance indicators in environmentally friendly raw materials. Suryaningrat et al. [10] determined the development of performance indicators in ribbed smoke sheet companies. According to the previous research, it is seen that different literature illustrates different combinations in developing performance measurement. This study contributes a new approach using GSCOR, AHP, OMAX, and TLS methods and the development approach in a new area based on the needs of the agriculture industry that focus on highland vegetables in several criteria, attributes, and performance indicators.

This research was conducted in a company specializing in agriculture, specifically highland vegetables that do seeding, cultivation, processing, packaging, and export. In adapting the green supply chain idea, the organization needs to examine its operations to ensure that this would construct its performance throughout the ecological area.

## Methods

This research was conducted with the conceptual framework design by examining the entire supply chain of the company, which includes suppliers to the customer. Hence, the concept begins with collecting data, processing the data gradually, and making a conclusion.

### Data Collection

Data was collected through interviews and questionnaires, which produced qualitative and quantitative data. Gathering data through interviews determined the needs of the industry. Collecting with questionnaires was divided into several steps, such as scoring the importance of each parameter with pairwise comparison.

### Systematic of Performance Measurement

Step 1: Designing The Measurement Model
To design the model, the GSCOR process is used to measure the environmental footprint based on the standards [7]. The first stage is designing the green requirement that considers industry, stakeholders, and literature review. Afterwards, the green objectives are developed from the green requirements. The final stage is forming the criteria, attributes, and performance indicator that refers to the green objective for each stakeholder 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 criteria, attributes, and performance indicators [11]. Data process using the AHP method assisted by the Software Expert Choice v.11, which help to calculate the weighting stage.

Step 3: Scoring System
Objective Matrix (OMAX) is applied to generate the performance score and the index for each parameter [12]. OMAX connects every criteria on performance into a model [13]. Moreover, the systematic of the OMAX method is first defined by establishing the level minimum score, which will be the minimum targeted achievement in performance indicators. Afterward, the value or score optimistic and pessimistic is established to determine for scale 10 (Optimistic) and 0 (Pessimistic) in the OMAX metrics (See table 5). To decide other scales in the metrics, it is calculated with an equation below.

$$\Delta X(l,h) = \frac{Y(h)-Y(l)}{X(h)-X(l)} \quad (1)$$

Where,
$\Delta X(l,h)$ is interval number level between highest scale and lowest scale
$X(h)$ is high number level scale
$X(l)$ is low number level scale
$Y(h)$ is high value level scale
$Y(l)$ is low value level scale

After determining each value in the scale, determine the level of achievement with current performance. Data weighting from AHP considers fulfilling the weight value in OMAX and multiple by the level of achievement from current performance. The result from OMAX is evaluated using a Traffic Light System (TLS), which measuring the results with three colors; green for an excellent results, yellow as the parameter for an average result, and red is category for poor results[14].

## Result and Discussion

This section shows the result of calculating performance from designing the model to a scoring system. For each stage, we discussed the model result, which consists of green requirement, green objective, and the GSCOR metrics. Then we use the parameters to apply the weighting and scoring system to identify performance.

### Green Requirements Identification

The preparation of green requirements consists of the needs from the industry that consider environmental aspects. Green requirements show the stakeholders are a part of the company concerned in the supply chain system, so defining the stakeholder will lead to the needs of each part of it. The following content is an overview of the green requirements with the code for each condition.

***Supplier***
1. Environmentally friendly material or substance (GR1).
2. Environmental Management System (EMS) or ISO 14001 certification (GR2).

***Direct Employee***
1. The employee understanding of Standard Operation Procedure (SOP) in the assigned task (GR3).
2. Training on environmental aspects and job requirements (GR4).

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

***Logistic***
1. Availability of packaging materials and storage media for delivery by the terms and the required quantity (GR 8).
2. Cleaner warehouse operation (GR9).
3. Complete shipping documentation and reliable information system (GR10).

***Marketing***
1. Legal and environmentally friendly requirements to minimize the number of customer complaints (GR 11).
2. Convenience administration (Document requirement, Estimate Time Arrival (ETA), etc.) (GR 12).

***Purchasing***
1. Purchase of environmentally friendly goods (GR 13).
2. Reliable information system to procure goods (GR 14).
3. Supplier monitoring (GR 15).

### Green Objective Identification

The objective is the result to be achieved at a particular time. The determination of the goal is considered with the correlation of stakeholder needs, such as selecting the right supplier according to environmental friendliness, which is considered by purchasing who needs to order environmentally friendly material. Table 1 illustrates the output of completing the green requirements with green objectives.

**Table 1.** Green Objective

| No | Green objective | Stakeholder | Realization of green requirement |
|---|---|---|---|
| 1 | Selection of the right supplier according to environmental friendliness | Purchasing | GR13 |
| 2 | Environmentally fiendly supplier performance | Supplier, purchasing | GR1, GR15 |
| 3 | Delivery with enviromental 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 |

**Formulation Metrics Green Supply Chain Operations Reference**

The preparation of criteria, attributes, and performance indicators refers to each green objective for each stakeholder. Each parameter is adopted from previous case studies. One of the determinations of this process is consideration of performance indicators on products returns, which fulfill the concept of food safety that the company must be able to ensure the safe production and environmentally friendly product, so there are no complaints from the customer regarding products that are not following the food safety and environmental concern. However, some parameters such as criteria and indicators in fuel consumption are added to develop the parameter (See table 2). Fuel consumption constitutes a significant proportion of emissions through agriculture, especially fuel that comes from fossil [15]. Therefore, determining the indicator is essential to reduce emission through the efficient use of fossil fuel from various agricultural activities [16]. In addition, enable criteria are added to know how exactly the industry is managing the human resources on the supply chain [7].

**Table 2.** GSCOR metrics

| Criteria | Configuration | Attributes | No | Performance indicator | References |
|---|---|---|---|---|---|
| Plan | Plan make , deliver | Reliability | 1 | Energy usage | [17,18] |
| | | | 2 | Water usage | |
| | | | 3 | Fuel consumption | |
| Source | Source stocked product | Reliability | 4 | % Synthetic chemical usage | [9,19] |
| | | | 5 | % Supplier with an EMS or ISO 14001 certification | |
| | | | 6 | % of suppliers meeting environmental metrics/criteria | |
| | | | 7 | % of hazardous material in inventory | |
| Make | Make to stock | Reliability | 8 | % Material efficiency | [20,21] |
| | | | 9 | % of recycleable product waste/scrap from production | |
| | | | 10 | % Hazardous waste as % of total waste | |
| | | | 11 | % Hazardous waste treatment | |
| Deliver | Deliver stocked product | Reliability | 12 | % of vehicle fuel derived from alternative fuels | [8] |
| Return | Return defective product | Reliability | 13 | % of product return | [10,21] |
| | | Responsiveness | 14 | % of complaints regarding missing environmental requirements from product | |
| Enable | Manage supply chain human resources | Assets | 15 | % Employee trained on enviromental requirements | [8] |

Metrics that have been used to measure the green supply chain model are defined as follows:

1. Energy usage (KPI1) is the total electricity used to produce products. Unit: kwh/ton
2. Water usage (KPI2) is the total use of water to produce products. Unit: m3/ton
3. Fuel consumption (KPI3) is the total use of fossil fuel, for example, solar, to deliver or produce products. Unit: liter/ton
4. % Synthetic chemical usage (KP4) is the percentage of total pesticides or other chemical in the production system, such as controlling pests and washing products.
5. % Suppliers with an EMS or ISO 14001 (KPI5) the portion of the overall supply companies with ecological accreditation.
6. % of suppliers meeting environmental metrics or criteria (KPI6) is the percentage of suppliers with environmentally friendly products or an agreement with the company.
7. % Hazardous materials in inventory (KPI7) is the percentage of materials that are unable to be recycled and causing environmental damage.
8. % Material efficiency (KPI8) is the percentage of raw material usage in production.
9. % of recyclable product waste or scrap (KPI9) is the percentage of recycled products in production.
10. % Hazardous waste as % of total waste (KPI10) is the percentage of hazardous waste such as chemical and non-recycled material.
11. % Hazardous waste treatment (KPI11) is the percentage of recycled hazardous waste.
12. % of vehicle fuel derived from alternative fuels (KPI12) is the percentage of total vehicles that are environmentally friendly.
13. % of product return (KPI13) is the percentage of returns from the customer.

14. % of complaints regarding missing environmental requirements from product (KPI14) is the number of customer complaints regarding the environment.
15. % employee trained on environmental requirements (KPI15) is the percentage of the number of workers equipped with knowledge of environmental friendliness.

The result from the GSCOR metric is configured to follow towards the accomplishment of the green objective through the performance indicator displayed in table 3.

**Table 3.** 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 |

**Weighting Result**

Weighting result is calculated using Expert Choice software v.11 that shows the weight of all the criteria, attributes, and performance indicators. The overall results on the weighting are shown in table 4. Based on table 4, the weighting results from the perspective of the most significant final weight on the enable criteria with attributes of assets, and KPI15, which are indicators of employee management in environmental training, are 0.453. Meanwhile, the final weight with the most negligible value is the return criteria on the responsiveness attribute regarding KPI14, which means that complaint handling has a total weight of 0.005.

**Table 4.** Weighting Result

| Criteria | Weight | Attributes | Weight | Performance indicator | Weight | Total weight |
|---|---|---|---|---|---|---|
| Plan | 0.190 | Reliability | 1 | KPI 1 | 0.054 | 0.010 |
| | | | | KPI 2 | 0.249 | 0.047 |
| | | | | KPI 3 | 0.105 | 0.020 |
| | | | | KPI 4 | 0.592 | 0.112 |
| Source | 0.190 | Reliability | 1 | KPI 5 | 0.091 | 0.017 |
| | | | | KPI 6 | 0.091 | 0.017 |
| | | | | KPI 7 | 0.818 | 0.155 |
| Make | 0.105 | Reliability | 1 | KPI 8 | 0.278 | 0.029 |
| | | | | KPI 9 | 0.043 | 0.005 |
| | | | | KPI 10 | 0.251 | 0.026 |
| | | | | KPI 11 | 0.428 | 0.045 |
| Deliver | 0.032 | Reliability | 1 | KPI 12 | 1 | 0.032 |
| Return | 0.029 | Reliability | 0.833 | KPI 13 | 1 | 0.024 |
| | | Responsiveness | 0.167 | KPI 14 | 1 | 0.005 |
| Enable | 0.453 | Assets | 1 | KPI 15 | 1 | 0.453 |

**Scoring System**

The scoring system uses the OMAX and TLS methods to determine the score and value of the green supply chain performance[22]. The assessment weight in the OMAX technique incorporates input from the AHP method. An example of the matrix calculation on the OMAX method is mentioned in table 5. Table 5 demonstrates that KPI1, KPI2, and KPI4 have a yellow color, representing average performance on every indicator. Also, KPI2 denotes an average performance that shows red color.

After calculating the entire scoring procedure, the overall scoring stages have depicted the outcome in Table 6. As indicated in Table 6, the overall score from each performance indicator gives a value of 6,357 and is categorized as yellow, which implies that the green supply chain is now in the average performance. From fifty 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.

In table 6, each result in several indicators needs to be improved, for example, high priority values in poor categories indicated red. The table shows that three indicators are in the red category (KPI7, KPI2, and KPI10). KPI7 describes hazardous materials stored in inventory, which means dangerous material is used to produce a product. KPI10 is an indicator of hazardous waste generated during the production process. To control and prevent KPI7 and 10, special handling of hazardous materials is required, such as using material safety data sheets. Therefore, the material can be replaced with more environmentally friendly materials such as green oil and lubricants[23] and biodegradable natural rubber latex gloves[24]. KPI2 is an indicator of water use to support the production of a product. To control waste of water, the water pinch analysis method can be added, and that is an approach to calculate the minimal water requirement (MWR) and minimal effluent treatment (MET) [25].

**Table 5.** OMAX Method on Plan-Criteria

| KPI | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Performance | | 225.128 | 210 | 92.908 | 98.822% |
| Scale | 10 | 213.872 | 190 | 83.617 | 88.822% |
| | 9 | 215.480 | 191.429 | 84.944 | 90.251% |
| | 8 | 217.088 | 192.857 | 86.271 | 91.679% |
| | 7 | 218.696 | 194.286 | 87.599 | 93.108% |
| | 6 | 220.304 | 195.714 | 88.926 | 94.536% |
| | 5 | 221.912 | 197.143 | 90.253 | 95.965% |
| | 4 | 223.520 | 198.571 | 91.580 | 97.393% |
| | 3 | 225.128 | 200 | 92.908 | 98.822% |
| | 2 | 228.880 | 208.333 | 96.004 | 99.215% |
| | 1 | 232.632 | 216.667 | 99.101 | 99.607% |
| | 0 | 236.384 | 225 | 102.198 | 100% |
| 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 6.** Scoring Result.

| Performance indicator | Value | Level achievement | Color |
|---|---|---|---|
| KPI 1 | 0.031 | 3 | |
| KPI 2 | 0.085 | 1.800 | |
| KPI 3 | 0.060 | 3 | |
| KPI 4 | 0.337 | 3 | |
| KPI 5 | 0.052 | 3 | |
| KPI 6 | 0.173 | 10 | |
| KPI 7 | 0.233 | 1.497 | |
| KPI 8 | 0.156 | 5.333 | |
| KPI 9 | 0.045 | 10 | |
| KPI 10 | 0.035 | 1.333 | |
| KPI 11 | 0.449 | 10 | |
| KPI 12 | 0.097 | 3 | |
| KPI 13 | 0.024 | 10 | |
| KPI 14 | 0.049 | 10 | |
| KPI 15 | 4.532 | 10 | |
| Total | | 6.357 | |

## Conclusion

According to the result, it can be inferred that the final number of the performance assessment using the GSCOR model is in yellow with a value of 6,357 which represents an average category. This outcome still requires improvement on numerous prioritized metrics that will lead to changing the way business processes in agriculture address environmental challenges. Further research is expected to improve the performance indicators that can be done by establishing standard indicators such as ISO 14001 or export standards from certain locations that have prioritized green industries.

## References


[1] J. B. Krolczyk, P. Sobczak, and W. Zukiewicz-Sobczak, "Sustainable Production in Food and Agriculture Engineering." [Online]. Available: www.mdpi.com/journal/sustainability.

[2] M. Petit *et al.*, "Cooperative Management Sustainable Agricultural Development Challenges and Approaches in Southern and Eastern Mediterranean Countries." [Online]. Available: http://www.springer.com/series/11891.

[3] S. J. Vermeulen, B. M. Campbell, and J. S. I. Ingram, "Climate change and food systems," *Annu. Rev. Environ. Resour.*, vol. 37, pp. 195–222, 2012, doi: 10.1146/annurev-environ-020411-130608.

[4] M. A. Miranda-Ackerman, C. Azzaro-Pantel, and A. A. Aguilar-Lasserre, "A green supply chain network design framework for the processed food industry: Application to the orange juice agrofood cluster," *Comput. Ind. Eng.*, vol. 109, pp. 369–389, 2017, doi: 10.1016/j.cie.2017.04.031.

[5] C. Achillas, D. D. Bochtis, D. Aidonis, and D. Folinas, *Green Supply Chain Management*. 2018.

[6] R. T. Wilkerson and R. Cash, "GreenSCOR Developing a Green Supply Chain Analytical Tool LG101T4 O Logistics Management Institute," Mclean, VA, 2003.

[7] A. S. C. Council, *Supply Chain Operations Reference Model*, vol. 10, no. 2. 2011.

[8] H. Saputra and P. Fithri, "PERANCANGAN MODEL PENGUKURAN KINERJA GREEN SUPPLY CHAIN PULP DAN KERTAS," 2012.

[9] A. Susanty, H. Santosa, and F. Tania, "Penilaian Implementasi Green Supply Chain Management di UKM Batik Pekalongan dengan Pendekatan GreenSCOR," *J. Ilm. Tek. Ind.*, vol. 16, no. 1, p. 56, 2017, doi: 10.23917/jiti.v16i1.3862.

[10] I. B. Suryaningrat and E. N. Erina Rezky, "PENERAPAN METODE GREEN SUPPLY CHAIN OPERATION REFERENCE (GSCOR) PADA PENGOLAHAN RIBBED SMOKE SHEET (RSS) (Studi Kasus Di PTPN XII Sumber Tengah Silo, Jember)," *J. Teknol. Ind. Pertan.*, vol. 15, 2021.

[11] T. L. Saaty, "Fundamentals of the Analytic Hierarchy Process," pp. 15–35, 2001, doi: 10.1007/978-94-015-9799-9_2.

[12] N. Aliafari, M. R. Suryoputro, and N. M. Rahman, "Productivity analysis on batik production line using objective matrix (OMAX) method," *Ind. Eng. Manag. Syst.*, vol. 18, no. 4, pp. 726–734, 2019, doi: 10.7232/iems.2019.18.4.726.

[13] M. A. Wibowo and M. N. Sholeh, "The analysis of supply chain performance measurement at construction project," *Procedia Eng.*, vol. 125, pp. 25–31, 2015, doi: 10.1016/j.proeng.2015.11.005.

[14] I. N. Mukharromah, P. Deoranto, S. A. Mustaniroh, and K. Sita, "Analisis pengukuran kinerja perusahaan dengan metode Green Supply Chain Management ( GSCM ) di unit bisnis teh hitam Analysis of company performance measurement using Green Supply Chain Management Method on bussiness unit of black tea," pp. 48–58, 2017.

[15] B. Jaiswal and M. Agrawal, "Carbon Footprints of Agriculture Sector," *Environ. Footprints Eco-Design Prod. Process.*, pp. 81–99, 2020, doi: 10.1007/978-981-13-7916-1_4.

[16] P. . Gerber *et al.*, *Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities*. Rome, 2013.

[17] F. Pulansari and A. Putri, "Green Supply Chain Operation Reference (Green SCOR) Performance Evaluation (Case Study: Steel Company)," *J. Phys. Conf. Ser.*, vol. 1569, no. 3, 2020, doi: 10.1088/1742-6596/1569/3/032006.

[18] A. Susanty, R. Putri, N. Hidayatika, and F. Jie, "Using GreenSCOR to measure performance of the supply chain of furniture industry," 2016.

[19] S. A. Mustaniroh, Z. Alvian, F. Kurniawan, and P. Deoranto, "Evaluasi Kinerja pada Green Supply Chain Management Susu Pasteurisasi di Koperasi Agro Niaga Jabung Performance Evaluation on Green Supply Chain Management of Pasteurized Milk at Koperasi Agro Niaga Jabung," vol. 8, pp. 57–66, 2019, doi: 10.21776/ub.industria.2019.008.01.7.

[20] F. Lestari and R. S. Dinata, "Green Supply Chain Management untuk Evaluasi Manajemen Lingkungan Berdasarkan Sertifikasi ISO 14001," *Ind. J. Teknol. dan Manaj. Agroindustri*, vol. 8, no. 3, pp. 209–217, 2019, doi: 10.21776/ub.industria.2019.008.03.5.

[21] B. Tundys and T. Wiśniewski, "The selected method and tools for performance measurement in the green supply chain-survey analysis in Poland," *Sustain.*, vol. 10, no. 2, pp. 1–26, 2018, doi: 10.3390/su10020549.

[22] T. Alda, K. Siregar, and A. Ishak, "Analisis Sistem Pengukuran Kinerja Dengan Metode Integrated Performance Measurement Systems Pada Pt. X," *J. Tek. Ind. USU*, vol. 2, no. 1, pp. 37–41, 2013.

[23] G. Karmakar, P. Ghosh, and B. K. Sharma, "Chemically modifying vegetable oils to prepare green lubricants," *Lubricants*, vol. 5, no. 4, pp. 1–17, 2017, doi: 10.3390/lubricants5040044.

[24] M. A. Misman and A. R. Azura, "Overview on the potential of biodegradable natural Rubber Latex gloves for commercialization," *Adv. Mater. Res.*, vol. 844, pp. 486–489, 2014, doi: 10.4028/www.scientific.net/AMR.844.486.

[25] S. J. Rad and M. J. Lewis, "Water utilisation, energy utilisation and waste water management in the dairy industry: A review," *Int. J. Dairy Technol.*, vol. 67, no. 1, pp. 1–20, 2014, doi: 10.1111/1471-0307.12096.

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


## ABSTRACT

The agriculture industry has proliferated in the last decades, increasing the environmental footprint. There are several development concepts such as integrating the ecological aspect to 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 showed that the performance measurement produces a 6.357 value in the yellow color category or with the average condition. The result from the performance indicator shows 6 KPI in the green, 6 in the yellow, and 3 with the red classification.



**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]. The biggest obstacle faced by the agriculture industry is the challenge of environmental issues[2]. According to Vermeulen et al.[3], 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[4]. Therefore, various concepts have been expertly developed to reduce environmental degradation, such as integrating ecological aspects and supply chain management, which produce green supply chain management concepts[5].

This solution aims to develop the performance of an organization regarding environmental management, performance supply chain, and green supply chain initiation [6,7]. However, measuring the green supply chain performance has been studied across a wide range of industries. Saputra et al. [8] conducted the performance development of pulp and paper companies, leading to integration between internal and external stakeholders. Susanty et al. [9] implemented a green supply chain that focused on developing performance indicators in environmentally friendly raw materials. Suryaningrat et al. [10] determined the development of performance indicators in ribbed smoke sheet companies. According to the previous research, it is seen that different literature illustrates different combinations in developing performance measurement. This study contributes a new approach using GSCOR, AHP, OMAX, and TLS methods and the development approach in a new area based on the needs of the agriculture industry that focus on highland vegetables in several criteria, attributes, and performance indicators.

This research was conducted in a company specializing in agriculture, specifically highland vegetables that do seeding, cultivation, processing, packaging, and export. In adapting the green supply chain idea, the organization needs to examine its operations to ensure that this would construct its performance throughout the ecological area.

**Commented [A1]:** Show significant KPIs that support the achievement of green supply chain performance, not just performance scores.

**Commented [A2]:** Briefly describe performance measurement that integrates internal and external stakeholders. What are the weaknesses or limitations of the measurements he does?

**Commented [A3]:** Is the measurement only environmentally friendly raw materials? Are other supply chain activities not being measured?

**Commented [A4]:** Briefly describe performance measurement in this company. What are the weaknesses of their measurements?

**Commented [A5]:** In accordance with the object studied in this research, explain what the research gap or lack of measurements from previous researches is?

**Commented [A6]:** Explain this statement by comparing it with the method of developing KPIs and calculating performance scores from previous research

## Methods

This research was conducted with the conceptual framework design by examining the entire supply chain of the company, which includes suppliers to the customer. Hence, the concept begins with collecting data, processing the data gradually, and making a conclusion.

### Data Collection

Data was collected through interviews and questionnaires, which produced qualitative and quantitative data. Gathering data through interviews determined the needs of the industry. Collecting with questionnaires was divided into several steps, such as scoring the importance of each parameter with pairwise comparison.

### Systematic of Performance Measurement

Step 1: Designing The Measurement Model
To design the model, the GSCOR process is used to measure the environmental footprint based on the standards [7]. The first stage is designing the green requirement that considers industry, stakeholders, and literature review. Afterwards, the green objectives are developed from the green requirements. The final stage is forming the criteria, attributes, and performance indicator that refers to the green objective for each stakeholder 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 criteria, attributes, and performance indicators [11]. Data process using the AHP method assisted by the Software Expert Choice v.11, which help to calculate the weighting stage.

Step 3: Scoring System
Objective Matrix (OMAX) is applied to generate the performance score and the index for each parameter [12]. OMAX connects every criteria on performance into a model [13]. Moreover, the systematic of the OMAX method is first defined by establishing the level minimum score, which will be the minimum targeted achievement in performance indicators. Afterward, the value or score optimistic and pessimistic is established to determine for scale 10 (Optimistic) and 0 (Pessimistic) in the OMAX metrics (See table 5). To decide other scales in the metrics, it is calculated with an equation below.

$$\Delta X(l,h) = \frac{X(h) - X(l)}{Y(h) - Y(l)} \quad (1)$$

Where,
ΔX (l , h) is interval number level between highest scale and lowest scale
X (h) is high number level scale
X (l) is low number level scale
Y (h) is high value level scale
Y (l) is low value level scale

After determining each value in the scale, determine the level of achievement with current performance. Data weighting from AHP considers fulfilling the weight value in OMAX and multiple by the level of achievement from current performance. The result from OMAX is evaluated using a Traffic Light System (TLS), which measuring the results with three colors; green for an excellent results, yellow as the parameter for an average result, and red is category for poor results[14].

## Result and Discussion

Commented [A7]: It is necessary to explain the relationship or support of each KPI (15 KPI) to the objective of green supply chain performance.

This section shows the result of calculating performance from designing the model to a scoring system. For each stage, we discussed the model result, which consists of green requirement, green objective, and the GSCOR metrics. Then we use the parameters to apply the weighting and scoring system to identify performance.

### Green Requirements Identification

The preparation of green requirements consists of the needs from the industry that consider environmental aspects. Green requirements show the stakeholders are a part of the company concerned in the supply chain system, so defining the stakeholder will lead to the needs of each part of it. The following content is an overview of the green requirements with the code for each condition.

***Supplier***
1. Environmentally friendly material or substance (GR1).
2. Environmental Management System (EMS) or ISO 14001 certification (GR2).

***Direct Employee***
1. The employee understanding of Standard Operation Procedure (SOP) in the assigned task (GR3).
2. Training on environmental aspects and job requirements (GR4).

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

***Logistic***
1. Availability of packaging materials and storage media for delivery by the terms and the required quantity (GR 8).
2. Cleaner warehouse operation (GR9).
3. Complete shipping documentation and reliable information system (GR10).

***Marketing***
1. Legal and environmentally friendly requirements to minimize the number of customer complaints (GR 11).
2. Convenience administration (Document requirement, Estimate Time Arrival (ETA), etc.) (GR 12).

***Purchasing***
1. Purchase of environmentally friendly goods (GR 13).
2. Reliable information system to procure goods (GR 14).
3. Supplier monitoring (GR 15).

### Green Objective Identification

The objective is the result to be achieved at a particular time. The determination of the goal is considered with the correlation of stakeholder needs, such as selecting the right supplier according to environmental friendliness, which is considered by purchasing who needs to order environmentally friendly material. Table 1 illustrates the output of completing the green requirements with green objectives.

**Table 1.** Green Objective

| No | Green objective | Stakeholder | Realization of green requirement |
|---|---|---|---|
| 1 | Selection of the right supplier according to environmental friendliness | Purchasing | GR13 |
| 2 | Environmentally fiendly supplier performance | Supplier, purchasing | GR1, GR15 |
| 3 | Delivery with enviromental aspect | Supplier, purchasing, logistic Supplier, direct | GR2, GR5, GR8, GR9, GR10, GR14 |
| 4 | Minimize the use of hazardous materials | 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 |

**Formulation Metrics Green Supply Chain Operations Reference**

The preparation of criteria, attributes, and performance indicators refers to each green objective for each stakeholder. Each parameter is adopted from previous case studies. One of the determinations of this process is consideration of performance indicators on products returns, which fulfill the concept of food safety that the company must be able to ensure the safe production and environmentally friendly product, so there are no complaints from the customer regarding products that are not following the food safety and environmental concern. However, some parameters such as criteria and indicators in fuel consumption are added to develop the parameter (See table 2). Fuel consumption constitutes a significant proportion of emissions through agriculture, especially fuel that comes from fossil [15]. Therefore, determining the indicator is essential to reduce emission through the efficient use of fossil fuel from various agricultural activities [16]. In addition, enable criteria are added to know how exactly the industry is managing the human resources on the supply chain [7].

**Table 2.** GSCOR metrics

| Criteria | Configuration | Attributes | No | Performance indicator | References |
|---|---|---|---|---|---|
| Plan | Plan make , deliver | Reliability | 1 | Energy usage | [17,18] |
| | | | 2 | Water usage | |
| | | | 3 | Fuel consumption | |
| Source | Source stocked product | Reliability | 4 | % Synthetic chemical usage | [9,19] |
| | | | 5 | % Supplier with an EMS or ISO 14001 certification | |
| | | | 6 | % of suppliers meeting environmental metrics/criteria | |
| | | | 7 | % of hazardous material in inventory | |
| Make | Make to stock | Reliability | 8 | % Material efficiency | [20,21] |
| | | | 9 | % of recycleable product waste/scrap from production | |
| | | | 10 | % Hazardous waste as % of total waste | |
| | | | 11 | % Hazardous waste treatment | |
| Deliver | Deliver stocked product | Reliability | 12 | % of vehicle fuel derived from alternative fuels | [8] |
| Return | Return defective product | Reliability | 13 | % of product return | [10,21] |
| | | Responsiveness | 14 | % of complaints regarding missing environmental requirements from product | |
| Enable | Manage supply chain human resources | Assets | 15 | % Employee trained on enviromental requirements | [8] |

Metrics that have been used to measure the green supply chain model are defined as follows:

1. Energy usage (KPI1) is the total electricity used to produce products. Unit: kwh/ton
2. Water usage (KPI2) is the total use of water to produce products. Unit: m3/ton
3. Fuel consumption (KPI3) is the total use of fossil fuel, for example, solar, to deliver or produce products. Unit: liter/ton
4. % Synthetic chemical usage (KP4) is the percentage of total pesticides or other chemical in the production system, such as controlling pests and washing products.
5. % Suppliers with an EMS or ISO 14001 (KPI5) the portion of the overall supply companies with ecological accreditation.
6. % of suppliers meeting environmental metrics or criteria (KPI6) is the percentage of suppliers with environmentally friendly products or an agreement with the company.
7. % Hazardous materials in inventory (KPI7) is the percentage of materials that are unable to be recycled and causing environmental damage.
8. % Material efficiency (KPI8) is the percentage of raw material usage in production.
9. % of recyclable product waste or scrap (KPI9) is the percentage of recycled products in production.
10. % Hazardous waste as % of total waste (KPI10) is the percentage of hazardous waste such as chemical and non-recycled material.
11. % Hazardous waste treatment (KPI11) is the percentage of recycled hazardous waste.
12. % of vehicle fuel derived from alternative fuels (KPI12) is the percentage of total vehicles that are environmentally friendly.
13. % of product return (KPI13) is the percentage of returns from the customer.

14. % of complaints regarding missing environmental requirements from product (KPI14) is the number of customer complaints regarding the environment.
15. % employee trained on environmental requirements (KPI15) is the percentage of the number of workers equipped with knowledge of environmental friendliness.

The result from the GSCOR metric is configured to follow towards the accomplishment of the green objective through the performance indicator displayed in table 3.

**Table 3.** 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 |

**Weighting Result**

Weighting result is calculated using Expert Choice software v.11 that shows the weight of all the criteria, attributes, and performance indicators. The overall results on the weighting are shown in table 4. Based on table 4, the weighting results from the perspective of the most significant final weight on the enable criteria with attributes of assets, and KPI15, which are indicators of employee management in environmental training, are 0.453. Meanwhile, the final weight with the most negligible value is the return criteria on the responsiveness attribute regarding KPI14, which means that complaint handling has a total weight of 0.005.

**Table 4.** Weighting Result

| Criteria | Weight | Attributes | Weight | Performance indicator | Weight | Total weight |
|---|---|---|---|---|---|---|
| Plan | 0.190 | Reliability | 1 | KPI 1 | 0.054 | 0.010 |
| | | | | KPI 2 | 0.249 | 0.047 |
| | | | | KPI 3 | 0.105 | 0.020 |
| | | | | KPI 4 | 0.592 | 0.112 |
| Source | 0.190 | Reliability | 1 | KPI 5 | 0.091 | 0.017 |
| | | | | KPI 6 | 0.091 | 0.017 |
| | | | | KPI 7 | 0.818 | 0.155 |
| Make | 0.105 | Reliability | 1 | KPI 8 | 0.278 | 0.029 |
| | | | | KPI 9 | 0.043 | 0.005 |
| | | | | KPI 10 | 0.251 | 0.026 |
| | | | | KPI 11 | 0.428 | 0.045 |
| Deliver | 0.032 | Reliability | 1 | KPI 12 | 1 | 0.032 |
| Return | 0.029 | Reliability | 0.833 | KPI 13 | 1 | 0.024 |
| | | Responsiveness | 0.167 | KPI 14 | 1 | 0.005 |
| Enable | 0.453 | Assets | 1 | KPI 15 | 1 | 0.453 |

**Scoring System**

The scoring system uses the OMAX and TLS methods to determine the score and value of the green supply chain performance[22]. The assessment weight in the OMAX technique incorporates input from the AHP method. An example of the matrix calculation on the OMAX method is mentioned in table 5. Table 5 demonstrates that KPI1, KPI2, and KPI4 have a yellow color, representing average performance on every indicator. Also, KPI2 denotes an average performance that shows red color.

After calculating the entire scoring procedure, the overall scoring stages have depicted the outcome in Table 6. As indicated in Table 6, the overall score from each performance indicator gives a value of 6,357 and is categorized as yellow, which implies that the green supply chain is now in the average performance. From fifty 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.

In table 6, each result in several indicators needs to be improved, for example, high priority values in poor categories indicated red. The table shows that three indicators are in the red category (KPI7, KPI2, and KPI10). KPI7 describes hazardous materials stored in inventory, which means dangerous material is used to produce a product. KPI10 is an indicator of hazardous waste generated during the production process. To control and prevent KPI7 and 10, special handling of hazardous materials is required, such as using material safety data sheets. Therefore, the material can be replaced with more environmentally friendly materials such as green oil and lubricants[23] and biodegradable natural rubber latex gloves[24]. KPI2 is an indicator of water use to support the production of a product. To control waste of water, the water pinch analysis method can be added, and that is an approach to calculate the minimal water requirement (MWR) and minimal effluent treatment (MET) [25].

**Table 5.** OMAX Method on Plan-Criteria

| KPI | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Performance | | 225.128 | 210 | 92.908 | 98.822% |
| Scale | 10 | 213.872 | 190 | 83.617 | 88.822% |
| | 9 | 215.480 | 191.429 | 84.944 | 90.251% |
| | 8 | 217.088 | 192.857 | 86.271 | 91.679% |
| | 7 | 218.696 | 194.286 | 87.599 | 93.108% |
| | 6 | 220.304 | 195.714 | 88.926 | 94.536% |
| | 5 | 221.912 | 197.143 | 90.253 | 95.965% |
| | 4 | 223.520 | 198.571 | 91.580 | 97.393% |
| | 3 | 225.128 | 200 | 92.908 | 98.822% |
| | 2 | 228.880 | 208.333 | 96.004 | 99.215% |
| | 1 | 232.632 | 216.667 | 99.101 | 99.607% |
| | 0 | 236.384 | 225 | 102.198 | 100% |
| 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 6.** Scoring Result.

| Performance indicator | Value | Level achievement | Color |
|---|---|---|---|
| KPI 1 | 0.031 | 3 | |
| KPI 2 | 0.085 | 1.800 | |
| KPI 3 | 0.060 | 3 | |
| KPI 4 | 0.337 | 3 | |
| KPI 5 | 0.052 | 3 | |
| KPI 6 | 0.173 | 10 | |
| KPI 7 | 0.233 | 1.497 | |
| KPI 8 | 0.156 | 5.333 | |
| KPI 9 | 0.045 | 10 | |
| KPI 10 | 0.035 | 1.333 | |
| KPI 11 | 0.449 | 10 | |
| KPI 12 | 0.097 | 3 | |
| KPI 13 | 0.024 | 10 | |
| KPI 14 | 0.049 | 10 | |
| KPI 15 | 4.532 | 10 | |
| Total | | 6.357 | |

## Conclusion

According to the result, it can be inferred that the final number of the performance assessment using the GSCOR model is in yellow with a value of 6,357 which represents an average category. This outcome still requires improvement on numerous prioritized metrics that will lead to changing the way business processes in agriculture address environmental challenges. Further research is expected to improve the performance indicators that can be done by establishing standard indicators such as ISO 14001 or export standards from certain locations that have prioritized green industries.

**Commented [A8]:** it is necessary to show strategic KPIs, namely KPIs that have a strong relationship or significantly support green supply chain performance, not limited to environmental performance scores that show the company's environmental performance achievements that are used as case studies.

## References


[1] J. B. Krolczyk, P. Sobczak, and W. Zukiewicz-Sobczak, "Sustainable Production in Food and Agriculture Engineering." [Online]. Available: www.mdpi.com/journal/sustainability.

[2] M. Petit *et al.*, "Cooperative Management Sustainable Agricultural Development Challenges and Approaches in Southern and Eastern Mediterranean Countries." [Online]. Available: http://www.springer.com/series/11891.

[3] S. J. Vermeulen, B. M. Campbell, and J. S. I. Ingram, "Climate change and food systems," *Annu. Rev. Environ. Resour.*, vol. 37, pp. 195–222, 2012, doi: 10.1146/annurev-environ-020411-130608.

[4] M. A. Miranda-Ackerman, C. Azzaro-Pantel, and A. A. Aguilar-Lasserre, "A green supply chain network design framework for the processed food industry: Application to the orange juice agrofood cluster," *Comput. Ind. Eng.*, vol. 109, pp. 369–389, 2017, doi: 10.1016/j.cie.2017.04.031.

[5] C. Achillas, D. D. Bochtis, D. Aidonis, and D. Folinas, *Green Supply Chain Management*. 2018.

[6] R. T. Wilkerson and R. Cash, "GreenSCOR Developing a Green Supply Chain Analytical Tool LG101T4 O Logistics Management Institute," Mclean, VA, 2003.

[7] A. S. C. Council, *Supply Chain Operations Reference Model*, vol. 10, no. 2. 2011.

[8] H. Saputra and P. Fithri, "PERANCANGAN MODEL PENGUKURAN KINERJA GREEN SUPPLY CHAIN PULP DAN KERTAS," 2012.

[9] A. Susanty, H. Santosa, and F. Tania, "Penilaian Implementasi Green Supply Chain Management di UKM Batik Pekalongan dengan Pendekatan GreenSCOR," *J. Ilm. Tek. Ind.*, vol. 16, no. 1, p. 56, 2017, doi: 10.23917/jiti.v16i1.3862.

[10] I. B. Suryaningrat and E. N. Erina Rezky, "PENERAPAN METODE GREEN SUPPLY CHAIN OPERATION REFERENCE (GSCOR) PADA PENGOLAHAN RIBBED SMOKE SHEET (RSS) (Studi Kasus Di PTPN XII Sumber Tengah Silo, Jember)," *J. Teknol. Ind. Pertan.*, vol. 15, 2021.

[11] T. L. Saaty, "Fundamentals of the Analytic Hierarchy Process," pp. 15–35, 2001, doi: 10.1007/978-94-015-9799-9_2.

[12] N. Aliafari, M. R. Suryoputro, and N. M. Rahman, "Productivity analysis on batik production line using objective matrix (OMAX) method," *Ind. Eng. Manag. Syst.*, vol. 18, no. 4, pp. 726–734, 2019, doi: 10.7232/iems.2019.18.4.726.

[13] M. A. Wibowo and M. N. Sholeh, "The analysis of supply chain performance measurement at construction project," *Procedia Eng.*, vol. 125, pp. 25–31, 2015, doi: 10.1016/j.proeng.2015.11.005.

[14] I. N. Mukharromah, P. Deoranto, S. A. Mustaniroh, and K. Sita, "Analisis pengukuran kinerja perusahaan dengan metode Green Supply Chain Management ( GSCM ) di unit bisnis teh hitam Analysis of company performance measurement using Green Supply Chain Management Method on bussiness unit of black tea," pp. 48–58, 2017.

[15] B. Jaiswal and M. Agrawal, "Carbon Footprints of Agriculture Sector," *Environ. Footprints Eco-Design Prod. Process.*, pp. 81–99, 2020, doi: 10.1007/978-981-13-7916-1_4.

[16] P. . Gerber *et al.*, *Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities*. Rome, 2013.

[17] F. Pulansari and A. Putri, "Green Supply Chain Operation Reference (Green SCOR) Performance Evaluation (Case Study: Steel Company)," *J. Phys. Conf. Ser.*, vol. 1569, no. 3, 2020, doi: 10.1088/1742-6596/1569/3/032006.
[18] A. Susanty, R. Putri, N. Hidayatika, and F. Jie, "Using GreenSCOR to measure performance of the supply chain of furniture industry," 2016.
[19] S. A. Mustaniroh, Z. Alvian, F. Kurniawan, and P. Deoranto, "Evaluasi Kinerja pada Green Supply Chain Management Susu Pasteurisasi di Koperasi Agro Niaga Jabung Performance Evaluation on Green Supply Chain Management of Pasteurized Milk at Koperasi Agro Niaga Jabung," vol. 8, pp. 57–66, 2019, doi: 10.21776/ub.industria.2019.008.01.7.
[20] F. Lestari and R. S. Dinata, "Green Supply Chain Management untuk Evaluasi Manajemen Lingkungan Berdasarkan Sertifikasi ISO 14001," *Ind. J. Teknol. dan Manaj. Agroindustri*, vol. 8, no. 3, pp. 209–217, 2019, doi: 10.21776/ub.industria.2019.008.03.5.
[21] B. Tundys and T. Wiśniewski, "The selected method and tools for performance measurement in the green supply chain-survey analysis in Poland," *Sustain.*, vol. 10, no. 2, pp. 1–26, 2018, doi: 10.3390/su10020549.
[22] T. Alda, K. Siregar, and A. Ishak, "Analisis Sistem Pengukuran Kinerja Dengan Metode Integrated Performance Measurement Systems Pada Pt. X," *J. Tek. Ind. USU*, vol. 2, no. 1, pp. 37–41, 2013.
[23] G. Karmakar, P. Ghosh, and B. K. Sharma, "Chemically modifying vegetable oils to prepare green lubricants," *Lubricants*, vol. 5, no. 4, pp. 1–17, 2017, doi: 10.3390/lubricants5040044.
[24] M. A. Misman and A. R. Azura, "Overview on the potential of biodegradable natural Rubber Latex gloves for commercialization," *Adv. Mater. Res.*, vol. 844, pp. 486–489, 2014, doi: 10.4028/www.scientific.net/AMR.844.486.
[25] S. J. Rad and M. J. Lewis, "Water utilisation, energy utilisation and waste water management in the dairy industry: A review," *Int. J. Dairy Technol.*, vol. 67, no. 1, pp. 1–20, 2014, doi: 10.1111/1471-0307.12096.

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

**Arjuna[1], Santoso[2*], Rainisa Maini Heryanto[3]**
[1,2,3]Faculty of Engineering, Department of Industrial Engineering, Universitas Kristen Maranatha
Jl. Prof. drg. Surya Sumantri M.P.H. No. 65, Bandung 40164
Email: junaar99@gmail.com, santoso@eng.maranatha.edu, rainisa.mh@eng.maranatha.edu

## ABSTRACT

The agriculture industry has proliferated in the last decades, increasing the environmental footprint. There are several development concepts such as integrating the ecological aspect to 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 showed that the criteria from parameter enable, which indicate the amount of realization to manage the employee on the environmental requirement, is crucial to impact the supply chain performance. Other criteria are also important, such as plan that consider the usage of every entity and source that consider 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 3 Key Performance Indicators (KPI), such as KPI 2, KPI7, and KPI10, 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]. The biggest obstacle faced by the agriculture industry is the challenge of environmental issues [2]. According to Vermeulen et al. [3], 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 [4]. Therefore, various concepts have been expertly developed to reduce environmental degradation, such as integrating ecological aspects and managing the supply chain, which produces green supply chain concepts [5].

This solution aims to develop the performance of an organization regarding environmental management, performance, and green initiation [6,7]. However, measuring performance in the green supply chain has been studied across a wide range of industries. Saputra et al. [8] conducted the performance development of pulp and paper companies that led to the integration between internal and external stakeholders in their supply chain such as the requirement for supplier and government or regulator with the limitation in following the systematic of SCOR model. Susanty et al. [9] implemented a green supply chain practice in small and medium enterprises that focused on batik business using an importance-performance analysis to concentrate more on their performance result on improving the performance indicators of using environmentally friendly raw materials. Suryanigrat et al. [10] determined the implementation of a green supply chain by evaluating and measuring the performance of ribbed smoke sheet companies, which minor detail on the measurement of entities between indicator and analysis of each parameter. According to the previous research, it is seen that various literature different combinations in developing performance measurement. 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.

**Commented [A1]:** Reviewer A:
Show significant KPIs that support the achievement of green supply chain performance, not just performance scores.

**Commented [A2R1]:** Response: According to the result, parameters that show a significant role in the measurement are criteria enable, including KPI 15 and criteria from plan and source that should be considered too as the essential aspect for measuring the supply chain performance.

**Commented [A3]:** Reviewer A: Briefly describe performance measurement that integrates internal and external stakeholders. What are the weaknesses or limitations of the measurements he does?

**Commented [A4R3]:** Response: the integrated from internal and external stakeholder are namely as supplier until the government or regulator.

According to the journal, the journal declares that the research is not following the systematic SCOR model but still considering the model.

**Commented [A5]:** Reviewer A: Is the measurement only environmentally friendly raw materials? Are other supply chain activities not being measured?

**Commented [A6R5]:** Response: They measured all the supply chain activity using IPA. However, after they got the result, they focused on improving the performance indicators in raw materials.

**Commented [A7]:** Reviewer A: Briefly describe performance measurement in this company. What are the weaknesses of their measurements?

**Commented [A8R7]:** Response: The determination aspect to measure in each parameter are not inform in detail.

**Commented [A9]:** Reviewer A: In accordance with the object studied in this research, explain what the research gap or lack of measurements from previous researches is?

**Commented [A10R9]:** Response: To the best our knowledge, there is no literature from Indonesia using GSCOR to measure the supply chain performance in the agriculture sector that focuses on highland vegetables.

This study contributes a new approach to the development of performance measurement using the conditions of industries with various literature in several criteria, attributes, performance indicators, and combination models with Analytical Hierarchy Process (AHP), Objective Matrix (OMAX), and Traffic Light System (TLS). The new approach delivers the priority scale, integrating all over parameters with different objectives in one scale and analyzing more easily to classify the priority categories for generating the performance measurement in highland vegetable industries. Furthermore, these method combinations are never been used to measure the supply chain performance with the GSCOR approach.

This research was conducted in a company specializing in agriculture, specifically highland vegetables that do seeding, cultivation, processing, and packaging, with focusing on export segment like Japan and Singapore. The company are comforted with multiple problem in the expert segment that should be meet the requirement such as green company and green products. Although, to ensure that the company can fulfill the requirement on their products and business process, the organization needs to examine its operations through ecological area.

**Commented [A11]:** Reviewer A: Explain this statement by comparing it with the method of developing KPIs and calculating performance scores from previous research

Reviewer B:
-What is the consideration for using these methods? What are the advantages of these methods compared to previous studies?
- The research gap is not clearly defined

**Commented [A12R11]:** Response: The consideration to generate the parameter are using the needs of industri according to the company and several literatures in GSCOR.

Combining each method will deliver a priority scale, integrating all parameters with one scale and analyzing more easily in one category.

## Methods

This research was conducted with the conceptual framework design by examining the entire supply chain of the company, which includes suppliers to the customer. Hence, the concept begins with collecting data, processing the data gradually, and making a conclusion.

### Data Collection

Data was collected through interviews and questionnaires, which produced qualitative and quantitative data. Gathering data through interviews determined the needs of the industry. Collecting questionnaires was divided into several steps, such as scoring the importance of each parameter with pairwise comparison.

### Systematic of Performance Measurement

Step 1: Designing The Measurement Model
To design the model, the GSCOR process is used to measure the environmental footprint based on the standards [7]. 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 indicator that refers to the green objective for each stakeholder 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 criteria, attribute, and performance indicators [11]. Data process using the AHP method assisted by the Software Expert Choice v.11, which helps to calculate the weighting stage.

Step 3: Scoring System
Objective Matrix (OMAX) is applied to generate the performance score and the index for each parameter [12]. OMAX connects every criteria on performance into a model [13]. Moreover, the systematic of the OMAX method is first defined by establishing the level minimum score, which will be the minimum targeted achievement in performance indicators. Afterward, the value or score optimistic and pessimistic is established to determine for scale 10 (Optimistic) and 0 (Pessimistic) in the OMAX metrics (see Table 5). To decide other scales in the metrics, it is calculated with an equation below.

$$\Delta X(l,h) = \frac{Y(h)-Y(l)}{X(h)-X(l)} \quad (1)$$

Where,
$\Delta X(l, h)$ is the interval number level between the highest scale and lowest scale
$X(h)$ is a high number level scale
$X(l)$ is a low number level scale
$Y(h)$ is a high-value level scale

$Y(I)$ is a low-value level scale
After determining each value in the scale, determine the level of achievement with current performance. Data weighting from AHP considers fulfilling the weight value in OMAX and multiple by the level of achievement from current performance. The result from OMAX is evaluated using a Traffic Light System (TLS) according to Mukharromah et al. [14] which measures the result with three colors that showed in Table 1 and how to described the value of its performance.

**Table 1.** OMAX Categories

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

## Result and Discussion

This section shows the result of calculating performance from designing the model to a scoring system. For each stage, the model result was discussed, which consists 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 in green areas. Defining the stakeholders will lead to the needs and consideration of measuring performance indicators.

***Supplier***
1. Environmentally friendly material or substance (GR1).
2. Environmental Management System (EMS) or ISO 14001 certification (GR2).

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

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

***Logistic***
1. Availability of packaging materials and storage media for delivery by the terms and the required quantity (GR 8).
2. Cleaner warehouse operation (GR9).
3. Complete shipping documentation and reliable information system (GR10).

***Marketing***
1. Legal and environmentally friendly requirements to minimize the number of customer complaints (GR 11).
2. Convenience administration (Document requirement, Estimate Time Arrival (ETA), etc.) (GR 12).

***Purchasing***
1. Purchase of environmentally friendly goods (GR 13).
2. Reliable information system to procure goods (GR 14).
3. Supplier monitoring (GR 15).

**Commented [A13]:** Reviewer B:
-How do you categorize the three colors and the range?

**Commented [A14R13]:** Response: According to Mukharromah, the level of each achievement are consider as 3 categories such as excellent 8-10 , 3-7 average , 0-2 Poor.

**Commented [A15]:** Reviewer A:
It is necessary to explain the relationship or support of each KPI (15 KPI) to the objective of green supply chain performance.

**Commented [A16R15]:** Response: In generating every KPIs, the requirement and objective are considered as a crucial step to the GSCOR. All the explanation is identified in every section of discussion as below.

**Commented [A17]:** Reviewer B:
How is the process for obtaining the green requirements?

**Commented [A18R17]:** Response: The green requirements are determined by considering stakeholders needs and literature review on performance indicator especially in green sector

### Green Objectives Identification

The green objective is defined by considering the correlation between the green requirements and the goal of the company. The objective is to be achieved at a particular time, which could be different in various industries. For example, the stakeholders in purchasing 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.

**Commented [A19]:** Reviewer B: How do you find the green objective?

**Commented [A20R19]:** Response: The green objectives are considered with the correlation of green requirements and the goal of the company. Every green requirement will be considering to fulfill the green objective as below.

**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 fiendly supplier performance | Supplier, purchasing | GR1, GR15 |
| 3 | Delivery with enviromental 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 |

### Formulation Metrics Green Supply Chain Operations Reference

The preparation of criteria, attributes, and performance indicators refers to each green objective for each stakeholder. Each parameter is adopted from previous case studies. One of the determinations of this process is consideration of performance indicators on products returns, which fulfill the concept of food safety that the company must be able to ensure the safe production and environmentally friendly product, so there are no complaints from the customer regarding products that are not following the food safety and environmental concern. However, some parameters such as criteria and indicators in fuel consumption are added to develop the parameter (See table 3). Fuel consumption constitutes a significant proportion of emissions through agriculture, especially fuel that comes from fossil [15]. Therefore, determining the indicator is essential to reduce emissions through the efficient use of fossil fuels from various agricultural activities [16]. In addition, enable criteria are added to know how exactly the industry is managing the human resources in the supply chain [7].

**Table 3.** GSCOR metrics

| Criteria | Configuration | Attributes | No | Performance indicator | References |
|---|---|---|---|---|---|
| Plan | Plan make, deliver | Reliability | 1 | Energy usage | [17, 18] |
| | | | 2 | Water usage | [18, 19] |
| | | | 3 | Fuel consumption | [15,17] |
| | | | 4 | % Synthetic chemical usage | [8, 20] |
| Source | Source stocked product | Reliability | 5 | % Supplier with an EMS or ISO 14001 certification | [9, 21] |
| | | | 6 | % of suppliers meeting environmental metrics/criteria | [21] |
| | | | 7 | % of hazardous material in inventory | [22] |
| Make | Make to stock | Reliability | 8 | % Material efficiency | [8, 10] |
| | | | 9 | % of recycleable product waste/scrap from production | [18, 21] |
| | | | 10 | % Hazardous waste as % of total waste | [8] |
| | | | 11 | % Hazardous waste treatment | [10] |
| Deliver | Deliver stocked product | Reliability | 12 | % of vehicle fuel derived from alternative fuels | [8] |
| Return | Return defective product | Reliability | 13 | % of product return | [21] |
| | | Responsiveness | 14 | % of complaints regarding missing environmental requirements from product | [10 ,19] |
| Enable | Manage supply chain human resources | Assets | 15 | % Employee trained on enviromental requirements | [17, 8] |

Metrics that have been used to measure the green supply chain model are defined as follows:

1. Energy usage (KPI1) is the total electricity used to produce products. Unit: kWh/ton
2. Water usage (KPI2) is the total use of water to produce products. Unit: m3/ton
3. Fuel consumption (KPI3) is the total use of fossil fuel, for example, solar, to deliver or produce products. Unit: liter/ton
4. % Synthetic chemical usage (KP4) is the percentage of total pesticides or other chemicals in the production system, such as controlling pests and washing products.
5. % Suppliers with an EMS or ISO 14001 (KPI5) are the portion of the overall supply companies with ecological accreditation.
6. % of suppliers meeting environmental metrics or criteria (KPI6) is the percentage of suppliers with environmentally friendly products or an agreement with the company.
7. % Hazardous materials in inventory (KPI7) is the percentage of materials that are unable to be recycled and causing environmental damage.
8. % Material efficiency (KPI8) is the percentage of raw material used in production.
9. % of recyclable product waste or scrap (KPI9) is the percentage of recycled products in production.
10. % Hazardous waste as % of total waste (KPI10) is the percentage of hazardous waste such as chemical and non-recycled material.
11. % Hazardous waste treatment (KPI11) is the percentage of recycled hazardous waste.
12. % of vehicle fuel derived from alternative fuels (KPI12) is the percentage of total vehicles that are environmentally friendly.
13. % of product return (KPI13) is the percentage of returns from the customer.

**Commented [A21]:** Reviewer B:
Please correct Table 3 to make it clear and easier to understand. It is better to give the references on each indicator, so that it can be distinguished whether the indicator has a reference or not

**Commented [A22R21]:** Response: overall, the table 3 has been revised according to the correct guideline and gave all the references in each parameters.

14. % of complaints regarding missing environmental requirements from the product (KPI14) is the number of customer complaints regarding the environment.
15. % employee trained on environmental requirements (KPI15) is the percentage of the number of workers equipped with knowledge of environmental friendliness.

The result from the GSCOR metric is configured to follow the accomplishment of the green objective through the performance indicator displayed in Table 4.

**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<br>KPI2<br>KPI8<br>KPI3 |
| 6 | Minimization and handling of hazardous waste | KPI4<br>KPI10<br>KPI11 |
| 7 | Reuse of resources | KPI9<br>KPI13 |
| 8 | Worker training regarding green business requirements | KPI15 |
| 9 | Food safety | KPI14 |

**Commented [A23]:** Reviewer B: Correct the table according to the journal writing guidelines

**Commented [A24R23]:** Response: Done

**Weighting Result**

The AHP method determines the weighting, which starts by modeling each GSCOR metrics parameter into a hierarchy model (see figure 1). The model considered in building the pairwise comparison metrics that show the relationship between criteria, attributes, and performance indicators using respondents to rate each parameter. Every parameter will calculate using Expert Choice Software V.11, which shows the hierarchy model, consistency index, eigenvalue, and consistency ratio to show the overall result.

**Commented [A25]:** Reviewer B: Explain how the use of AHP to get the weights and the hierarchical structure as well

**Commented [A26R25]:** Response: AHP method using to determine weight from building hierarchy to assign the pairwise comparison metrics.

AHP method calculate using Expert Choice Software in order to get the weighting result.

The overall results of the weighting are shown in Table 5. The weighting result from metrics GSCOR on the enable criteria are the most significant parameters used in the metrics. This criterion showed that the amount of realization in 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 criteria on the return are the most negligible value among other criteria that showed to handle customers.

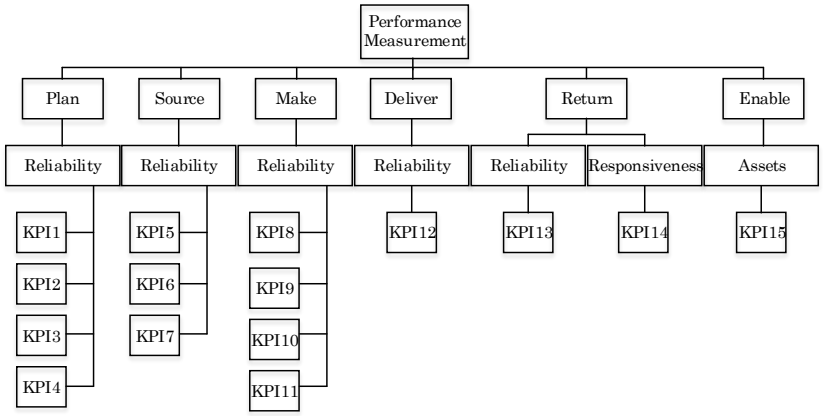



**Figure 1.** Hierarchy Model

**Table 5.** Weighting Result

| 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 |

**Scoring System**

The scoring system uses the OMAX and TLS methods to determine score and value in the green supply chain performance [23]. 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 multiply with the weight of parameters. The assessment weight in the OMAX technique incorporates input from the AHP method and will calculate with the level of achievement (Score) to show the value of each parameter. An example of the matrix calculation on the OMAX method is mentioned in Table 6.

After calculating the entire scoring procedure, the overall scoring stages have depicted in the outcome in Table 6. Table 7 illustrates the scoring system with each parameter's level of achievement and value. For example, the KPI7 is characterized as red color with a 0.233 value which reveals that the hazardous material in inventory is still at a higher number because it does not fulfill the minimum target for the parameter that has been created. Another example is the KPI8 indicated as yellow with 0.156 value recognized as efficiency usage in the raw material; the number of the value meets the minimum of the target in the parameters.

As indicated in Table 7, the overall score from each performance indicator gives a value of 6,357 and is categorized as yellow, which implies that the green supply chain is now in average performance. From fifty 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.

**Commented [A27]:** It should be "fifteen"

In Table 7, each result in several indicators needs to be improved to achieve the objective. The table shows that three indicators are in the red category need to be enhanced immediately in the yellow category. For example, the KPI7, which illustrates the red category, should be improved because of the poor performance of the parameter. The parameter is crucial according to the weight and hazardous material management rather than the KPI8, which showed as a yellow category with average performance on material efficiency. Furthermore, the value from KPI 7 is higher than KPI 8 because of the goals from the company which more focusing to minimize of the hazardous material rather than consideration of the cost from material efficiency, the level of achievement of the KPI 7 should be higher because the importance of the performance indicator, but the company still in the early phase to develop the parameters.

In order to handle the red category, special handling of hazardous material is required to develop the KPI in the red category, such as using a material datasheet. The material can be substituted with more environmentally friendly materials such as green oil lubricants [24], and biodegradable natural rubber latex gloves [25]. To control water waste, the water pinch analysis method can be added to calculate the minimal water requirement (MWR) and minimal effluent treatment (MET) [26].

**Commented [A28]:** Reviewer B:
- Provide analysis from GSCOR model, not only from KPI results
-Please explain the contribution of this research

**Commented [A29R28]:** Response: The analysis from GSCOR model is show in weighting result.

the contribution of this research is to provide the development of each parameter and combination in measuring the supply chain.

**Table 6.** OMAX Method on Plan-Criteria

| KPI | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Performance | | 225.128 | 210 | 92.908 | 98.822% |
| Scale | 10 | 213.872 | 190 | 83.617 | 88.822% |
| | 9 | 215.480 | 191.429 | 84.944 | 90.251% |
| | 8 | 217.088 | 192.857 | 86.271 | 91.679% |
| | 7 | 218.696 | 194.286 | 87.599 | 93.108% |
| | 6 | 220.304 | 195.714 | 88.926 | 94.536% |
| | 5 | 221.912 | 197.143 | 90.253 | 95.965% |
| | 4 | 223.520 | 198.571 | 91.580 | 97.393% |
| | 3 | 225.128 | 200 | 92.908 | 98.822% |
| | 2 | 228.880 | 208.333 | 96.004 | 99.215% |
| | 1 | 232.632 | 216.667 | 99.101 | 99.607% |
| | 0 | 236.384 | 225 | 102.198 | 100% |
| 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 | |
| KPI2 | 0.085 | 1.8 | |
| KPI3 | 0.060 | 3 | |
| KPI4 | 0.337 | 3 | |
| KPI5 | 0.052 | 3 | |
| KPI6 | 0.173 | 10 | |
| KPI7 | 0.233 | 1.497 | |
| KPI8 | 0.156 | 5.333 | |
| KPI9 | 0.045 | 10 | |
| KPI10 | 0.035 | 1.333 | |
| KPI11 | 0.449 | 10 | |
| KPI12 | 0.097 | 3 | |
| KPI13 | 0.024 | 10 | |
| KPI14 | 0.049 | 10 | |
| KPI15 | 4.532 | 10 | |
| Total | | 6.357 | |

**Commented [A30]:** Reviewer B:
Please give the explanation for value compared to level achievement. For example: the level achievement of KPI 7 is lower than KPI 8. However, the value of KPI 7 is higher than KPI 8. What is your justification for it.

**Commented [A31R30]:** Response: explanation is on page 8 in the result of table 7

## Conclusion

According to the result, it can be inferred that the most significant parameter to assess the performance is the parameter from the enable criteria with the importance in realization of governance planning to achieve the green supply chain, especially in highland vegetable industries, and also criteria from plan and source are important to support in the performance measurement. The performance assessment using the GSCOR model is in yellow with a value of 6.357, representing an average category. This outcome still requires improvement on numerous prioritized metrics that will change the way business processes in agriculture address environmental challenges. However, the performance measurement metrics might be different in the other similar companies but this research are meant to be the references for the base of constructing the performance metrics. Further research is expected to improve the performance indicators that can be done by establishing standard indicators such as ISO 14001 or export standards from specific locations that have prioritized green industries.

## References


1. J. B. Krolczyk, P. Sobczak, and W. Zukiewicz-Sobczak, "Sustainable Production in Food and Agriculture Engineering," 2020. [Online]. Available: www.mdpi.com/journal/sustainability.
2. M. Petit *et al.*, "Cooperative Management Sustainable Agricultural Development Challenges and Approaches in Southern and Eastern Mediterranean Countries," 2015. [Online]. Available: http://www.springer.com/series/11891.
3. S. J. Vermeulen, B. M. Campbell, and J. S. I. Ingram, "Climate change and food systems," *Annu. Rev. Environ. Resour.*, vol. 37, pp. 195–222, 2012, doi: 10.1146/annurev-environ-020411-130608.
4. M. A. Miranda-Ackerman, C. Azzaro-Pantel, and A. A. Aguilar-Lasserre, "A green supply chain network design framework for the processed food industry: Application to the orange juice agrofood cluster," *Comput. Ind. Eng.*, vol. 109, pp. 369–389, 2017, doi: 10.1016/j.cie.2017.04.031.
5. C. Achillas, D. D. Bochtis, D. Aidonis, and D. Folinas, *Green Supply Chain Management*. 2018.
6. R. T. Wilkerson and R. Cash, "GreenSCOR Developing a Green Supply Chain Analytical Tool LG101T4 O Logistics Management Institute," Mclean, VA, 2003.
7. A. S. C. Council, *Supply Chain Operations Reference Model*, vol. 10, no. 2. 2011.
8. H. Saputra and P. Fithri, "PERANCANGAN MODEL PENGUKURAN KINERJA GREEN SUPPLY CHAIN PULP DAN KERTAS," 2012.
9. A. Susanty, H. Santosa, and F. Tania, "Penilaian Implementasi Green Supply Chain Management di UKM Batik Pekalongan dengan Pendekatan GreenSCOR," *J. Ilm. Tek. Ind.*, vol. 16, no. 1, p. 56, 2017, doi: 10.23917/jiti.v16i1.3862.
10. I. B. Suryaningrat and E. N. Erina Rezky, "PENERAPAN METODE GREEN SUPPLY CHAIN OPERATION REFERENCE (GSCOR) PADA PENGOLAHAN RIBBED SMOKE SHEET (RSS) (Studi Kasus Di PTPN XII Sumber Tengah Silo, Jember)," *J. Teknol. Ind. Pertan.*, vol. 15, 2021.
11. T. L. Saaty, "Fundamentals of the Analytic Hierarchy Process," pp. 15–35, 2001, doi: 10.1007/978-94-015-9799-9_2.
12. N. Aliafari, M. R. Suryoputro, and N. M. Rahman, "Productivity analysis on batik production line using objective matrix (OMAX) method," *Ind. Eng. Manag. Syst.*, vol. 18, no. 4, pp. 726–734, 2019, doi: 10.7232/iems.2019.18.4.726.
13. M. A. Wibowo and M. N. Sholeh, "The analysis of supply chain performance measurement at construction project," *Procedia Eng.*, vol. 125, pp. 25–31, 2015, doi: 10.1016/j.proeng.2015.11.005.
14. I. N. Mukharromah, P. Deoranto, S. A. Mustaniroh, and K. Sita, "Analisis pengukuran kinerja perusahaan dengan metode Green Supply Chain Management ( GSCM ) di unit bisnis teh hitam Analysis of company performance measurement using Green Supply Chain Management Method on bussiness unit of black tea," pp. 48–58, 2017.
15. B. Jaiswal and M. Agrawal, "Carbon Footprints of Agriculture Sector," *Environ. Footprints Eco-Design Prod. Process.*, pp. 81–99, 2020, doi: 10.1007/978-981-13-7916-1_4.
16. P. . Gerber *et al.*, *Tackling Climate Change Through Livestock: A Global Assessment of Emissions*


**Commented [A32]:** Reviewer A:
it is necessary to show strategic KPIs, namely KPIs that have a strong relationship or significantly support green supply chain performance, not limited to environmental performance scores that show the company's environmental performance achievements that are used as case studies

**Commented [A33R32]:** Response: According to the result, parameters from enable, plan, and source with all the metrics inside (KPIs) are significant to support measurement in supply chain performance.

**Commented [A34]:** Reviewer B:
Check the references writing guidelines

**Commented [A35R34]:** Response: Done

*and Mitigation Opportunities*. Rome, 2013.
17. A. Susanty, R. Putri, N. Hidayatika, and F. Jie, "Using GreenSCOR to measure performance of the supply chain of furniture industry," 2016.
18. S. A. Mustaniroh, Z. Alvian, F. Kurniawan, and P. Deoranto, "Evaluasi Kinerja pada Green Supply Chain Management Susu Pasteurisasi di Koperasi Agro Niaga Jabung Performance Evaluation on Green Supply Chain Management of Pasteurized Milk at Koperasi Agro Niaga Jabung," vol. 8, pp. 57–66, 2019, doi: 10.21776/ub.industria.2019.008.01.7.
19. F. Pulansari and A. Putri, "Green Supply Chain Operation Reference (Green SCOR) Performance Evaluation (Case Study: Steel Company)," *J. Phys. Conf. Ser.*, vol. 1569, no. 3, 2020, doi: 10.1088/1742-6596/1569/3/032006.
20. P. Nicolopoulou-Stamati, S. Maipas, C. Kotampasi, P. Stamatis, and L. Hens, "Chemical Pesticides and Human Health: The Urgent Need for a New Concept in Agriculture," *Front. Public Heal.*, vol. 4, no. July, pp. 1–8, 2016, doi: 10.3389/fpubh.2016.00148.
21. B. Tundys and T. Wiśniewski, "The selected method and tools for performance measurement in the green supply chain-survey analysis in Poland," *Sustain.*, vol. 10, no. 2, pp. 1–26, 2018, doi: 10.3390/su10020549.
22. F. Lestari and R. S. Dinata, "Green Supply Chain Management untuk Evaluasi Manajemen Lingkungan Berdasarkan Sertifikasi ISO 14001," *Ind. J. Teknol. dan Manaj. Agroindustri*, vol. 8, no. 3, pp. 209–217, 2019, doi: 10.21776/ub.industria.2019.008.03.5.
23. T. Alda, K. Siregar, and A. Ishak, "Analisis Sistem Pengukuran Kinerja Dengan Metode Integrated Performance Measurement Systems Pada Pt. X," *J. Tek. Ind. USU*, vol. 2, no. 1, pp. 37–41, 2013.
24. G. Karmakar, P. Ghosh, and B. K. Sharma, "Chemically modifying vegetable oils to prepare green lubricants," *Lubricants*, vol. 5, no. 4, pp. 1–17, 2017, doi: 10.3390/lubricants5040044.
25. M. A. Misman and A. R. Azura, "Overview on the potential of biodegradable natural Rubber Latex gloves for commercialization," *Adv. Mater. Res.*, vol. 844, pp. 486–489, 2014, doi: 10.4028/www.scientific.net/AMR.844.486.
26. S. J. Rad and M. J. Lewis, "Water utilisation, energy utilisation and waste water management in the dairy industry: A review," *Int. J. Dairy Technol.*, vol. 67, no. 1, pp. 1–20, 2014, doi: 10.1111/1471-0307.12096.

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

Feedback and Response:

| Comment | Response | Feedback |
|---|---|---|
| Reviewer A: Show significant KPIs that support the achievement of green supply chain performance, not just performance scores. | According to the result, parameters that show a significant role in the measurement are criteria enable, including KPI 15 and criteria from plan and source that should be considered too as the essential aspect for measuring the supply chain performance. | In the introduction, it is necessary to describe previous research related to KPIs, or it is limited that KPIs are determined according to a reference. |
| Reviewer A: Briefly describe performance measurement that integrates internal and external stakeholders. What are the weaknesses or limitations of the measurements he does? | The integrated from internal and external stakeholder are namely as supplier until the government or regulator.<br><br>According to the journal, the journal declares that the research is not following the systematic SCOR model but still considering the model. | It is in accordance with the reviewer's request. |
| Reviewer A: Is the measurement only environmentally friendly raw materials? Are other supply chain activities not being measured? | They measured all the supply chain activity using IPA. However, after they got the result, they focused on improving the performance indicators in raw materials. | This needs to be explained in the introduction explicitly, just show a few. |
| Reviewer A: Briefly describe performance measurement in this company. What are the weaknesses of their measurements? | The determination aspect to measure in each parameter are not inform in detail. | It is necessary to briefly describe the weaknesses of the performance measurement used by the company so far. |
| Reviewe A: In accordance with the object studied in this research, explain what the research gap or lack of measurements from previous researches is? | To the best our knowledge, there is no literature from Indonesia using GSCOR to measure the supply chain performance in the agriculture sector that focuses on highland vegetables. | It is in accordance with the reviewer's request. |
| Reviewer A: Explain this statement by comparing it with the method of developing KPIs and calculating performance scores from previous research | The consideration to generate the parameter are using the needs of industry according to the company and several literatures in GSCOR.<br><br>Combining each method will deliver a priority scale, | State clearly the needs of the industry. |

| Comment | Response | Feedback |
|---|---|---|
| Reviewer B:<br>-What is the consideration for using these methods? What are the advantages of these methods compared to previous studies?<br>- The research gap is not clearly defined | integrating all parameters with one scale and analyzing more easily in one category. | |
| Reviewer B:<br>-How do you categorize the three colors and the range? | According to Mukharromah, the level of each achievement are consider as 3 categories such as excellent 8-10 , 3-7 average , 0-2 Poor. | |
| Reviewer A:<br>It is necessary to explain the relationship or support of each KPI (15 KPI) to the objective of green supply chain performance. | In generating every KPIs, the requirement and objective are considered as a crucial step to the GSCOR. All the explanation is identified in every section of discussion as below. | It is in accordance with the reviewer's request. |
| How is the process for obtaining the green requirements? | The green requirements are determined by considering stakeholders needs and literature review on performance indicator especially in green sector | |
| Reviewer B: How do you find the green objective? | The green objectives are considered with the correlation of green requirements and the goal of the company. Every green requirement will be considering to fulfill the green objective as below. | |
| Reviewer B:<br>Please correct Table 3 to make it clear and easier to understand. It is better to give the references on each indicator, so that it can be distinguished whether the indicator has a reference or not | overall, the table 3 has been revised according to the correct guideline and gave all the references in each parameters. | |
| Reviewer B: Correct the table according to the journal writing guidelines | Done | |
| Reviewer B: Explain how the use of AHP to get the weights and the hierarchical structure as well | AHP method using to determine weight from building hierarchy to assign the pairwise comparison metrics.<br><br>AHP method calculate using Expert Choice Software in order to get the weighting result. | |

| Comment | Response | Feedback |
|---|---|---|
| Reviewer B:<br>- Provide analysis from GSCOR model, not only from KPI results<br>-Please explain the contribution of this research | The analysis from GSCOR model is show in weighting result.<br><br>The contribution of this research is to provide the development of each parameter and combination in measuring the supply chain. | |
| Reviewer B:<br>Please give the explanation for value compared to level achievement. For example: the level achievement of KPI 7 is lower than KPI 8. However, the value of KPI 7 is higher than KPI 8. What is your justification for it. | explanation is on page 8 in the result of table 7 | |
| Reviewer A:<br>it is necessary to show strategic KPIs, namely KPIs that have a strong relationship or significantly support green supply chain performance, not limited to environmental performance scores that show the company's environmental performance achievements that are used as case studies | According to the result, parameters from enable, plan, and source with all the metrics inside (KPIs) are significant to support measurement in supply chain performance. | It is in accordance with the reviewer's request. |
| Reviewer B:<br>Check the references writing guidelines | Done | |