# Supply chain performance measurement and improvement of palm oil agroindustry: A case study at Riau and Jambi Province

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# Supply chain performance measurement and improvement of palm oil agroindustry: A case study at Riau and Jambi Province

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**Abstract**. Supply chain performance measurement and improvement is required to control the performance and define a strategy to improve agroindustry's competitiveness. The objectives of the research were to identify supply chain configuration and mechanism, and to analyze the supply chain performance and define the supply chain performance improvement for palm oil agroindustry. The research was conducted at Riau Province and Jambi Province as the central palm oil production in Indonesia. The Supply Chain Operation Reference (SCOR) and Analytical Hierarchy Process (AHP) were applied to analyze the supply chain performance and the performance improvement strategies were formulated descriptively with expert discussion. The results showed that the average performance of farmers, traders and refinery at Riau Province were 77.77%, 74.60% and 79.20%. The average performance of farmers, traders and refinery at Riau Province were 72.66%, 75.39% and 83.11%. This research had succeeded to define the strategies to improve palm oil supply chains at Riau Province and Jambi Province. The strategies were focused on good agricultural and good handling practice, specifying the palm oil prices refractions based on quality and implementing the information system to improve the supply chain performance.

**Keywords:** Supply chain, performance improvement, palm oil, SCOR

## 1. Introduction

Oil palm has been recognized as pivotal commodity with high economic value since it is used in various industries, primarily as main ingredient for foods and cosmetics. It serves as economically important plantation product contributing to national economy; Indonesia is also one of the highest palm oil exporters [1]. In terms of domestic demand, numerous palm oil-based industries have been established in downstream sides. Inevitably, this tremendous opportunity needs for exact operationalization, which make palm oil competitiveness significantly increased.

Attempts to elevate the value-addition of the palm oil commodity requires numerous processes and involves stakeholders that are distinct and specifically interconnected. The proper approach to raise competitiveness of the commodity is proposed to use a precise and comprehensive supply chain management (SCM). SCM of palm oil contains attempts and practices for value-addition of the

commodity that connects with stakeholders from diverse sectors in order to meet consumer needs. Primary stakeholders encompassed in value-addition activities of raw material and products in SCM of palm oil included independent farmers, traders, and refinery that have their own business activities and distinctively interconnected each other.

An effort to improve value-added palm oil based on SCM approach can be achieved through measurement and improvement of supply chain performance. The measurement and improvement of supply chain was reported to effectively increase competitiveness of agroindustrial products since it is processed comprehensively and encompassed various measuring dimensions [2]. Improvement of palm oil agroindustry performance necessitates initial information related to its current position; thus, the required main attempt is to understand supply chain performance through comprehensive assessment. Besides, as a part of effort to increase competitiveness, measurement of supply chain performance is also needed to assist agroindustries reaching their formulated goals [3], to map relative position of competitors as well as determine direction of performance improvement [4], manage coordination and integration of supply chain to meet all consumer needs [5,6] and optimize supply chain model for increasing efficiency and effectivity of supply chain.

Enhancement of supply chain performance can be formulated from position of supply chain decomposed from measurement of supply chain measurement. It is also carried out through constructing strategic concepts according to weaknesses and strengths of agroindustries [2], improving relations between supply chain stakeholders [7] or coordinating among supply chain stakeholders in relation to improve performance and efficiency [8]. This current work aimed to design strategy for improving supply chain performance retrieved from measurement of supply chain performance. Therefore, strategy obtained can be in accordance with real objectives of supply chain with regard to improvement of performance and competitiveness of palm oil agroindustry.

This present work aimed to investigate supply chain performance in palm oil agroindustry and determine strategies for improving supply chain performance. The involved stakeholders included independent farmers, trader, and palm oil refinery. The farmers managed their oil palm plantation independently, without help of companies. Location of research was in Riau and Jambi Province as both are considered as the major producers with the greatest number of oil palm farmers in Indonesia.

## 2. Methodology

Construction of strategies for improving supply chain performance needs initial configuration of supply chain, enabling to adjust to the current conditions [9]. Configuration of supply chain was identified according to information including mechanism of supply chain, stakeholders and the roles. In this stage, there is also a need to identify measurement metrics of palm oil agroindustry supply chain, in order to make these metrics calculable based on real conditions.

Metrics used in measuring supply chain performance in palm oil are retrieved from a framework based on *Supply Chain Operation Reference* (SCOR). This is based on [10], that measuring complex supply chain performance such palm oil agroindustry always needs metrics with precise scales. In this case, SCOR is considered a proper standard guide for helping firms to evaluate their performance through identification and measurement of supply chain performance metrics [11]. Therefore, each stakeholder of the supply chain involved in performance measurement can be described by different metrics, depending on business activities of the stakeholder.

The efforts for improving supply chain performance of palm oil are synthesized from situational analysis on measurement and evaluation of the supply chain performance. Such attempts are strategic ways comprehensively constructed in order to accommodate metrics having low performance values for each stakeholder. The strategy developed is practical and tactical, thus it can be directly implemented to raise performance of metrics with low score. Framework of this present work is depicted in figure 1.

*2.1. Identification of supply chain and performance metrics*

Identification of configuration constitutes an initial step for situational analysis in palm oil supply chain, which includes determination of stakeholders and their business activities. In more detail, configuration of supply chain in palm oil agroindustry is identified using framework adopted from [12].

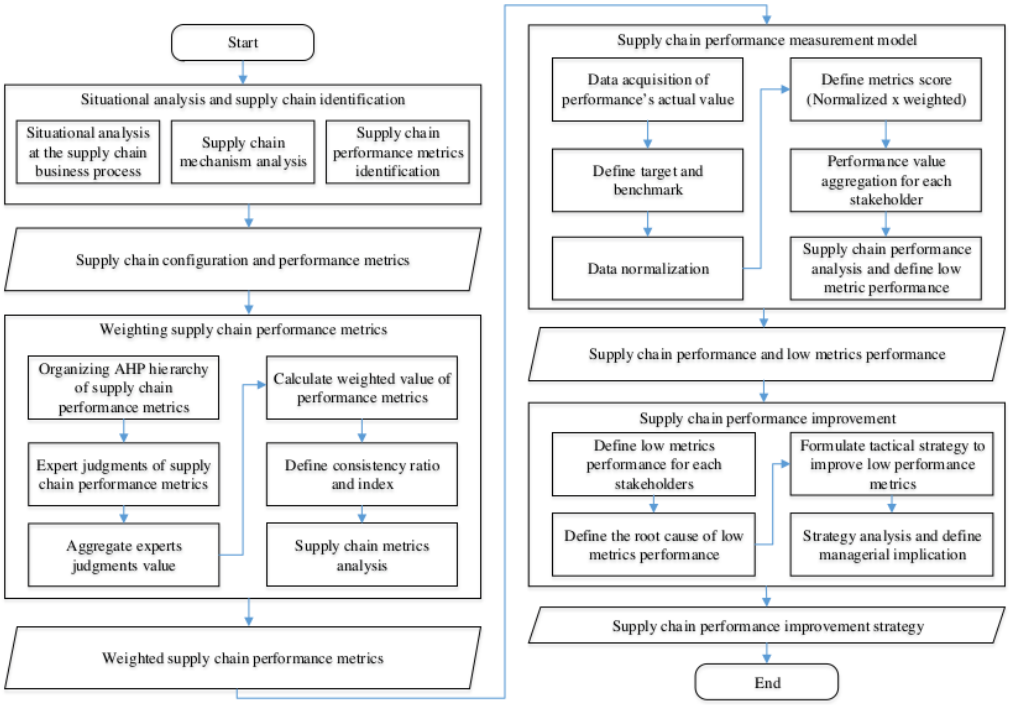


**Figure 1.** Research framework.

This identification stage also needs to determine measurement metrics for supply chain performance that enables to represent each stakeholders. The metrics are required as measurement standard for supply chain performance, thus, performance score can be expressed in both numeric and compared with benchmark. In this case, metrics are adopted from SCOR [13] capable of assessing supply chain performance based on process approach. Using SCOR approach, there are 5 dimensions of supply chain performance measurement, i.e. reliability, responsiveness, agility, cost, and asset management.

*2.2. Weighting the metrics*

Metrics for measuring supply chain performance represent a standard guide for evaluating performance of stakeholders within supply chain, expressed as numeric score and comparable with benchmark. Each model may have dissimilar importance of dimension and metrics, depending on characteristics of agroindustry and business process of the stakeholders [14]. Hence, we need to identify importance of dimension and metrics for assessing performance of each stakeholder in palm oil supply chain.

Determining degree of importance (weighting) of dimension and metrics for measuring supply chain performance was performed by using Analytical Hierarchy Process (AHP). First, hierarchy of metric weighting was set, consisting of purpose level, dimension and metrics for measurement of supply chain performance. Level of metrics importance was determined through pairwise comparison to compare factors collected from experts by the scale 1-9. The pairwise comparison and aggregation of geometric means from 3 experts was calculated using 1, 2 and 3.

$$\bar{X}_{ij} = \sqrt[n]{\prod_{k=1}^{n} X_k} \quad (1)$$

$$\boldsymbol{Y} = \boldsymbol{X} \times \boldsymbol{X} \quad (2)$$

$$W(I_i) = VP_i = \frac{\sum_{j=1}^{J} Y_{ij}}{\sum_{i=1}^{I}\sum_{j=1}^{J} Y_{ij}} \quad (3)$$

Determination of geometric means in decision metric of AHP was presented in row *i* and column *j* ($\bar{X}_{ij}$) in metric $\boldsymbol{X}$ (Formula 1), where $X_k$ means score given by expert k with *n* as number of experts. Subsequently, the metrics $\boldsymbol{X}$ was multiplied by $\boldsymbol{X}$ itself, yielding a new metric **Y**. Afterwards, priority vector for each factor/indicator was determined at performance measurement *i* ($VP_i$), equally expressed as prioritized weight of performance indicator *i* symbolized as $W(I_i)$, in which it was formed by sum of pairwise comparison at line *i* and column *j* ( $\sum_{j=1}^{J} Y_{ij}$) divided by total metric *i, j* ($\sum_{i=1}^{I}\sum_{j=1}^{J} Y_{ij}$).

*2.3. Supply chain performance measurement model for palm oil*

Performance of palm oil agroindustry was assessed using performance metric adopted form SCOR, while the degree of importance was obtained from AHP. The model for measuring palm oil supply chain performance was initiated with determination of standard score and benchmark for each performance metric *(B(Ii))*. This enables to ease normalization and calculation of performance score in each metric *(I(i))*. The metric may possess maximum *(max (i))* or minimum *(min (i))* target in accordance with dimension and score for each metric towards stakeholder objectives.

Normalization of score in each metric according to minimum or maximum target is presented in Formula 4 and 5, respectively. As a reference, minimum and maximum value was obtained from all metric values in all supply chain respondents *(n)*. The reference value for minimum and maximum value for each metric can be observed in Formula 6 and 7. Furthermore, benchmark score for each indicator was obtained from the best score *(B(Ii))* of all regions *(j)* within province according to each indicator, as expressed in Formula 8 and 9.

$$\boldsymbol{N(I_i)} = \begin{cases} \frac{I_i - \min(i)}{B(I_i) - \min(i)} ; \boldsymbol{if\ I_i \le B(I_i)} \\ \boldsymbol{1} \qquad\qquad ; \boldsymbol{if\ I_i \ge B(I_i)} \end{cases} \quad (4)$$

$$\boldsymbol{N(I_i)} = \begin{cases} \boldsymbol{1} \qquad\qquad ; \boldsymbol{if\ I_i \le B(I_i)} \\ \frac{\max(i) - I_i}{\max(i) - B(I_i)} ; \boldsymbol{if\ I_i \ge B(I_i)} \end{cases} \quad (5)$$

$$\boldsymbol{\min(i) = \min(I_1, \ldots, I_n)} \quad (6)$$

$$\boldsymbol{max(i) = max(I_1, \ldots, I_n)} \quad (7)$$

$$\boldsymbol{B(I_i) = max(I_1, \ldots, I_j)} \text{ , if Target = max} \quad (8)$$

$$\boldsymbol{B(I_i) = min(I_1, \ldots, I_j)} \text{ , if Target = min} \quad (9)$$

Normalization results in value for each metric of supply chain performance in the interval [0,1]. Furthermore, performance score of stakeholder is determined according to level of importance for each metric *(W(I(i))* and normalized metric value *(N(I(i))*. The final score of supply chain performance in stakeholder *A* ($K_A$) is obtained from sum of all metric scores *(n)* after multiplied with metric weight and normalized performance metric score, as expressed in Formula 10. The standard value of palm oil supply

chain performance was adopted from [15] with modification in accordance with characteristics of palm oil supply chain performance (table 1).

$$K_A = \sum_{i=1}^{n} W(I_i) \times N(I_i) \quad (10)$$

**Table 1.** Standard score for supply chain performance.

| Performance score (%) | Criteria |
|---|---|
| 85-100 | Excellent |
| 80-84 | Good |
| 70-79 | Moderate |
| 65-69 | Poor |
| 60-64 | Very poor |
| <60 | Bad |

*2.4. Supply chain performance improvement*

Formulation of strategy for improving palm oil supply chain performance was developed according to results of situational analysis and supply chain performance measurement. Afterwards, the selection of the best strategy was obtained from discussion and recommendation from experts. First, to create formulation of strategy begins with identification and analysis of metrics with a poor performance in each stakeholder. Subsequent stage is attempt to find out major cause of such bad performance in each metric. The results of the both activities can be a base for formulating relevant strategies which are practical and tactical solution. Thereby, the strategy is possible to be implemented.

*2.5. Research location and time*

This study was carried out in main producer of palm oil in Indonesia, located in Riau Province and Jambi Province, as reported by [16]. Data were collected from January to March 2019 in both provinces, through some activities, namely field observation, interview with stakeholders (using structured questionnaire), interview, discussion with experts, and focused group discussion involving stakeholders in palm oil supply chain.

*2.6. Data collection*

This present work analyzed primary and secondary data. Secondary data were collected from review of relevant literatures published in scientific journals and research reports, and database sourced from BPS-Statistics, Ministry of Agriculture, Ministry of Industry, Ministry of Commerce, Department of Food Crop and Plantation, Department of Industry and Commerce (province), reports on palm oil agroindustry, national palm oil outlook, and other sources related to agroindustry and farmer's institution in palm oil.

Meanwhile, primary data were collected through several ways as follows:

1. **Field observation**. Researchers collect the data themselves, focusing on operational management and stakeholder activities within supply chain of palm oil agroindustry. First, we need to clarify amount of palm oil producers needed to observe, carried out using stratified sampling by grouping production capacity and location, as presented in table 2 (Riau) and table 3 (Jambi). Afterwards, purposive-snowballing sampling was employed to collect data from independent farmers and traders from palm oil producers.
2. **Interview and discussion.** Data were collected directly from stakeholders involved in palm oil supply chain. We also confirmed our findings during research.
3. **Focus Group Discussion (FGD).** FGD was conducted to recognize current situation of palm oil supply chain in the study sites. Researchers gathered counterparts in both locations from local

institution, palm oil producers, to farmers. This activity is expected to produce the most up-to-date description and constraints in attempt of improving supply chain performance in the study sites.

**Table 2.** Samples to observe at Riau province.

| Region | Number of palm oil-based industry | Number of respondents | | | |
|---|---|---|---|---|---|
| | | Industry by capacity of 30-45 Ton/Hour | Industry by capacity of 120 Ton/Hour | Trader | Farmer |
| Kampar | 35 | 3 | 1 | 8 | 16 |
| Siak | 27 | 3 | 1 | 8 | 16 |
| Rokan Hulu | 39 | 3 | 1 | 8 | 16 |
| Rokan Hilir | 28 | 3 | 1 | 8 | 16 |

**Table 3.** Samples to observe at Jambi province.

| Region | Number of respondents | | |
|---|---|---|---|
| | Palm oil-based industry | Trader | farmer |
| Batanghari | 2 | 4 | 8 |
| Tanjung jabung timur | 2 | 4 | 8 |
| Muaro bungo | 2 | 4 | 8 |
| Merangin | 2 | 4 | 8 |

4. **Expert opinion**. Data were directly collected from experts via questionnaire and direct interview, based on their experience, intuition and knowledges. Determination of involved experts was carried out through puposive sampling, considering their expertise aspects and availability.

## 3. Results and discussion

### *Situation analysis and supply chain configuration*

Indonesia is the one of the main palm oil producers globally with high demands. Along this time, the production of palm oil in Indonesia faces many obstacles in efficiency and productivity. One of the main aspects to consider the low performance of supply chain is stakeholder's coordination in supply chain configuration [17]. Configuration of supply chain was based on primary and secondary stakeholders, focusing on how they meet consumer's demands [18]. Primary stakeholders are defined as actors that play and involve in supply of the raw material, information and finance, while secondary stakeholders exist to assist the business activities of primary stakeholders [2]. Mechanism and configuration of palm oil supply chain is presented as a result of field observation and interviews in Riau and Jambi.

Supply chain performance measurement has an important role to improve and integrate stakeholders in upstream and downstream of the business process [19]. Measurement and improvement of performance is only conducted in primary stakeholders, since they exist as a single actor that performs supply chain activities. Besides, their activities are measurable using numeric scale and comparable with benchmarks. In palm oil supply chain, primary stakeholders include independent farmers, traders, and refinery industries (palm oil producers), as diagrammatically exhibited in figure 2.

The research object with regard to measurement and improvement of the palm oil supply chain performance highlights the role of farmers, traders, and producers. This is in line with [20] and [21] findings that the farmers are so far known to have poor competitiveness, as well as low profitability. In fact, although the independent farmers are larger in number than partnership farmers, their productivity and competitiveness is still weak. In this research, measurement and improvement of the palm oil supply chain performance is focused on independent farmers, traders and palm oil producers, allowing to produce results useful for determining further strategic actions to increase farmer's competitiveness.

Analysis and description of the supply chain actors is directed to the primary stakeholders, which is then employed as base for measurement and improvement of the supply chain performance. The results of analysis describe outputs of field observation and interview with stakeholders in both sites conducted from January to March 2019.

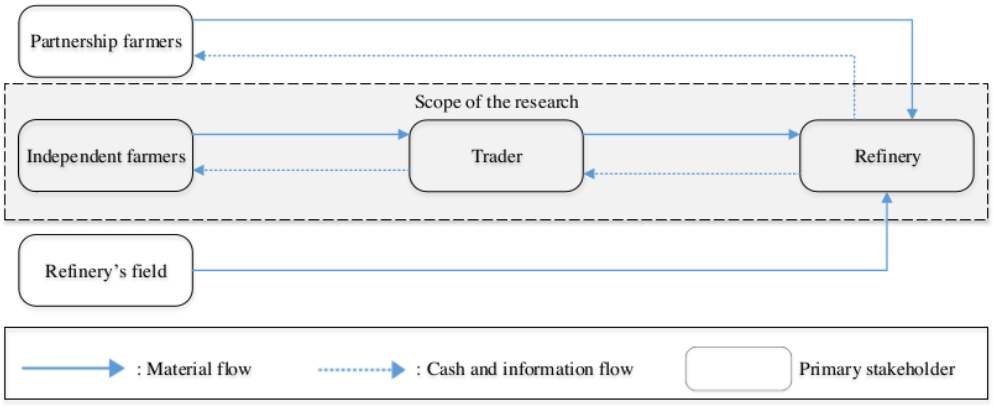


**Figure 2.** Configuration of palm oil supply chain.

*3.1.1. Independent farmers*. Independent farmers act as the top upstream stakeholder, managing the farms using their own knowledge and cost, not related to any firms. Business activities in this stage include land preparation, seeding, fertilization and maintenance, harvesting, payment, fresh fruit bunch (FFB) selling, and distribution. This agricultural sector is consider more profitable compared to other agricultural products, while fresh fruit bunch (FFB) tends to be easily handled.

*3.1.2. Traders*. Traders account for buying FFB from farmers and selling it to palm oil producers. Their business activities must be approved through Delivery Order (DO) issued by palm oil producers. DO document is also important to guarantee the quality of palm fruits, in which the quality already meets the standard and the product is supplied from unconflicting farmers. In short, the core business activities of the traders are (a) buying FFB from independent farmers, (b) selling the FFB to palm oil producers, and (c) transporting FFB from the farmers to palm oil producers. The farmers have role to determine the price at producer level and receive profit as a margin between buying and selling price.

*3.1.3. Refinery (palm oil producer)*. Producers transform FFB as raw material into Crude Palm Oil (CPO) through a set of physical and chemical processes which enhance the value of the product. The buying price by the producers is based on price reference based on agreement of government and stakeholders. However, there is a price gap, which may be due to excessive and deficient supply of FFB in a particular season.

*3.2. Determination of metrics to measuring palm oil supply chain performance*

The performance of palm oil supply chain was assessed in each primary stakeholders, namely independent farmers, traders, and producers. Therefore, the metric needs to be determined in each stakeholder, allowing to assess the performance numerically in all performance dimensions. The metric of supply chain performance is decomposed from performance dimensions, i.e. reliability, responsiveness, agility, cost, and asset management.

The SCOR framework for measuring supply chain performance is made according to business process approach, thus we need to uncover the business process in each stakeholder. Business activities of independent farmers include land preparation, seeding, fertilization and maintenance, harvesting,

payment, and distribution. The metric of supply chain performance is derived from these business activities, resulting in 23 metrics of supply chain performance, elaborated into dimensions as follows: reliability (9 metrics), responsiveness (6 metrics), agility (2 metrics), cost (4 metrics), and asset management (2 metrics). Generally, table 4 presents performance metric, minimum value, maximum value, and benchmark value.

**Table 4.** Performance metrics for measuring supply chain performance in independent farmers.

| No | Business process | Performance metrics | Code | Units | Target |
|---|---|---|---|---|---|
| **Reliability** | | | | | |
| 1 | Harvesting | Production of FFB per harvesting cycle | FSC1-1 | Ton/Ha | Max |
| 2 | Harvesting | Harvesting cycle period | FSC1-2 | | Min |
| 3 | Harvesting | Plant age | FSC1-3 | Year | Min |
| 4 | Harvesting | Number of brondolan per harvesting cycle | FSC1-4 | Kg | Min |
| 5 | Delivery | Availability of transportation facilities | FSC1-5 | Boolean (1/0) | Max |
| 6 | Delivery | Capacity of transportation facilities | FSC1-6 | Ton | Max |
| 7 | Seeding | Certified or not certified seed | FSC1-7 | Boolean (1/0) | Max |
| 8 | Maintenance | Fertilizer certification | FSC1-8 | Boolean (1/0) | Max |
| 9 | Harvesting | Weight of FFB | FSC1-9 | Kg | Max |
| **Responsivity** | | | | | |
| 10 | Seeding | Waiting period for seed supply | FSC2-1 | Day | Min |
| 11 | Land preparation | Period of replanting preparation | FSC2-2 | Month | Min |
| 12 | Maintenance | Period of immature oil palm | FSC2-3 | Year | Min |
| 13 | Harvesting | Harvesting time in each planting cycle | FSC2-4 | Day | Min |
| 14 | Maintenance | Fertilizing cycle | FSC2-5 | Time | Max |
| 15 | Delivery | FFB demand | FSC2-6 | Linguistic (1 – 5) | Max |
| **Agility** | | | | | |
| 16 | Seeding | Number of seed suppliers | FSC3-1 | Individual | Max |
| 17 | Maintenance | Number of fertilizer suppliers | FSC3-2 | Individual | Max |
| **Cost** | | | | | |
| 18 | Land preparation | Preparation cost (New Planting) | FSC4-1 | Rp | Min |
| 19 | Seeding | Seed cost, immature oil palm | FSC4-2 | Rp | Min |
| 20 | Maintenance | Labor cost | FSC4-3 | Rp | Min |
| 21 | Delivery | Delivery cost | FSC4-4 | Rp | Min |
| **Asset management** | | | | | |
| 22 | Payment | Payment contract system | FSC5-1 | Cash/non-cash (0/1) | Max |
| 23 | Payment | Payment period | FSC5-2 | Day | Min |

Regarding to the traders, the metric was derived from following business activities, namely FFB buying, distribution of FFB from farms to palm oil producers, and payment from palm oil producers. Decomposition of business process and dimension of supply chain performance results in 17 metrics, including 9 metrics for reliability dimension, 2 metrics for responsiveness dimension, 1 metric for agility dimension, 3 metrics for cost dimension, and 2 metrics for asset management dimension. The detail is described in table 5.

Regarding to palm oil producers, the metric was derived from theur core business activities, including FFB handling, sortation, payment, and processing, which results in 18 metrics: 4 metrics for reliability dimension, 5 metrics for responsiveness dimension, 2 metrics for agility dimension, 4 metrics for cost dimension, and 3 metrics for asset management dimension, as fully presented in table 6.

**Table 5.** Performance metrics for measuring supply chain performance in traders

| No | Business activities | Performance metrics | Code | Unit | Target |
|---|---|---|---|---|---|
| **I.** | **Reliability** | | | | |
| 1 | FFB purchase | Compliance of FFB demand | TSC1-1 | Linguistic (1 – 5) | Max |
| 2 | FFB purchase | FFB price from farmers | TSC1-2 | Rp/kg | Min |
| 3 | Payment receiving | Selling price of FFB to palm oil producers | TSC1-3 | Rp/kg | Max |
| 4 | FFB purchase | FFB price information | TSC1-4 | Know/not know (1/0) | Max |
| 5 | FFB delivery | Delivery period | TSC1-5 | Time a day | Max |
| 6 | FFB delivery | Number of FFB delivery to palm oil producers | TSC1-6 | Ton | Max |
| 7 | FFB delivery | Number and capacity of transportation facilities | TSC1-7 | Fruit | Max |
| 8 | FFB delivery | Punctuality in FFB delivery | TSC1-8 | % | Max |
| 9 | FFB purchase | Punctuality in FFB pick-up | TSC1-9 | Lingustic (1 – 5) | Max |
| **II.** | **Responsiveness** | | | | |
| 10 | FFB delivery | Frequency of FFB delivery to palm oil producer | TSC2-1 | Time a day | Max |
| 11 | FFB delivery | Duration of FFB delivery from traders to palm oil producers | TSC2-2 | Hour | Min |
| **III.** | **Agility** | | | | |
| 12 | FFB delivery | Fulfillment of extreme demand | TSC3-1 | Number of alternative suppliers | Max |
| **IV.** | **Cost** | | | | |
| 13 | FFB delivery | Retribution cost | TSC4-1 | Rp | Min |
| 14 | FFB delivery | Delivery cost | TSC4-2 | Rp | Min |
| 15 | FFB delivery | Return cost | TSC4-3 | Rp | Min |
| **V.** | **Asset management** | | | | |
| 16 | Payment receiving | Payment contract system | TSC5-1 | Contract/not (1/0) | Max |
| 17 | Payment receiving | Payment period | TSC5-2 | Day | Min |

### *3.3. Weighting the metrics for measuring palm oil supply chain*

The metric weighting aims at determining degree of importance for each metric influential to performance score. It is carried in all stakeholders since they may have various performance metrics. Weighting hierarchy in each stakeholder was first determined. In this work, the hierarchy for all studied stakeholders was successfully constructed after decomposing performance metrics from SCOR and achieving approval from experts, as illustrated in figure 3.

Further step is to determine weight of element in each hierarchy level. The determination of weight for each element was carried out using assessment from experts by means of pairwise comparison between hierarchy levels. Data collected from the experts are treated according to principles of AHP, as obviously exhibited in Formula 1-3. Ultimately, the weight of each metric was then applied to calculate performance of the supply chain. The level of importance in each metric for the studied stakeholders, i.e. independent farmers, traders, and palm oil producers is presented after this section.

**Table 6.** Performance metrics for measuring supply chain performance in palm oil-based industry.

| No | Business activities | Performance metrics | Code | Unit | Target |
|---|---|---|---|---|---|
| **I.** | **Reliabiliy** | | | | |
| 1 | FFB processing | Volume of CPO production and raw material | RSC1-1 | % | Max |
| 2 | FFB processing | CPO production capacity | RSC1-2 | % | Max |
| 3 | FFB sortation | FFB quality | RSC1-3 | % best quality | Max |
| 4 | FFB processing | CPO quality | RSC1-4 | Certified/not(1/0) | Max |
| **II.** | **Responsiveness** | | | | |
| 5 | FFB receiving | Raw material supply cycle | RSC2-1 | Hour | Min |
| 6 | FFB processing | Duration for processing | RSC2-2 | Hour | Min |
| 7 | FFB processing | Production cycle per day | RSC2-3 | Time | Max |
| 8 | FFB processing | Work hour per day | RSC2-4 | Hour | Max |
| 9 | FFB processing | Maintenance cycle | RSC2-5 | Hour | Min |
| **III.** | **Agility** | | | | |
| 10 | FFB receiving | Safety Stock | RSC3-1 | Ton | Max |
| 11 | FFB processing | Overtime | RSC3-2 | Hour | Min |
| **IV.** | **Biaya** | | | | |
| 12 | FFB processing | Raw material cost | RSC4-1 | Rp | Min |
| 13 | FFB processing | Raw material return cost | RSC4-2 | Rp | Min |
| 14 | FFB sortation | Labor salary and management | RSC4-3 | Rp | Min |
| 15 | FFB processing | Energy cost | RSC4-4 | Rp | Min |
| **V.** | **Asset management** | | | | |
| 16 | FFB payment | Payment contract system | RSC5-1 | Contract/not (1/0) | Max |
| 17 | FFB payment | Payment system | RSC5-2 | Cash/non-cash(1/0) | Max |
| 18 | FFB payment | Pay-off period | RSC5-3 | Day | Min |

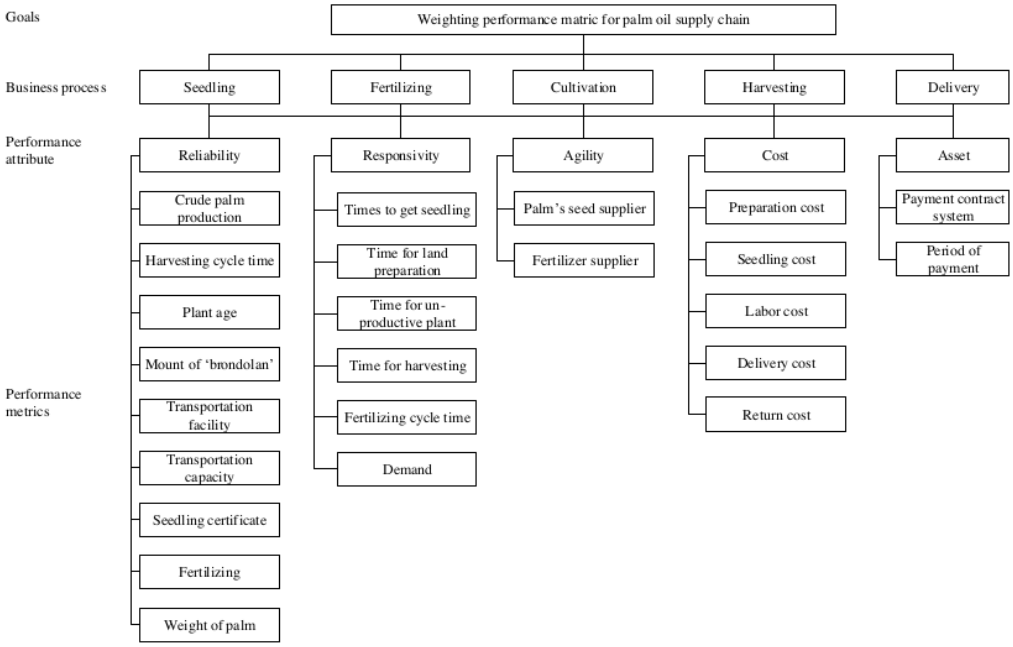


**Figure 3.** Hierarchy for weighting the metrics in measurement of supply chain performance.

### *3.4. Supply chain performance measurement*

Measuring performance of palm oil supply aims at understanding to what extent the efficiency and effectiveness in business activities is performed by stakeholders, with the help of SCOR framework. As previously mentioned, the SCOR framework consists of 5 dimensions, i.e. reliability, responsiveness, and agility (for evaluating effectiveness), cost and asset management (for evaluating efficiency).

SCOR is selected as the framework for developing measurement model since it comprises of dimensions and metrics which are comprehensive, systematic, and able to evaluate stakeholder and formulate strategies for performance improvement [22,23]. This framework allows us to use different metrics for each stakeholder, depending on business activities. Assessment of stakeholder performance is also meaningful for obtaining more detail information related to existing conditions and problems faced by stakeholders.

To measure supply chain performance requires the metrics' weight, actual metrics value, as well as benchmark performance in each stakeholder, which is systematically explained in Formula 9. We also present analysis and description of performance measurement for each palm oil supply chain stakeholder in province of Riau and Jambi. Furthermore, referring to data collection framework, the supply chain performance of both regions was determined, covering 4 regions in each province. The following section discusses analysis and description of supply chain performance for palm oil supply chain stakeholders in the regions.

**Table 7.** Score for supply chain performance of independent farmers in Siak, Riau.

| No | Metrics | Units | Min value | Max value | Actual value | Benchmark | Normalized | Weight | Score |
|---|---|---|---|---|---|---|---|---|---|
| 1 | FSC1-1 | Ton/Ha | 1.800 | 24.000 | 11.798 | 22.863 | 0.475 | 0.018 | 0.860 |
| 2 | FSC1-2 | | 10.000 | 15.000 | 14.688 | 9.500 | 0.057 | 0.013 | 0.074 |
| 3 | FSC1-3 | Year | 5.000 | 20.000 | 12.188 | 10.938 | 0.862 | 0.011 | 0.954 |
| 4 | FSC1-4 | Kg | 0.001 | 0.030 | 0.012 | 0.012 | 1.000 | 0.005 | 0.503 |
| 5 | FSC1-5 | Boolean | 0.000 | 0.000 | 0.000 | 1.000 | 1.000 | 0.008 | 0.805 |
| 6 | FSC1-6 | Ton | 10.000 | 10.000 | 10.000 | 10.000 | 1.000 | 0.007 | 0.704 |
| 7 | FSC1-7 | Boolean | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.016 | 1.610 |
| 8 | FSC1-8 | Boolean | 0.000 | 1.000 | 0.938 | 1.000 | 0.938 | 0.011 | 1.037 |
| 9 | FSC1-9 | Kg | 8.000 | 80.000 | 25.813 | 30.000 | 0.810 | 0.022 | 1.792 |
| 10 | FSC2-1 | Days | 0.000 | 360.000 | 58.467 | 0.000 | 0.838 | 0.013 | 1.095 |
| 11 | FSC2-2 | Months | 0.500 | 72.000 | 7.656 | 0.969 | 0.906 | 0.008 | 0.729 |
| 12 | FSC2-3 | Year | 3.000 | 3.000 | 3.000 | 3.000 | 1.000 | 0.017 | 1.710 |
| 13 | FSC2-4 | Days | 15.000 | 15.000 | 15.000 | 15.000 | 1.000 | 0.037 | 3.722 |
| 14 | FSC2-5 | Times | 2.000 | 4.000 | 2.938 | 4.125 | 0.441 | 0.055 | 2.441 |
| 15 | FSC2-6 | Linguistic | 3.000 | 4.000 | 3.875 | 4.500 | 0.583 | 0.046 | 2.700 |
| 16 | FSC3-1 | People | 1.000 | 2.000 | 1.133 | 1.133 | 1.000 | 0.090 | 8.954 |
| 17 | FSC3-2 | People | 1.000 | 2.000 | 1.167 | 1.333 | 0.500 | 0.090 | 4.477 |
| 18 | FSC4-1 | Rp | 585 000.00 | 50 000 000.00 | 15 294 090.91 | 15 294 090.91 | 1.000 | 0.128 | 12.777 |
| 19 | FSC4-2 | Rp | 29 250.00 | 50 400 000.00 | 15 849 916.67 | 11 363 636.36 | 0.885 | 0.069 | 6.144 |
| 20 | FSC4-3 | Rp | 1 500 000.00 | 115 000 000.00 | 40 928 571.43 | 6 000 000.00 | 0.680 | 0.128 | 8.682 |
| 21 | FSC4-4 | Rp | 0 | 200.00 | 39.333 | 0.000 | 0.803 | 0.034 | 2.748 |
| 22 | FSC5-1 | Boolean | 0 | 1.00 | 0.875 | 1.000 | 0.875 | 0.043 | 3.785 |
| 23 | FSC5-2 | Days | 0 | 4.00 | 0.313 | 0.250 | 0.983 | 0.130 | 12.762 |
| | | | | | | | **Total score** | | **81.065** |
| | | | | | | | **Category** | | **Moderate** |

*3.4.1. Smallholder supply chain performance*. Supply chain performance of independent farmers was calculated according to measurement on 24 metrics using aforementioned formula. Briefly, the result of performance measurement for independent farmers in Siak, Riau Province, can be seen in table 7.

For instance, normalization of performance metrics FSC1-1 is obtained from Formula 4, considering that the target is max. The performance score FSC1 – 1 represents the result of multiplication between normalized score and metrics weight previously calculated using AHP. Total score is the sum of performance scores from 23 metrics for independent farmer item, illustrated as follows:

$$Normalization\ of\ FSC\ 1-1 = \frac{I_i - \min(i)}{B(I_i) - \min(i)} = \frac{11.798 - 1.800}{24.000 - 1.800} = 0.475$$

$$Performance\ score\ of\ FSC\ 1-1 = W(I_i) \times N(I_i) = 0.018 \times 0.475 = 0.860$$

The results show that supply chain performance for independent farmers in Siak of Riau Province reaches 81.065, categorized in moderate level referring to Monczka *et al*. (2016). This indicates that four metrics may show a low performance. The lowest performance score comes from normalized score of 0.500. We found some metrics responsible for that low score, including production of FFB in each harvesting cycle, harvesting cycle period, fertilizing cycle, and number of fertilizer suppliers. Furthermore, supply chain performance for independent farmers in Kampar of Riau Province is recorded at 82.473, equal to moderate level. Four perfomance metrics accounting for that low score includes plant age, length of replanting preparation, delivery cost, and payment contract.

Additionally, the performance score for independent farmer in Rokan Hulu of Riau Province reaches 63.539, categorized as very poor level. There are 6 performance metrics related to the score, namely production of FFB in each harvesting cycle, seed certification, weight per FFB, waiting period for seed availability, number of fertilizer suppliers, payment period. Furthermore, the performance score for independent farmers in Rokan Hilir of Riau Province reaches 83.989, equal to moderate level. In this case, there are 4 metrics that have a low score, namely production of FFB in each harvesting cycle, harvesting cycle period, seed certification, and period for replanting preparation.

In terms of independent farmers in Jambi Province, the research was also conducted in 4 regions, i.e. Batanghari, Tanjung Jabung Timur, Merangin and Bungo. As a result, performance score for independent farmers in Batanghari is 79.857, which is at poor level. There are 5 metrics with low score, including transportation facilities, weight per FFB, period for replanting preparation, number of fertilizer suppliers, delivery cost. The lower score is found in Tanjung Jabung Timur, with the score of 69.373 equal to very poor. This condition closely relates to a high number of metrics with low score, i.e. plant age, capacity of transportation facilities, production of FFB per harvesting cycle, seed certification, period for replanting preparation, fertilization cycle, replanting cost, labor cost, and delivery cost.

The performance score for independent farmers in Merangin of Jambi Province is 73.672, classified as poor. The low performance comes from 4 metrics with low score, i.e. production of FFB per harvesting cycle, capacity of transportation facilities, number of fertilizer suppliers, and delivery cost. Afterwards, the worse condition is found in Bungo with performance score of 67.719, equal to very poor. Such condition relates to 9 metrics with low score, namely production of FFB per harvesting cycle, plant age, availability of transportation facilities, capacity of transportation facilities, weight per FFB, number of fertilizer suppliers, replanting cost, seed cost, and labor cost.

Overall, the results suggested that performance score for independent farmers in Riau and Jambi ranged from very poor to average level and from poor to average level, respectively. The results are summarized in table 8. In short, we can argue that supply chain performance of independent farmers in Riau is slighly better than in Jambi.

As further strategies, improvement strategies need to more consider metrics with low score. The improvement activities focus on 12 supply chain metrics in Riau and 15 supply chain metrics in Jambi. The prioritized metrics are then presented in table 9.

**Table 8**. Summary for performance of studied farmers in Riau and Jambi during period of January and February 2019.

| No | Region | Score | Category |
|---|---|---|---|
| **Riau Province** | | | |
| 1 | Siak | 81.065 | Good |
| 2 | Kampar | 82.473 | Good |
| 3 | Rokan Hulu | 63.539 | Very low |
| 4 | Rokan Hilir | 83.989 | Good |
| **Mean** | | **77.767** | **Moderate** |
| **Jambi Province** | | | |
| 1 | Batanghari | 79.857 | Moderate |
| 2 | Tanjung Jabung Timur | 69.373 | Low |
| 3 | Merangin | 73.672 | Moderate |
| 4 | Bungo | 67.719 | Low |
| **Mean** | | **74.602** | **Moderate** |

**Table 9.** Low score-performance metrics for independent farmers in Riau and Jambi Province.

| Regions | Dimensions | No | Metrics |
|---|---|---|---|
| **Provinsi Riau** | Reliability | 1 | Production of FFB per harvesting cycle |
| | | 2 | Harvesting cycle period |
| | | 3 | Seed certification |
| | | 4 | Plant age |
| | | 5 | FFB weight |
| | Responsiveness | 6 | Fertilization cycle |
| | | 7 | Period of replanting preparation |
| | | 8 | Waiting period for seed supply |
| | Agility | 9 | Number of fertilizer suppliers |
| | Cost | 10 | Delivery cost |
| | Asset management | 11 | Payment contract system |
| | | 12 | Payment period |
| **Provinsi Jambi** | Reliability | 1 | Availability of transportation facilities |
| | | 2 | FFB weight |
| | | 3 | Plant age |
| | | 4 | Capacity of transportation facilities |
| | | 5 | Production of FFB per harvesting cycle |
| | | 6 | Seed sertification |
| | Responsiveness | 7 | Period of replanting preparation |
| | | 8 | Fertilization period |
| | Agility | 9 | Number of fertilizer suppliers |
| | | 10 | Number of seed suppliers |
| | Cost | 11 | Preparation cost (New Planting) |
| | | 12 | Labor cost |
| | | 13 | Delivery cost |
| | | 14 | Seed cost, immature oil palm |

*3.4.2. Trader performance*. Traders serve as important actors in connecting independent farmers with palm oil producers. Their activities are legalized with a document named as DO (delivery order), revealing that the traders are eligible to conduct trading for supplying FFB to palm oil producers, while

also providing quality assurance. In this case, the core business of the traders include buying and distributing FFB, as well as receiving payment from the firms.

Furthermore, there is a necessity to uncover the efficiency and effectiveness of business activities performed by stakeholders, aiming to elevate the competitiveness of palm oil supply chain. For this reason, a total of 17 metrics need to receive further concern. The evaluation on supply chain performance for palm oil producers in Riau and Jambi is based on decomposition from measurement in each region. As a result, supply chain performance for traders in Siak of Riau Province is 60.453, equal to very poor. The score may result from unsatisfied performance in 4 metrics, i.e. delivery period, volume of FFB for palm oil producers, period of FFB delivery from traders to producers. For instance, determination of supply chain performance for traders in Siak is presented in table 10.

**Table 10.** Performance score for traders in Siak, Riau.

| No | Metrics | Units | Min value | Max value | Actual value | Benchmark | Normalized | Weight | Score |
|---|---|---|---|---|---|---|---|---|---|
| 1 | TSC1-1 | Linguistic | 1.000 | 5.000 | 5.000 | 4.000 | 1.000 | 0.028 | 2.800 |
| 2 | TSC1-2 | Rp/kg | 850.000 | 1290.000 | 1087.143 | 1087.000 | 0.999 | 0.017 | 1.699 |
| 3 | TSC1-3 | Rp/kg | 1075.000 | 1300.000 | 1213.125 | 1307.048 | 0.595 | 0.030 | 1.786 |
| 4 | TSC1-4 | Boolean | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.074 | 7.400 |
| 5 | TSC1-5 | Kali | 5.000 | 30.000 | 20.714 | 42.750 | 0.416 | 0.021 | 0.874 |
| 6 | TSC1-6 | Ton | 8.000 | 100.000 | 32.375 | 63.000 | 0.443 | 0.040 | 1.773 |
| 7 | TSC1-7 | Number | 2.000 | 4.000 | 3.125 | 3.750 | 0.643 | 0.022 | 1.414 |
| 8 | TSC1-8 | % | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.036 | 3.600 |
| 9 | TSC1-9 | Lingustic | 1.000 | 4.000 | 3.000 | 4.000 | 0.667 | 0.037 | 2.467 |
| 10 | TSC2-1 | Times a day | 2.000 | 5.000 | 2.857 | 42.750 | 0.021 | 0.053 | 0.111 |
| 11 | TSC2-2 | Hour | 40.000 | 60.000 | 53.125 | 35.000 | 0.275 | 0.053 | 1.458 |
| 12 | TSC3-1 | Number | 2.000 | 4.000 | 3.125 | 4.000 | 0.563 | 0.270 | 15.188 |
| 13 | TSC4-1 | Rp | 0.000 | 1 350 000.000 | 518 750.00 | 625.000 | 0.616 | 0.034 | 2.094 |
| 14 | TSC4-2 | Rp | 100 000.000 | 1 900 000.000 | 821 428.57 | 25 000.500 | 0.575 | 0.154 | 8.859 |
| 15 | TSC4-3 | Rp | 0.000 | 10.000 | 1.25 | 0.000 | 0.875 | 0.025 | 2.188 |
| 16 | TSC5-1 | Boolean | 0.000 | 1.000 | 0.571 | 1.000 | 0.571 | 0.013 | 0.743 |
| 17 | TSC5-2 | Days | 0.000 | 1.000 | 0.429 | 0.000 | 0.571 | 0.093 | 5.314 |
| | | | | | | | | **Score** | **60.453** |
| | | | | | | | | **Category** | **Very low** |

The results show that supply chain performance for traders in Kampar reaches 85.223, regarded as very good. This condition needs to be improved through considering 2 metrics with lower score, including payment contract system and payment period. This condition is much higher in comparison with that in Rokan Hulu, reaching only 73.431 equal to poor level, which may be caused by several metrics such as delivery period, number of FFB to palm oil producer, supply frequency, retribution cost, and return cost. Similar condition is observed in Rokan Hilir, with the score of 79.301, which is also classified as poor level. In this case, several metrics still have low score, namely delivery period, volume of FFB, supply frequency, retribution cost, and return cost.

In case of Jambi, Batanghari shows the low performance score of 61.080, equal to very poor. There are 7 metrics strongly linked to the unsatisfied condition, including compliance of FFB demand, FFB buying price from farmers, selling price to palm oil producer, availability and capacity of transportation facilities, supply frequency to palm oil producer, retribution cost, and delivery cost. Subsequently, the better condition is observed in Tanjung Jabung Timur with performance score of 80.118, equal to good level. Some metrics are identified to possess low score, namely FFB buying price, delivery period, punctuality, period of FFB delivery from traders to palm oil producers, retribution cost, return cost, and payment contract system. The average level is achieved in Merangin, reaching score of 76.636. The improvement is needed, particularly focusing on following metrics, namely selling price to palm oil

producer, FFB price information, delivery period, number and frequency of FFB delivery to palm oil producer. The satisfied condition is found in Bungo, reaching the score of 83.744. Despite good level, some metrics need to be enhanced, including compliance of FFB demand, selling price to palm oil producer, delivery period, delivery period from traders to palm oil producers, retribution and return cost. The assessment results indicate that supply chain performance for traders in Riau and Jambi show a variability, ranging from very poor to very good (table 11). In general, we argue that supply chain performance in both regions is relatively comparable, while also needs improvement of supply chain performance and competitiveness. For this reason, particular concern should be addressed to low score-metrics. In summary, the supply chain performance in Riau can be upgraded by concerning 5 metrics of supply chain, and 9 metrics in Jambi. Those metrics in both provinces with low score are listed in table 12.

**Table 11.** Summary for trader performance in Riau and Jambi during period of Jan and Feb 2019.

| No | Region | Score | Category |
|---|---|---|---|
| **Riau province** | | | |
| 9 | Siak | 60.453 | Very poor |
| 2 | Kampar | 85.223 | Very good |
| 3 | Rokan Hulu | 73.431 | Moderate |
| 4 | Rokan Hilir | 79.301 | Moderate |
| **Mean** | | **74.602** | Moderate |
| **Jambi province** | | | |
| 1 | Batanghari | 61.080 | Very poor |
| 2 | Tanjung Jabung Timur | 80.118 | Good |
| 3 | Merangin | 76.636 | Moderate |
| 4 | Bungo | 83.744 | Good |
| **Mean** | | **75.395** | Moderate |

**Table 12.** Low score-performance metrics for traders in Riau and Jambi Province.

| Regions | Dimensions | No | Metrics |
|---|---|---|---|
| **Riau province** | Reliability | 1 | Delivery periode |
| | | 2 | Number of FFB delivery to palm oil producers |
| | Responsiveness | 3 | Frequency of FFB delivery to palm oil producers |
| | Agility | - | - |
| | Cost | 4 | Retribution cost |
| | | 5 | Return cost |
| | Asset management | - | |
| **Jambi province** | Reliability | 1 | Compliance to demand |
| | | 2 | Purchase price from farmers |
| | | 3 | Selling price to palm oil producers |
| | | 4 | Delivery period |
| | Responsiveness | 5 | Frequency of FFB delivery to palm oil producers |
| | | 6 | Delivery period to palm oil producers |
| | Agility | - | |
| | Cost | 7 | Retribution cost |
| | | 8 | Return cost |
| | Asset management | 9 | Payment contract system |

*3.4.3. Refinery supply chain performance.* The core business activities of the producers are to convert FFB into Crude Palm Oil (CPO), and deliver it to consumers. The set of activities in CPO production

aims to produce value addition to the palm oil, enabling to enhance competitiveness and supply chain advantages.

Regarding to efficiency and effectiveness of the supply chain, we analyzed 18 metrics adopted from SCOR. The calculation of the performance of palm oil producers was based on regions spread in two provinces, Riau and Jambi, allowing to produce detail and specific further strategies.

In case of Riau, measurement results of the supply chain performance of Siak are described in table 13. The results indicate that Siak showed a very good level, with score of 89.641. In spite of satisfied condition, improvement is possible to conduct through considering following metrics as follows: FFB quality, processing time. The poor level is observed in Kampar, reaching score of 68.584. Even though it is not satisfied, some metrics with low score can be upgraded to rise the level, including volume of CPO production, return cost, energy cost, payment system, and pay-off period.

Rokan Hulu ranks at good level, with score of 83.574. Improvement of the performance is still possible by upgrading only one metrics, i.e. vailability of raw materials. Meanwhile, Rokan Hilir ranks at average level, with score of 75.001. The further improvement should be addressed in several metrics, including quality of FFB, return cost, and pay-off period.

**Table 13.** Performance score for palm oil producers in Siak, Riau.

| No | Metric | Units | Min value | Max value | Actual value | Benchmark | Normalized | Weight | Score |
|---|---|---|---|---|---|---|---|---|---|
| 1 | RSC1-1 | % | 105.000 | 7 666.667 | 2 114.167 | 2 270.476 | 0.928 | 0.023 | 2.169 |
| 2 | RSC1-2 | % | 45.000 | 60.000 | 55.000 | 49.667 | 1.000 | 0.013 | 1.275 |
| 3 | RSC1-3 | % | 0.000 | 0.300 | 0.100 | 0.236 | 0.424 | 0.041 | 1.756 |
| 4 | RSC1-4 | Boolean | 0.000 | 1.000 | 0.750 | 0.933 | 0.804 | 0.050 | 4.014 |
| 5 | RSC2-1 | Hour | 0.167 | 1.167 | 0.667 | 1.121 | 1.000 | 0.079 | 7.864 |
| 6 | RSC2-2 | Hour | 4.000 | 6.000 | 5.250 | 4.091 | 0.393 | 0.040 | 1.586 |
| 7 | RSC2-3 | Times | 2.000 | 3.000 | 2.500 | 2.800 | 0.625 | 0.069 | 4.317 |
| 8 | RSC2-4 | Hour | 8.000 | 8.000 | 8.000 | 8.000 | 1.000 | 0.037 | 3.719 |
| 9 | RSC2-5 | Hour | 1.600 | 4.000 | 2.900 | 3.273 | 1.000 | 0.014 | 1.382 |
| 10 | RSC3-1 | Ton | 90.000 | 833.333 | 405.833 | 203.939 | 1.000 | 0.114 | 11.371 |
| 11 | RSC3-2 | Hour | 2.000 | 8.000 | 3.500 | 2.714 | 0.851 | 0.038 | 3.257 |
| 12 | RSC4-1 | Rp | 0.400 | 0.400 | 0.400 | 0.550 | 1.000 | 0.097 | 9.671 |
| 13 | RSC4-2 | Rp | 0.200 | 0.390 | 0.292 | 0.204 | 0.526 | 0.026 | 1.341 |
| 14 | RSC4-3 | Rp | 0.300 | 0.300 | 0.300 | 0.204 | 1.000 | 0.032 | 3.188 |
| 15 | RSC4-4 | Rp | 0.200 | 0.200 | 0.200 | 0.308 | 1.000 | 0.026 | 2.550 |
| 16 | RSC5-1 | Boolean | 1.000 | 1.000 | 1.000 | 0.914 | 1.000 | 0.078 | 7.758 |
| 17 | RSC5-2 | Boolean | 0.000 | 1.000 | 0.750 | 0.533 | 1.000 | 0.032 | 3.188 |
| 18 | RSC5-3 | Days | 0.000 | 0.000 | 0.000 | 0.733 | 1.000 | 0.192 | 19.235 |
| | | | | | | | **Performance score for refinery** | | **89.641** |
| | | | | | | | | **Category** | **Moderate** |

In case of Jambi, Batanghari ranks at very good level, with score of 90.733. Improvement is possible by enhancing some metrics, including volume and capacity of CPO production, CPO quality, maintenance time cycle. However, Tanjung Jabung Timur is found at average level, with score of 74.157. the improvement can be performed by upgrading 4 metrics as follows: volume of CPO production, processing time, availability of raw material stock, and payment system. Similarly, the supply chain performance of palm oil producers in Merangin reaches 89.584, equal to very good. There are 4 metrics possibly improved, namely quality of FFB, maintenance time cycle, overtime and payment system. However, Muara Bungo ranks at average level, with score of 77.984. The performance can be enhanced by focusing on several metrics as follows: CPO production, quality of FFB, processing time, availability of raw material stock, and overtime.

Overall, we can report that performance of supply chain for palm oil producers in Riau and Jambi is at range of poor to very good and average to very good, respectively. Therefore, this indicates that Jambi

shows better results in term of supply chain performance for the producers, as summarized in table 14. The improvement of supply chain in both regions can be carried out, underlining the metrics with low score in order to prepare future strategies (table 15).

**Table 14.** Summary for palm oil performance in Riau and Jambi during period of January and February 2019.

| No | Regions | Score | Level |
|---|---|---|---|
| **Riau Province** | | | |
| 9 | Siak | 89.641 | Very Good |
| 2 | Kampar | 68.584 | Poor |
| 3 | Rokan Hulu | 83.574 | Good |
| 4 | Rokan Hilir | 75.001 | Average |
| **Mean** | | **79.200** | **Average** |
| **Jambi Province** | | | |
| 1 | Batanghari | 90.733 | Very Good |
| 2 | Tanjung Jabung Timur | 74.157 | Average |
| 3 | Merangin | 89.584 | Very Good |
| 4 | Bungo | 77.982 | Average |
| **Mean** | | **83.114** | **Good** |

**Table 15.** Low score-performance metrics for palm oil producer in Riau and Jambi Province.

| Regions | Dimension | No | Metrics |
|---|---|---|---|
| **Riau province** | Reliability | 1 | FFB quality |
| | Responsiveness | - | - |
| | Agility | - | - |
| | Cost | 2 | Raw material return cost |
| | Asset management | 3 | Pay-off period |
| **Jambi province** | Reliability | 1 | Production of CPO |
| | | 2 | FFB quality |
| | Responsiveness | 3 | Maintenance time cycle |
| | | 4 | Time required for processing |
| | Agility | 5 | Safety stocks |
| | | 6 | Overtime |
| | Cost | - | - |
| | Asset management | 7 | Payment system |

*3.4.4. Supply chain performance improvement*. In this section, strategies for improving supply chain performance are proposed in table 16 and 17, designed to increase competitiveness. Based on situational analysis and supply chain performance measurement in each stakeholder and region, some low score-performance metrics are successully identified. As response to this finding, we investigate the major cause of these unsatisfied metrics and then create practical strategies, based on analysis and discussion with experts.

**Table 16.** Low-score metrics and the strategy to improve performance at Riau Province.

| Low score metrics | Factors | Strategies and solutions |
|---|---|---|
| 1. Low production of FFB | Difficulties in improving productivity of Dura and Pisifera as common species used by farmers | ✓ Application of GAP, regular extension service<br>✓ Replanting with tenera seed (certified seed) |
| 2. Not certified FFB | Expensive price of sertified seed, lack of knowledge on high quality seeds | ✓ Replanting with certified seeds<br>✓ Distribution of certified seed by government<br>✓ Leveraging breeder's knowledge on certified seeds<br>✓ Easy access towards certified seed<br>✓ Assistanship and intensificaiton of cultivation and seeding technique by state-owned company (BUMN) and reputable plantation |
| 3. Long period of harvesting time | Un-standardized of good agricultural and good handling practice by farmers | ✓ Implementation of GAP, regulat extension activities<br>✓ Provision of plantation production facilities |
| 4. Limited fertilizer suppliers | Availability of fertilizer<br>Fertilizer distribution chain | ✓ Proliferating stalls or suppliers of fertilizer, accessible by independent farmers |
| 5. Limited number of FFB supply for palm oil producers | Production depending on seasons | ✓ Regulation on number of palm oil producers in a region<br>✓ Re-scheduling operational activities in one group producers, achieving optimum capacity |
| 6. High retribution cost | Lack of knowledge | ✓ Evaluation on retribution cost<br>✓ Control towards any violation |
| 7. High return rate of FFB from palm oil producers | Poor grade of FFB | ✓ Enhancement of FFB quality through GAP and GHP<br>✓ Assistanship for farmers and traders related to integrity<br>✓ Dissemination of current detection technique on maturity (mature FFB indicated by 3 – 5 fallen fruits) |
| 8. Low quality of FFB | Poor seed quality<br>Poor harvesting time | ✓ Implementation of price refraction based on quality<br>✓ Implementation of GHP<br>✓ Guiding on the fertilizing techniques, in accordance with guidance and SOP<br>✓ Reduction of harvesting process and delivery<br>✓ Composing the schedule for FFB delivery |
| 9. High rejection level of FFB by refinery | Low quality of FFB from farmers and traders | ✓ Implementation of price refraction, based on FFB quality<br>✓ Introducing and guiding the implementation of GHP<br>✓ Proper fertilizing programs based on SOP |
| 10. Long pay-off period | Poor cashflow | ✓ Determination of due date<br>✓ Controlling implementation of regulation Ministry of Agriculture No 1 of 2018 |

**Table 17.** Low-score metrics and the strategy to improve performance at Riau Province.

| Low score metrics | Factors | Strategies and solutions |
|---|---|---|
| 1. FFB weight | Related to type and quality of seed | ✓ Replanting with certified seed<br>✓ Strict control on breeder of certified seed<br>✓ Easy access towards certified seed<br>✓ Assistanship and intensification of farming and seeding techniques by state-owned company or reputable plantation<br>✓ Finance support for purchasing certified seeds |
| 2. Olderly tree (low productivity) | No replanting activity due to high cost<br>Low income during immature plants | ✓ Replanting with certified seeds<br>✓ Provision of living allowance for farmers<br>✓ Replanting schedule |
| 3. Low production of FFB | Low productivity of Dura and Pisifera | ✓ Implementation of GAP and regular extension service<br>✓ Replanting using tenera seed (certified seed) |
| 4. Long planting preparation | Related to type of land, dominated by marshland<br>Lack of facilities and access towards certified seed | ✓ Introducing mechanization program in marshland for independent farmers |
| 5. Number of fertilizer suppliers | Price and low fertilizer quality | ✓ Recommendation on fertilizer subsidy program for plantation crops<br>✓ Proliferating fertilizer suppliers or stalls to make easier access<br>✓ Table-designed fertilizer, properly applied in marshland |
| 6. Expensive cost for planting preparation and labor | Related to type of land in Jambi<br>Lack of supporting facilities | ✓ Introducing mechanization program in marshland for independent farmers |
| 7. Compliance of demand from palm oil producer | Lack of FFB supply, due to harvesting failure / low productivity (famine condition) | ✓ Developing extensification and increasing productivity of independent farmers<br>✓ Regulating number of palm oil producers in one region<br>✓ Operational schedule in palm oil producers within group, for capacity fufillment |
| 8. High FFB price during famine period | Lack of FFB supply<br>Some producers did not have own plantation | ✓ Dissemination through information system, and price control based on existing regulation |
| 9. Low FFB price to palm oil producers | Poor quality | ✓ Enhancing quality of FFB<br>✓ Dissemination through information system, and price control based on existing regulation |
| 10. High retribution cost | Lack of knowledge on retribution rule by traders | ✓ Reviewing the regulation of retribution cost<br>✓ Control towards frauds on retribution |
| 11. Low CPO production | Lack of safety stocks | ✓ Controlling fraction of quality during FFB received from traders/farmers<br>✓ Limitation on number of mature palm fruits, affecting FFA |
| 12. Lack of safety stock | Related to famine and peak season | ✓ Rescheduling production<br>✓ Improving productivity of oil palm |

| Low score metrics | Factors | Strategies and solutions |
|---|---|---|
| 13. High overtime | Related to harvesting in peak season<br>Limitation on production capacity | ✓ Shift management<br>✓ Increasing production capacity |

*3.4.5. Managerial implication*. Measuring and improving the supply chain performance is essential aspect as an effort to increase competitiveness of palm oil agroindustry. Thus, these activities need to be regularly carried out, enabling to evaluate the cause of inefficient practices in agroindustry. The framework of this performance measurement can be implemented to understand supply chain performance for a particular period of time. Besides, in terms of operational practices, there is a need for real-time information system to measure supply chain performance in all stakeholders involved. The enhancement of supply chain performance receives its importance for evaluating the low supply chain performance. Numerous alternative solutions provided by our research can be a base, in accordance with the low score-performance metrics. However, it is noteworthy that to reach expected outcome requires coordination between stakeholders in palm oil supply chain. Each solution needs to involve all stakeholders, capable of reducing the poor supply chain performance directly.

## 4. Conclusion and recommendation

### *4.1. Conclusion*

This present work successfully identified mechanism of supply chain in palm oil agroindustry and formulated model for measurement and improvement of supply chain performance. Analysis of palm oil supply chain was conducted in two largest palm oil producers in Indonesia, i.e. Riau and Jambi, while the analysis is intended to focus on primary stakeholders including independent farmers, traders, and palm oil producers. As a result, the average performance score for independent farmers, traders, and palm oil producers in Riau reached 77.77%, 74.60% and 79.20%, respectively, categorized as poor level. Meanwhile, the average score in Jambi tended to be more satisfied, reaching up to 72.66%, 75.39% and 83.11%, respectively, grouped as average level. In addition, there is clear a need for future comprehensive improvement in order to rise the competitiveness of supply chain.

### *4.2. Recommendation*

Attempts in enhancement of supply chain performance are inevitable in order to rise competitiveness of supply chain in palm oil agroindustry. The results of this present work has been considerable for providing relevant recommendations in line with principles of Good Agriculture and Good Handling Practice, creating better facilities and price refraction based on the quality, as well as the use of information system for achieving a better supply chain performance.

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