SCOR-Based Information Modeling for Managing Supply Chain Performance of Palm Oil Industry at Riau and Jambi Provinces, Indonesia

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***Abstract*— The challenges for providing timely and concise performance reports along all components in Palm Oil agro-industry supply chain are urgent, particularly in terms of managing each metrics of the stakeholders. This SCOR (Supply Chain Operation Reference)-based information model attempts to represent the real requirements of each stakeholder. Initially, all relevance stakeholder's requirement for supply chains such as agility, assets, cost, reliability, and responsiveness are mapped into respectful definition in the field of palm oil agro-industry. The related attribute is derived into metrics of evaluation for measuring specific performance according to the proposed formulation. Performance measurement in each attribute is then benchmarked on available best practice in the fields. A framework of business process modelling and notation (BPMN) based Rapid Application Development (RAD) integrates these required processes of the model with the cloud-based database access. The integration of JavaScript-based front-end with the SCOR-based database operation is ready for mobile and desktop usage. With a series of visualization, this model provides fast interpretation and understanding in each performance measurement, such us spider chart, histogram, and line chart as well as ETL (Extract, Transform, and Load) features. This model successfully showed a functional evaluation by using real-world data derived from two major provinces of palm oil agro-industry in Indonesia, namely Jambi and Riau provinces. A quick comparison based on geographical location is ready for inquiry in different user levels of the farmer, trader, and palm oil mill.**

Keywords*—Agro-industry, Information modeling, Palm Oil, Performance, SCOR*

1. Introduction

Performance is defined as a combination of goals and relational models for enabling a company to achieve them in the appropriate time. The definition of performance is varied depending on the time, the needs, and the place. The performance should be related to the process, activity, and the effect of series processes. The processes and the value of the consequences must be benchmarked to a standard value as a reference achievement. Three key concepts were defined by Ref. [1]. Those are the goal that expresses the performance to achieve, a relation that highlight the relation of the environment to the company and characteristics that summarized the company's performance such as quality, flexibility, and cost. The characteristics of supply chains should be explored and measured by performance dimensions and indicators.

A supply chain is a coordinated business process of stakeholders involves retailers, distributors, industry, and suppliers to fulfil consumer demands and achieve appropriate profits [2]. Information technology is very important in coordinating supply chain stakeholders, in planning and control, speeding up the flow of product to market, minimizing inventory levels, overall costs. Hopefully, these activities may improve efficiency and fulfil customer satisfaction [3], [4].

Implementation of performance measurement in supply chain operation has significantly attracted attention both academic and professional. This field

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is essential to smooth the supply chain goals achievement and solve related problems [5]. Various performance measurement models have proposed by many scholars such as Data Evolvement Analysis (DEA), Activity Based Costing [6], [7], Balanced Score Card [8], [9] and Supply Chain Operations Reference (SCOR) model which is the most frequently applied [1], [4], [5].

SCOR that is proposed by the Supply Chain Council can be used in a systematic way as a planning tool. The SCOR is useful for identification, measurement, reorganization, and improvement of supply chain (SC) processes in any industries. SCOR is the first and complete cross-industry model and concept for descripting and improving supply chain performance and reorganizing the management [6], [7], [10]. The SCOR consist of four levels: i.e. Level 1 that provides a business definition involve a plan, source, make, deliver process types; Level 2 that provide main business process activities; Level 3 that provides information for planning and setting goals successfully for supply chain improvements; and Level 4 that focuses on key performance indicator in implementation. Further, as the first stage of supply chain performance measurement, it is required a business process identification, understanding the supply chain problems then define the supply chain metrics [11].

The SCOR model proposes attributes and metrics to evaluate supply chain performance. The SCOR model uses supply chain agility, assets, cost, reliability, and responsiveness as the main attributes for evaluating the performance of a supply chain model. Therefore, quantification of the importance level for supply chain performance metrics is a multi-criteria decision-making problem since were adopted from various perspectives, dimensions, and criteria. There are various techniques to quantify the importance level of supply chain performance metrics such as Analytical Hierarchy Process (AHP) [5], [12] and Analytical Network Process (ANP) [13].

This paper is organized as follows. In section 2, the literature reviews which are related to the research field are discussed. In section 3, the research framework and methods are delivered. Then in section 4, the result and discussion of applying the mathematical model and code to a case study are presented also the information system architecture is provided. Finally, the conclusion of this research and recommendation for future works are presented in section 5.

2. Literature review

The system is a collection of components or elements that work together to provide a safe and efficient movement of people and goods. A measurement system that keeps the efficiency of supply chain systems is a requirement for organizational success [5], [9]. Any supply chain organizations should deploy a performance measurement project for all detail processes to increase efficiency and responsiveness. These tools ensure to achieve their goals and continue to improve their processes.

There is a number of frameworks about the evaluation of the supply chain in the literature. The first is Ref. [12] designing an performance evaluation model in agriculture. Firstly, they explore the crucial issue of supplier performance for entire supply chain competitive advantage. Then, they found the main issue to improve in supply chain, involve communication and information sharing, also product competitiveness. Ref. [14] is organized a literature review in the field of performance measurement systems in supply chains. In order to improve the efficiency of the supply chain processes, a systemic performance measurement system model is required. Therefore, supply chain performance measurement model shortly is explained in this part.

One of important information system integration proposed supply chain performance metrics based on four major supply chain processes involve a plan, source, make, and deliver at the strategic, tactical and the operational levels [3], [4]. Completely, Supply Chain Operation Reference (SCOR) proposed a full framework for managing supply chain performance [6]. SCOR decomposed business process through 5 attributes of reliability, responsiveness, agility, cost, and management assets. Supply chain performance using SCOR is simple to adopt by using benchmark value to target or the best value in the same business process for each metrics and attributes. The simplicity and completion of SCOR have adopted by many authors, involve Ref. [5], [15]–[18].

An information system in supply chain essentially has a strategic function for improving the performance, share information among stakeholders and particularly to formulate business strategies to win the market competition [3], [19], [20]. The requirement of a framework for supply chain should cover three main operation capabilities, namely process, information technology (IT) and organization capabilities.

Each capability is divided into related sub capabilities, where it constitutes of 11 sub-capabilities from six processes, two IT and three organizational. These capabilities are asked for the companies to measure and evaluate the key performance indicators [21].

Oil palm industry supply chain is organized by some stakeholders to fulfil consumer demand. The palm oil supply chain is organized by primary and secondary stakeholders. The primary stakeholder is who involves the main business process while the second supports the primary stakeholder. In this case, the supply chain stakeholders which involve are farmers, trader and oil palm mill which call as primary stakeholders. As stated by Ref. [22] the palm oil farmers have lower supply chain performance and lower bargaining position, therefore they should be integrated into other stakeholders in the business process. It is an opportunity in the palm oil business to analyze the performance which can improve stakeholder coordination and integration [23]. Indonesia is one of the palm oil producers in the world therefore its performance will affect many sectors. Measuring supply chain performance of the oil palm industry in Indonesia faces obstacle and complexity in define the appropriate metrics, therefore it will be described in this paper.

3. Methodology

3.1 Research framework

The research framework is detailed in Figure 1. The performance of the palm oil agro-industry supply chain is seen comprehensively, from farmers, traders to palm oil mills. Measuring supply chain performance is complex and involves various actors and sectors, so it requires attributes and metrics for performance measurement so that the measurement is clear and well-defined [5], [24]. More specifically, the performance attributes used as a reference for measuring the performance of palm oil agro-industry supply chains are reliability *(Real)*, responsiveness *(Resp)*, agility *(Agil)*, cost *(Cost)* and asset *(Asset)*.

This study adopts supply chain performance metrics based on the Supply Chain Operation Reference (SCOR) framework compiled by the Supply Chain Council (SCC) [6]. The actors of farmers, traders and palm oil mills have different types and amounts of metrics due to the business processes carried out are also unique and specific. The results of the field survey and expert discussion produced 23, 17, and 18 performance measurement metrics respectively for farmers, traders, and palm oil mills. These performance metrics are decomposed from the performance attributes of reliability, responsiveness, agility, and cost.

The attributes and performance metrics assigned to each palm oil supply chain actor are assumed to have accommodated the entire business process. The development of mathematical models in the next section is based on the attributes and performance metrics of each actor. Furthermore, each stakeholder and business process have a different level of importance for each performance metric [25]. To determine the level of importance of each of these metrics, pairwise comparison is needed through interviews with experts in the palm oil supply chain. Further, the detail weighted value of attributes and metrics for stakeholder's business process is adopted from Ref. [26].

The need to identify the importance level of palm oil stakeholder performance metrics needs to be arranged in a hierarchical structure decomposed from SCOR. There are three levels of hierarchy, namely business processes, attributes, and metrics. A business process is a macro activity carried out by actors in meeting consumer demand and getting profits. Attributes are obtained from the SCOR framework to reflect the performance of actors on the 5 measurement attributes. Performance metrics are detailed forms of performance measurement frameworks that have units and can be calculated. A hierarchy of performance evaluation metrics for palm oil mills can be seen in Figure 2.

This study developed a supply chain performance appraisal information system for palm oil agro-industry. Information systems in the implementation of business processes have significant benefits to meet consumer demand, optimal service and ensure business sustainability [27]. The development of performance appraisal information systems begins with the design of each shareholder's mathematical performance appraisal model, the design of the Unified Modelling Language (UML) and the system's implementation. UML is a standard language used to illustrate the framework for implementing information systems. More specifically, UML translates a mathematical model of performance appraisal and a data processing framework in producing the appropriate output.

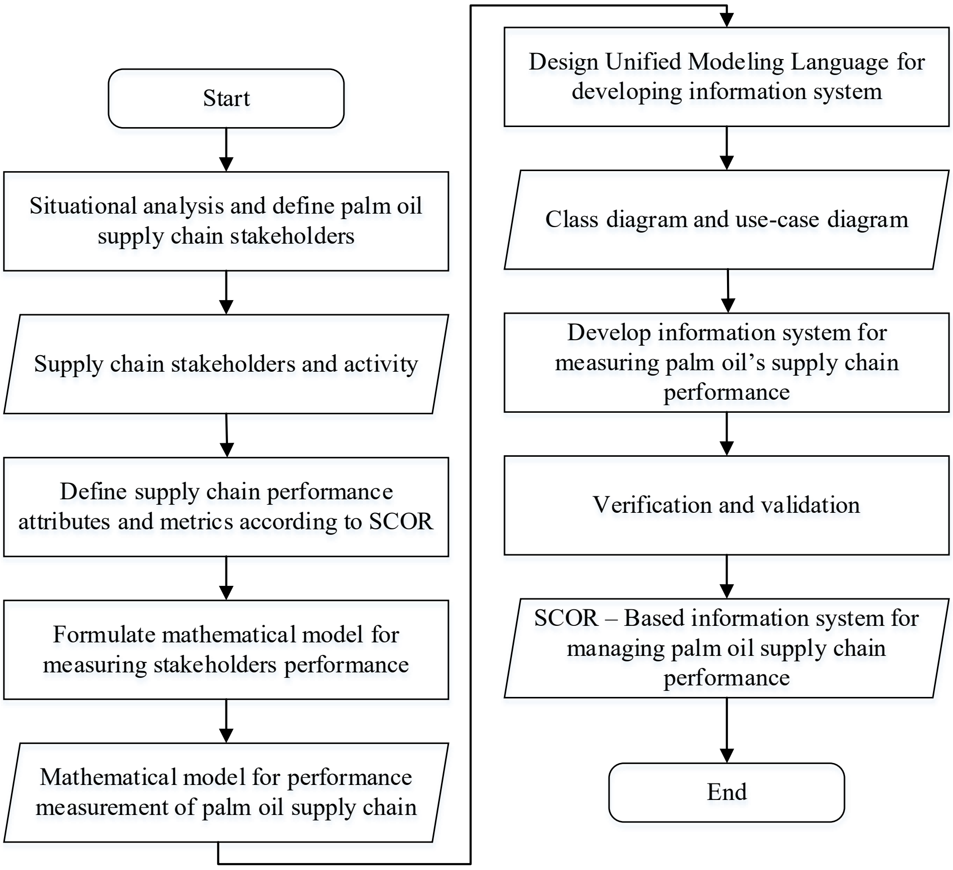

Figure 1. Research framework

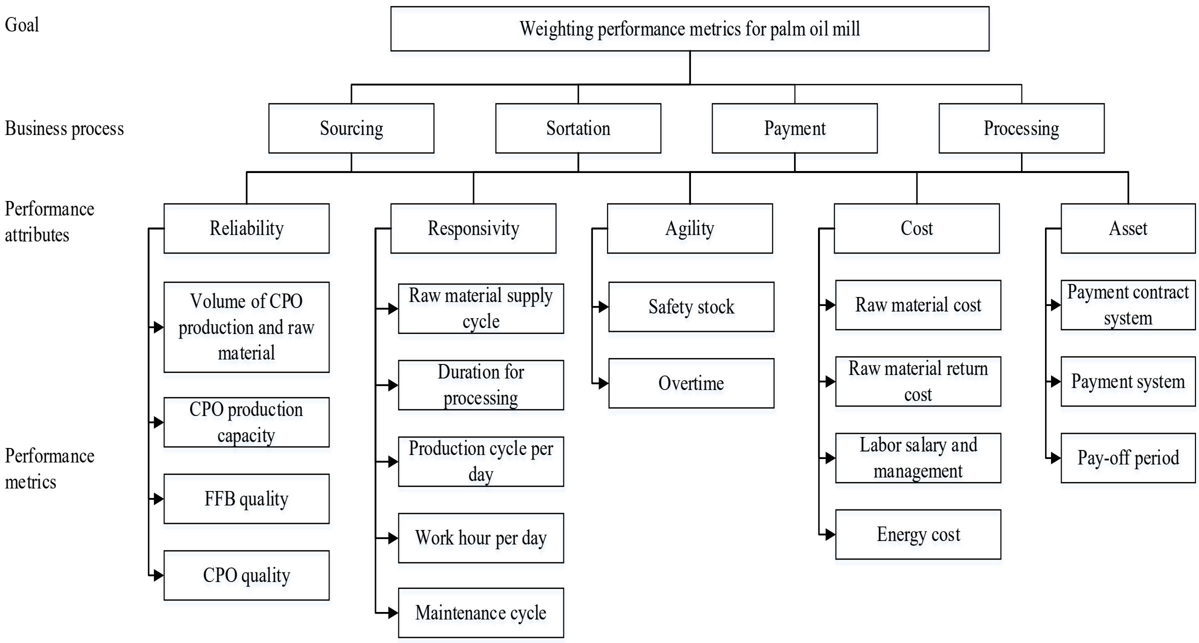

Figure 2. Hierarchy of supply chain performance measurement model for palm oil mill

The UML that designed in this study is a class diagram and use-case diagram. A class diagram is required to define the structure of the system and making the system implementation easier. Use-case diagram illustrates the stakeholder and system entity relation and interaction which facilitate the developer to design the information system workflow and each page functions.

This research proposed an information system for managing the palm oil's supply chain based on SCOR framework. After all mathematical model defined and UML has designed, the verification and validation are required. This stage is the last step to proof the model are correct and fulfil the system requirement.

3.2 Data and information collection

Each data source of this work was collected from respectively actors at Riau and Jambi Province, Indonesia. Available plantation in two provinces is the main producers of Palm Oil in Indonesia. As soon as the framework of the model as described above available for data and information acquisition, a parallel field survey to obtain current facts was set between January to March 2019. These field observation and in-depth interview are concurrently designed in line with the requirement to catch what business processes on each supply chain actors perform. Three sets of questionnaires with the content of the business process model were then launched to accompany field enumerators collect and compile relevant data and information.

The data structure based on all collected data, information and processes for each actor was then translated into databases for cloud configuration. Some additional reference data such as location identification, single identity number and all related profile information were then added to ensure each process of data transaction based on the model run in synchronicity.

4. Result and Discussion

4.1 Palm oil's supply chain situation

Supply chain situation analysis is the ultimate stage of understanding the current performance situation of palm oil agro-industry. In this stage, the mechanism, stakeholder, and business process activity are defined. This research is conducted at Riau and Jambi province, which may represent the major situation of supply chain and are the central production of palm oil in Indonesia.

The goal of supply chain management is to fulfil consumer demand and maximize profit. To achieve the objective, generally, palm oil supply chain management is organized by some stakeholders, involved smallholder, palm oil trader, palm oil mill, down-streaming palm oil agro-industry and the end consumer.

Each palm oils supply chain stakeholder manages a unique business and coordination to fulfil the demand of consumer or the next stakeholder in the supply chain. For example, the farmer manages the palm oil cultivation to provide the raw material for the palm oil mill. Our field observation found two kinds of palm smallholder in Riau and Jambi province, they are independent smallholder and partnership smallholder. The partnership smallholder has structural cooperation with the palm oil mill in providing raw material, price, and quality guarantee. Generally, the partnership stakeholder has a strong position in transporting their field production to the mill. the strong position of the partnership is also supported by a cooperative organization which is facilitated by the palm oil mill. Besides that, the independent farmer has not any cooperation with the palm oil mill and generally face many obstacles in pricing, quality, and business capital for cultivation. Trading the Fresh Fruit Bunch (FFB) of smallholder's palms is supported by the intermediary trader. The trader has the Delivery Order (DO) for transporting the FFB to the mill but smallholder does not.

As found in the field and reported by Ref. [26], the raw material is not only provided by the independent and partnership smallholder but also by the palm oil plantation of the mill. It means that the palm oil mill also has some Hectares (Ha) of the plantation as buffer raw material. For the raw material flow and transportation, the palm oil from the partnership smallholder and the palm oil field of the mill is straight to the palm oil mill without any intermediary stakeholder. It is different from the independent smallholder which has no cooperation agreement with the palm oil, then the transportation to the mill is facilitated by the trader as the intermediary stakeholder.

Further, the palm oil mill produces Crude Palm Oil (CPO) for further processing. Generally, CPO is transported for the exported market or provide as the raw material for the down-streaming palm oil agro-industry at the domestic market. The CPO price follows the international market price and determines the FFB price at the smallholder and trader level. The supply chain stakeholder and mechanism of palm oil's agroindustry is shown in Figure 3.

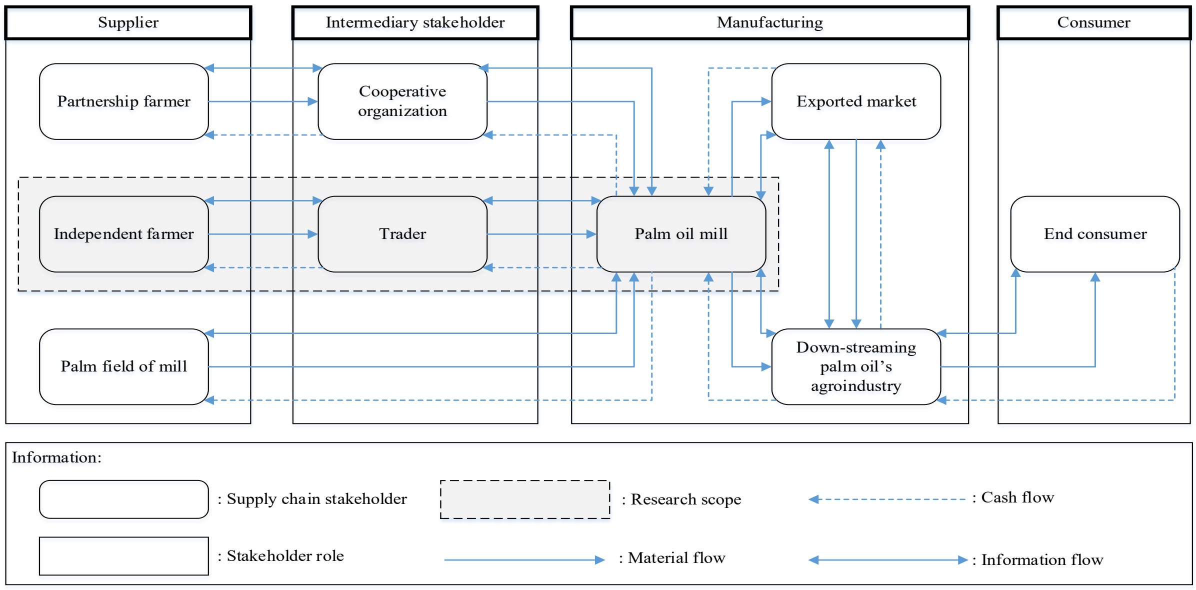

Figure 3. Palm oil's supply chain stakeholders and mechanism

As reported by Ref. [28], independent smallholder holds the major production of fresh fruit bunch (FFB) of palm. In-fact, smallholder does not have any bargaining position, lower-income, less attention in capital provisioning by any stakeholder and lower capability in good agricultural practice [22], [29]. This condition may be affected all performance of palm oil's supply chain due to smallholder as the key stakeholder in providing raw material. Therefore, this research focus on managing the independent smallholder than partnership palm field of the mill which has good management.

As independent smallholder has chosen, then the trader must involve at the discussion. The trader is the intermediary stakeholder to relate the independent smallholder and palm oil mill. Therefore, the scope of the research only involving smallholder farmer, trader, and palm oil mill. This research does not involve the down-streaming palm oil agro-industry, because the major supply chain performance problem found at these stakeholders

4.2 Mathematical model for performance measurement

Measuring the performance of supply chain requires the attributes and metrics. This research adopts Supply Chain Operation Reference (SCOR) framework to define the attributes and metrics and are adjusted for the palm oil's supply chain. This research defined 23, 17 and 18 performance measurement metrics for smallholder, trader, and palm oil mill, respectively while the attributes are decomposed from reliability, responsiveness, agility, cost, and assets.

To measure the supply chain performance at each stakeholder using supply chain metrics, it requires mathematical equation. The mathematical equations may define on how to get the value of stakeholder performance and enable for tracking the lower metrics performance. This research formulates the mathematical model for each performance attributes which consist of metrics for each supply chain stakeholder. Below are defined the supply chain metrics and mathematical formulation for each supply chain stakeholder.

4.2.1 Supply chain performance measurement model for smallholder

Measuring supply chain performance on smallholder is determined by 23 metrics. These metrics is decomposed by 8 metrics of reliability, 6 metrics of responsiveness, 2 metrics of agility, 4 metrics of cost and 2 metrics of assets. The notation and definition of each metrics is defined at Table 1.

For the sake of completing the whole mathematical model for independent smallholder farmer performance evaluation, next are in sequentially formulated as below.

Suppose that $Relx_i$ as the *i-th* independent smallholder farmer *(x)* value of reliability performance and $NRel_1x_i$ as Normalized metric value of $Relx_i$ as a result of benchmark to target comparison. Therefore, the reliability performance of smallholder is represented at Equation 1.

Table 1. Metrics and notation for smallholder

No	Notations	Description	Range
1	*Rel*	Reliability	*{1, ..., Rel}*
2	*Resp*	Responsiveness	*{1, ..., Resp}*
3	*Agil*	Agility	*{1, ..., Agil}*
4	*Cost*	Cost	*{1, ..., Cost}*
5	*Assets*	Assets	*{1, ..., Assets}*
6	Rel_1	Production of FFB per harvesting cycle	*{1, ..., Rel_1}*
7	Rel_2	Harvesting cycle period	*{1, ..., Rel_2}*
8	Rel_3	Plant age	*{1, ..., Rel_3}*
9	Rel_4	Number of bunches per harvesting cycle	*{1, ..., Rel_4}*
10	Rel_5	Availability of transportation facilities	*{1, ..., Rel_5}*
11	Rel_6	Capacity of transportation facilities	*{1, ..., Rel_6}*
12	Rel_7	Certified or not certified seed	*{1, ..., Rel_7}*
13	Rel_8	Fertilizer certification	*{1, ..., Rel_8}*
14	Rel_9	Weight of FFB	*{1, ..., Rel_9}*
15	$Resp_1$	Waiting period for seed supply	*{1, ..., $Resp_1$}*
16	$Resp_2$	Period of replanting preparation	*{1, ..., $Resp_2$}*
17	$Resp_3$	Period of immature palm	*{1, ..., $Resp_3$}*
18	$Resp_4$	Harvesting time in each planting cycle	*{1, ..., $Resp_4$}*
19	$Resp_5$	Fertilizing cycle	*{1, ..., $Resp_5$}*
20	$Resp_6$	FFB demand	*{1, ..., $Resp_6$}*
21	$Agil_1$	Number of seed suppliers	*{1, ..., $Agil_1$}*
22	$Agil_2$	Number of fertilizer suppliers	*{1, ..., $Agil_2$}*
23	$Cost_1$	Preparation cost (New Planting)	*{1, ..., $Cost_1$}*
24	$Cost_2$	Seed cost, immature oil palm	*{1, ..., $Cost_2$}*
25	$Cost_3$	Labor cost	*{1, ..., $Cost_3$}*
26	$Cost_4$	Delivery cost	*{1, ..., $Cost_4$}*
27	$Assets_1$	Payment contract system	*{1,..., $Assets_1$}*
28	$Assets_2$	Payment period	*{1,..., $Assets_2$}*

$$\begin{aligned} \mathrm{Re}lx_i &= N\mathrm{Re}l_1x_i \times W\mathrm{Re}l_1x_i + N\mathrm{Re}l_2x_i \times \\ & W\mathrm{Re}l_2x_i + N\mathrm{Re}l_3x_i \times W\mathrm{Re}l_3x_i + \\ & N\mathrm{Re}l_4x_i \times W\mathrm{Re}l_4x_i + N\mathrm{Re}l_5x_i \times \\ & W\mathrm{Re}l_5x_i + N\mathrm{Re}l_6x_i \times W\mathrm{Re}l_6x_i + \\ & N\mathrm{Re}l_7x_i \times W\mathrm{Re}l_7x_i + N\mathrm{Re}l_8x_i \times \\ & W\mathrm{Re}l_8x_i + N\mathrm{Re}l_9x_i \times W\mathrm{Re}l_9x_i \end{aligned} \tag{1}$$

Suppose that $\mathrm{Re}spx_i$ as the *i-th* independent smallholder farmer *(x)* value of responsiveness performance and $N\mathrm{Re}sp_1x_i$ as Normalized metric value of $\mathrm{Re}spx_i$ as a result of benchmark to target comparison. Therefore, the responsiveness performance of smallholder is represented at Equation 2.

$$\begin{aligned} \mathrm{Re}spx_i &= N\mathrm{Re}sp_1x_i \times W\mathrm{Re}sp_1x_i + N\mathrm{Re}sp_2x_i \times \\ & W\mathrm{Re}sp_2x_i + N\mathrm{Re}sp_3x_i \times W\mathrm{Re}sp_3x_i + \\ & N\mathrm{Re}sp_4x_i \times W\mathrm{Re}sp_4x_i + N\mathrm{Re}sp_5x_i \times \\ & W\mathrm{Re}sp_5x_i + N\mathrm{Re}l_6x_i \times W\mathrm{Re}l_6x_i \end{aligned} \tag{2}$$

Suppose that $Agilx_i$ as the *i-th* independent smallholder farmer *(x)* value of agility performance and $NAgil_1x_i$ as Normalized metric value of $Agilx_i$ as a result of benchmark to target comparison. Therefore, the agility performance of smallholder is represented at Equation 3.

$$\begin{aligned} Agilx_i &= NAgil_1x_i \times WAgil_1x_i + \\ & NAgil_2x_i \times WAgil_2x_i \end{aligned} \tag{3}$$

Suppose that $\mathrm{Cos}\,tx_i$ as the *i-th* independent smallholder farmer *(x)* value of cost performance and $N\mathrm{Cos}\,t_1x_i$ Normalized metric value of $\mathrm{Cos}\,tx_i$ as a result of benchmark to target comparison. The cost performance for smallholder is defined at Equation 4.

$$\begin{aligned} \mathrm{Cos}\,tx_i &= N\mathrm{Cos}\,t_1x_i \times W\mathrm{Cos}\,t_1x_i + N\mathrm{Cos}\,t_2x_i \times \\ & W\mathrm{Cos}\,t_2x_i + N\mathrm{Cos}\,t_3x_i \times W\mathrm{Cos}\,t_3x_i + \\ & N\mathrm{Cos}\,t_4x_i \times W\mathrm{Cos}\,t_4x_i \end{aligned} \tag{4}$$

Suppose that $Assetx_i$ as the *i-th* independent smallholder farmer *(x)* value of cost performance and $NAsset_1x_i$ Normalized metric value of $Assetx_i$ as a result of benchmark to target comparison. The cost performance for smallholder is defined at Equation 5.

$$\begin{aligned} Assetx_i &= NAsset_1x_i \times WAsset_1x_i + \\ & NAsset_2x_i \times WAsset_2x_i \end{aligned} \tag{5}$$

4.2.2 Supply chain performance measurement model for trader

The supply chain performance of trader is decomposed by 17 metrics performance. These metrics consists of 9 metrics of reliability, 2 metrics of responsiveness, 1 metric of agility, 3 metric of cost and 2 metrics of assets. The notation and definition of each metrics for measuring trader performance is listed at Table 2.

In the following part, a sequence of mathematical models for trader performance evaluation is proposed as below. Suppose that $Rely_i$ represented as the *i-th* trader *(y)* value of reliability performance, then the reliability performance for trader is described at Equation 6.

$$\begin{aligned} \mathrm{Re}ly_i &= N\mathrm{Re}l_1y_i \times W\mathrm{Re}l_1y_i + N\mathrm{Re}l_2y_i \times \\ & W\mathrm{Re}l_2y_i + N\mathrm{Re}l_3y_i \times W\mathrm{Re}l_3y_i + \\ & N\mathrm{Re}l_4y_i \times W\mathrm{Re}l_4y_i + N\mathrm{Re}l_5y_i \times \\ & W\mathrm{Re}l_5y_i + N\mathrm{Re}l_6y_i \times W\mathrm{Re}l_6y_i + \\ & N\mathrm{Re}l_7y_i \times W\mathrm{Re}l_7y_i + N\mathrm{Re}l_8y_i \times \\ & W\mathrm{Re}l_8y_i + N\mathrm{Re}l_9y_i \times W\mathrm{Re}l_9y_i \end{aligned} \tag{6}$$

If the responsiveness of trader *(y)* is notated as $Respy_i$, then the responsiveness performance of trader y is defined at Equation 7.

$$\begin{aligned} \mathrm{Re}spy_i &= N\mathrm{Re}sp_1y_i \times W\mathrm{Re}sp_1y_i + N\mathrm{Re}sp_2y_i \times \\ & W\mathrm{Re}sp_2y_i \end{aligned} \tag{7}$$

The *i-th* trader *(y)* value of agility performance is represented as $Agily_i$. The mathematical model for measuring the agility performance for trader is defined at Equation 8.

$$\begin{aligned} Agily_i &= NAgil_1y_i \times WAgil_1y_i + \\ & NAgil_2y_i \times WAgil_2y_i \end{aligned} \tag{8}$$

Suppose that $Costy_i$ as the *i-th* trader *(y)* value of cost performance, then the cost performance of trader *y* is described at Equation 9.

$$\begin{aligned} \mathrm{Cos}ty_i &= N\mathrm{Cos}t_1y_i \times W\mathrm{Cos}t_1y_i + N\mathrm{Cos}t_2y_i \times \\ & W\mathrm{Cos}t_2y_i + N\mathrm{Cos}t_3y_i \times W\mathrm{Cos}t_3y_i + \\ & N\mathrm{Cos}t_4y_i \times W\mathrm{Cos}t_4y_i \end{aligned} \tag{9}$$

The $Assety_i$ represents the *i-th* trader *(y)* value of asset performance and the asset performance for the trader *y* is defined at Equation 10.

$$\begin{aligned} Assety_i &= NAsset_1y_i \times WAsset_1y_i + \\ & NAsset_2y_i \times WAsset_2y_i \end{aligned} \tag{10}$$

Table 2. Metrics and notation for trader

No	Notations	Description	Range
1	*Rel*	Reliability	*{1, …., Rel}*
2	*Resp*	Responsiveness	*{1, …., Resp}*
3	*Agil*	Agility	*{1, …., Agil}*
4	*Cost*	Cost	*{1, …., Cost}*
5	*Assets*	Assets	*{1, …., Assets}*
6	Rel_1	Compliance of FFB demand	$\{1, …., Rel_1\}$
7	Rel_2	FFB price from farmers	$\{1, …., Rel_2\}$
8	Rel_3	Selling price of FFB to producers	$\{1, …., Rel_3\}$
9	Rel_4	FFB price information	$\{1, …., Rel_4\}$
10	Rel_5	Delivery period	$\{1, …., Rel_5\}$
11	Rel_6	Number of FFB delivery to palm oil producers	$\{1, …., Rel_6\}$
12	Rel_7	Number and capacity of transportation facilities	$\{1, …., Rel_7\}$
13	Rel_8	Punctuality in FFB delivery	$\{1, …., Rel_8\}$
14	Rel_9	Punctuality in FFB pick-up	$\{1, …., Rel_9\}$
15	$Resp_1$	Frequency of FFB delivery to palm oil mill	$\{1, …., Resp_1\}$
16	$Resp_2$	Duration of FFB delivery from traders to palm oil producers	$\{1, …., Resp_2\}$
17	$Agil_1$	Fulfillment of extreme demand	$\{1, …., Agil_1\}$
18	$Cost_1$	Retribution cost	$\{1, …., Cost_1\}$
19	$Cost_2$	Delivery cost	$\{1, …., Cost_2\}$
20	$Cost_3$	Return cost	$\{1, …., Cost_3\}$
21	$Assets_1$	Payment contract system	$\{1, …., Assets_1\}$
22	$Assets_2$	Payment period	$\{1, …., Assets_2\}$

4.2.3 Supply chain performance measurement model for palm oil mill

The performance of palm oil mill is determined by 18 metrics performance. These metrics is decomposed by 4 metrics of reliability, 5 metrics of responsiveness, 2 metrics of agility, 4 metrics of cost and 3 metrics of asset. The metrics notation and definition for the palm oil mill is defined at Table 3.

Suppose that $Relz_i$ represent the *i-th* palm oil-based industry *(z)* value of reliability performance. The mathematical model to measure the reliability performance of palm oil mill is defined at Equation 11.

Table 3. Metrics and notation for palm oil mill

No	Notations	Description	Range
1	*Rel*	Element attribute of Reliability	*{1, …., Rel}*
2	*Resp*	Element attribute Responsiveness	*{1, …., Resp}*
3	*Agil*	Element attribute Agility	*{1, …., Agil}*
4	*Cost*	Element attribute Cost	*{1, …., Cost}*
5	*Assets*	Element attribute Assets	*{1, …., Assets}*
6	Rel_1	Volume of CPO production and raw material	$\{1, ..., Rel_1\}$
7	Rel_2	CPO production capacity	$\{1, ..., Rel_2\}$
8	Rel_3	FFB quality	$\{1, ..., Rel_3\}$
9	Rel_4	CPO quality	$\{1, ..., Rel_4\}$
10	$Resp_1$	Raw material supply cycle	$\{1, ..., Resp_1\}$
11	$Resp_2$	Duration for processing	$\{1, ..., Resp_2\}$
12	$Resp_3$	Production cycle/ day	$\{1, ..., Resp_3\}$
13	$Resp_4$	Work hour per day	$\{1, ..., Resp_4\}$
14	$Resp_5$	Maintenance cycle	$\{1, ..., Resp_5\}$
15	$Agil_1$	Safety Stock	$\{1, ..., Agil_1\}$
16	$Agil_2$	Overtime	$\{1, ..., Agil_2\}$
17	$Cost_1$	Raw material cost	$\{1, ..., Cost_1\}$
18	$Cost_2$	Raw material return cost	$\{1, ..., Cost_2\}$
19	$Cost_3$	Labor salary and management	$\{1, ..., Cost_3\}$
20	$Cost_4$	Energy cost	$\{1, ..., Cost_4\}$
21	$Assets_1$	Payment contract system	$\{1, ..., Assets_1\}$
22	$Assets_2$	Payment system	$\{1, ..., Assets_2\}$
23	$Assets_3$	Pay-off period	$\{1, ..., Assets_3\}$

$$\mathrm{Re}lz_i = N\mathrm{Re}l_1z_i \times W\mathrm{Re}l_1z_i + N\mathrm{Re}l_2z_i \times W\mathrm{Re}l_2z_i + N\mathrm{Re}l_3z_i \times W\mathrm{Re}l_3z_i + N\mathrm{Re}l_4z_i \times W\mathrm{Re}l_4z_i \quad (11)$$

The responsiveness of the *i-th* palm oil-based industry *(z)* is represented as $Respz_i$. The responsiveness performance of palm oil mill is defined at Equation 12.

$$\mathrm{Re}spz_i = N\mathrm{Re}sp_1z_i \times W\mathrm{Re}sp_1z_i + N\mathrm{Re}sp_2z_i \times W\mathrm{Re}sp_2z_i + N\mathrm{Re}sp_3z_i \times W\mathrm{Re}sp_3z_i + N\mathrm{Re}sp_4z_i \times W\mathrm{Re}sp_4z_i \quad (12)$$

$Agilz_i$ represented the *i-th* palm oil-based industry *(z)* value of reliability performance. The mathematical model for measuring the agility performance of palm oil mill is described at Equation 13.

$$Agilz_i = NAgil_1z_i \times WAgil_1z_i + NAgil_2z_i \times WAgil_2z_i \quad (13)$$

Suppose that $Costz_i$ represents the *i-th* palm oil-based industry *(z)* value of cost performance. The cost performance of palm oil mill is defined at Equation 14.

$$\mathrm{Cos}tz_i = N\mathrm{Cos}t_1z_i \times W\mathrm{Cos}t_1z_i + N\mathrm{Cos}t_2z_i \times W\mathrm{Cos}t_2z_i + N\mathrm{Cos}t_3z_i \times W\mathrm{Cos}t_3z_i + N\mathrm{Cos}t_4z_i \times W\mathrm{Cos}t_4z_i \quad (14)$$

Suppose that $Assetz_i$ represents the *i-th* palm oil-based industry *(z)* value of asset performance. The mathematical model for agility performance of palm oil mill is defined at Equation 15.

$$Assetz_i = NAsset_1z_i \times WAsset_1z_i + NAsset_2z_i \times WAsset_2z_i + NAsset_3z_i \times WAsset_3z_i + NAsset_4z_i \times WAsset_4z_i \quad (15)$$

In order to find the value of each metrics in defining the stakeholder's performance, it requires a normalization value processing and specific benchmark value for each metrics (N). Benchmark, if target of Rel_1 is maximum, then normalized value of $Rel_1x_i(N(Rel_1x_i))$ is defined as Equation 16. Benchmark, if target of Rel_1 is maximum, then normalized value of $Rel_1x_i(N(Rel_1x_i))$ is defined as Equation 17. The variable of $B(Rel_1x_i)$ represents benchmark value of metric Rel_1x_i.

The first objective (1) is to measure total performance of reliability, responsiveness, agility, cost, and asset attributes. The total performance is obtained by multiplying the performance attribute value (SC) with the *weight (W)* of each of attributes, concluding the performance value of an attribute. As an example, the total value of reliability performance independent smallholder farmers *i* (x_1) is obtained by multiplying the Rel_1x_i, Rel_2x_i, Rel_3x_i, Rel_3x_i, Rel_4x_i, Rel_5x_i, Rel_6x_i, Rel_7x_i, Rel_8x_i and Rel_9x_i; multiply to each of the attributes' weight *(W)*. The second objectives (2) is to measure the performance of each stakeholder, the value is obtained by aggregating the attributes value. Using these requirements will conclude the stakeholders' performances reliability, responsiveness, agility, cost, and asset (x_i) attributes.

$$N(\mathrm{Re}\, l_1 x_i) = \begin{cases} \dfrac{\mathrm{Re}\, l_1 x_i - \min(\mathrm{Re}\, l_1 x_i, ..., \mathrm{Re}\, l_1 x_n)}{B(\mathrm{Re}\, l_1 x_i) - \min(\mathrm{Re}\, l_1 x_i, ..., \mathrm{Re}\, l_1 x_n)}; if\ \mathrm{Re}\, l_1 x_i \leq B(\mathrm{Re}\, l_1 x_i) \\ 1; if\ \mathrm{Re}\, l_1 x_i \geq B(\mathrm{Re}\, l_1 x_i) \end{cases} \quad (16)$$

$$N(\mathrm{Re}\, l_1 x_i) = \begin{cases} 1; if\ \mathrm{Re}\, l_1 x_i \leq B(\mathrm{Re}\, l_1 x_i) \\ \dfrac{\max(\mathrm{Re}\, l_1 x_i, ..., \mathrm{Re}\, l_1 x_n) - \mathrm{Re}\, l_1 x_i}{\max(\mathrm{Re}\, l_1 x_i, ..., \mathrm{Re}\, l_1 x_n) - B(\mathrm{Re}\, l_1 x_i)}; if\ \mathrm{Re}\, l_1 x_i \geq B(\mathrm{Re}\, l_1 x_i) \end{cases} \quad (17)$$

4.3 System implementation

4.3.1 Information system framework

Based on description above an information system for managing the supply chain performance based on SCOR is designed with provision of four layers of data, namely Application, collaboration, and presentation. The detail contents of layers are described at Table 4.

The user of the information system is managed in 3 levels of supply chain stakeholders, institution user and administrator. The detail of user level of the information system is depicted at Figure 4.

Table 4. Information system layers

Layer	Layers name	Contents
I	Presentation layer	• KPI's scorecard • Reports, Dashboards • BI web parts
II	Collaboration layer	• Content management • Knowledge management • Collaboration and communication
III	Application layer	• Business process management (BPM) • Business data catalogue • Web service
IV	Data layer	• Data warehouse • Data connection libraries • Single sign-on (SSO)

4.3.2 Unified Modeling Language (UML)

Main software engineering approach of UML is deployed to develop the whole requirement of system analysis and design. For the sake of maintenance and portability the proposed model coded in fully compatible language such as JavaScript language in a compact framework called as Bonita. This work preliminarily designs a use-case to illustrate function and interaction among system entity and assisted in implemented the code.

As the preliminary requirement for system development, a concise use-case diagram provided developer on how each actor interact and complete a real-world scheme in palm-oil agroindustry. This use case involves farmer, trader, and oil-palm processor in this agroindustry. For an illustration, the use case diagram for farmer is depicted at Figure 5.

As required in UML framework for initial software development, the object's parameters in class was set to ensure SCOR based model prepares for whole data, information, processes, and actors' requirement. Demand was based on the composite object from class Date and Product. Similarly, the object's parameters in class Stock. As required, Class diagrams depicts the static structures of functional system and provide adequate information for developer to generate each component and feature of this information system. The Class Diagram for this information system is depicted at Figure 6.

4.3.3 Implementation of the proposed model in a case study

The need for a real-world implementation of the proposed model reflect the required output according to what previously extracted from series of mathematical model above. In the following passages, a description of output provides as follows

As basic real-world actor in the oil palm industry, it is crucial to provide performance appraisal system on three types of outputs for actors namely Farmers, Traders and Palm Oil Mill. As required these 3 stakeholders voluntarily filled out every input facility available in the system to determine supply chain performance. The palm oil supply chain performance appraisal information system displays 4 displays that explain the value of the performance of each stakeholder and is equipped with recommendations that are recommended to improve the performance value. As an illustration, a display of supply chain performance values can be seen in Figure 7.

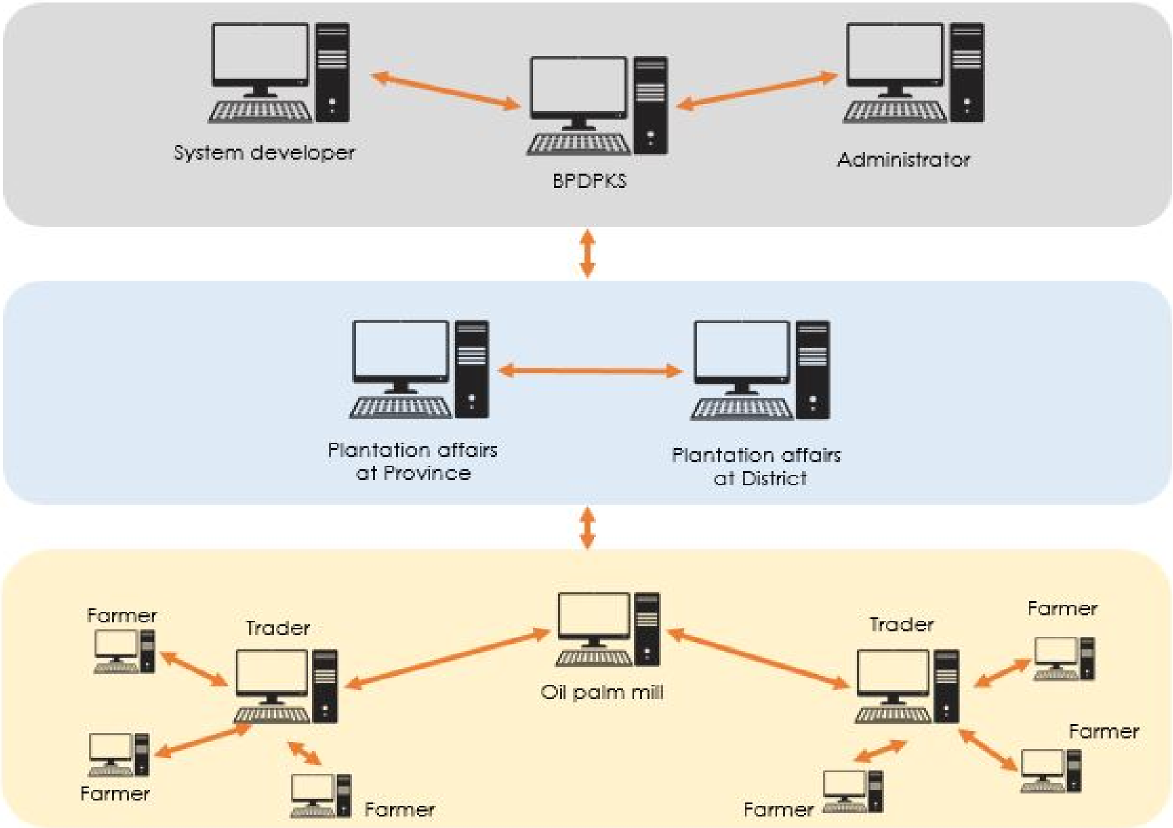

Figure 4. User management of the information system

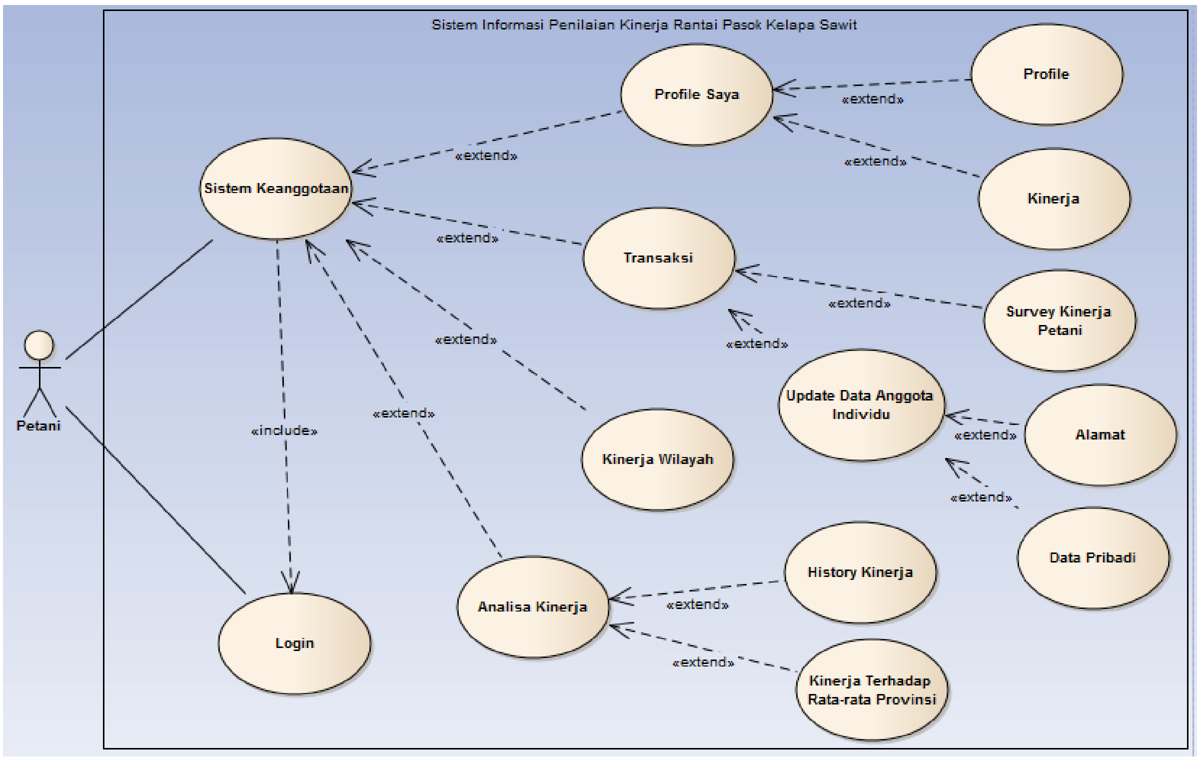

Figure 5. Use-case diagrams for performance measurement at farmer level

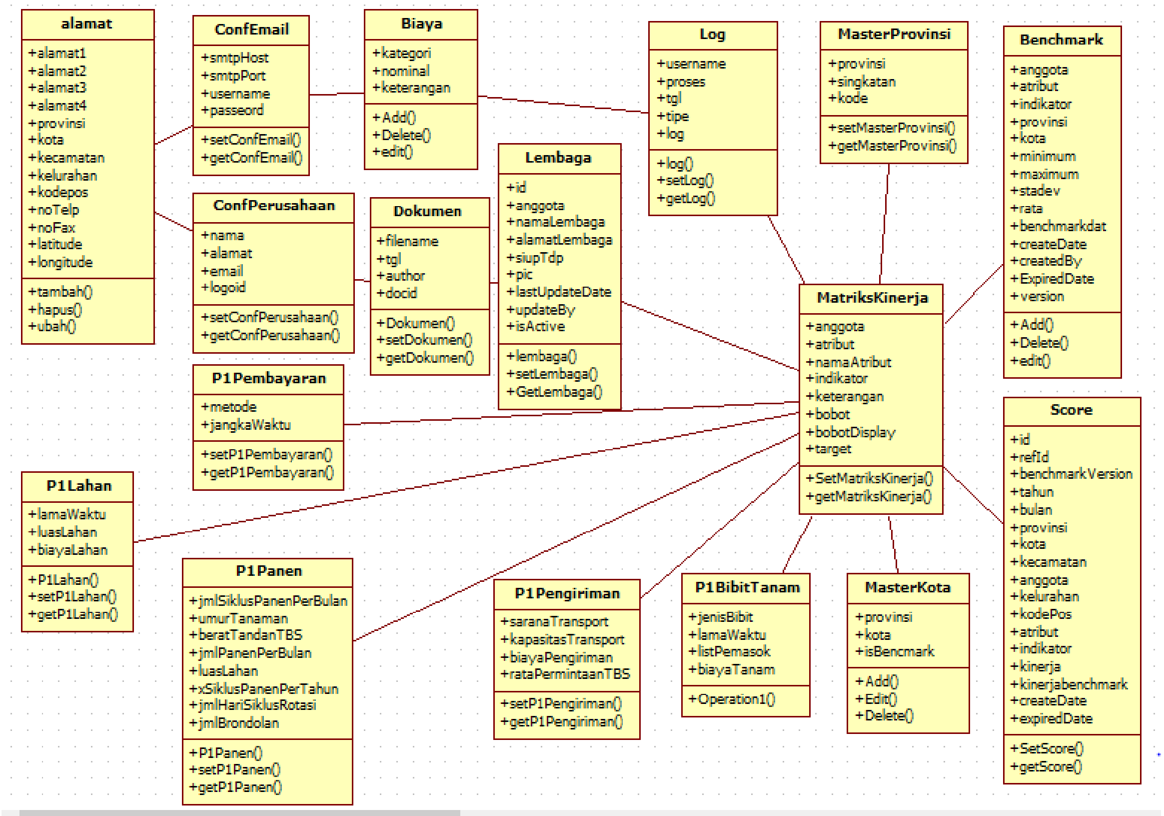

Figure 6. Class diagram of the performance measurement business data models

Supply chain performance values are displayed based on the value of each attribute (reliability, responsiveness, agility, costs, and assets) and the total value of performance. Attribute values and total values have a scale of 1-100 and are grouped into 6 levels, namely poor performance, very low, low, medium, good and very good which refers to Ref. [30]. The low metric value is recommended to be improved so that it can increase the value of supply chain performance.

The illustration of supply chain performance appraisal results on palm-oil mill is shown in Figure 8. Results of performance appraisal on palm-oil mill show a total performance of 64.00 which means it is still poor. The low performance can be seen from the low value of the attributes of responsiveness, agility, cost, and assets. Efforts to improve performance need to be focused on performance metrics that have low values.

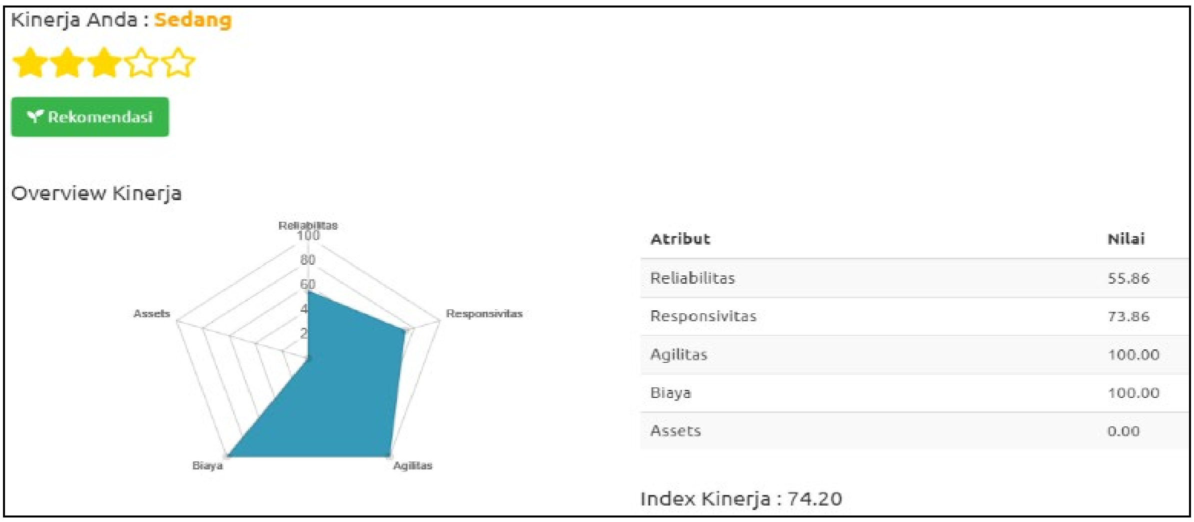

Figure 7. System interfaces for supply chain performance value information for oil palm farmers

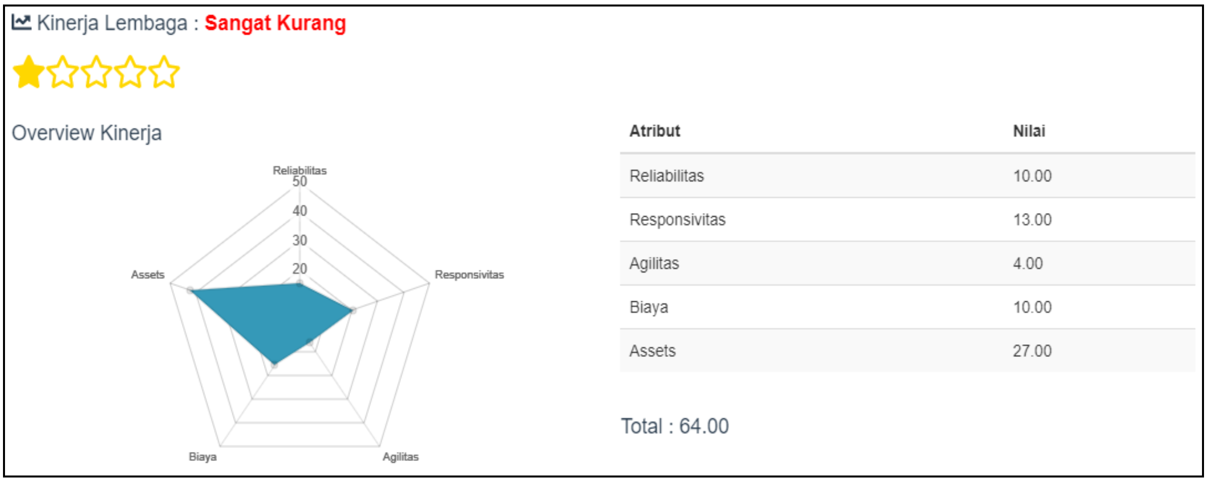

Figure 8. Interface for palm oil mill performance evaluation

In addition, the palm oil supply chain performance appraisal information system is also enabled to present historical performance value information. The information is needed to be able to track efforts to improve the supply chain performance of each stakeholder. Then, attractively, the information system also presents a comparison of the value of stakeholder performance with the average performance value in specific geographical areas. Thus, stakeholders are possible to compare the value of their performance with the average performance value in the region. The system display for performance history values and performance comparison with the regional average values can be seen in Figures 9 and 10.

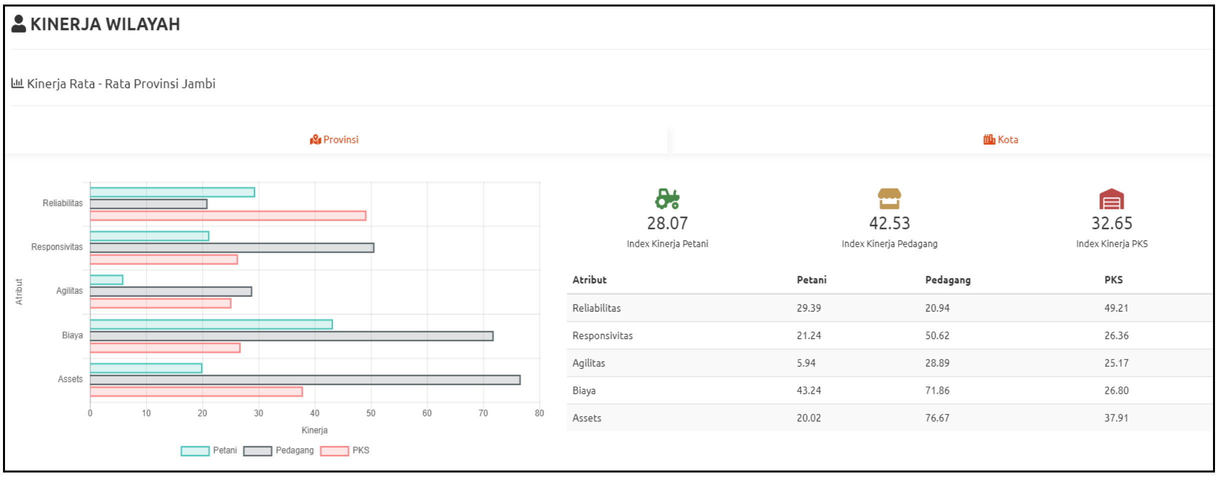

Figure 9. Stakeholders performance geographically

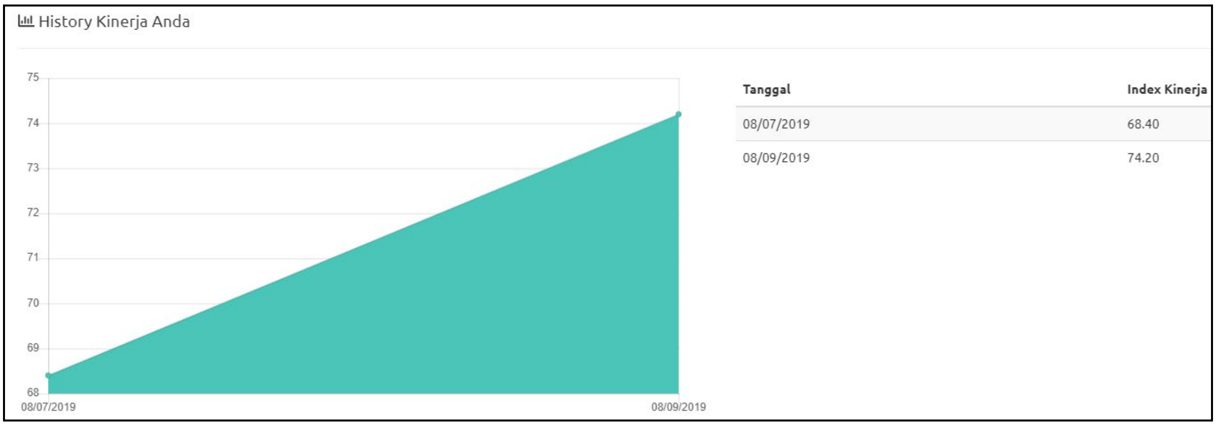

Figure 10. System Interface for performance history

4.4 Verification and validation

Verification for the model was considered on each mathematical model of goals and constraints as explained before. The verification process provides comparation values of results from the model with a manual mathematical calculation using the help of MS. Excel. The data for the verification and validation of this study refer to Ref. [26].

Verification and validation of the information system has been done in the field and obtained the value of the performance of the supply chain stakeholders. Verification and validation are carried out on the performance evaluation of farmers, traders and palm oil mills in Riau and Jambi provinces.

The verification and validity of the model shows that the palm oil supply chain performance appraisal information system has been able to describe the performance value of palm oil supply chain stakeholders in Riau and Jambi Provinces. As an illustration, the results of the performance calculation for the verification and validation of the performance information system for evaluating the performance of the palm oil agro-industry supply chain in Riau and Jambi Provinces can be seen in Table 5.

Table 5. Verification result for performance measurement in Riau and Jambi provinces

Stakeholder	Riau (%)	Jambi (%)
Farmer	77.77	72.66
Trader	74.60	75.39
Palm oil mill	79.20	83.11

5. Conclusions and Recommendations

5.2 Conclusions

A SCOR based information system model was built for quick and integrated evaluating the performance of the palm oil agro-industry supply chain. This system provides a fast interpretation and understanding of supply chain performance in each reliability, responsiveness, agility, cost, and assets measures with each unique metric for each supply chain stakeholders. The mathematical model and UML for assessing the performance of palm oil agro-industry supply chains have been successfully embedded to provide supply chain performance evaluation as well as to see the historical development of supply chain performance values, comparing with the average value of regional performance and determine metrics for performance improvement. In a full perspective, this system quickly displays the supply value of supply chain stakeholders in a specific aggregate at a geographical location. Thus, the existence of these functions can be utilized by related institutions to take policies to improve supply chain effectiveness and efficiency.

5.3 Recommendations

Further improvement of this proposed system required for location-based services and the Internet of Things (IoT) integration. Future implementation needs for a set of standard operating procedure for each stakeholder's data collection and system management to ensure long support for the operation.

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