Decision Support System for Natural Rubber Supply Chain Management Performance Measurement: A Sustainable Balanced Scorecard Approach

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***Abstract*— Performance evaluation and decision making application on natural rubber agro industry productivity improvement along its supply chain is a complex and uncertain process which needs decision support system (DSS). The research objectives were: (1) to analyse natural rubber supply chain decision-making models; (2) to formulate performance measurement model by using sustainable balanced scorecard approach; and (3) to develop decision support system prototype using systems approach. The DSS model consisted of four sub-models, i.e. supply chain performance measurement using sustainable balanced scorecard approach and fuzzy analytical hierarchy process (F-AHP); latex quality improvement strategy selection using F-AHP; prospective product selection using exponential comparison technique; and supply chain performance improvement strategy selection using strengths, weaknesses, opportunities and threats (SWOT) analysis. The developed DSS was implemented and tested by using real cases at Indonesia natural rubber industries. This research gave promising result in improving the natural rubber industry supply chain management performance.**

***Keywords*—** *DSS, Supply Chain, Natural Rubber, Sustainable Balanced Scorecard, Fuzzy AHP*

1. Introduction

Rubber is one of the leading commodities in Indonesia. In 2012, Indonesian rubber plantation area was the largest in the world, but Indonesia has an average productivity of natural rubber which is still low at around 40% of its potential production [1]. On the other hand the demand for natural rubber is continually increasing, driven by the growth of the automotive industry. One effort that can be done to increase the productivity of natural rubber plantation and industry is improving the supply chain management performance [2]. An optimal supply chain performance which plays crucial roles will support the company to continually grow [3].

The complexity of the natural rubber supply chain ranging from latex tapping to the production of refined products require special attention in order to achieve company's supply chain management goal. There are several reasons for the existence of this complexity. First, lack of information and knowledge that supports related decision. The information was incomplete, uncertain or imprecise or even inconsistent. Second there are different goals and conflicting objectives and there are many different types of restrictions. Third, there are time limits for decision making in a changing environment. Fourth, there is a tendency in group decision-making in which various types of consensus occurred in the process [4]. In order to optimize business processes quality, supply chain performance measurement become an important factor to continuously evaluate and boost supply chain performance.

Supply chain performance measurement can be performed accurately and efficiently by using a supply chain performance measurement system. It is used to determine the measurement parameters which should always be monitored in order to create a fit between supply chain strategy and goal of the company [5]. Sustainable balanced scorecard (SBSC) approach can be used to assess supply chain management as a whole. Sustainable balanced scorecard concept considered four

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balanced scorecard perspectives, i.e.: financial, customer, internal process, and learning and growth perspectives as well as environment and social aspect as important part of the main focus. Sustainable balanced scorecard concept in supply chain management enables companies to develop business sustainability in three dimensions of sustainability simultaneously which are economic, social and environmental sustainability.

The objectives of this research were to analyse the natural rubber supply chain decision-making models a long its supply chain; to formulate its performance measurement model by using sustainable balanced scorecard approach; and to develop the decision support system prototype.

In this research, a thematic balanced scorecard [6] was chosen to develop supply chain performance measurement model in a state-owned plantation company in Indonesia (X-Corporation). It measures the supply chain performance which covers the activities in the plantation until the rubber refined products produced at the factory. This format is an adaptation of the one proposed by [7]. Therefore, in this paper, the term triple bottom line will refer to the environmental and social aspects of supply chain performance and its financial aspects. This is in line with [8], focusing on creating value not only in financial terms but also in ecological and social terms.

Fuzzy AHP model was used in the weighting of the key performance indicator (KPI) for the supply chain performance measurement model. Fuzzy AHP was chosen because it combines the concepts of fuzzy theory and analytical hierarchy structure [9]. AHP uses a hierarchical structure among goal, attributes and alternatives. It applied pairwise comparison to evaluate relative importance/preference of criteria/objectives through eigenvector or other simplified methods [10]. But sometimes, the preference of decision maker is completely subjective and it may contain vague expressions. Fuzzy sets were proposed to deal with such vague expressions. Fuzzy AHP helps decision maker to provide an ability of giving interval judgments instead of point judgments [11].

Besides performance measurement, there are some important decisions to be taken in the natural rubber supply chain management including the selection of latex quality improvement strategies, the selection of prospective product and the selection of strategies for improving supply chain performance. Strategies to improve latex quality become important to produce high quality material and to lower its cost. High quality material is one of the important added values in supply chain management [12]. Selection of prospective products needed to determine the potential products based on certain criteria which directly affect product value. By applying the exponential comparison method, decision making will be purposeful, because it will compare several alternatives with using a number of criteria which are determined and weighted by the experts [13]. Appropriate strategies are also needed in order to improve supply chain performance. It is required to boost productivity throughout the supply chain of natural rubber business. Faced with complexity, the uses of strengths, weaknesses, opportunities and threats analysis for strategy formulation can be effective. It helps in gaining insights for solutions which directly related to the existing problems [14].

Performance measurement and decision-making in supply chain management requires several stages of process and experts' analysis in the field. This process requires a relatively long time and considerable expense. Therefore another alternative is needed. Decision support systems (DSS) would be a solution. A DSS is intended to describe in detail the elements of the system so it can support the decision making and performance measurement process. Evaluation and decision-making can be done more efficiently because it is faster, cost-effective and more practical.

In order to get the whole process of implementing sustainable balanced scorecard approach in the DSS, this paper systematically describes the conceptual framework of sustainable balanced scorecard implementation in natural rubber supply chain followed by process design of performance measurement models and implementation of decision support system software prototype. The discussion of the performance measurement result by using the developed DSS prototype in X-Corporation has been elaborated in the latter part.

2. Literature Review

2.1 Review of Related Subject

Ago industrial development is strategic in nature when it is integrated and sustainably managed. Sustainable model was developed by [15] to develop natural rubber agroindustry. Among the constraints of agro industrial development were small scale of agro-processing units and separated location to gain the sufficient operation scale. Development factors gained from aggregated experts' judgment was applied using pairwise comparison technique and Analytical Hierarchy Process (AHP). Ref. [2] mapped and analyzed green productivity of a natural rubber supply chain and formulate scenarios for increasing its green productivity level. The case studies were conducted in private enterprises engaged in natural rubber plantation and processing. Material flow analysis was performed using the green material flow map to analyze the seven sources of green wastes. The best strategy for green productivity improvement was determined by using the Analytic Hierarchy Process (AHP).

Performance measurement of an entire supply chain is important to track the efficacy and efficiency failures rendering more informed decision making process based on the chain design. Based on a review by [16], performance measurement in supply chain may be unique to each individual organization, or unit within an organization, reflecting its fundamental purpose and its environment. Ref. [17] added that stakeholders (internal and external) over the last few decades have caused organizations to consider the environment in their business process. Ref. [18] developed an integrated performance measurement system that contains financial as well as non-financial indicators combined with the specific characteristics of agri-food supply chains. Efficiency, flexibility, responsiveness, and food quality are identified as key performance components of the tomato supply chain performance measurement system. Ref. [19] developed Performance measurement of supply chain management using a balanced scorecard approach. The paper further suggests that a balanced SCM scorecard can be the foundation for a strategic SCM system. Ref. [20] developed a framework to promote a better understanding of the importance of SCM performance measurement. Their paper explained how performance measurement and metrics have an important role to play in setting objectives, evaluating performance, and determining future courses of actions.

The use of decision support system (DSS) in business or organizational decision-making activities is growing rapidly. A decision tools used to analyze and measure the magnitude of the environmental impact in closed supply chains was made by [21]. Their paper proposes a multi criteria decision-aid (MCDA) approach to aid the decision maker in selecting the best end-of-life alternatives. This paper also proposed that sustainability can be obtained by changing the objectives from economy driven towards economy, environment and society driven. Ref. [22] propose a method for supporting decision makers in the domain of supply chain management based on combination of the simulation and optimization techniques which includes a multi-objectives optimization module and a simulation module. As a conclusion, the decision support system can provide Optimum solution that is the best feasible solution that achieves the objective of the optimization problem. Ref. [23] also developed decision support systems in reverse supply chain management. The role of pacing technologies to support green manufacturing development with main emphasis on issues such as agent technologies, cloud computing, big data and cyber physical systems is explained on their work.

Fuzzy AHP has been widely used for multi criteria decision making in various areas. Ref. [11] used it for prioritization of organizational capital measurement indicators. In education sector, [10] used fuzzy AHP approach to evaluate knowledge portal development. Ref. [24] used it for consultant selection (using either the company's own consultants or outsourcing) to each project in Turky. Ref. [25] used fuzzy AHP to evaluate success factors of e-commerce. Ref. [26] also developed a fuzzy AHP-based decision support system for selecting enterprise resource planning (ERP) systems by using balanced scorecard.

2.2 Thematic Balanced Scorecard Format Used for Measurement

In the BSC all relevant aspects to achieve a competitive advantage are to be permanently incorporated into the four BSC perspectives. The existence of the strategy map in the generic BSC model shows the interrelationship between strategic objectives and KPIs in each perspective. It helps managers to monitor the success and failure of strategies chosen by the firm [6]. Along with the expansion of the problems in a business process management, sustainability has become necessary in company development.

Measuring performance using balanced scorecard can be done in three main steps, i.e. (1) identify measurements for each strategic goal, (2) identify sources for measurement and (3) define how the measurement is performed and reported [27]. Formulation of BSC objectives and measures in all perspectives are derived from long-term financial goals in a top-down process. The hierarchical structure of the BSC ensures that all business activities are successful implementation of business strategies. These characteristics enable BSC to cover the three dimensions of sustainability. It may integrate the management of environmental and social aspects into the core business activities [7].

Basically there are three possibilities to integrate environmental and social aspects in the BSC. First, environmental and social aspects can be integrated in the existing four standard perspectives. Second, the additional perspective can be added to explore aspects of the environmental and social evaluation. Third, a specific formulation scorecard can be made for the environmental aspects and/or social [28]. Environmental and social aspects may be included under the existing four BSC perspectives as all other relevant strategic and potential aspects. This means those aspects are integrated into four perspectives through relevant strategic goals or performance indicators [29]. Through top-down derivation, environmental and social aspects will become an integral part of conventional scorecard and automatically integrated in it as well as having a causal and hierarchical connection and oriented on financial perspective [28].

Ref. [30] in [31] introduced a fifth perspective in the balanced scorecard to cope with strategic orientation of the organization in terms of sustainability management. By creating a separate report, an organization can be easier in assessing implementation of relevant indicators, measurement procedures and whether it is based on financial and non-financial perspective. But with the advent of the fifth perspective it would be difficult to make a set of measurements that only evaluate the social and environmental performance while not related to the other four perspectives [31].

The process of formulating the SBSC must meet some basic requirements. First, the business process should lead to the integration of social and environmental management into business management. Second, a SBSC that meet the characteristics and requirements of the environmental and social aspects of the business units should not be general. This process must be able to ensure, that the SBSC are formulated for specific business units. The social and environmental aspects together with business units should be integrated according to company's strategic relevance [28].

The result of preparing BSC can be shown graphically using a strategy map. In a strategy map, all aspects of economic, environmental and social networks were identified in the hierarchical chain of causation. After the identification and alignment process for relevant strategic aspects, the next step is to determine the indicators, targets and measures to control and direct company's performance to achieve goals and make sustainable contribution.

3. Method

This decision support system designed to help the operation head or director of X-Corporation in the strategic decision making process on supply chain management. Besides supply chain performance measurement model, to support the decision-making process in supply chain, the system is also equipped with a green value stream map (GVSM) of ribbed smoked sheet production process. Green value stream map by [32] is an approach to determine production process efficiency by considering the seven green wastes. Research framework can be seen in Figure 1.

Supply chain performance measurement sub-model was designed to assist users in evaluating performance and provide recommendations on processes occurring in the supply chain management. This model was developed using a sustainable balanced scorecard approach (SBSC). This concept is expected to improve the company's performance in the three dimensions of sustainability namely the economic, social and environmental dimensions simultaneously. The performance measurement modelling began by compiling a map of the company's supply chain management strategy. Strategy map which consists of four main perspectives in SBSC was formulated based on focus group discussion and in-depth interview with experts. On strategy map, strategic goals for each perspective were formulated based on company's goals and objectives. Furthermore, analysis continued by determining the KPIs for the performance measurement of the supply chain which was tailored with strategic goals of company supply chain management. The next step was weighting of KPIs and determining strategies for improving each KPI in conditional function. The last step was designing interface of the model.

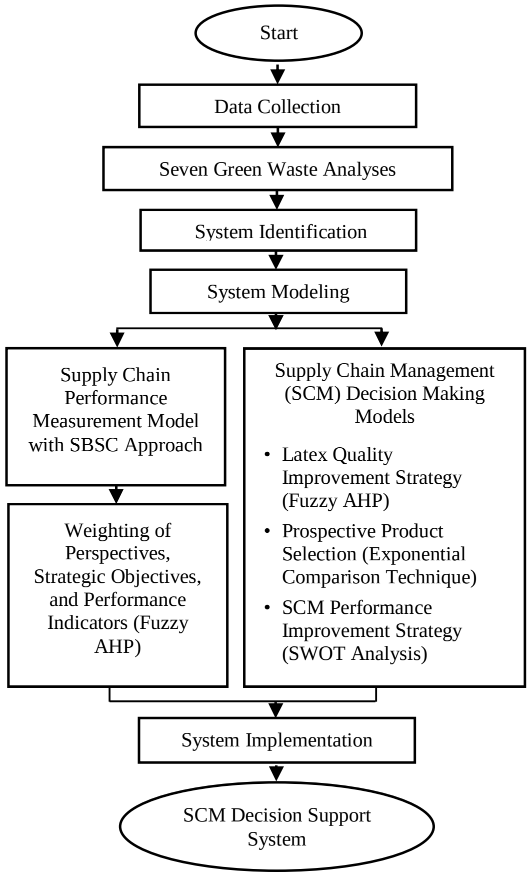

Figure 1. Research framework

The second sub-model was latex quality improvement strategy selection. This sub-model developed by using fuzzy AHP. Preparation of the hierarchy and weighting conducted with experts in the field of natural rubber. This sub-model results in the order of strategic alternatives priority. The third sub-model, prospective product selection, was designed to determine the top production priorities of natural rubber refined products. Exponential comparison method was used in this section. The stages of the modelling process were formulating of criteria, weighting of criteria, and followed by interface design of the model. The development flow diagram of these models can be seen in Figure 2 and Figure 3.

The forth sub-model, supply chain performance improvement strategy selection was developed by using SWOT analysis. This sub-model was designed to choose the best strategy to improve supply chain performance based on the analysis of strengths (S), weaknesses (W), opportunities (O) and threats (T) to X-Corporation in managing the supply chain management of natural rubber. Analysis began with the identification of internal factors (strengths and weaknesses) and external factors (opportunities, and threats). Then a SWOT matrix was created based on the factors that have been identified. It contains strategies for improving supply chain performance. The next step was the weighting of the factors, followed by interface design of the model. Experts' opinion was always involved in every formulation process of criteria and alternatives and also in the weighting process in all sub-models. The development flow diagram of supply chain performance improvement strategy selection is presented in Figure 4.

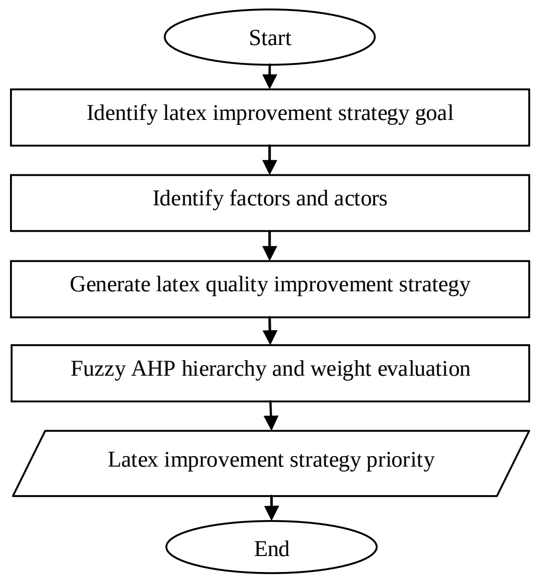

Figure 2. Model development flow diagram of latex improvement strategy selection

In this paper, Fuzzy AHP was used in weighting of KPIs in performance measurement sub-model and once in latex quality improvement strategy selection sub-model. This study used a triangular fuzzy number of $\tilde{1} - \tilde{9}$ to represent subjective judgment on dubious pairwise comparison [33]. This was used to improve the conventional nine-point scale used on conventional AHP.

Fuzzy numbers is a special fuzzy set F = {(x, μf (x)), x ε R}, where x is the value of real numbers, R: $-\infty < x < +\infty$ and μf (x) is a continuous mapping of R to the closed interval [0, 1]. A triangular fuzzy number is expressed as $\widetilde{M}$ = (l, m, u), with l ≤ m ≤

u as a triangular membership functions. Its functions are defined as Eq. (1).

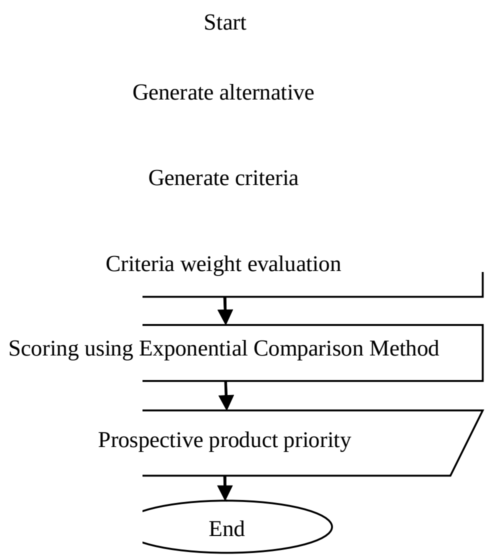

Figure 3. Model development flow diagram of prospective product selection

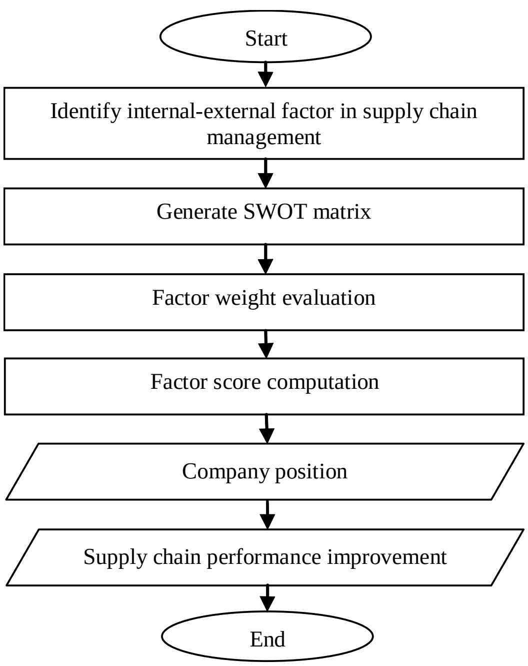

Figure 4. Model development flow diagram of supply chain performance improvement strategy selection

Five class of fuzzy representation were used in this study as described in Figure 5 [34]. The definitions of fuzzy membership number can be explained by Table 1 [35]. This fuzzy set is defined by confidence level of α and optimism index of ω.

$$\mathrm{uF(x)} = \begin{cases} 0, & x < l \\ \mathrm{x - l/m - l}, & l \le x \le m \\ \mathrm{u - x/\,u - m}, & \mathrm{m \le x \le u} \\ 0, & x > u \end{cases} \quad (1)$$

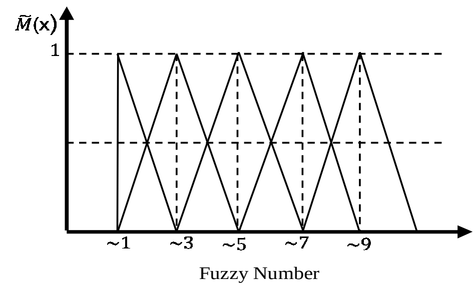

Figure 5. Fuzzy membership function $\widetilde{M}$(x) for the value of linguistic criteria and alternative [34]

Table 1. Definitions and Functions of Fuzzy Membership Number [35]

Level of importance	Fuzzy number	Definition	Fuzzy set
1	~ 1	Equally important	(1,1,2)
3	~ 3	Slightly more important	(2,3,4)
5	~ 5	Clearly more important	(4,5,6)
7	~ 7	Very clearly more important	(6,7,8)
9	~ 9	Absolutely more important	(8,9,10)

The hierarchy of the identified problems was set before performing the weighting procedure. The first stage of fuzzy AHP weighting procedure is the pairwise comparisons. In this stage, the triangular fuzzy numbers are used to perform an indication of the relative importance for each pair of elements in the same hierarchy level. The second stage is creating fuzzy comparison matrix. Fuzzy comparison matrixes $\widetilde{A}_{(ij)}$ are defined as Eq. (2).

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \cdots & \cdots & \vdots \\ \vdots & \vdots & \cdots & \cdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \cdots & 1 \end{bmatrix} \quad (2)$$

$$with\ \tilde{a}_{ij}^{a} = 1 \text{ if } i = j, \text{and } \tilde{a}_{ij}^{a} = \tilde{1}, \tilde{3}, \tilde{5}, \tilde{7}, \tilde{9}, \text{or } \tilde{1}^{-1}, \tilde{3}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1} \text{ if } i \ne j$$

The third stage is to calculate the relative importance value (fuzzy eigen value) of all elements based on elements on the higher level in the hierarchy structure [36]. Fuzzy eigen value is a fuzzy number to complete the Eq. (3).

$$\tilde{A}\ \tilde{x} = \tilde{\lambda}\ \tilde{x} \qquad (3)$$

$\tilde{A}$ is (nxn) fuzzy matrix containing fuzzy numbers $\tilde{a}_{ij}$ *and* $\tilde{x}$ is $(nx1)$ fuzzy vector containing fuzzy numbers $\tilde{x}_i$

In order to obtain this eigen values, triangular fuzzy values in the matrix needs to be converted into the range of confidence level (α-cut fuzzy). The upper limit and lower limit of fuzzy numbers in the matrix is determined based on the value of α-cut by using the Eq. (4).

$$\tilde{1}_\alpha = [1, 3 - 2\alpha]$$

$$\tilde{3}_\alpha = [1 + 2\alpha, 5 - 2\alpha],\ \tilde{3}_\alpha^{-1} = \left[\frac{1}{5-2\alpha}, \frac{1}{1+2\alpha}\right]$$

$$\tilde{5}_\alpha = [3 + 2\alpha, 7 - 2\alpha],\ \tilde{5}_\alpha^{-1} = \left[\frac{1}{7-2\alpha}, \frac{1}{3+2\alpha}\right]$$

$$\tilde{7}_\alpha = [5 + 2\alpha, 9 - 2\alpha],\ \tilde{7}_\alpha^{-1} = \left[\frac{1}{9-2\alpha}, \frac{1}{5+2\alpha}\right]$$

$$\tilde{9}_\alpha = [7 + 2\alpha, 11 - 2\alpha],\ \tilde{9}_\alpha^{-1} = \left[\frac{1}{11-2\alpha}, \frac{1}{7+2\alpha}\right] \quad (4)$$

This paper used α = 0.5, which means experts have an average level of confidence at the time of judgment. The α-cut comparison matrix values then converted again into crisp values using the Eq. (5). This paper used optimism index of 0.5.

$$\tilde{a}_{ij}^{a} = \omega a_{ij}^{a} + (1-\omega) a_{ijl}^{a}, \qquad \forall \omega \epsilon [0,1] \qquad (5)$$

According to [36], the weight of priority in a crisp matrix can be calculated using Eq. (3) which is converted into Eq. (6). Priority weight on each alternative is obtained by taking into account the weight of every element on each level of the hierarchy. To control the outcome of this method, there are consistency ratio calculation for each matrix and the entire hierarchy.

$$x_i = \frac{\sum_{i=1}^{n}\left(\frac{a_{ij}}{\sum_{j=1}^{n} aij}\right)}{n} \qquad (6)$$

The decision support system designed consists of several main parts: a centralized processing system, database management system (DBMS), model base management system (MBMS), and dialogue management system. System development was conducted using object-oriented development stages based on the unified modelling language (UML) which consists of three phases, which were: problem identification phase, system analysis phase and system design phase [37]. The subsequent activities were the system verification and validation. System configuration can be seen in Figure 6. The object-oriented development was conducted by using Power Designer 16.5. The DSS software was developed by using Java[tm] programming language of NetBeans IDE 7.0.1.

The verification process of the program was done by black box testing method. Black box testing was performed by testing the suitability of data input display data output, by not seeing the source code [38]. Numerical validation was done by simulation as well as the actual data.

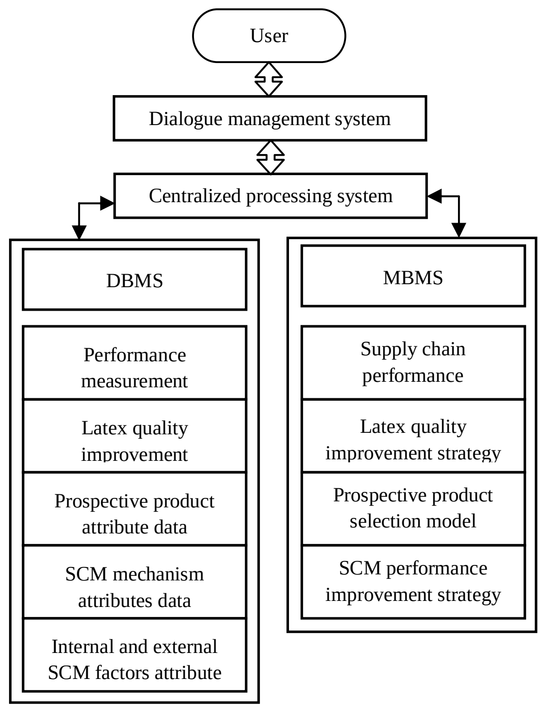

Figure 6. System configuration

4. Results and Discussion

4.1 Strategy Map of Company's Supply Chain Management

Strategy map would show linkages and causal relationships between strategic objectives both within and between perspectives. On this paper, environmental and social aspects are integrated in the existing four perspectives of BSC. In perspective, strategic objectives are equipped with

KPI. The lead indicators are used to trigger the achievement of strategic objectives. Meanwhile lag indicators are used as quantitative measure for achieving the strategic objectives.

The lowermost perspective of the BSC was the learning and growth. Ref. [19] used innovation and learning perspective which focus on cost reduction and product differentiation as lowermost perspective, meanwhile [26] was prioritizing on organizational structure and personnel management. In supply chain management of state-owned natural rubber company in Indonesia, there was a need of tendency in learning and growth perspective to focus on human resource development. This is due to most of the main activities of the production process require special skills and without the uses of heavy machines, such as latex tapping, latex coagulation process, and sheet grinding process. On the other hand, the majority of the workers were not well-trained workforce. In addition, total productivity is strongly influenced by the productivity of each worker. So, the human resource development perspective used on the map contains three points as company's strategic objectives, including the worker and business unit safety, worker capacity improvement, and worker satisfaction.

An internal process perspective was placed after human resource development. Ref. [18] measured the performance of supply chain process with four categories of performance indicators consist of efficiency, flexibility, responsiveness, and quality. With the aspect of sustainability added to this work, it will complete those four categories. In this perspective, there are five strategic objectives of which two of them are the strategic objectives which refers to environmental sustainability aspects. It is used as an attempt to improve the quality of environmental maintenance and also for the resource efficiency. Those two are the energy, water, raw materials and working capital efficiency and the more environmentally friendly production processes. This is in line with [2], the optimization of production process and the efficient uses of resources are the best strategies to improve natural rubber supply chain productivity. Other strategic objectives in internal process perspective are the fulfilment of natural rubber raw material supply and the optimization of delivery performance. The four them along with the strategic objective of worker satisfaction from human resource development will directly support the achievement of the fifth and top objective on perspective, which is the productivity improvement. For the KPI, [20] used cost-oriented lead indicators to measure production performance, whereas this work used more technical approaches such as the lag indicator of rework level.

The third perspective is the perspective of customers. The first strategic objective on this perspective is the customer satisfaction. The second one is the creating the environmental awareness image. The third strategic objective is the good society relations along supply chain. This perspective is aimed to improve performance in the social dimension. The presence of social aspect on supply chain strategy map complements the concept of environmental sustainability on supply chain that has been put forward by [16] and [17]. The last objective is growing market share which is directly supported by the three strategic objectives before. Meanwhile financial perspective is composed of two strategic objectives. The first one is the supply chain operational cost reduction which directly supported by the top objective on the internal process perspective. The objective of the improvement in company’s net profit is in the peak of strategy map that describes the company's main goal.

4.2 Weighting in Performances Measurement Model

Ref. [11], [24], and [26] developed three levels AHP hierarchy while in this study the AHP hierarchy is consisted of four levels, namely (1) goal, (2) perspective, (3) strategic objective and (4) key performance indicator. Weighting conducted by four experts with professional and academic background. Each expert conducts pairwise comparison gradually starting from the level of goal to the KPI. Experts provide judgment in the form of fuzzy linguistic scale. Consistency checks are also carried out at each stage of pairwise comparison. The provided data then processed by fuzzy AHP method to get the weight of KPIs, strategic objectives, perspectives, and goals.

The goals identified and ordered by priority were (1) market access improvement, (2) sustainable partnership, (3) build financial strength, (4) operational efficiency improvement, (5) decrease supply chain risk and (6) product value added improvement respectively. Perspectives identified and ordered by priority were (1) customer, (2) financial, (3) human resource development, and (4) internal process respectively. Strategic objectives identified and ordered by priority were (1) supply chain operational cost, (2) net profit, (3) worker satisfaction, (4) customer satisfaction, (5) market share, (6) worker capacity improvement, (7) worker and business unit safety, (8) supply fulfilment, (9) society relations, (10) environmental awareness image, (11) energy, water, supply, working capital efficiency, (12) productivity improvement, (13) environmentally friendly production process and (14) delivery performance respectively. Furthermore, key performance indicators identified and ordered by priority were : (1) net profit margin, (2) net revenue, (3) worker satisfaction, (4) customer complaints, (5) market growth rate, (6) average SCM training hours per FTE, (7) work accident frequency, (8) program budget spent, (9) PROPER conduct, (10) rework level, (11) liquid waste treatment percentage, (12) quality requirement fulfilment percentage, (13) quantity fulfilment percentage, (14) production schedule accuracy percentage, (15) unit output per direct labour hours and (16) delivery on time respectively. The result of the weighting of goals, perspectives, strategic objectives and key performance indicators by experts can be seen in Table 2.

Table 2. Weight of goals, perspectives, strategic objectives and key performance indicators

Level	**Priority**		**Weight**
Goal	1	Market access improvement	0.234
	2	Sustainable partnership	0.207
	3	Build financial strength	0.174
	4	Operational efficiency improvement	0.174
	5	Decrease supply chain risk	0.127
	6	Product value added improvement	0.085
Perspective	1	Customer	0.318
	2	Financial	0.270
	3	Human resource development	0.228
	4	Internal process	0.184
Strategic Objective	1	Supply chain operational cost	0.155
	2	Net profit	0.115
	3	Worker satisfaction	0.099
	4	Customer satisfaction	0.092
	5	Market share	0.090
	6	Worker capacity improvement	0.074
	7	Worker and business unit safety	0.055
	8	Supply fulfillment	0.051
	9	Society relations	0.048
	10	Environmental awareness image	0.048
	11	Energy, water, supply and working capital efficiency	0.046
	12	Productivity improvement	0.041
	13	Environmentally friendly production process	0.030
	14	Delivery performance	0.016
Key Performance Indicator	1	Net profit margin	0.155
	2	Net revenue	0.115
	3	Worker satisfaction	0.099
	4	Customer complaints	0.092
	5	Market growth rate	0.090
	6	Average SCM training hours per FTE	0.074
	7	Work accident frequency	0.055
	8	Program budget spent	0.048
	9	PROPER conduct	0.048
	10	Rework level	0.046
	11	Liquid waste treatment percentage	0.030
	12	Quality requirement fulfillment percentage	0.028
	13	Quantity fulfillment percentage	0.023
	14	Production schedule accuracy percentage	0.022
	15	Unit output per direct labor hours	0.019

	16	Delivery on time ratio	0.016

4.3 Latex Quality Improvement Strategy

The AHP structure consisted of four levels, namely (1) goal, (2) factor, (3) actor and (4) alternative. The goals identified were (1) latex quality, (2) latex quantity, and (3) tree age. Factors identified were (1) skill and resilience, (2) technology, (3) facilities and infrastructure, (4) clone variety, (5) tapping procedure, (6) plantation location. Actors identified were (1) enterprise and (2) research and development facilities. Alternatives identified were : (1) improve tapping procedure, (2) search and apply new technology, (3) nursery and plantation procedure improvement, (4) choose best topography for plantation, (5) facilities and infrastructure procurement, (6) company staff training, (7) establish task force, (8) clone variety development, and (9) improve staff performance. The result of latex quality improvement strategy selection by experts is illustrated in Table 3.

Table 3. Goals, factors, actors and alternatives based on priority

Level	Priority		Weight
Goal	1	Latex Quality	0.444
	2	Latex Quantity	0.314
	3	Tree age	0.242
Factor	1	Skill and resilience	0.248
	2	Technology	0.231
	3	Facilities and infrastructure	0.170
	4	Clone variety	0.135
	5	Tapping procedure	0.126
	6	Plantation location	0.090
Actor	1	State owned enterprise plantation	0.587
	2	Research and development facilities	0.413
Alternative	1	Improve tapping procedure	0.201
	2	Search and apply new technology	0.159
	3	Nursery and planting procedure improvement	0.116
	4	Choose best topography for plantation	0.106
	5	Facilities and infrastructure procurement	0.092
	6	Company staff training	0.087
	7	Establish task force	0.083
	8	Clone variety development	0.083
	9	Improve staff performance	0.072

4.4 Prospective Product Selection

Prospective product was selected amongst several potential products, i.e. ribbed smoked sheet 1 (RSS 1), ribbed smoked sheet 2 (RSS 2), ribbed smoked sheet 3 (RSS 3), brown creep 1X (BRCR 1X), brown creep 2X (BRCR 2X), standard Indonesian rubber 10 (SIR 10), standard Indonesian rubber 20 (SIR 20), and concentrated latex (CL). The result of prospective product selection is illustrated in Table 4.

Table 4. Prospective product selection

No	Criteria	Weight	RSS1	RSS2	RSS3	BRCR 1X	BRCR 2X	SIR10	SIR20	CL
1	Product demand	***5***	5	3	1	2	1	4	3	3
2	Production facility availability	***4***	3	2	2	3	2	5	4	3
3	Profit/Kg product	***4***	5	4	3	2	3	5	2	2
4	Human resource availability	***4***	4	3	2	3	3	4	1	5
5	Production time	***3***	2	4	3	2	3	3	2	4
6	Perishability risk	***3***	3	2	2	3	1	4	3	3
7	Product shelf life	***3***	3	2	3	3	2	2	3	3
Total score			4149	676	176	272	215	2629	578	1083

Alternative priority	1	4	8	6	7	2	5	3

4.5 Supply Chain Performance Improvement Strategy

The SWOT matrix was created based on internal and external factors that have been identified. It contains strategies for improving supply chain performance. The SWOT matrix in supply chain performance improvement model can be seen in Figure 7.

Internal Factors / External Factors	**Strengths (S)** 1. The high ratio of net income/revenue. 2. High availability of funds for investment. 3. Provided with customer trust and loyalty. 4. The availability of satisfied production facilities and infrastructure. 5. Produce high quality product. 6. Good employees' performance.	**Weaknesses (W)** 1. The available land is limited. 2. Non-optimal material handling. 3. The processing technology is not well developed yet. 4. Training employees were still slightly. 5. Non-availability of SIR product processing center.
Opportunities (O) 1. There is available land for any purposes. 2. The increased consumption of natural rubber product worldwide. 3. The fast development of natural rubber science and technology. 4. High demand of SIR product.	**(SO)** 1. The use of vacant land for business opportunities of woody plants. (S_2 & O_1) 2. Perform production activities with emphasis on quality. ($S_{3,4,5,6}$ & $O_{2,3}$) 3. Ensuring the expansion of the market, either by sales promotion or cooperation with other firms. ($S_{3,5}$ & O_2) 4. Build up SIR processing center. ($S_{1,2}$ & O_4)	**(WO)** 1. Make training programs related to production activities for employees. ($W_{2,3,4}$ & O_3) 2. Cooperation with research institutions to solve various problems related to the plant cultivation and enhances the technology of natural rubber product production process. ($W_{2,4}$ & O_3) 3. Focus on maintaining the quality of raw material (latex). ($W_{1,2,5}$ & O_3)
Threats (T) 1. The price of processed rubber products is fluctuating. 2. The low cost of production in other countries. 3. The bargaining power of workers increases every year.	**(ST)** 1. Focus on declining production costs by performing a variety of efficiency. ($S_{2,6}$ & $T_{1,3}$) 2. Maintain the quality of products as strong value to compete with another company. (S_5 & T_2)	**(ST)** 1. Provide better fostering for organization and employees to improve company performance. ($W_{2,4,5}$ & T_2) 2. Apply the Total Quality management in the whole process. ($W_{1\text{-}5}$ & $T_{1,2}$)

Figure 7. SWOT matrix

4.6 Implementation of Decision Support System Software

The DSS was built in a Java^{tm} program package named AHAt. 01. The main subsystem of this program contains supply chain performance measurement sub-model. This sub-model was designed to be used for seven years forward. This sub-model also provides information to support the process of performance measurement. The main output of this sub-model was the overall total score in percent and improvement recommendations for each KPI.

The measurement on supply chain performance measurement sub-model based on actual data showed that the overall performance index was 78.57%. Some targets were not achieved. The lowest target achieve was on the perspective of human resource development which was equal to 67.43%. The cause of its low value among other was the very low average SCM training hours. This is a similar problem faced by Indonesian natural rubber private enterprises. Farmers' access to recommended technology is very limited and they don’t have adequate assistance agencies to give training [15]. So this became one of the main problems of productivity improvement [2].

Furthermore, customer perspective achieved 72.55%. The objective of creating an environmental awareness image did not reach the target. It was because X-Corporation did not have any PROPER predicate (environmental management performance rating given by Environment Ministry of Indonesia to industry). Meanwhile, the internal process perspective achieved 80.68%. The lag indicator that had not been properly fulfilled was the percentage of rework level. Poor work control resulting in lots of wasted resources. This can be seen from the lots of products that need to be reprocessed. Related to this, the low level of green productivity in industry is an opportunity to apply the new techniques and approaches of sustainability [17]. Definitely it is for both environmental and social sustainability.

And lastly, the peak perspective performance was at 93.67%. The performance measurement results display in DSS can be seen in Figure 8. In addition, this sub-model also proposed specific recommendations for each KPI, so there are 16 recommendations, such as add more often and uniformly employee training hours, correct the procedures in production process of refined products, proposed better environmental management system, improve service quality to partners and customers and increase sales with new customers.

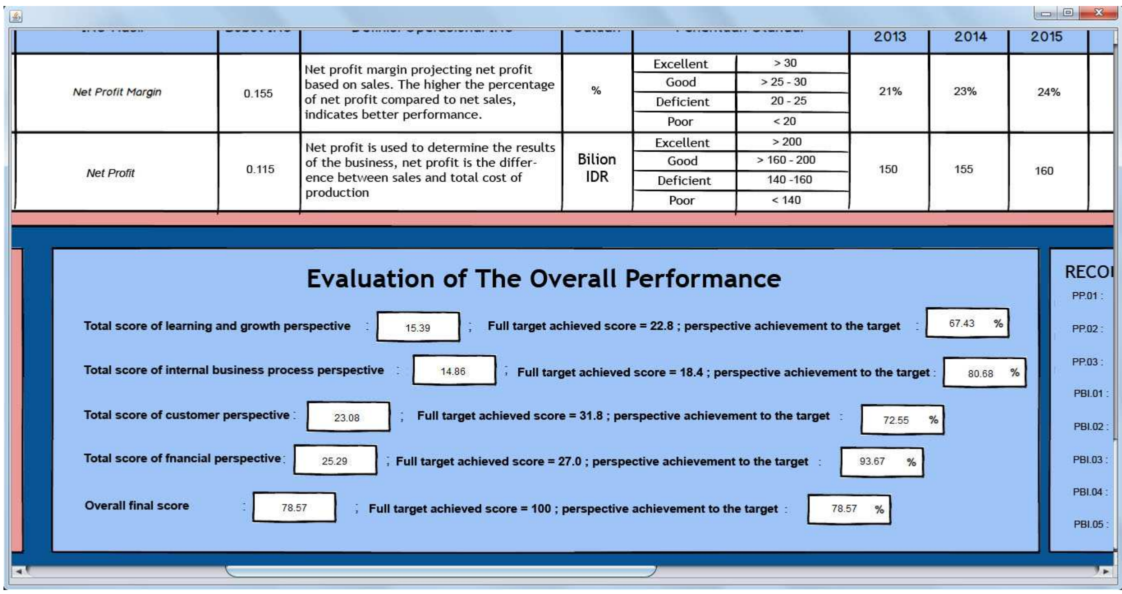

Figure 8. Sample of supply chain performance measurement Result in AHAt.01.

The second subsystem contains a latex quality improvement strategy selection sub-model. Based on experts' assessment, the improvement on tapping procedures to match the best practice of tapping behaviour has the highest weight, which is 0.201. Followed by strategy to search and implement new technologies on harvest and post-harvest process with 0.159. The third sub-model contains a prospective product selection model which is based on experts determined criteria. This sub-model's output were the product total score and product ranking. Based on the ECM method, the alternatives were weighted and resulted as RSS 1 as the best, followed by SIR 10, concentrated latex, RSS 2, SIR 20, brown crepe 1X, brown crepe 2X and RSS 3. Those were based on demand on the market, the availability of production facilities, profit/Kg, the availability of human resources, processing time, risk of damage, and its shelf life.

The forth sub-model contains a strategy selection model for improving supply chain performance based on SWOT models. Based on the assessment provided by the company, this model indicated that the X-Corporation was in quadrant II in SWOT diagram with the internal factor evaluation score of 1.392 and the external factor evaluation score of -0.018. There were two strategies recommended by the system. First, was to decline production costs by performing a variety of efficiency. Second, was to maintain the quality of products as strong value to compete with another company.

The last sub-model contains green value stream map information of X-Corporation. Based on green value stream map information of X-Corporation, there was high potential for efficient use of water resources and electricity. Water savings can be made by using a water arm control in each water hose while the electrical energy savings can be made by replacing incandescent lamps with energy saving lamps.

4.7 Managerial Implication

The several strategies which have been proposed by this decision support system is important to apply because those strategies were formulated based on various criteria formulated together with experts and user to create better business opportunities. Increased productivity can be achieved with the application of the right strategies and good control. The results of the evaluation of internal and external factors showed that X-Corporation had to focus to use all strength to cope with the threat. Availability of infrastructure and good employees allowed the company to perform a variety of efficiency while maintaining product quality. These need to be done considering the competition both at home and abroad are increasingly stringent. Supply chain performance measurement which was done on a regular monthly basis can be a control for the efficiency efforts. Along with the rise of consumer and public awareness about the importance of implementing environmentally conscious and socially insightful business processes, the inclusion of environmental and social aspects in assessment of supply chain performance has been supporting X-Corporation to anticipate the challenges of the future.

Supply chain performance measurement model in this study can also be applied to private rubber plantation. Strategy map in this study can be adapted for private rubber plantation, definitely with adjustment on performance indicators and target according to the needs of the company.

5. Conclusions and Suggestions

It can be concluded that supply chain performance measurement model can be designed with the three dimensions of sustainability (economic, social, and environment) simultaneously using the adjusted sustainable balanced scorecard approach. In X-Corporation, customer perspective has the highest weight of importance followed by financial, human resource development and internal process perspective.

The models of decision-making and performance measurement have been implemented in a DSS computer program named AHAt.01. The DSS was proved able to help performance measurement process and provide recommendations and suggestions for improvement of natural rubber supply chain management.

Study of other important decisions in management of natural rubber supply chain needs to be done, such as rubber plant clone selection, cultivation technology and processing selection, and additional production facilities procurement.

For future work, this DSS can be enhanced for solving more adaptive and dynamic decision making problems. The availability of the facility to make changes to attributes, criteria, alternatives, and weight used in DSS would help users to customize DSS with the development of natural rubber supply chain management.

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