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A Model of Green Value Stream Mapping for Rubber Based Automotive Products

Dewi Auditiya Marizka[a*], Taufik Djatna[b], Yandra Arkeman[c]

[a]Politeknik STMI, Ministry of Industry Rep. Indonesia
[b]Department of Agroindustrial Technology, Faculty of Agricultural Technology, Bogor Agricultural University,
[c]Campus IPB Darmaga, Bogor 16680, Indonesia.

Abstract

Productivity and quality problems of pre-processed rubber with ignorance of environmental consideration are the main obstacles in the development of the rubber based agro-industry. In order to solve such problems, main objectives of this research are to obtain productivity improvement formulation of pre-processed rubber and model its green productivity. Green Productivity Index of bokar processing was calculated using (1) Environmental impact was calculated using formula (2) Green Productivity improvement model was designed in ensuring products quality to customer while at the same time decrease environmental impact. The model deployed synthesizing tools, i.e. Green Value Stream Mapping (GVSM), the Green Productivity Index (GPI) and Multi Attribute Utility Theory (MAUT). The model enabled to minimize environmental impact while keeping the indicator of economic growth. An improvement initiative based on plantation management was combined with the green productivity approach to form the best improvement scenario. The production process analysed and mapped each stream process using GVSM and induced GPI calculation. GVSM resulted to seven green waste generators. MAUT weighted the final total priority of improvement alternative to formulate productivity improvement. Based on overall analysis showed the best scenario of a Final Total Priority Value (FTPV) with weight of 0.612 where University and Research Institution role maximized than Government weight with FTPV of 0.609.

Keywords: GVSM, GPI, MAUT, Pre-processed Rubber, seven green waste generators

1. Introduction

Rubber has an essential role in today's society. Rubber industry can be divided into two main sectors, namely *tire manufacturers* and *industrial rubber manufacturers* and produce a wide variety of products that people commonly rely on in their daily life. They are used either as tires on cars, as sealing material on windows or as hoses with which flowers are watered in gardens. By far, automotive industry is the most important market for both tires and other industrial rubber products.

The main raw material needed in production is pre-processed rubber or known as *bokar* in Indonesia. The *bokar* is produced by small holder plantation which is usually poor in quality and low in productivity. Poor quality and low productivity are usually obtained by manufacturer due to various causes such as a non-transparent quality assurance system, bokar supply scarcity and many others. In other words, manufacturers tend to be permissive in bokar quality. Such practice causes greater environmental burden in the form of energy and water usage as well as more pollutants caused by greater usage of machinery. A vicious circle arises between low quality of bokar, low productivity of small holder plantation yield as well as environmental impact. Therefore, an approach integrating quality, productivity and environmental impact needs to be applied in the productivity improvement of crumb rubber.

Process analysis was done by analyzing *bokar* processing and raw material requirement. It was done by identifying every activity affecting *bokar* productivity rate using *Green Value Stream Mapping* (GVSM), obtaining seven green waste generators [13]. The seven green waste generators were then used for calculating environmental and economical indicators and to measure productivity [12], [13]. Green productivity calculation was done based on measurements developed by [3], [10], [15], [18], and [19]. Green Productivity Index of bokar processing was calculated using formula (1). Environmental impact was calculated using formula (2). The Green Productivity Index (GPI) depicts producers ability in production of environment friendly products. In other words, high GPI means better ability in producing environmental friendly product [8]. After calculating GPI, the next step was to convert multiple performance measures to a scalar performance measure using Multiple Attribute Utility Theory (MAUT). MAUT can be used instead of a costing approach when good cost data are not available. Alternatively, MAUT can be used to embellish costing information that is considered to be incomplete (e.g.,to Theory account for the intangibles).

* Corresponding author. Tel.: N/A; fax:N/A.
E-mail address: iburizkakoe@yahoo.co.id

The aim of this research are: Identify the factors that affect productivity through a Green Value Stream Mapping (GVSM) and obtain the best strategy that will be used to improve the productivity of pre-processed rubber of tires with a green productivity. In this paper,we focused on the third approach and combine AHP with MAUT using the indifference zone approach. The goal is to select the best project configuration from a set of K configurations when project performance is measured over multiple performance measures.

2. Research Framework and Methodology

The method used in this research is illustrated in Fig.1. The methodology is based upon Green Productivity principles.It was done by initial analysis in order to grasp the situation at hand and derive possible elements and sub-elements for institutional analysis. The research accommodate the complexity of natural rubber supply chain in terms of institutional structure which resulted on low productivity of natural rubber yield, low qualiy and environmental impact. The institutional analysis applied processing and raw material requirement. It was done by identifying every activity affecting *bokar* productivity rate using GVSM obtaining seven green waste generators [13]. The seven green waste generators were then used for calculating environmental and economical indicators and to measure productivity [12],[13]. Green productivity calculation was done based on measurements developed by [3], [10], [15], [18], and [19]. Green Productivity Index of bokar processing was calculated using formula (1). Environmental impact was calculated using formula (2). The Green Productivity Index (GPI) depicts producers ability in production of environment friendly products. In other words, high GPI means better ability in producing environmental friendly product [8].

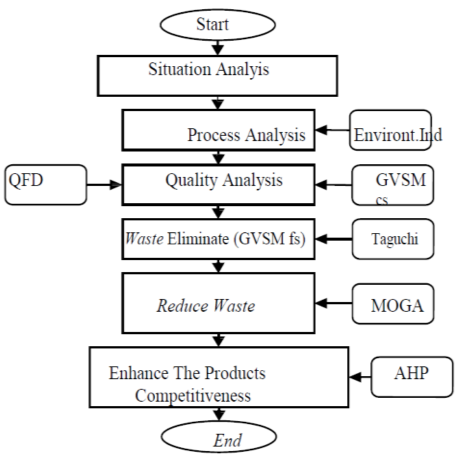

Fig. 1. The Research Framework

The environmental impact of natural rubber production process is defined as the accumulation of all three weights environment variable includes Solid Waste Generation (SWG), Gasesous Waste Generator (GW) and the Water Consumption (WC) as described in equation (1.2).

$$EI = A\,(SWG) + B\,(GWG) + C\,(WC) \qquad (1)$$

where:

EI: Environmental impacts
GWG: Gas waste generator
WC: Water consumption
SWG: Solid waste generator

The magnitude of the increase in productivity green natural rubber production process is obtained through the ratio of the initial condition value of the productivity index. The value alternative chosen strategy as described in equation (2) [7].

$$GP_{ratio} = \frac{\dfrac{SP_{alt}/PC_{alt}}{EI_{alt}}}{\dfrac{SP_{cur}/PC_{cur}}{EI_{cur}}} = \frac{SP_{alt} \times PC_{cur}}{SP_{cur} \times PC_{alt}} \times \frac{EI_{cur}}{EI_{alt}} \qquad (2)$$

where:

GPI : Green productivity index
SP : Selling price
PC : Production cost

The result obtained was then used in decision making in improving *bokar* productivity. Productivity improvement based on the GP approach was deployed by minimizing and eliminating resource consumption which has negative impact on the environment. Several improvement strategies was then generated and weighted based on the Analytical Hierarchy Process (AHP) method [4],[8],[13]. Subsequently, several scenarios were derived based on the highest strategy obtained from the AHP a. GPI calculation of the best selected strategy scenarios obtained was done as well.nd MAUT.

Furthermore, selected scenario with the highest green productivity index was then visually deployed in future state GVSM. It exhibits how the future condition would look like by undertaking the improvement scenario obtained [5].

Quantitative and qualitative data were collected by direct observation, discussion and deep interview with respondents and expert on rubber industry and small holder rubber plantation.

2.1 Green Productivity approach

Productivity is a very important part in the activities of an industry because productivity is a success key of the industry to convert raw materials activity into finished products that ready for market. Productivity is one of the indicators of sustainability for the future. Agroindustry with

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high productivity will be able to survive in the era of industrial competition today. Conversely, agroindustry with low productivity can lead traveled stranded because they could not compete with other industries. Productivity is often defined as the ratio between the output to the input [1]. The research was conducted in small medium smallholder plantation where *bokar* productivity and quality was considered low. The research implemented the Green Productivity approach, abbreviated GP, as a conceptual basis of the research. The GP has been used in several researches concerning productivity, environmental as well as quality improvement.

2.2 Multi-Attribute Utility Theory (MAUT)

MAUT is one of the major analytical tools associated with the field of decision analysis [25]. A MAUT analysis of alternatives explicitly identifies the measures that are used to evaluate the alternatives, and helps to identify those alternatives that perform well on a majority of these measures, with a special emphasis on the measures that are considered to be relatively more important. In order to carry out the analysis, some facts regarding each of the alternatives are required, and in some cases some assumptions will be needed to estimate the performance of the alternatives on the measures. As an example, different assumptions may lead to optimistic and pessimistic cost estimates for the alternatives. The MAUT methodology for the evaluation of a set of alternatives typically consists of the following steps:

1. Identification of alternatives and measures,
2. Estimation of the performance of the alternatives with respect to the measures,
3. Development of utilities and weights for the measures, and
4. Evaluation of the alternatives and sensitivity analysis.

The cells of the matrix contain estimates of the performance of each alternative on each of the measures. When these estimates are uncertain, it is often appropriate to quantify them with ranges or with probability distributions determined using risk analysis methods, i.e., simulation [15],[21].

Step three generates a single attribute utility function over each measure that is scaled from 0 to 1, a weight for each measure, and a multiple attribute utility function derived from the single attribute utility functions and the weights. A single attribute utility function is a scoring function that maps a performance measure from its range of possible values to 0.1. Common forms of this function include concave for risk averse behavior, convex for risk seeking behavior, linear for risk neutral behavior, and "S" shaped for a hybrid of the convex and concave functions. For theoretical and practical reasons, one popular form for single attribute utility function is

$$U(X)\ A \qquad Be^{(X/RT)} \qquad (1)$$

(Clemen, 1991, page 379).

The quantities A, B, and RT are parameters that must be set by the decision maker. Several assessment techniques exist for eliciting utility functions from decision makers, i.e., for setting the parameters A, B and RT in the case of (1) (Logical Decisions, 1996, page 113). Figure 2 contains a graph of (1) for the productivity utility of transport vehicle utilization in our project example where A, B, and RT are approximately equal to 1.019; 2.679; and 0.2; respectively.

See Section 6 for additional information on this utility function. Trade-off method, includes all n (>1) performance measures in n-1 pairwise tradeoffs. In each tradeoff the decision maker is asked to judge on which measure it is more important to improve performance. This procedures in conjunction with the constraint that the weights must sum to one uniquely determines weights. Another popular methods is the Analytical Hierarchy Process (AHP) [20].

2.3 Aggregation with MAUT Functions

Once the performance of each alternative on each measure in the alternatives-by-measure matrix has been obtained, the next step in the analysis involves assembling the measures into a "super-measure" of the desirability of each alternative. Utility theory provides the basis for the appropriate approach to aggregate the seemingly disparate measures. It is a logically consistent and tractable means of representing the degree to which each alternative fulfills decision maker's objectives. The use of utility theory ensures that any recommendation reflects:

MAUT is based on two equations that help to determine utility values and normalize the scales. Equation 3.1 displays how the utility values are determined for each alternative[15]. Equation 3.2 shows how the normalized criteria values are determined from single-attribute utility functions on normalized scales [25].

$$U_j = \sum_{k=1}^{n_k} w_k n_{kj} \qquad (2)$$

$$n_{kj} = f_k(s_{kj}) \qquad (3)$$

Where:
j U = utility of alternative *j*;
k w = weight of the *kth* criterion;
kj n = normalized criterion *k* value for alternative *j*;
kj s = value of criterion *k* for alternative *j*;
f (*x*) *k* = single attribute utility function on a normalized scale.

Using the equations above, a normalized scale helps to compare and measure the utilities. Once the utilities are determined, the alternatives can be chosen based on the single-attribute utility function results, simplifying the decision making process.The steps in the process of MAUT are:

1. Make a decision framework, by defining the problem.
2. Generate (raised) the alternatives that might be able to solve the problem.
3. Make a list (list) of all aspects that affect the decision.
4. Give weight to every aspect. Existing weights should reflect how important these aspects of the problem.
5. Give also the weight of the existing alternatives. For each alternative, define how satisfying alternatives for each aspect.
6. The process of evaluation of each alternative on the aspects that exist to get a decision.

3. Analysis and Discussion

In this study, the analysis of each process on the map material flow, and has obtained data and material flow in the value stream map. Results filming the entire material flow in GVSM activity (current state) are presented in the Appendix. Based on expert opinion and Darmawan's research, there are four alternative strategies for improving productivity of green, ie the optimization of the production process, the control characteristics of raw materials, auxiliary materials substitution and reuse of water. Alternative strategies are selected based on expert opinion back with heavy water use expert opinion was 0.37. Green productivity index value ribbed smoked sheet production by implementing alternative chosen strategy was 0.69, while for the production of brown crepe is equal to 3.8. Green productivity index ratio ribbed smoked sheet production process between alternative implementations chosen strategy with initial condition was 2.57, while for the production of brown crepe is equal to 3.57.

3.1 Environmental Impact Indicators

In the calculation of the environmental impact, the results of the seventh generation analysis of waste that has been obtained from green material flow map (current state) process these activities are classified into four GPI environment variables. Emissions in the process of gaseous wast are classified as variable generation (GWG), water use is classified into variable water consumption (WC), the waste generated is classified into solid waste generation (SW), and the use of classified material to a variable land contamination (LC) [4],[7],[12],13] . Based on the data which have been obtained from analysis of seven sources of waste generator, then do the calculations changing environmental impact as follows:

• Total Production bokar / ha, 14 kg / ha

• It is the assumption of farmers with land area of 1 ha with a total of 300 productive trees of 500 trees per one-time lead. So as to obtain 1 ton production base bokar at least do 72 times leads.

• Plant Waste Gas (GWG) 20.44 kg per vehicle can transport all 1 tonne payload.

• Use of Water (WC) Water used in the manufacture of 3741.40 tonnes bokar 1 liter. Because the density of water 1 kg / liter, the water consumption of 3741.40 kg

Solid Waste Generators (SWG) 230.50 kg

• Represents waste derived from the cultivation and yield polybag material such as twigs, sand, gravel, and bark shavings litter the sap of rubber trees.

• Soil Pollution (LC) 4479.50 kg. From these calculations, the environmental impact (EI) resulting from the process can be summarized as follows:

EI = (0.375 x GWG) + (0.25 x WC) + (0.125 x SWG) + (0.25 x LC) EI = (0.375 x 20.44) + (0.25 x 3741.40) + (0.125 x 230.50) + (0.25 x 4479.50) EI = 2091.70 kg

The result of environmental impacts from activities generate leads pre-processed rubber once after sowing productive is 2091.70 kg or 2.09 tonnes .

3.2 Economic Indicators

Cost of materials produced from seed transportation costs and delivery bokar assuming fuel consumption 1:11 km. Thus produced 2.27 liter for a distance of 25 km once the delivery of seeds and 5.45 liters for a 60 km transmission 1 ton bokar. By calculating the total cost of the production process needs to Rp 8.401.145 bokar can generate a ton bokar or rubber slab. Then a big income derived from the sale of a thin slab of rubber products/milled as follows: sales revenue/sales price of a ton slab/slab rollers assumptions selling prices per kg = Rp 20,000. So the selling price of a tonne of slab is Rp 20,000,000. The calculation of economic indicators calculated as the ratio between product sales revenue with total production cost of the product.

3.3 Process Analysis

The result of the process analysis was then deployed in Green Value Stream Map to map current-situation[4],[12],13],[23],[24].

The Current-state and future state GVSM is exhibited in Fig. 2 and Fig.. 3.

3.4 The Green Productivity Index (GPI)

Based on the environmental impact and economic indicators productivity index is then calculated the green (current state) yielded 1.14 was calculated as:

GPI = 2.38: 2.09 = 1.14

This value indicates the level of productivity is still higher than the environmental impact from the activities undertaken.

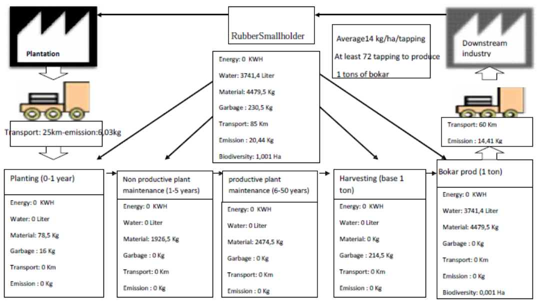

Fig. 2. The current state Value Stream Mapping of pre processed rubber

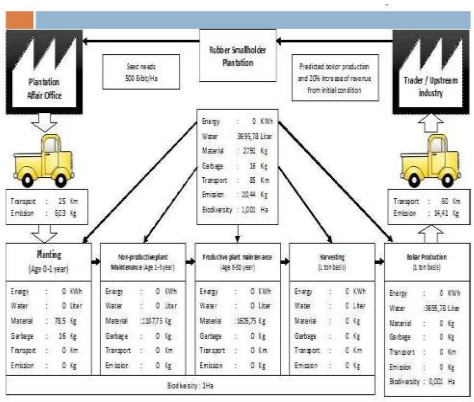

Fig. 3. The future state value stream mapping of pre processed rubber

3.5 The Multi Attribute Utility Theory (MAUT)

Based on AHP and MAUT strategy implementation progress in this research using some assumptions based on data and research findings derived from several sources related literature. Based on the five alternative remediation efforts undertaken by AHP approach, it can be developed two scenarios.

The first scenario with the role of farmers (fig. 5) and the second scenario , farmers do not also play a role in increasing the productivity of green (GP) (figure 6). In the second scenario the role of farmers is eliminated, this assumption is used because of the situation we bokar productivity and quality is still low. This is due to only one factor in the absence of the role of the farmer in conducting joint marketing system (KUD) who actively monitor and supervise the quality bokar and improve farmers' bargaining position against the collector [1, 2].

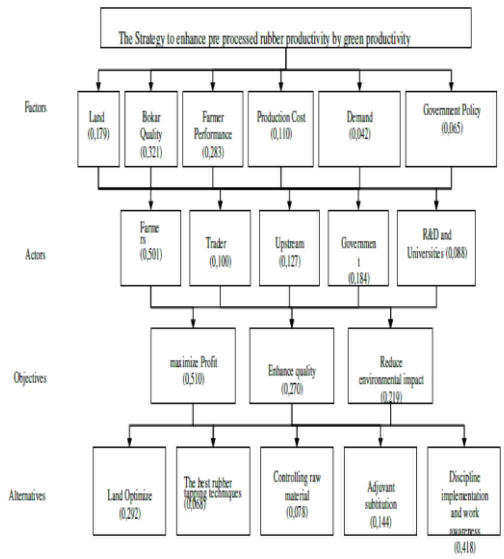

Fig. .4. The AHP of pre processed rubber.

MAUT Method							
w(ahp)	0,33939394	0	0,015151515	0,115151515	0,53030303		
	land optimize	tapping	raw material controll	supporting material subtitution	awareness&discipline	MAUT	
	2	10	4	10	7		
trader	0,87	0	0,4	0,7	0	0,382	0,313
upstream	0,99	0,5	0	0,6	0,36	0,596	0,470
government	0	0,18	1	0,55	1	0,609	0,555
farmer	0,4	1	0,2	0,1	0	0,150	0,382
R&D and Univ	1	0,83	0,4	0,75	0,11	0,490	0,611
w(ahp)	0,292	0,068	0,078	0,144	0,418	0,418	0,068
onverted w(ahp	0,64	0	0,028571429	0,217142857	1		
	0,33939394	0	0,015151515	0,115151515	0,53030303		

Fig.5. The MAUT's 1st scenario of pre processed rubber

The first scenario results with calculations obtained by the MAUT method heavy sub criteria or Final Total Priority Value (FTPV) of 0.382 dealers ; 0.596 upstream industry ; 0.609 government ; 0.150 farmers and Universities and Research Institutions 0.490 . While the second scenario the weight of sub criteria 0.140 farmer dealer; 0.441 upstream industry; 0.516 Government and Higher Education and Research Institutions 0.612.

Metode MAUT

w(ahp)	0	0,47919005	0,095823602	0,201961472	0,223024873		
	land optimize	tapping	raw material controll	supporting material subtitution	awareness&discipline	MAUT	
	2	10	4	10	7		
trader	0,87	0	0,4	0,7	0	0,180	0,313
upstream	0,99	0,5	0	0,6	0,36	0,441	0,470
government	0	0,18	1	0,55	1	0,516	0,555
R&D and Univ.	1	0,83	0,4	0,75	0,11	0,612	0,611
w(ahp)	0,03831384	0,42570584	0,115780589	0,201585714	0,218614017	0,42570584	0,03831384
converted w(ahp	0	1	0,19996993	0,421464241	0,465420498		
	0	0,47919005	0,095823602	0,201961472	0,223024873		

Fig.6. The MAUT's 2nd scenario of pre processed rubber

4. Conclusion

The factors that affect productivity through a Green Value Stream Mapping (GVSM) based on the data which have been obtained from analysis of seven sources of waste generator, then the result of environmental impacts from activities generate leads pre-processed rubber once after sowing productive is 2091.70 kg or 2.09 tonnes. The calculation of economic indicators is Rp. 20,000,000 (the selling price of a tonne of slab) calculated as the ratio between product sales revenue with total production cost of the product.

Based on the environmental impact and economic indicators productivity index, the value of the Green Productivity Index (GPI) yielded 1.14 indicates the level of productivity is still higher than the environmental impact from the activities undertaken. Through the implementation of selected strategic alternatives, the productivity index green natural rubber production process can be improved.

After doing more research, the results of the implementation analysis strategy pursued by the AHP and Multi Attribute Utility Theory (MAUT) so obtained Final Total Priority Value (FTPV) which is a global priority, which is based on five alternatives remediation efforts undertaken by AHP approach, it can be developed two kinds of repair scenarios. The first scenario the farmers also play a role in increasing the green productivity and The second scenario without farmers or the farmers do not play a role in increasing the green productivity (GP). The results of first scenario MAUT weighted the final total priority value of improvement alternative to formulate productivity improvement. Based on overall analysis showed the best scenario of a Final Total Priority Value (FTPV) with weight of 0.612 where University and Research Institution role maximized than Government weight with FTPV of 0.60.

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