A Model Development of Green Supplier Selection in Small Medium Enterprise: Woodcraft Industries Case Application

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Abstract: Supplier selection is one of the biggest problem faced by SMEs in improving supply chain performance. Most of SMEs are not considering the environmental aspect in supplier selection process. Whereas in international scale competition, some countries have implemented a new regulations on products or services that are safe for environment. Therefore, the development of a new model of supplier selection on SMEs by considering environmental aspect is needed. SMEs in woodcraft industries sector is used as the case study. A model development of green supplier selection is done using modified analytic hierarchy process through four stages, i.e. identify criteria, prioritizing criteria, prioritizing supplier alternatives and supplier selection. The result shows that there are five criteria in green supplier selection for woodcraft industries, i.e. costs (0,31), quality (0,31), environmental management (0,22) delivery (0,05) and pollution control (0,11). Modification of analytic hierarchy process has been successfully implemented and produced a best supplier with a highest selection priorities score 0,36.

Keywords; green supplier selection; modified AHP; woodcraft industries

I. INTRODUCTION

The increasing number of green consumers is directly change the customer behavior in purchasing a product. An environmental performance of a product and its production process become an important customers needs that should be fulfilled by each industry. In recent periods, every industry is trying to evaluate and reduce some environmental impact along the supply chain. Implementation of green supply chain management is an important strategy to respond the new customers needs (Environmental Protection Agency, 2006).

One of industrial sector that required to implement green supply chain management to face the global competition is small and medium enterprises (SMEs). Total population of SMEs in Indonesia are

increased about 2,5 % on each year. The industrial sectors that contributes more than other industries are fashion and handicraft industries (Ministry of Cooperatives and SMEs, 2013).

The growth of SMEs is not supported with manufacturing activities based on environmental regulation. This condition lead to a new problem for SMEs in international economic trade. Most of SMEs are not prepared a specific strategy that integrate the environmental issues along the supply chain. The SMEs products will have no competitive advantage for some countries such as Japan, China and Korea that already implement environmental regulations on products or services (Asian Productivity Organization, 2010). Several countries in Europe and America also already integrate some environmental issues in the enterprise business process (Ramakrishnan *et al*, 2015). Therefore, SMEs in Indonesia requires some stages in creating a green industry in order to improve its competitiveness in international competition.

Supply chain is one of business competitiveness in improving industrial activity for SMEs (Ramakrishnan *et al.*, 2015). Environmental issues related to production waste can be integrated to improve supply chain performance. Management systems such as ISO 14001 provided a specific guidance for industry to minimize production waste, toxic raw materials and negative impact to environment as well as reverse logistics (Azevedo *et al.*, 2011). Supply chain performance improvement by minimizing the negative impact to environment, can be done by implementing green supply chain (Seman et al, 2012). By using the green concept, supply chain performance will be evaluated during the product life cycle. Potential environmental impacts caused by a product is integrated into the products design process, planning of raw materials and sources, energy used, emissions from manufacturing process, production waste, transportation process, the product used by customer, disposal process to recycling a used product.

Green materials management is an important factor to optimize raw materials and other supported materials quality including the source selection (Ghobakhloo *et al.*, 2013). A green supplier is required to improve supply chain performance in accordance with government regulations about environmental management in several Japanese companies that have been certified ISO 14001 (Arimura *et al.*, 2011). The supplier contributions to save the environment will be evaluated periodically to control supplier commitments.

Supplier selection is a common problem in SMEs to improve supply chain performance. In general, there are several supplier selection criteria, i.e. quality, delivery, service, technical capabilities and financial conditions (Cheragi *et al.*, 2004). Environmental criteria are not being considered by most SMEs for the supplier selection process. So that the implementation of green supplier selection is needed to reduce some potential errors in evaluating supplier performance based on environmental concept (Lee and Klassen, 2009).

Green procurement is a procurement process for an industry based on environmental standards and regulations (Asian Productivity Organization, 2010). In green procurement, the purchasing decisions considered environmental criteria instead of the other criteria i.e. price and supplier performance (Ramakrishnan *et al.*, 2015). This is done to reduce environment impact while improving the procurement process efficiency.

There are several criteria in supplier selection to reduce environmental impact. Some environmental criteria that being considered in selecting suppliers are recycling, product life cycles and impacts of products, both physically and socially (El Tayeb *et al.*, 2010). The criteria of quality, environment, price,

delivery, service and supplier relationships are used in green supplier selection of a pharmaceutical industry (Puspitasari and Yancadianti, 2016).

Supplier selection process is one of multi criteria decision making problem. The analytic hierarchy process (AHP) method is a method that can be used to solve a multi criteria decision making problem. Criteria and its priorities will be generated using this method. This method has been broadly implemented in service and manufacturing industry.

The AHP method has successfully implemented for a computer supplier selection based on multiple criteria in Turkey (Ozkan *et al.*, 2011). AHP method has also been implemented for supplier evaluation at universities in Turkey (Royendegh and Erkan, 2012). The result shows the priority of some criteria, i.e. cost, flexibility, quality, delivery and variety of products to determine the best alternative supplier.

Based on green supply chain concept, the development of a new model of supplier selection on SMEs, especially woodcraft industry is needed. Therefore, the research is done by identifying the supplier selection criteria and its priorities to reduce the environmental impact of a procurement process. Results from this study is expected to provide an alternative supplier selection process that can improve the SMEs product competitiveness.

II. BASIC THEORY

(A) Green Supply Chain Management (GSCM)

GSCM is a development of SCM, in which environmental factors are integrated in supply chain management (Chin *et al.*, 2015). There is an additional goal of SCM from the previous period that the supply chain goals are efficient and responsive become GSCM to get a supply chain that responsive, efficient and have a minimize environmental impact along the supply chain. Pollution of air, water, soil and other waste resulting from supply chain activities from selection of raw materials to end of products life is reduced with the implementation of this concept.

In GSCM, green product design is made to produce a product that meet the customer needs while minimizing the environmental impact during product life cycle. Green materials management is required to obtain raw materials that safe to the ecosystem. In this phase, green procurement is done.

The environmental impact is also integrated in every stage of production using green manufacturing. Evaluation of production emissions and waste are generated. This is done to sustain natural resources for future generations (Rehman and Shrivastava, 2013). The green distribution is used to optimize the transportation process of a product from manufacturer to customer based on environmental standard. At the end of supply chain, reverse logistics is done to manage the used products from customers. The used product is pulled back into the supply chain to get re-using, recycling and reducing process.

(B) Green Procurement

Green procurement is a part of green supply chain that focus on a procurement process between suppliers and manufacturers. The processes consist of materials and supplier selection by considering the environmental impacts. The involvement and support from suppliers becomes important to get that goal.

Suppliers involved in producing green raw materials from a green distribution, tools and technologies and manufacturing process.

There is one main obstacle in green procurement implementation i.e. the cost of eco-friendly programs is high (Min and Galle, 1997). The production waste management i.e. recycling and reusing process can help the industry to reduce cost. The strategy has been successfully implemented by several companies in Southeast Asia who actively participate in waste reduction program (Rao and Holt, 2005).

(C) Analytic Hierarchy Process (AHP)

Qualitative aspect that represents an intangible benefit of a decision can be identified using AHP. All factors that affect the problem will be relatively compared (Saaty, 1988). The relative comparisons is done to get priority of some alternative sollution. There are several stages in problem solving using AHP (Mulyono, 1996):

a)   Defining the problem and alternative solutions.

b)   Develop a problem hierarchical structure that consist of criterias, sub critrerias and possible alternative solutions.

c)   Perform a pairwise comparison matrix.

d)   Compute eigenvalues and test the consistency. If the consistency ratio < 0,1, the relative value is consistent so it can be used in decision making process. If the consistrency ratio > 0,1, the relative value is inconsistent. The rating input can be revised up to two times.

Priority decisions can be calculated from priority weight of criteria (PW criteria) and priority weight of alternative sollution (PW alternative) using this formulation:

$$PK = \Sigma \ PW \ Criteria \ x \ PW \ Alternative \tag{1}$$

III. RESEARCH METHOD

A model development of supplier selection in green procurement using modified *analytic hierarchy process* is done through four main stages. The first stage is to identify some supplier selection criteria based on woodcraft industries needs and determine main criterias and sub criterias using pareto analysis. The second stage is weighting phase that aims to prioritize main criteria and sub criterias of supplier selection in green procurement. The third stage is analysis phase to prioritize some suppliers alternatives based on actual performance using modified analytical hierarchy process. The method is modified by changing data input. In this research, actual performance value of each supplier based on each sub criteria is used as data input. The data then being normalized based on priority direction and subsequently used to evaluate each suppliers performance based on green procurement. The last stage is supplier selection phase of the best supplier alternative based on the results from previous stage.

IV. RESULT AND DISCUSSION

(A) Identification of Green Supplier Selection Criteria

Information about supplier needs of woodcraft industry is used as the basis for green supplier selection model. Supplier selection is done to get the best Albasiah wood supplier. The survey was conducted with

30 woodcraft industry participation from West Java, Indonesia. The data then being statistically tested before being used for model development. Based on the survey, there are five main criteria i.e. cost, quality, environmental management, delivery and pollution control as shown in Figure 1.
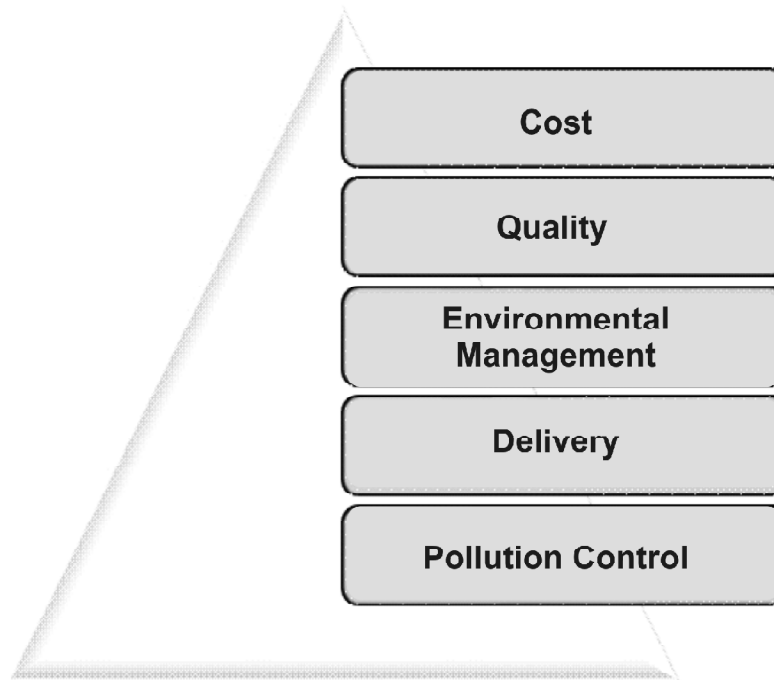
Figure 1: Green Supplier Selection Criteria in Woodcraft Industry

Cost become the first green supplier selection criteria in woodcraft industry. The industrial scale that categorized in small and medium enterprises may affect this result. There are two sub-criteria in cost, i.e. raw material cost and shipping costs. Raw material costs represent costs incurred by SMEs associated with price of Albasiah wood for a certain quantities. While shipping costs consist some various costs associated with raw materials shipment from suppliers to SMEs location.

Quality criteria is an indicator of Albasiah wood quality. Albasiah quality will significantly influence the finished product that being produced by SMEs. There are three sub-criteria to evaluate Albasiah wood quality, i.e., healthy wood, durability and compresive strength. An Albasiah wood is categorized as healthy wood if there are no wood diseases that physically apear. While durability can be determined by calculating the time duration which the product perform its main function. Compressive strength is sub-criteria that can be evaluated from the main mineral composition of wood.

Environmental management is represents the supplier ability to integrate environmental aspects into supplier business processes. There are four sub-criteria, i.e. materials optimization, environmental impact, environmental rehabilitation and supplier commitment to environmental conservation. Albasiah wood comes from Albasiah tree. In this case, the supplier should be able to take advantage of other parts of a tree i.e. leaves, roots, flowers or sap for positive purposes. So the portion of Albasiah tree besides the wood, can be used to evaluate suppliers performance in optimizing the materials.

Production activities performed by suppliers are evaluated through an environmental impact assessment report in certeain period. To reduce the environmental impact of cutting the tree, i.e. landslides and floods, every suppliers must replanted Albasiah trees on a certain land size. This is done to implement the environmental rehabilitation. To support the environmental management, a commitment of top management is needed. The commitment can be evaluated through a number of budget allocated for environmental conservation.

On delivery criteria, the raw materials transportation process from suppliers to SMEs location is evaluated using three sub-criterias, i.e. distance, lead time and accuracy. The distance is determine from suppliers and SMEs location. While the lead time is a unit time required by suppliers to complete the SMEs order. In sub-criteria accuracy of delivery, evaluation of exact time, quantity and quality is done.

Pollution control is a process to reduce production waste. There are two sub-criteria to be evaluated, i.e. reuse and recycle activity. Percentage of production waste that utilized by suppliers into a value added goods can be used to evaluated sub-criteria reuse. While sub-criteria recycle can be evaluated based on the number of products produced by the supplier from production waste.

(B) Prioritizing Green Supplier Selection Criteria

Weighting the green supplier selection criterias is conducted to determine the priority of each criteria to the other criteria. The method that being used is the analytic hierarchy process. Based on the consistency ratio calculation, all respondents information has a value below 0,1. So the data can be used for the next stage. There are two criteria that have a high level of importance, i.e. cost and quality (0,31) as shown in Table 1.

Table I
Priority Value of Green Supplier Selection Criteria

No.	Criteria	Weight	Sub Criteria	Weight
1	Cost	0,31	Raw material cost	0,83
			Shipping cost	0,17
2	Quality	0,31	Healthy wood	0,33
			Durability	0,55
			Compresive strength	0,12
3	Environmental Management	0,22	Material optimization	0,09
			Environmental impact	0,15
			Environmental rehabilitation	0,38
			Commitment of environmental conservation	0,38
4	Delivery	0,05	Distance	0,57
			Lead time	0,33
			Accuracy	0,10
5	Pollution Control	0,11	Reuse	0,75
			Recycle	0,25

A supplier that able to provide a good quality of raw materials at competitive price become a major requirement for woodcraft industry. Purchasing cost become the dominant sub criteria in cost with priority score 0,83. In terms of quality, the raw material durability is more important because it can affect the woodcraft industry's products.

The next priority is environmental management with priority score 0,22. This criteria is used to ensure that suppliers conduct the business processes based on green industrial concept. In this condition, SMEs can have an environmentally safe production input from raw materials produced by suppliers. Environmental rehabilitation and management's commitment in environmental conservation become the most important sub-criteria.

Pollution control is the fourth priority with priority score 0,11. Reuse is sub-criteria that mostly being considered in pollution control. The SMEs can evaluate the proportion of production waste that utilized by supplier become other products.

Delivery is the last priority criteria with priority score 0,25. In this criteria, distance is mostly used for assessing the suppliers performance. SMEs will choose a supplier with a shorter distance from the production site so the exhaust emissions that generated from raw materials transportation process can be minimized.

(C) Selection of Alternative Supplier

Green supplier selection is done using a case study on a woodcraft industry in West Java, Indonesia. This SMEs is chosen because most of the customers began to consider environmental aspects in purchasing decision. So this SMEs start to implement a green industrial concept. The SMEs have three alternative suppliers to supply Albasiah wood i.e. supplier A, B and C.

All suppliers performance will be evaluated based on green procurement concept. Supplier performance evaluation conducted using a modified analytic hierarchy process. The data used in supplier performance evaluation is an objective data or an actual data from each supplier. Actual data obtained through all sub criteria indicators in green supplier selection that already predetermined. This modification is done to get the best alternative supplier according to the actual conditions evaluation of each alternative suppliers.

The result shows that each alternative supplier has a strength in several sub-criteria. Supplier B offer Albasiah wood price at lowest level around Rp. 650,000, - in every 20 units. This supplier also offer Albasiah wood with a lowest shipping cost since the location is close to the SMEs. The Shipping fee rates is offered only Rp. 100.000, - / delivery.

In sub-criteria a healthy wood, supplier A and C produce Albasiah wood with disease probability only 1% in every 20 units of wood. While for durability, Albasiah wood from all suppliers can last up to three years. Supplier A produced Albasiah wood with finest wood mineral is about 90%. It means that this supplier is able to produce Albasiah wood with a good compresive strength.

Supplier C is use other part of Albasiah tree i.e. leaves for animals food and twigs of wood for fuel. Supplier A is the most active supplier in reducing the environmental impact of its production processes. This supplier make a comprehensive environmental analysis document periodically. For environmental

rehabilitation, supplier C planting the greatest number of trees around 1200 units per year. This is because the supplier land is the largest. The commitment of environmental conservation, suppliers A allocate funds with the highest value of Rp. 400.000, - / month. The funds is used for reducing production waste.

The nearest distance from supplier to the SMEs is supplier B with only 15 KM. This supplier also offer Albasiah wood with short lead time around three days. For accuracy in delivery, supplier A has the best performance around 100% of raw materials are delivered on exact quantity and time.

For pollution control, the largest percentage of residual wood from production waste that utilized become another product (reuse) is supplier B around 85%. The residual woods is processed into wood craft items. While other production waste such as wood dust is recycled into two types of products, i.e. cabinet and pedestal on hamster cage in supplier B.

All of actual suppliers performance data then being normalized as a percentage based on the priority direction. This is done to avoid data conflicts caused by some differences in priority direction. There are six sub criterias in green supplier selection that have smallest priority direction, i.e. raw material cost, shipping cost, healthy wood, compressive strength, distance and lead time. It means that if supplier perform a smaller value of that sub-criteria, then the supplier performance is better. The other eight sub criterias, i.e. durability, materials optimization, environmental impact, environmental rehabilitation, commitment of environmental conservation, accuracy, reuse and recycle have biggest priority direction. It means that the greater value is better.

The normalized data then being used in evaluating each alternative suppliers using analytic hierarchy process. Supplier B have the highest score for cost criteria around 0,36 as shown in Table 2. For Albasiah wood quality criteria, there are two best suppliers i.e. supplier A and C. Supplier A also have the best performance in environmental management criteria with a score of 0,36. For delivery criteria and pollution control, supplier B have the highest scores of 0,39 and 0,37.

Table II
Performance Evaluation of Green Supplier Alternative

No	Criteria	Supplier Score		
		A	B	C
1	Cost	0,33	**0,36**	0,31
2	Quality	**0,35**	0,31	**0,35**
3	Environmental Management	**0,36**	0,30	0,34
4	Delivery	0,33	**0,39**	0,28
5	Pollution Control	0,35	**0,37**	0,28

Alternative supplier performance scores in each green supplier selection criteria then used as the basis for supplier selection priority. Priorities is made using criteria priority weights that already predetermined. Supplier A is selected because it have the highest performance score of 0,35 as shown in Table 3. Comparison of the total score of each supplier did not vary significantly as each supplier has its own strength on a certain criteria.

Table III
Priority Value of Green Supplier Selection

No.	Supplier	Total Score	Priority
1	A	0,35	1
2	B	0,33	2
3	C	0,32	3

V. CONCLUSSION

Based on the research that has been conducted in green supplier selection with woodcraft industries as case study, it can be concluded that the criteria selecting best supplier by integrating environmental concept are cost (0,31), quality (0,31), environmental management (0,22), delivery (0,05) and pollution control (0,11). The priority weight of green supplier selection criteria is used for determining best supplier in a woodcraft industry using a modified analytic hierarchy process. Method modification is done by changing the data input. An actual supplier performance data based on each sub criteria is used. The best supplier with highest priorities value is supplier A.

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REFERENCES

Arimura, T.H., Darnalln N., Katayama, H., (2011), Is ISO 14001 a gateway to more advanced voluntary action? The case of green supply chain management, *Journal of Environmental Economics and Management*,Vol. 61, pp 170–182.

Asian Productivity Organization, (2010), Green Procurement And Green Purchasing: SME Focus, *APO News*, Tokyo, Japan.

Azevedo, S.G., Carvalho, H., & Machado, V.C., (2011) The Influence of Green Practices on Supply Chain Performance: A Case Study Approach, *Transportation Research Part E*, Vol. 47, pp 850-871.

Cheragi, S.H, Dadashzadeh, M., Subramanian, M., (2009), Critical Success Factors For Supplier Selection: An Update, *Journal of Applied business Research*, Vol.20, No.2.

Chin, T.A, Tat, H.H., Sulaiman, Z., (2015), Green Supply Chain Management, Environmental Collaboration and Sustainability Performance, *Procedia CIRP*, Elsevier Ltd, Vol 26, pp.695-699.

El Tayeb, T.K., Zailani, S., Jayaraman, K., (2010), The Examination On The Drivers For Green Purchasing Adoption Among EMS 14001 Certified Companies in Malaysia, *Journal of Manufacturing Technology Management*, Vol.21, No.2, pp206-225.

Environmental protection Agency, (2006) Life Cycle Assessment: Principles and Practice, Scientific Applications International Corporation, EPA / 600 / R-06/060.

Ghobakhloo, M, Tang, S.H, Zulkifli, N., Ariffin, M.K.A, (2013), An Integrated Framework of Green Supply Chain Management Implementation, *International Journal of Innovation, Management and Technology*, Vol.4, No.1.

Lee, S. and Klassen, R.D.(2009), Drivers and enablers that foster environmental management capabilities in small- and medium-sized suppliers in supply chains, Production and Operations Management, Vol. 17 No. 6, pp. 573-586.

Ministry of Cooperatives and SMEs, (2013), Fashion dan Kerajinan Dominasi Industri Kreatif, *www.kemenperin.go.id*, accessed date 1 Agustus 2016.

Min, H., Galle, W.P., (1997), Green Purchasing Strategies: Trends and Implications, *Journal of Supply Chain Management*, Vol. 33, Issue 2., pp.10-17.

Mulyono, S. ,(1996).,*Teori Pengambilan Keputusan*, Lembaga Penerbit Fakultas Ekonomi Universitas Indonesia.,Jakarta.

Ozkan, B., Bashgil, H., Sahin, N, (2011), Supplier Selection Process: An Application From Turkey, *Proceeding of The World Congress on Engineering*, Vol III, London, UK.

Puspitasari, N.B., Yancadianti, K.H., (2016), Analisa Pemilihan Supplier Ramah Lingkungan Dengan Metode Analytical Network Process (ANP) pada PT Kimia Farma Plant Semarang, *Jurnal Teknik Industri*, Vo.XI, No.1, pp 1-8.

Ramakrishnan, P., Haron, H., Goh, Y.N, (2015), Factors Influencing Green Puchasing Adoption For Small And Medium Enterprises (SMEs) In Malaysia, *International Journal of Business and Society*, Vol.16, No.13, pp 39-56.

Rao, P., Holt, D., (2005), Do Green Suppy Chains Lead To Competitiveness And Economic Performance?, *International Journal of Operations & Production Management*, Vol. 25, Issue 9, pp.898-916.

Rehman, M.A.A.A., Shrivastava, R.L., (2013), Green Manufacturing (GM): Past, Present and Future (a State of Art Review, *World Review of Science Technology and Sustainable Development*, VOL.10, pp. 17-55.

Royendegh, B.D., Erkan, T.E., (2012), Selecting The Best Supplier Using Analytic Hierarchy Process (AHP) Method, *African Journal of Business and Management*, Vol 6, pp.1455-1462.

Saaty, T.L., (1988), *The Analytic Hierarchy Process*, University of Pittsburgh, Pittsburgh.

Seman, N.A.A., Zakuan, N., Jusoh, A., Arif, M.S.M (2012), Green Supply Chain Management: A Review and Research Direction, *International Journal of Managing Value and Supply Chains*, Vol. 3, No.1, pp. 01-18.