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# A Sustainable Supply Chain Model of Manufacturer-Buyer Relationship in Export Oriented Furniture Industry in Indonesia

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**Abstract**

Furniture made from teak wood has an important role in Indonesia's economic growth. It has contribution to boost country income from export and to provide high employment for community. However many obstacles occur as challenges that must be overcome by this industry. Beside limited supply of high quality teak wood and production inefficiency as the main problems, furniture industry also faces sustainability problem in their activities. Export destination countries impose strict requirement for furniture exporters to comply with social and environmental issues. This paper proposes sustainability supply chain management model that considers economic, social, and environmental factors. In solving the problems, we use goal programming method because the model consists of several conflicting objectives that must be satisfied simultaneously. A numerical trial is used to illustrate how the model can satisfy the goals. The results can be used to analyze the trade-off among several set of alternative solutions.

**Keywords:** Export oriented furniture industry, sustainable SCM, goal programming, manufacturer-buyer relationship

## 1. Introduction

Central Java teak wood furniture industry has strategic roles because it produces more than 30% of total furniture exports in Indonesia, creates employment opportunities, and improves the welfare of society (REDI 2007; CRDCCP 2010; CJPFO 2011). However, the industry now faces many obstacles in maintaining its continuity and growth. This is reflected in the decreasing number of small and medium enterprises in teak furniture from year to year and there is a trend of decreasing the total exports. From 2007 to 2011, wooden furniture export generally decreasing about 9% per year for the export volume and about 6% per year for the export value (Ministry of Forestry 2010, BPS-Statistics Indonesia 2012). Aside from limited supply of high quality teak wood and production inefficiency as the main problems, furniture industry also faces sustainability problem in their activities. Export destination countries and foreign buyers impose strict requirement for furniture exporters to comply with several policy, i.e. environmentally benign and labor rights protection (Hisjam et al. 2010; 2011[a]).

Hisjam et al. (2011[b]) stated that although Perum Perhutani, a state-owned forestry company in Indonesia that supplies high quality teak wood, has put a great effort to comply with government policy about forest management, it still could not provide adequate teak supply because this effort required a huge amount of money to recover forest area. In other words, the reforestation conflicted with economic aspect of its business activities. Furthermore, teak requires time to grow and to be able to be harvested as log, thus the reforestation effort cannot provide present teak demand.

Production inefficiency brings negative impacts on manufacturing cycle as most companies have a less efficient production processes, labor with low productivity, and produce low quality products (Effendi and Dwiprabowo 2005). Furniture industry that has no well-trained human resources and modern organizations generally cannot penetrate to global market although wood furniture demand in global market is very high (Loebis and Schmitz 2005). Global markets are generally not only looking for a cheap product with a high variation, but also favoring to buy products from companies that promote health and safety environment, employment equality, and environment sustainability in which importers can conduct more stringent oversight (Posthuma 2003). In addition, there is an increasing attention to green products which consider clean production and environmental benign (D'Souza 2004, do Paço et al. 2009).

## 2. Research Methods

Raw material for furniture industry in this paper is teak (*Tectona grandis L.f.*) wood. Furniture industry faces many obstacles that must be overcome in order to achieve economic aspects while preserving environmental and social aspects. This paper proposes s-SCM of manufacturer-buyer of export oriented furniture in Indonesia. The proposed model considers economic, environmental, and social aspects faced by furniture manufacturer. Economic aspect is achieved by maximizing profit from its business activities whereas environment aspect is achieved by minimizing waste generated from the production and carbon emission in recycling process. Social aspect is measured by the ability to fulfill consumer demand and maximizing number of employment. It is possible that all aspects are conflicted; hence decision maker must choose the suitable set of feasible solutions that satisfy desired goals. Goal programming (GP) is the right tool for decision makers to do so.

This paper is an extension of our previous work (Hisjam et al. 2011[a], Devi et al. 2012). Hisjam et al. (2011[a]) conducts observation to identify the problems that faced by furniture industry in Indonesia and we propose a research framework as an alternative solution for the problems. Devi et al. (2012) proposes a manufacturer-buyer model based on our study in private furniture industry. For private industry, economic aspects are considered most in running the business, while environmental and social aspects are considered because of the demand of the customer. Whilst in this paper, the model is developed based on the study in state-owned company that should consider environmental and social aspects more, while economic aspect is considered for the sustainability of the business.

### *2.1 Sustainable Supply Chain Model (s-SCM)*

In this paper we propose an s-SCM that consists of two entities namely furniture manufacturer and buyer as depicted in Figure 1. Buyer gives all data and information of furniture demand. The data contain furniture types, demand quantity, and delivery time. Based on this information, manufacturer determines raw material needed, i.e. teak wood log supply from supplier, and production schedule, and then compares the aggregate demand with its production capacity. Manufacturer will decide whether to increase production capacity in order to satisfy manufacturers' demand or to retain its production capacity.

### *2.2 Sustainable Production Activity by Manufacturer*

In s-SCM model, manufacturer produces furniture to fulfill buyer demand. Many researches in SCM include sustainability which can be categorized as economic, environmental, and social sustainability. As previously discussed above, buyer requires that furniture be made comply with green manufacturing principles, i.e. production process to manufacture products must be environmentally benign. Manufacturer also must put social sustainability into business practice. In order to satisfy the sustainability aspects, manufacturer faces several notable problems: log supply from wood supplier, production waste, and production capacity. While economic aspect is the main priority, manufacturer cannot neglect the environmental and social aspects of sustainability. These aspects are often conflicting. Goal programming is a suitable tool for facing these conflicting objectives. Decision makers can see and analyze the trade-off among several alternative scenarios. The next section will briefly describe goal programming (GP) method as a suitable tool to solve and analyze the multi-objectives in the s-SCM.

### *2.3 Goal Programming (GP)*

Both manufacturer and buyer in s-SCM have many objectives that must be satisfied based on the previous discussion above. However, these objectives are often conflicted. In order to analyze the trade-off between these objectives, suitable tool is required and GP has proven to be appropriate to give decision makers set of alternative solutions that satisfy the objectives. Although GP was first proposed in 1961, but since its inception until now, there seems to be an increasing use of GP in the academic publications (Jones and Tamiz, 2010). The common terminologies used in GP are as follows. Goal refers to criterion which decision makers must be achieved. Target level is the numeric value of a goal criterion. Deviational variables measure the difference between target level and actual value of solutions. A generic form of GP can be described as:

 

$$\text{Min} f(g) = \sum_{i=1}^{g} \omega_i f\left(d_i^-, d_i^+\right) \tag{1}$$

Where denotes number of goals, denotes achievement function that must be minimized, and denote negative and positive deviational of goals, and denotes the weighted of the goal. A goal or criterion can also be called soft constraints. A goal formulation can be formulated as follows

$$f_g\left(\overline{x}\right) + d_g^- - d_g^+ = b_g \tag{2}$$

where denotes the function of goal that must be achieved, denotes the decision variables vector, and denotes the target level set by the decision makers (Jones and Tamiz, 2010).

*2.4 Model Formulation*

In this section, we develop s-SCM model for teak wooden furniture manufacturer-buyer relationship. We begin by introducing notation and variables used throughout the paper, and then we formulate the mathematical model for s-SCM in furniture industry.

Table 1 represents manufacturer's and buyer's parameters in the s-SCM. Additional notation in Table 2 is used to develop goal programming model. The model can be considered as a multi-objective optimization problem, since it seeks optimal solution between conflicting objectives.

In order to utilize GP technique, several things that must be considered are: soft constraints or goals that must be achieved, desired value, positive and negative deviational variables of the corresponding goals, and hard constraints. First, we define goals in sustainable supply chains as follows:

2.4.1 Economic Sustainability Goal

In s-SCM, economic sustainability is given by the profit that must be achieved by furniture manufacturer. This goal involves maximizing revenue while simultaneously minimizing relevant cost. The expression above can describe the corresponding objectives and goal as:

$$TR = \sum_{t \in T} \sum_{f \in F} \left(p^f - c^f\right) q_t^f \tag{3}$$

$$HC = \sum_{t \in T} \sum_{f \in F} \sum_{l \in L} \left(h_f I_t^f + h_l I_t^l\right) \tag{4}$$

$$PC = \sum_{t \in T} \sum_{l \in L} p^l q_t^l \tag{5}$$

$$CC = \sum_{t \in T} c^\alpha \alpha_t + c^\beta \beta_t \tag{6}$$

$$RC = \sum_{t \in T} \sum_{m \in M} X_t^m c^m w_t \tag{7}$$

$$F1 = TR - HC - PC - CC - RC \tag{8}$$

$$F1 + d_1^- - d_1^+ = b_1 \tag{9}$$

Equation (3) represents total revenue minus the production and distribution cost faced by manufacturer. The total revenue consists of furniture sales, scrap sales, and recycle product sales. Equation (4) represents inventory cost of furniture and raw material. The cost to purchase raw material is expressed in (5). Production level change which consists of the cost to increase and decrease production level is expressed in (6). Recycling process of wood scrap is expressed in (7). The overall objective function of the manufacturer is expressed in (8). Equation (8) is relaxed to become the economic goal by adding and which are negative and positive deviational variables as well as the target level of the corresponding goal which is determined by the decision maker as in (9).

2.4.2 Environmental Sustainability Goal

Green production practices must comply some regulations that imposed by importers. One of the requirement is log excess must be minimum. A log type can be made into several furniture types by cutting process. Cutting process generates a large amount of wood scrap due to log type width cannot fit the entire furniture dimension requirement. Currently, manufacturer has technology that utilizes wood scrap excess so that wood scrap can be used further into production process. The technology is restricted by the amount of wood that can be processed again.

Table 3 presents the available technology that can be used to recycle the excess wood along with carbon emission. For instance, Technology 1 can recycle the wood scrap maximum 5% of 1 $m^3$ volume wood and emits 10 $kg/m^3$ of carbon. Technology 2 can recycle larger volume of wood scrap with lower carbon emission and so on. However, the cost of corresponding technology is increase as the maximum wood scrap that can be recycled increase. In order to fulfill demand of furniture, manufacturer must decide which type of technology must be implemented to satisfy buyer requirements, i.e. the green production that must be achieved by producing furniture that environmentally benign. Hence, related to the environmental sustainability, manufacturer must choose the technology that minimizes waste, but considering cost. The environmental sustainability can be expressed as:

$$\sum_{t\in T} w_t + d_2^- - d_2^+ = b_2 \tag{10}$$

$$\sum_{t\in T} E_t + d_3^- - d_3^+ = b_3 \tag{11}$$

Where and are given by:

$$w_t = \sum_{f\in F} q_t^f \rho^f \left(1 - r^m\right) \tag{12}$$

$$E_t = \sum_{m\in M}\sum_{f\in F} q_t^f \rho^f X_t^m E_t^m \tag{13}$$

Equation (10) states that total waste that is generated by manufacturer must not exceed the target level set by the decision maker in order to achieve the environmental goal. Equation (11) expresses the goal carbon emission goal. Equation (12) expresses that waste for every period is the sum of quantity of log need which is calculated by multiplying furniture produced and its conversion factor subtracted by the recycled quantity from certain technology. Carbon emission of the chosen technology is in (13).

2.4.3 Social Sustainability Goal

Social sustainability aspect must be included in s-SCM consideration. We propose three social aspects that must be considered in the furniture industry. The first is measured as furniture demand fulfillment as the goal that must satisfies consumer expectation. The second is measured by the number of labor that can be employed in furniture industry as a linear function of quantity of furniture produced. Finally, the last aspect is buyer's profit. The formulation of the above objectives and the corresponding goals as follows:

$$L_t = aQ_t^f + \gamma \tag{14}$$

$$L_t + d_4^- - d_4^+ = b_4 \tag{15}$$

$$\sum_{t\in T}\sum_{f\in F}\left(q_t^f / \partial_t\right) + d_5^- - d_5^+ = b_5 \tag{16}$$

We define the number of labors in manufacturer in (14) where and denote parameters. The goal related to labor involved in manufacturer is expressed in (15). The second goal in social sustainability of social aspects is expressed in (16).

*2.5 Hard Constraints*

Hard constraints are imposed so that they restrict the decision variables that must be satisfied in order the solution to be implementable. For the s-SCM, hard constraints that must be restricted are given below.

$$\sum_{f\in F} q_t^f \le \sum_{f\in F} \delta_t^f, \forall t \tag{17}$$

$$\sum_{f\in F}\left(I_{t-1}^f + q_t^f - I_t^f\right) = \delta_t^f, \forall t \tag{18}$$

$$\sum_{f\in F} \alpha_t^f \ge \sum_{f\in F}\left(q_t^f - q_{t-1}^f\right), \forall t \tag{19}$$

$$\sum_{f\in F} \beta_t^f \ge \sum_{f\in F}\left(q_{t-1}^f - q_t^f\right), \forall t \tag{20}$$

$$\sum_{f\in F} q_t^f \le \sum_{f\in F} q_t^l, \forall t \tag{21}$$

$$\sum_{f\in F}\left(q_t^l + I_t^f + I_t^l\right) \le K, \forall t \tag{22}$$

$$\sum_{m\in M} X_t^m = 1, \forall t \tag{23}$$

Equation (17) states that furniture sold must not exceed demand. Equation (18) expresses the inventory level, production level, and demand. Equation (19) and (20) represent the production level balance. Equation (21) expresses quantity of furniture produced must not exceed the log supply. Equation (22) is the storage capacity constraint. The technology chosen for every period is expressed in (23) which states that only one technology can be used for every period.

*2.5 Objective Function of Goal Programming (GP)*

The objective function of GP is to minimize positive and negative deviational variables from target level set by decision makers in all soft constraints or goals by considering to its priority and importance or weight. Priority and importance of all goals are determined by decision makers. It is common for decision makers to treat the priority as parameters that can be changed and modified and then search the best combination of priority that satisfied all goals. In s-SCM, we treat all priority of goals are equals so the objective function can be formulated as follows

$$\text{Min} Z = d_1^- + d_2^+ + d_3^+ + \left(d_4^- + d_4^+\right) + \left(d_5^- + d_5^+\right) \tag{24}$$

We want to maximize the profit obtained by manufacturer. In GP, it is achieved by minimizing the negative deviational variable. On the contrary, production changed cost and waste are must be minimized thus the positive deviational variables must be minimized. Hence, a GP formulation in s-SCM is minimizing (25) over set of soft constraints in (9), (10), (11), and (16), and set of hard constraints in (17)-(23).

## 3. Results and Discussion

To illustrate the capabilities of the model, we run numerical trial based on our observation in furniture manufacturer in Central Java, Indonesia. The period is taken from 12 months activities. The manufacturer produces two types of furniture made from two types of raw material and the demand of the furniture is given in Table 4 and the log supply is given in Table 5. All costs and revenues are in IDR. Furniture demand and log are in $m^3$.

In conducting its business, decision maker determines target level that must be achieved in order to satisfy the goals. The following are the target level determined by the decision maker:

- Goal 1: profit for manufacturer
- Goal 2: waste generated
- Goal 3: carbon emission in recycling process

 

- Goal 4: number of employment
- Goal 5: demand must be fulfilled

Two scenarios are made based on economic objectives and environmental objectives priority. Environmental objective is determined by setting the permissible amount of carbon emitted as the target level in Goal 3. The results of the Pareto efficient solution for economic objective priority are given in Fig. 2 and Table 7. The profit of manufacturer is 15,647,500 whereas waste generated and carbon emission is 1,089 and 6,050 respectively.

For the second scenario, the Pareto efficient solution for the goal programming (GP) with environmental objective priority is given in Fig. 3 and Table 8. The value of profit of manufacturer is 15,561,420 and waste generated and carbon emission is 1,150 and 3,000 respectively. It can be seen there is a decrease in profit if environmental objective is set as the main priority.

Hence, furniture manufacturers in Indonesia faced by the trade-off objectives. The first objective is if economic objective is given the main priority which result the bigger profit than the second objective, which is environmental objective. However, the first objective will emit large amount of carbon. Since green production has become a hot topic in manufacturing paradigm, furniture manufacturers must take into account the environmental objective in its activities.

## 4. Conclusion

The objectives especially economic and environmental objectives are conflicted and presented by Goal Programming (GP). The trade-off analysis can be used to analyze the decision that must be made by the decision makers in furniture industry.

Further analysis can be conducted with giving more priority (higher weighting) to one aspect that will influence to the achievement of other aspects.

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Table 1: Parameters and variables

| Manufacturer's parameters | | Buyer's parameters | |
|---|---|---|---|
| $p^f$ | furniture *f* price | $c^e$ | distribution cost to buyer *e* |
| $p^l$ | log *l* price | $c^f$ | production cost of furniture *f* |
| $q_t^f$ | quantity of furniture *f* sold to buyer | $w_t$ | waste generated by manufacturer |
| $q_t^l$ | quantity of log *l* purchased by manufacturer | $c^\alpha$ | cost to increase production level |
| $I_t^f$ | inventory of furniture *f* | $\alpha_t^f$ | production increase of furniture *f* |
| $I_t^l$ | inventory of log *l* | $c^\beta$ | cost to decrease production level |
| $P_t$ | production level | $\beta_t^f$ | production decrease of furniture *f* |
| $\partial_t^f$ | demand of furniture *f* | $K$ | storage capacity |
| $\rho^f$ | conversion factor of furniture type *f* | $r^m$ | percentage of scrap utilization of technology *m* |
| $X_t^m$ | 1 if technology *m* is used in recycling process, otherwise 0 | $c^m$ | cost of using technology *m* |
| $E_t^m$ | carbon emission of technology *m* | | |

Table 2. Goal notations

| | | | |
|---|---|---|---|
| $t$ | time index | $d_g^-$ | negative deviational |
| $g$ | goal index | $f$ | furniture index |
| $f(g)$ | achievement function | $m$ | technology index |
| $b_g$ | desired value for corresponding goal | $l$ | log type index |
| $d_g^+$ | positive deviational | $e$ | buyer index |

Table 3. Recycling technology

| Technology | Cost per $m^3$ scrap | $r^m$ | Carbon emission (kg/10$m^3$) |
|---|---|---|---|
| T1 | 7,000 | 5% | 10 |
| T2 | 10,000 | 8% | 8 |
| T3 | 12,500 | 10% | 5 |

Table 4. Furniture demand

| Furniture | Period | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| GF | 34 | 13 | 34 | 34 | 12 | 13 | 34 | 38 | 36 | 39 | 47 | 46 |
| Indoor | 18 | 33 | 48 | 25 | 34 | 18 | 42 | 26 | 13 | 18 | 37 | 34 |

Table 5. Log supply (m$^3$)

| Log | Period | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| AII | 16 | 16 | 19 | 10 | 20 | 16 | 12 | 17 | 14 | 13 | 11 | 15 |
| AIII | 245 | 219 | 217 | 240 | 239 | 211 | 209 | 230 | 224 | 238 | 212 | 207 |

Table 6: Pareto efficient solution of scenario I

| Goal | Value |
|---|---|
| Profit | IDR 15,647,500 |
| Waste | 1,089 m$^3$ |
| Carbon emission | 6,050 kg |
| Labor | 45 |
| Demand fulfillment | 100% |

Table 7. Pareto efficient solution of scenario II

| Goal | Value |
|---|---|
| Profit | IDR 15,561,420 |
| Waste | 1,150 m$^3$ |
| Carbon emission | 3,000 kg |
| Labor | 45 |
| Demand fulfillment | 100% |

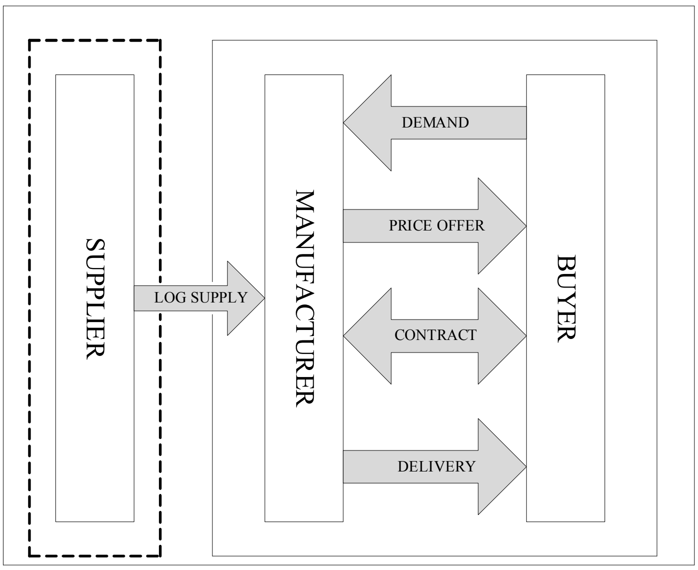


Figure 1: s-SCM framework

 

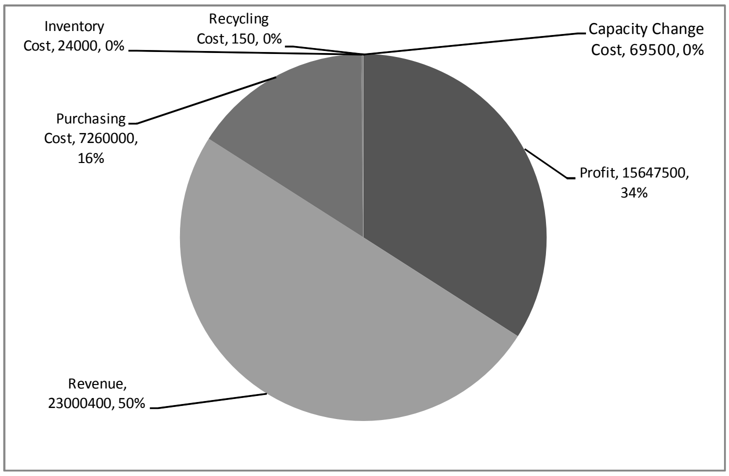


Figure 2. Pareto efficient solution of economic aspect of scenario I

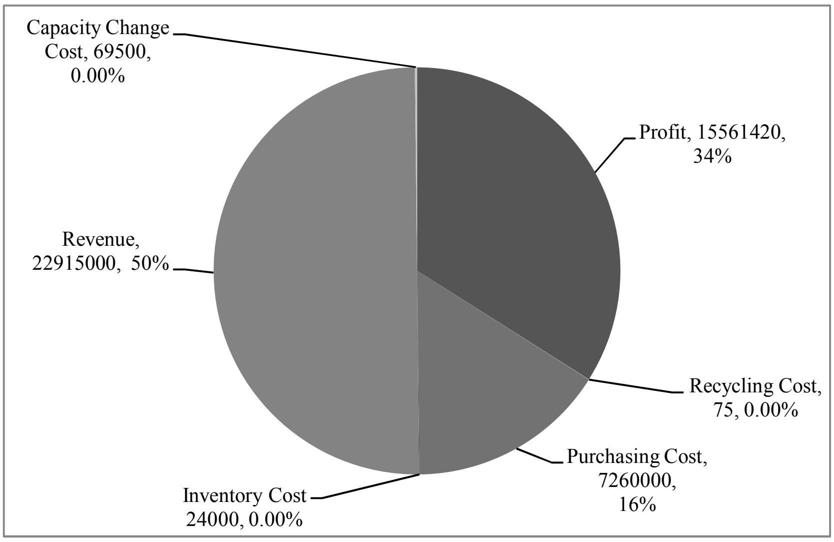


Figure 3. Pareto efficient solution of economic aspect of scenario II