A Facility Location-Allocation Model for Determining Number of Depot to Distribute Material in the Rattan Furniture Industry by Considering Dynamic Demand

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Abstract - *This paper is a study of a facility location-allocation problem in the rattan furniture industry. There are six production centers (PCs) of rattan furniture in Surakarta and its surroundings. However, their export sales are decline due to some possible problems in raw rattan distribution network from the sources centers (SCs), e.g. Borneo and Celebes Island to production centers. In the previous research, the model was expanded to support local government decide to determine optimal number of depot by consider static demand. This policy is aimed to cut the distribution channel and reduce total supply chain costs. Due to changing of global market, the demand is fluctuate. The previous model cannot anticipate this situation; consequently the local government needs a facility location-allocation model by considering dynamic demand. The objective of this research is to develop a model for supporting the local government to decide optimal number of depot by considers dynamic demand. A mixed integer non-linear programming (MINLP) was proposed to minimize total supply chain costs. The proposed model assumed that the demand for multiple products is known in advance. The potential raw rattan depot and source locations as well as their maximum capacities are also known. Finally, the proposed model can be used as instrument decision making to determine facility location-allocation.*

Keywords: *dynamic demand, a facility location-allocation model, rattan industry competitiveness, total supply chain costs.*

1. INTRODUCTION

Indonesia has been emerged as one of main suppliers of rattan furniture products to the global market (Loebis and Schmitz, 2005; Usaid, 2006; Asmindo, 2008). Most of rattan producers spread over in Java Island especially in Cirebon, Solo Raya, Semarang, Surabaya and Gresik. Since the last few decades, the price competitiveness of Indonesia's rattan furniture in global market had relatively dropped against the similar products from other countries

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(Tambunan, 2006). The manufacturers from Solo Raya also suffered this condition (Sutopo, 2007). There are six production centers (PCs) of rattan furniture *i.e.* Trangsan, Luwang, Grogol, Baki, Kartasura and Surakarta (Yuniaristanto, *et. al*, 2009; 2010). The raw material and/or raw rattan come from Borneo and Celebes Island. The supply chain from origin to destination is very long, involves many distribution channels and organized by Inter-island traders and logistics companies. This network was triggering some possible problems in raw rattan supply for instant: unsustainable and insufficient of raw rattan supply; inconsistence of raw rattan quality; and high fluctuation of raw material cost (Sutopo, 2007; Reichert, 2007). Whereas, Indonesia is a main producer 85% rattan in the world and the rest 15% of world rattan supply spread over in many countries such as China, Philippines, Myanmar, Vietnam, Africans and South America (Asmindo, 2007). For solving raw rattan problems, Asmindo Solo region has been pursuing a plan to establish a raw material storage facility for furniture producers in Solo region (Reichert, 2007). Furthermore, this plan needs further support to ensure the synergy and involvement from all stakeholders, especially local government and related institutions, to strengthen the rattan industry competitiveness.

Yuniaristanto, *et. al* (2009; 2010) proposed the new supply network which reduces the number of echelons and establish the raw rattan depot to supply raw material to the rattan industries in Solo Raya. We consider the capacitated, two stage, multi commodity, multi-periods, dynamic facility location with the reopening and closing costs. Those 2 models were expanded to offer alternatives solution for local government or Asmindo Solo Region when will determine optimal number of depot. The previous models have not considered the inventory and processing cost of raw rattan at the depot.

2. PROBLEM DESCRIPTION

This research is not only for solving the real problem of raw rattan material supply chain network in Solo Raya but also trying to fill the research gaps in the area of facility location-allocation. We investigated the real condition to determine the relevant system then we studied several researches available regarding this issue performed before. The relevant system of the problem is illustrated in Fig. 1. It consists of three main components namely supply side, demand side, and location-allocation center. The design of raw rattan distribution network is adopted from Yuniaristanto, *et. al.*, (2009). This relevant system was captured trading activities from multiple sources and involved farmers, local collector, sources centers (SCs), rattan depot, and production centers. The procurement will be given to the first trader and local collector then the raw material supplied will be stored in the depot. Therefore, rattan depot had 2 objectives as follow: to guarantee the sustainability and sufficiency of raw rattan supply and to keep raw material cost at low fluctuation. The simplifications of real system are described as follow:

- The rattan SCs locations and their demand for multiple products are known in advance,
- The rattan PCs locations and their demand for multiple products are known in advance, and
- The potential raw rattan depot locations as well as their maximum capacities are also known, *i.e.* Grogol, Baki, Transan, Tembusan and Luwang.

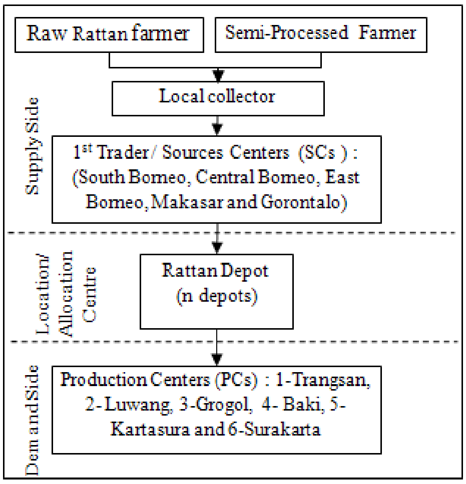

Figure 1: An overview of relevant system

Many contributors, for instant Jayaraman and Pirkul (2001), Canel *et al.* (2001), Wouda *et al.* (2002), Klose and Drexl (2005), Altiparmak et al. (2005); Schulze and Li (2009), Behmardi and Lee (2009), Yuniaristanto, *et. al* (2009; 2010) have dealt with the location-allocation problem considering multi-stages, multi commodity and multi-periods. Jayaraman and Pirkul (2001) developed a facility location-allocation model using heuristics procedure and considering static demand. The rest models were developed considering dynamic demand. Klose and Drexl (2005) review some of the work which has contributed to the current state-of-the-art of facility location-allocation model. Hinojosa *et al.* (2008) investigate a dynamic two-echelon multi-commodity location model where potential new facilities can be opened and existing facilities can be closed. Schulze & Li (2009) and Behmardi & Lee (2009) were developed models considering supply chain strategies such as commonality and postponement strategies and dynamic supply chain. Yuniaristanto, *et. al* (2009; 2010) proposed a facility location-allocation model for distributing raw rattan material considering dynamic demand.

The objective of this research is to develop the capacitated, two stage, multi commodity, multi-periods, dynamic facility location with the reopening and closing costs by considering inventory and processing cost of raw rattan. Furthermore, Supply Chain Management (SCM) may be able to solve it because the problems above can be seen as an integration of key business processes from the integrated system point of views that include people (SCs), materials (raw rattan), equipments (distribution channels), and energy (financial and information). The integration of key business processes is required to achieve the suitable economic results and to leverage benefits (Simchi-Levi, *et al.* 2003, Chopra and Meindl, 2004). In this work, a strategic level of supply chain network design problem is addressed, that is the decision on number and location of rattan depot to guarantee the sustainability and sufficiency of raw rattan supply at rational price for producers.

3. THE DYNAMIC LOCATION-ALLOCATION MODEL

This paper deals with a multi-period two echelons multi-commodity capacitated facility location problem (Fig. 2). The objective is to minimize total supply chain costs such as procurement cost, transportation cost, holding cost, raw rattan processing cost, depot fixed cost as well as reopening and closing costs during the planning horizon. The model developed uses the following notations:

Sets:

$t \in$ Set of time periods,
$i \in$ Set of suppliers,
$j \in$ Set of potential depots,
$k \in$ Set of production centers,
$n \in$ Set of semi-finished rattan

Decision variables:

X_{ijt} The total volumes of raw rattan that is shipped to potential depot j from potential supplier i in time t,
Y_{jknt} Indicate 1 if semi-finished rattan n is delivered from potential opened depot j to production centers k in time t and 0 otherwise,
g_{jt} Indicate 1 if the potential depot j is opened to the and 0 otherwise,
A_{jnt} The total volumes of semi-finished rattan n that is processed at depot j in time t,
B^{+}_{jt} The on-hand stock of raw rattan at depot j in period t,
B^{-}_{jt} The shortage of raw rattan at depot j in period t,
I^{+}_{njt} The on-hand stock of semi-finished rattan n at depot j in period t,
I^{-}_{njt} The shortage stock of semi-finished rattan n at depot j in period t.

Parameters:

Cb_{it} Procurement cost of raw rattan from supplier i in period t.
Ct_{ijt} Transportation cost of raw rattan from supplier i to depot j in period t.
Ct_{jknt} Transportation cost of semi-finished rattan n from depot j to production center k in period t.
Cp_{jnt} Processing cost of semi-finished rattan n at depot j in period t
H_{jt} Holding cost of raw rattan at depot j in period t.
E_{jt} Shortage cost of raw rattan at depot j in period t
H_{jnt} Holding cost of semi-finished rattan n at depot j in period t.
E_{jnt} Shortage cost of semi-finished rattan n at depot j in period t
F_{jt} Fixed cost of depot j in period t.
W_{jt} Holding capacity of depot j in period t.
S_{it} Supply capacity of supllier j in period t.
a_{jt} Reopening cost of depot j in period t.
b_{jt} Closing cost of depot j in period t.
D_{knt} Demand of semi-finished rattan n from each of production center k in period t.
r_n Fraction of raw rattan that processed to be semi-finished rattan n

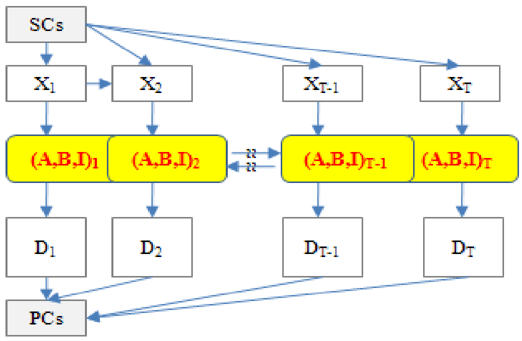

Figure 2: Commodity flow model with dynamic demand

The following objectives function is used in the formulation of minimal supply chain costs:

$$Z_{\min} = \sum_{t=1}^{T}\sum_{j=1}^{J}\left[\begin{array}{l} \left(\sum_{i=1}^{I} Cb_{it}X_{ijt}\right) + \left(\sum_{i=1}^{I} Ct_{ijt}X_{ijt}\right) + \left(\sum_{k=1}^{K}\sum_{n=1}^{N} Ct_{jknt}Y_{jknt}.D_{knt}\right) + \\ \left(\sum_{n=1}^{N} Cp_{jnt}A_{jnt}\right) + \left(H_{jt}B^{+}_{jt} + E_{jt}B^{-}_{jt}\right) + \\ \left(\sum_{n=1}^{N} \left(H_{jnt}I^{+}_{jnt} + E_{jnt}I^{-}_{jnt}\right)\right) + \left(F_{jt}g_{jt}\right) + \\ \left(\begin{array}{l} a_{jt}g_{jt}(1 - g_{j,(t-1)}) \\ + b_{jt}g_{jt}(1 - g_{j,(t+1)}) \end{array}\right) \end{array}\right] \tag{1}$$

Subject to:

$$\sum_{j=1}^{J} X_{ijt} \le S_{it}, \forall \; t \tag{2}$$

$$\sum_{k=1}^{K}\sum_{n=1}^{N} Y_{jknt}D_{knt} + B_{jt} + \sum_{n=1}^{N} I_{jnt} \le g_{jt}W_{jt} \;, \forall \; t \tag{3}$$

$$\sum_{j=1}^{J} \;{}_{jt} \le V_t ,\forall \tag{4}$$

$$\sum_{j=}^{J} \;{}_{jknt} = \;,\forall \quad n,t \tag{5}$$

$$B_{jt} = {}_{j(t-\;)} + \sum_{i=}^{I} \;{}_{ijt} - \sum_{n=}^{N} \;{}_{it} A_{jnt} \;,\forall \quad t \tag{6}$$

$$I_{jnt} = \;{}_{jn(-\;)} + A_{jnt} - \sum_{k=}^{K} \;{}_{knt} Y_{jknt} \quad ,\forall \quad n,t \tag{7}$$

$$A_{jnt} = \sum_{k=}^{K} \;{}_{knt} Y_{jknt} \quad ,\forall \quad n,t \tag{8}$$

$$B_{jt} = B_{jt}^{+} - B_{jt}^{-} ,\forall \quad t \tag{9}$$

$$I_{jnt} = \;{}_{jnt}^{+} - \;{}_{jnt}^{-} ,\forall \quad n,t \tag{10}$$

$$Y_{jknt}, g_{jt} \in \{1\;\} \forall \quad k,n,t \tag{11}$$

$$X_{ijt}, A_{jnt}, B_{jt}^{+}, B_{jt}^{-}, I_{jnt}^{+}, I_{jnt}^{-} \ge \;) \;,\forall \quad j,n,t \tag{12}$$

The constraint set (2) ensures that each supplier is shipped raw rattan under their capacity. The constraint set (3) represents the capacity restriction of potential depots. The constraint set (4) ensures that we locate at most W_t depots. Equation (5) guarantees that each PCs is only connected to one depot. Equation (6) sets a balance between the raw rattan processed to stock of raw rattan. Set equations (7) – (10) ensure that the stock of semi-finished rattan is sufficient to fulfill PCs demand. Constraint set (11) enforces the binary number of the decision variables and constraint. Equation (12) enforces the non-negativity restriction on the decision variables used in the model.

4. SOLUTION METHOD AND ANALYSIS

The optimal solution can be obtained by solving the pre-emptive of the mixed integer non-linear programming (MINLP) above. The methodology to solve the proposed problem is described as follow: (i) set the parameters of the a facility location-allocation; (ii) formulate the objectives function in the MINLP; (iii) formulate all the constraints of the solution model, and (iv) solve this model by using software Premium Solver Platform V9.0.

In order to illustrate the capabilities of the proposed-model, a numerical example has been studied. Data input was obtained from Indonesia Furniture Association, Industrial and Trading Department of Sukoharjo and Surakarta Regencies, and Rattan Industries in Solo Raya. We were calculated decision variables for five years planning horizon. The results are summarized as below:

- The Depot in Luwang should be opened and operated at the beginning until the end of horizon planning, while depot in Baki will be opened at second year,
- During first year, all PCs demand will supplied by the depot in Luwang then the depot in Baki will change to support rattan for Trangsan production center.
- The allocation of raw rattan from SCs to Depots is presented in Appendix-Table 1.
- The location of raw rattan from Depots to PCs is presented in Appendix-Table 2.
- The total supply chain cost in current system is Rp. 113.526 billions while proposed system will only expend Rp. 77.567 billions. The proposed system will reduce costs up to 31.67% (Appendix-Table 3).

5. SUMMARY AND EXTENSIONS

A proposed location-allocation model is formulated considering multi-stages, multi commodity, multi-periods and dynamic demand. The model can be used to make decisions not only the number and location of facilities, but also the decisions on purchasing and distributing of commodity. A mixed integer non-linear programming (MINLP) was proposed to solve this problem.

The ongoing research is dedicated to develop decision support system (DSS) for assisting model application. This paper has a certain limitation due to some assumptions to simplify the model. It is clear that the relaxation of these assumptions will provide additional challenges in future research.

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APPENDIX-TABLES

Table 1: The allocation of raw rattan from SCs to Depots (Tons)

X_{ijt}	Supplier, i	South Borneo	Central Borneo	East Borneo	Makasar	Gorontalo
Period-1	Luwang	3,040	4,500	2,790	7,930	2,550
Period-2	Baki	3,040	4,500	2,790	0	0
	Luwang	0	0	0	7,930	2,550
Period-3	Baki	0	4,500	0	0	1,206
	Luwang	3,040	0	2,790	7,930	1,344
Period-4	Baki	0	0	0	196	0
	Luwang	3,040	4,500	0	5,985	0
Period-5	Baki	0	0	0	0	0
	Luwang	0	0	0	0	0

Table 2: The location of raw rattan from Depot Luwang to PCs (tons)

Depot Luwang :

TRANGSAN	**LUWANG**	**TEMBUNGAN**	**BAKI**	**GROGOL**	**KARTASURO**
D111 : 3076	D211 : 768	D311 : 186	D411 : 162	D511 : 46	D611 : 92
D121 : 828	D221 : 207	D321 : 50	D421 : 44	D521 : 12	D621 : 25
D131 : 1118	D231 : 279	D331 : 68	D431 : 59	D531 : 17	D631 : 34
D141 : 559	D241 : 140	D341 : 34	D441 : 29	D541 : 8	D641 : 17

Table 3: Total Supply Chain Costs (Million Rp.)

Periods	**1**	**2**	**3**	**4**	**5**	**Total**
Transportation cost to depot	Rp220	Rp262	Rp304	Rp363	Rp444	Rp1,593
Trans. cost from Supplier	Rp42,946	Rp46,038	Rp49,353	Rp33,592	Rp0	Rp171,929
Operating cost	Rp128	Rp274	Rp293	Rp314	Rp337	Rp1,346
Opening/Closing Costs	Rp240	Rp257	Rp0	Rp0	Rp0	Rp497
Procurement Cost	Rp124,860	Rp133,850	Rp143,487	Rp101,419	Rp0	Rp503,616
Processing Cost	Rp13,702	Rp16,157	Rp19,052	Rp22,466	Rp26,492	Rp97,869
Holding Cost of raw rattan	Rp61	Rp120	Rp177	Rp164	Rp0	Rp0
Total	**Rp182,156**	**Rp196,958**	**Rp212,666**	**Rp158,318**	**Rp27,273**	**Rp776,850**