MODEL FOR SUPPLY CHAIN NETWORK DESIGN WITH PROFIT BALANCING CONSIDERATION

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ABSTRACT

Network design is a common problem in supply chain and logistics management. In a supply chain network, a chain with task to supply downstream chain usually called as facility. The decision about the number of facility, its location and the supply link are the issues that received greater attention from previous researchers. However, most of the previous researches were discussed about total cost minimisation. That kind of model will give lowest cost of the supply chain system but it does not guaranty that every opened facility receives a well-balanced profit. In this paper, we propose a new paradigm of supply chain network design modelling for two level echelons distribution system with the objective is to balance profit for each facility while keeping minimum total logistic cost. The model is developed based on mixed integer programming approach and based on the given numerical example, it could be seen that the proposed model is work well to achieve the objective.

Key words: *Facility location problems, network design, two level echelon distribution system, mixed integer programming, profit balancing.*

1. INTRODUCTION

Network design is a common problem in supply chain and logistics management. In a supply chain, an information from upstream chain is modelled backward while product supply is modelled forward. A chain with task to supply downstream chain usually called as facility. The network design covers several topics such as the decision about the number of facility, its location and the supply link. Decision about such problems are important because it will affect significantly to the total cost of logistics. Therefore, Ballou (2004) categorised this problem as strategic decision for high level management.

Facilities number and location problem has been widely investigated by several previous researcher. Dupont (2008) investigated facilities location problem by considering investment, production and distribution costs. Similar study that consider investment budget constraint has also been conducted by Yang et al. (2009). Drezner et al. (2002) focused on transportation costs and volume of product while Miranda and Garrido (2009) considered investment, transportation and storage costs as the total costs to be minimised when deciding the opening of facilities. All of that models are limited to the capacity of each facilities.

Common method that is used to get the solution is heuristic methods which is basicaly use ingenuity, creativity and experience of the researcher to find the best solution or develop from existing solutions (Daellenbach, 1994). Drezner et.al (2002) conducted comparison study on descent algorithms, simulated annealing, tabu search and genetic algorithms to find a solution of supply chain network design. Dupont (2008) used Branch and Bound algorithm to define the location of facilities and the number of products distributed by the facilities. Kahraman et al (2003) built multi-attribute fuzzy logic for selecting the location of the facilities by considering quantitative and qualitative criteria.

Most of previous studies on facilities design focused on minimising the total cost of supply chain system. However, model that consider profit balancing of each facility has never been investigated by previous researchers. In the established supply chain system, profit balancing is one of the important solution that must be considered to keep all of the chains get win-win solution. Optimisation model with the objective is to minimise the total supply chain cost usually give radical solution to close established facilities or the number of distributed product in each facility is extremely different. This research develop a mathematical model to solve facilities location problem with consider profit balancing of each facility. This model is very applicable for an established supply chain system where the cost minimisation is not the one and only purpose. Supply chain systems that belonged to this category are usually the supply chain system with government involvement in decision making, with the object are products or services that people need such as health care system, education facilities, primary commodities, energy, and so on. Further, the model will be applied in distribution system of a product in an area in Indonesia to determine optimum number and location of facilities and agents.

2. THEORETICAL BACKGROUND

Logistics is the integration of information, transportation, inventory, warehousing, material handling, and packaging, in which all of the parts interact each other and form a whole logistics management (Bowersox et al, 2000). Stock and Lambert (2001) mentioned that logistics is part of supply chain for planning, implementing, and controlling the product flow, inventory, service, and related information from point of origin to point of destination in order to fulfil customers need. Logistics planning consists of four main problems, there are level of service, facility location, inventory, and transportation (Ballou, 2004).

Facility is defined as a place (site) or something used as production or storage. Facility, according to Dupont (2008), could be a warehouse, factories, public facilities or even transmitters. Facility location is an important issue that form the structure of the supply chain including determination of the number, location and size of the facility. This research is inspired from two main models that proposed by Dupont (2008) and Miranda and Garrido (2009). The purpose of the two models are to determine the location of several facilities in a supply chain network to fulfil the demand of customers who are geographically dispersed. The objective function of that model is to minimise the total cost that consist of three types of cost that generally approach to the linear model. The purpose of this research is to design a distribution network in a two-echelon supply chain using through two formula. First formula is to optimise the level of service and the second formula is to determine location of the facilities.

3. RESEARCH METHOD

The first step of this research is a preliminary study on analysis of the problem to obtain deep understanding of the investigated system and also system characteristic. Previous studies in the facility problem focused on decisions making with objective is minimising the total cost of logistics. This model does not guaranty that every facility get balanced profit. This research develops a model to determine the location of a new facility by considering the balanced profits of each facility. Model development is carried out after getting the whole picture of the system supported by a theoretical study. Model is developed by determining the objective function, decision variables, parameters, assumptions and limitations. The overall characteristics of the system are formulated in a mathematical models. A commercial well known software called LINGO.9 is utilised in order to solve the mathematical model. A numerical example is also presented to test the validity and performance of the proposed mathematical model.

4. SUPPLY CHAIN SYSTEM DESCRIPTION

In the investigated system there is no constraint about the number of facility to be opened. The number and location of customer that should be served and also the average demand of every customer are known in advance. There are two entities involved in the investigated supply chain system namely distributor, as a facility that will be opened, and retailer, as customer to be served by the distributor. It is assumed that each distributor orders from the same manufactures and the ordering cost is equal for every distributor. Hence, the system only examine the relationship between the two levels of the supply chain which are distributor and retailer. The relationship between the distributor and retailer can be explained graphically as shown in Figure 1.

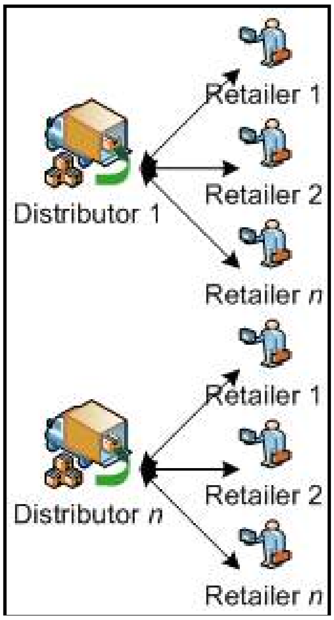

Figure 1. Relationship between the distributor and the retailer

The network designs process can be illustrated as in Figure 2.

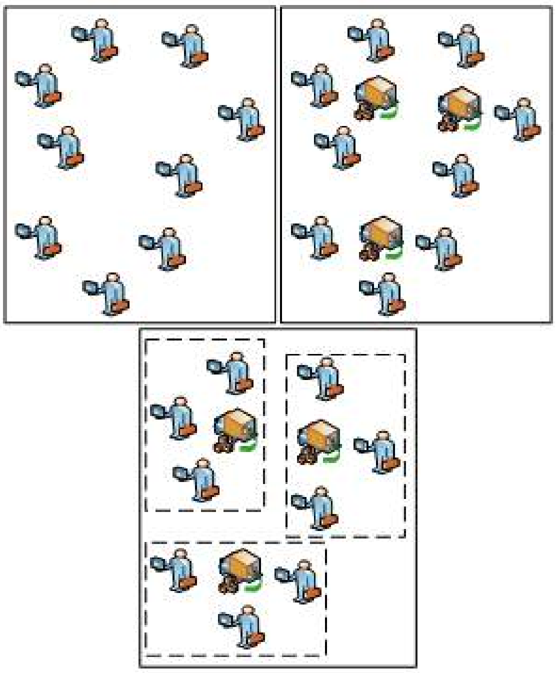

Figure 2. Illustration of Network Design

Retailers group to be served by a distributor is determined based on the shortest distance from each retailer to the distributor subject to the capacity of the distributor. Other policy is that every retailer should be serviced by only one distributor and all of retailers demand must be fulfilled by the distributor, so that it is possible for a distributor to serve more than one retailers

5. MATHEMATICAL MODEL

The objective of the model is to minimise gap of profit of each opened distributor. Since the profit of each opened distributor will be varying during optimisation process, then, in order to reduce computational burden, a big constant will be used as reference point. Hence, gap of profit of each opened is defined as the difference between opened distributor's profit from the big constant. There are several assumption in modelling as follow:

a. Each distributor has the same capacity.
b. Total delivered products from distributors to retailers is equal to the demand at the retailers.
c. There is no inventory in the distributor.
d. Transportation cost from a distributor to retailers per kilometres is constants.
e. Fixed costs to open a distributor is only one, that is investment costs.
f. The variable cost is subject to frequency of the distributor.
g. Delivery time of products is continue.
h. Lost cost is defined based on residual capacity of the distributor

The mathematical model is as follow:

$Min\,\Delta P_{tot} = \sum_{j=1}^{N}(M - P_j)$ (1)

Where:

$N = \sum X\, ij$ (2)

$P_j =$
$[\sum_{k=1}^{K} H_s V_{jk} X_{ij}] - [\sum_{k=1}^{K} H_b V_{jk} X_{ij} + \sum_{k=1}^{K} TD_{jk} F_{jk} Y_{jk} +$
HiCjXij−k=1KVjkYij+ (3)

Subject to:

$\sum_{k=1}^{K} v_{jk} \leq C_j X_{ji} \quad \forall j \in J$ (4)

$\sum_{j=1}^{J} Y_{jk=} \; 1 \; \forall \; k \in K \;)$ (5)

$\sum_k \; v_{jk} \;\; \leq M X_{ji} \;\; \forall i \in I, j \in J, \forall k \in K$ (6)

$V_{jk} = d_k V_{jkt} \leq C_t \quad \forall \; j \in J$ (7)

X_j^i , Y_{kj} $\in \{1,0\}$ (8)

$N, V_{jk}, F_{jk}, dk \geq 0$ and integer (9)

$P_j \geq 0$ (10)

H_s :Selling price of product from distributor to retailer (Rp/unit)
H_b :Purchase price of product from distributor to manufactures (Rp/unit)
H_l :Opportunity cost per unit ((Rp/unit)
d_{jk} :Distance from distributor *j* to retailer *k* (km)
T :Transportation cost per distance unit from distributor to retailer (Rp/km)
I_j :Fix investment cost to open distributor (Rp/year)
O_v :Variable investment cost (Rp/delivery)
D_k :Demand on retailer *k* (unit/year)
C_j :Capacity at facility *j* (unit/year)
C_t :Capacity of truck (unit/delivery)
M :Big number (Rp/year)
P_j :Profit at distributor *j* (Rp/year)
R_j :Revenue at distributor *j* (Rp/year0
F_{jk} :Frequency of delivery product from distributor *j* to retailer *k*
V_j :Delivery volume at distributor *j* (unit/year)

From the model above, it can be seen that there is a multiplication operation between two decision variables. It is impossible to obtain a decision variable using pure analytical calculation. Using numerical data, the pattern or behaviour of the model will be analysed from the objective function value with the change of decision variable *N* which is the number of distributors that will be opened. Because there is no information about the number of facilities to be opened, it makes the model is need to be solved by enumeration approach. Test will be carried out at each possible number of existing distributor facilities from 1 to *n*+1. With this step, the location, optimum number of facility and retailers to be served by every distributor or facility can be obtained.

6. NUMERICAL EXAMPLE

In order to test the performance of the proposed model, a numerical example is given. Table 1, Table 2 and Table 3 show the data about the distance between region, demand at retailers and several parameter values respectively.

Table 1. Distance between region

i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	18	14	23	19	15	35	51	33	31	38	55	50	45	64	49	59
2	18	0	10	19	18	23	40	60	38	33	34	48	48	47	70	54	64
3	14	10	0	17	23	31	46	66	41	28	29	41	44	45	73	57	65
4	23	19	17	0	10	22	30	50	24	16	15	32	29	28	56	39	46
5	19	18	23	10	0	12	23	43	20	16	24	42	34	30	56	35	46
6	15	23	31	22	12	0	16	33	20	22	35	52	42	34	44	35	46
7	35	40	46	30	23	16	0	21	11	22	36	52	37	27	35	19	32
8	51	60	66	50	43	33	21	0	28	38	52	68	48	36	23	19	30
9	33	38	41	24	20	20	11	28	0	11	26	42	27	15	32	16	28
10	31	33	28	16	16	22	22	38	11	0	15	32	19	14	40	22	32
11	38	34	29	15	24	35	36	52	26	15	0	18	22	21	33	61	50
12	55	48	41	32	42	52	52	68	42	32	18	0	21	33	60	53	49
13	50	48	44	29	34	42	37	48	27	19	22	21	0	12	40	31	28
14	45	47	45	28	30	34	27	36	15	14	21	33	12	0	30	18	17
15	64	70	73	56	56	44	35	23	32	40	33	60	40	30	0	16	12
16	49	54	57	39	35	35	19	19	16	22	61	53	31	18	16	0	12
17	59	64	65	46	46	46	32	30	28	32	50	49	28	17	12	12	0

Table 2. Demand at Retailers

i	Region	Demand	i	Region	Demand
1	Kretek	54,236	10	Bantul	64,584
2	Sanden	53,924	11	Pajangan	39,988
3	Srandakan	51,220	12	Sedayu	66,456
4	Pandak	87,620	13	Kasihan	96,044
5	Bambanglipuro	62,400	14	Sewon	116,376
6	Pundong	38,896	15	Piyungan	130,000
7	Imogiri	214,864	16	Pleret	112,996
8	Dlingo	108,680	17	Banguntapan	124,904
9	Jetis	102,128			

Tabel 3. Parameters value

Nu	Parameters	Value
1	Hs	Rp. 12.000
2	Hb	Rp. 11.000
3	Cj	360.000 unit/year
4	Ct	500 unit/delivery
5	Hl	Rp100/unit
6	Ov	Rp.40.000/delivery
7	T	Rp.1000/km

The developed model will then be solved using LINGO 9.0. The enumeration approach for the number of facility is start from *J* = 1 to *J* = 17. For the number of agent from 1 to 4, feasible solution is not found. It is happened because the constraints are not met. The capacity of agents can not cover the entire demand of retailer. The optimum solution is obtained at the enumeration 5(*m*+1). The distribution network design given by the proposed model is presented in the Figure 3.

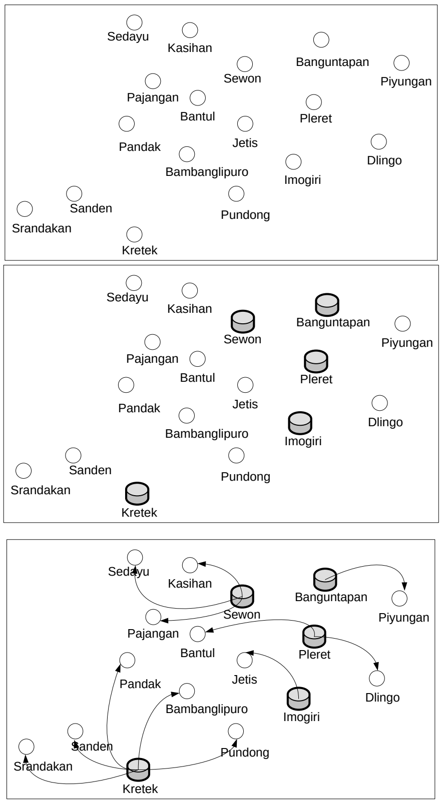

Figure 3. Distribution network design

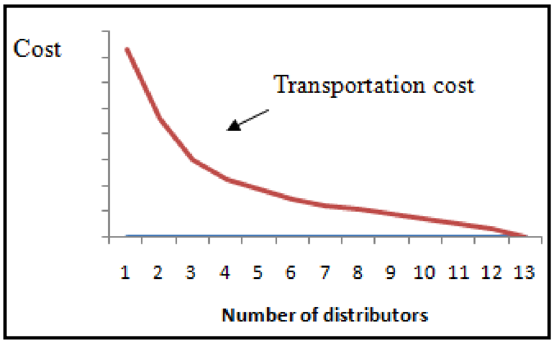

Figure 4. Relationship between number of distributors and transportation cost

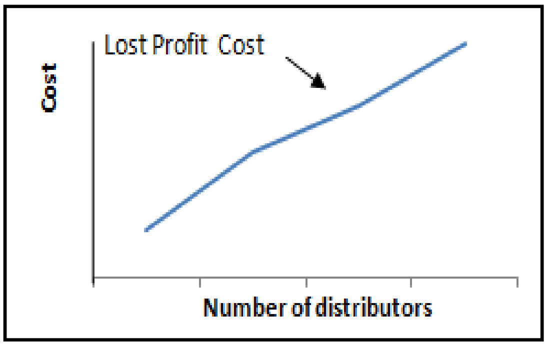

Figure 5. Relationship between the number of distributor and opportunity cost

To understand the characteristics of the proposed model, it will be compared to another model which has objective function to minimise the total cost. Equation 11 shows the objective function of the another model that compared to the proposed model while Table 4 shows the result of the comparison. Figure 4 shows the relationship between the number of distributor and transportation cost while Figure 5 shows the relationship between the number of distributor and opportunity cost.

$\text{Min TC} = [\sum_{k=1}^{K} H_b V_{jk} X_{ij} + \sum_{k=1}^{K} T\, d_{jk}\ F_{jk}\, Y_{jk} +$
Hl. CjXij−k=1KVjkYjk (11)

Tabel 4. Computational result comparison

Criteria	Balance Profit Model	Cost Minimum Model
The number of distributors built	5	6
Total logistic system	Rp. 16,839,276,920.00	Rp. 16,778,476,000.00
Percentage of maximum differences profit	140%	500%
The average percentage of profit gap between distributor	18,78%	47,45%

Conceptually, the more number of opened distributors will decrease the total cost of transportation. It can be understood because a lot of distributors can be located near to customer to fulfil the demand so that the distance of product transportation can be reduced. The more the number of opened distributors leads to grater total lost profit. This is happened because there will be a lot of unused capacity in the distributors.

7. CONCLUSION

The proposed mathematical model is a model of facility location optimisation by considering the balanced profit. Output of this model are the number and location of the facilities, the number and location of units served by each facility, the volume and frequency of product delivered to the unit serviced. The future research would concern with the following issues: (i) the use of other heuristic algorithm to obtain solution such as genetic algorithm, taboo search, and so on (ii) linear model approach to find the solution.

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