A Multi-Objective Approach for Multi Capacity warehouse Location within Distribution Supply Chain Problem

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Abstract: In this paper, we propose a mixed integer programming formulation for a location distribution problem. We have a two layer supply chain, central warehouses/stocks, regional warehouses and customers. Stocks should satisfy the multi-commodity customers demand. Our objectives are to minimize transportation cost of goods, from stocks to regional warehouses and from regional warehouses to customers, and installing cost of warehouses and to maximize average service level of customers. Our model determines a set of Pareto optimal solution for considering these two conflicting objectives. We have a three type alternatives for both stocks and regional warehouses with varying installing costs and capacities. Regarding the long term decision making for a location problem, we consider time value of money to have more assumptions of real worlds. As a result, a case study is indicated to show efficiency of model to solve the industrial problems; a sensitivity analysis is also implemented upon the rate of return and the life of cycle of the supply chain system.
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1. Introduction

Supply chain management (SCM) is the process of planning, implementing and controlling the operations of the supply chain in an efficient way. SCM spans all movements and storage of raw materials, work-in-process inventory, and finished goods from the point-of-origin to the point-of-consumption (Council of Supply Chain Management Professionals 2007, Simchi-Levi et al. 2004).

There are more works in literature considering concepts of SCM in variant areas that we state some of them as follows. Altiparmak et al. (2006) developed a multi-objective genetic algorithm (MOGA) to find a set of optimal pareto solution for Supply chain network (SCN) design. Thanh et al. (2008) proposed a mixed integer programming (MIP) formulation to design and plan a production – distribution system along the supply chain. Pujari et al. (2008) presented an integrated approach for incorporation of location, production, inventory and transportation issues within a supply chain. Shu and Karimi (2009) developed two heuristic algorithms for considering concept of safety stock in supply chain networks. Kaminsky and Kaya (2008) proposed effective heuristics for inventory positioning in supply chain networks involving several centrally managed production facilities and external suppliers. Monthatipkul and Yenradee (2008) introduced an MIP model to find an optimal inventory/distribution plan (IDP) control system for a one-warehouse/multi-retailer supply chain system. Chauhan et al. (2009) designed a heuristic for Multi-commodity supply network planning and a branch and price for large-sized problems. Khouja formulated a three-stage supply chain model and investigate effect of change from two-stage from three-stage in cost reduction. Seliaman and Ahmad consider three-stage supply chain with stochastic demand to optimize inventory decision. Santoso et al. (2005) proposes a stochastic programming formulation for supply chain under uncertain environment. Newly, a single vendor and multiple retailers supply chain retailers is modeled (Darwish and Odah, to be published). For more detailed study, Gunasekaran and Ngai (2009) and Minner (2003) can be useful.

Facility location is and has been a well established research area within Operations Research (OR). Numerous papers and books are witnesses of this fact. The development of SCM started independently of OR and only step by step did OR enter into SCM. As a consequence, facility location models have been gradually proposed within the supply chain context (including reverse logistics), thus opening an extremely interesting and fruitful application domain (Melo et al. 2009). Here, some previous researches worked on location within supply chain, are described. Gebennini presented a model for location-allocation problem to optimize safety stocks and customer service level. Snyder et al. (2007) proposed a stochastic version of the location model with risk pooling (LMRP) that include location, inventory, and allocation decisions under uncertainty.

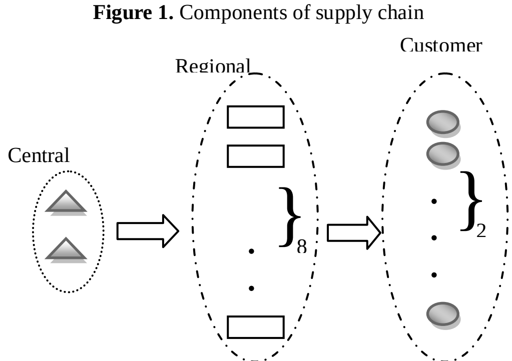
Syam (2002) extend facility location problem considering several concepts of logistic as holding, ordering, and transportation costs. He used two lagrangian relaxation and a simulated annealing (SA) based heuristics algorithm for comparing experimental results. Thanh et al. (2008) consider facility location problem in supply chain within planning horizon. Melo et al. (2009) reviewed facility location problem in a well-organized way that it can be useful for being depth in this area. There are other problems derived from facility location problem as transfer point location, hub location and etc.

In this paper, we present a multi-objective mixed integer programming formulation for location within network distribution problem considering time value of money, TVM. Objectives are to minimize total cost including establishment and transportation cost and to maximize customer satisfaction. The problem describes two location layers in single period. We determine the volume of the inventory in both stocks and middle warehouses. There is a few resea considering TVM as Rastpour and Esfehani (2010). They proposed a mathematical formulation for input/output point of department in facility layout considering time value of money. The remainders of paper are as follows. Model description is stated in section II. In, Section III, mathematical model is formulated, computational results are indicated in section IV and conclusions are discussed in section V.

2. Model formulation

The Components of supply chain such as are illustrated in Figure 1 are introduced. Central warehouses: the main stocks of supply chain that demands are supplied here. There are two potential location for central warehouses, capital of country and south port. Regional warehouses: stocks between central warehouses and customers that demands are distributed here. There are 8 potential locations for regional warehouses that they are in the capital of provinces. Customers: there are 28 customers that are located in the cities of the provinces. Goods: Five types of commodities can be supplied for the customers demanding five families of cars.

Figure 1. Components of supply chain



Assumptions of problem are as follows:
1. There are two potential central warehouses that at least one of them should be located,
2. There are limited capacities for both central and regional warehouses.
3. Transportation cost per unit is as a coefficient of distance between central and regional warehouses and between regional warehouses and customers.
4. There is a minimum level of customer satisfaction.

There are two objectives for supply chain, minimizing total cost including establishment and transportation cost and maximizing customer satisfaction.

Sets and indices

P Sets of central warehouses $(|P| = p, k \in P)$,
M Sets of regional warehouses $(|M| = m, j \in M)$,
N Sets of customers $(|N| = n, i \in N)$,
O Sets of good types $(|O| = o, t \in O)$, .
L Sets of type of warehouses $(|L| = L, l \in L)$,

Variables

v_{kl} is 1 if the potential point k is selected as a stock with capacity type l, otherwise 0.
u_{jl} is 1 if the potential point of j is selected for a regional warehouse with capacity type l.
x_{ijt} Percentage of demand customer i for commodity t that is supplied by regional warehouse j,
y_{jkt} Percentage of demand regional warehouse j for commodity t that is supplied by central warehouse k

Parameters

M Number of month in a year,
a_{it} Demand of customer i for commodity t,
b_{ijt} Capacity of regional warehouse j with type l for commodity t,
c Cost of transportation per unit,
d_{ij} Distance between regional warehouse j and customer i,
d'_{jk} Distance between regional warehouse j and central warehouse k,
e_{ktl} Capacity of central warehouse k with type l for commodity t,
P Coefficient of total cost in objective function,
q_{kl} Cost of installation central warehouse k with type l,
S_{it} Minimum level of customer satisfaction i for commodity t
W_{jl} Cost of installation regional warehouse j with

type l,

$$\min z_1 = P.\sum_{t=1}^{o}\sum_{j=1}^{m}\sum_{i=1}^{n} cd_{ij}a_{it}x_{ijt} + P\sum_{t=1}^{o}\sum_{k=1}^{p}\sum_{j=1}^{m} cd'_{jk}a_{it}y_{jkt}$$
$$+P\left(\sum_{l=1}^{L}\sum_{j=1}^{m} w_{jl}u_{jl} + \sum_{k=1}^{p} q_{kl}v_{kl}\right)(A/P, i/M\%, nM)$$

$$\max Z_2 = (1-P)\sum_{t=1}^{o}\sum_{i=1}^{n}\sum_{j=1}^{m} x_{ijt}/no$$

$$\sum_{t=1}^{o}\sum_{i=1}^{n} x_{ijt} \le no\sum_{l=1}^{L} u_{lj} \qquad \forall j \qquad (1)$$

$$\sum_{t=1}^{o}\sum_{j=1}^{m} y_{jkt} \le mo\sum_{l=1}^{L} v_{lk} \qquad \forall k \qquad (2)$$

$$\sum_{t=1}^{o}\sum_{i=1}^{n} a_{it}x_{ijt} \le \sum_{t=1}^{o}\sum_{l=1}^{L} b_{jtl}u_{lj} \qquad \forall j \qquad (3)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{t=1}^{o} y_{jkt}a_{it} \le \sum_{l=1}^{L}\sum_{t=1}^{o} e_{ktl}v_{kl} \qquad \forall k \qquad (4)$$

$$\sum_{j=1}^{m} x_{ijt}a_{it} \ge s_{it}a_{it} \qquad \forall i,t \qquad (5)$$

$$\sum_{k=1}^{p} b_{jtl}y_{jkt} + \sum_{i=1}^{n}\sum_{t=1}^{o} a_{it}(1-u_{jl}) \ge \sum_{i=1}^{n} a_{it}x_{ijt} \qquad \forall j,t,l \qquad (6)$$

$$\sum_{i=1}^{n} x_{ijt} \le 1 \qquad \forall j,t \qquad (7)$$

$$u_{jl}, v_{kl} \in \{0,1\}$$

First objective Z_1, is summation of present cost, installation cost, and annually cost, transportation cost: Transportation cost between central and regional warehouses, $\sum_{t=1}^{o}\sum_{j=1}^{m}\sum_{i=1}^{n} c.d_{ij}a_{it}x_{ijt}$ Transportation cost between regional warehouses $\sum_{t=1}^{o}\sum_{k=1}^{p}\sum_{j=1}^{m} c.d'_{jk}a_{it}x_{ijt}$ and customer, Installation cost for central warehouses, $\sum_{l=1}^{L}\sum_{j=1}^{m} w_{jl}u_{jl}$ and Installation cost for regional warehouses, $\sum_{l=1}^{L}\sum_{k=1}^{p} q_{kl}v_{kl}$ that is multiplied by weighted coefficient P. Second objective, Z_2 is the summation of the level of the customer satisfaction that is multiplied by $(1-P)$. Constraints (1) and (2) states if regional warehouse j or central warehouse k satisfy the demand, it has been installed. Constraints (3) and (4) show capacity restriction for each regional warehouse. Constraint (5) implies that there is a minimum level of customer satisfaction i for commodity t. Constraint (6) considers that amount of supply should be greater than amount of demand. Finally, constraint (7) state that for service level of each goods for each customer is less than 100%.

3. Computational Results

We run the model without considering TVM and with considering TVM. Table 1 and 2 show the results of the model. We show Pareto set of solution the model both before and after TVM (Figure 2) and we show effect of rate and life cycle in the service level (Fig. 3).

Table 1. Computational result before considering TVM in the model

n=20						n=30					
i=10%			i=20%			i=10%			i=20%		
α	$Z_1 \times 10^3$	Z_2%	α	$Z_1 \times 10^3$	Z_2%	α	$Z_1 \times 10^3$	Z_2%	α	$Z_1 \times 10^3$	Z_2%
1	10.26	29.5	1	5.8	20.3	1	11.25	30.3	1	5.91	30
0.9	10.27	29.7	0.9	5.81	20.4	0.9	11.26	30.4	0.9	5.93	30.1
0.8	10.27	29.8	0.8	5.82	20.4	0.8	11.28	31.8	0.8	5.94	30.3
0.7	10.28	30	0.7	5.83	22.1	0.7	11.29	31.9	0.7	5.94	30.4
0.6	10.29	31.9	0.6	5.84	22.2	0.6	11.3	32	0.6	5.95	31.9
0.5	10.31	32.1	0.5	5.86	22.4	0.5	11.3	32.2	0.5	5.95	32
0.4	10.32	32.2	0.4	5.87	23.2	0.4	11.31	32.3	0.4	5.95	32.5
0.3	10.32	32.3	0.3	5.87	35.5	0.3	11.32	32	0.3	6	35.5
0.2	10.34	35.5	0.2	5.89	36.5	0.2	11.33	35.5	0.2	6.1	36.5
0.1	10.34	37	0.1	5.92	39	0.1	11.34	36.5	0.1	6.1	39
0	10.6	43	0	6.31	46.5	0	11.6	42.5	0	6.3	46

Table 2. Computational result after considering TVM in the model

n=20						*n*=30					
i=10%			*i*=20%			*i*=10%			*i*=20%		
α	$Z_1 \times 10^3$	Z_2%	α	$Z_1 \times 10^3$	Z_2%	α	$Z_1 \times 10^3$	Z_2%	α	$Z_1 \times 10^3$	Z_2%
1	9.51	32	1	5.4	32	1	10.5	32	1	5.5	32
0.9	9.56	40.5	0.9	5.44	41	0.9	10.5	40.5	0.9	5.5	41
0.8	9.59	41.4	0.8	5.49	42.7	0.8	10.6	41.4	0.8	5.5	42.7
0.7	9.67	42.7	0.7	5.49	42.7	0.7	10.6	42.7	0.7	5.5	42.7
0.6	9.67	42.7	0.6	5.63	44	0.6	10.6	42.7	0.6	5.7	44
0.5	9.7	43	0.5	7.36	55	0.5	10.6	42.7	0.5	7.4	54.5
0.4	10.4	46	0.4	7.8	57	0.4	11.1	45	0.4	8	57
0.3	13.4	56	0.3	7.85	57.2	0.3	14.6	56	0.3	8	57
0.2	13.8	57.1	0.2	7.85	57.2	0.2	15.2	57.2	0.2	8	57
0.1	13.8	57.2	0.1	7.85	57.2	0.1	15.2	57.2	0.1	8	57
0	13.8	57.2	0	7.85	57.2	0	17.4	57.2	0	8	57
0.95	9.53	39	0.55	5.75	45	0.35	14.1	54.5	0.55	5.7	44
0.98	9.52	36.5	0.525	5.9	46	0.38	11.3	45.5	0.525	6	46
0.35	12.9	55	0.51	7.27	54.5	0.36	11.4	46	0.5125	7.4	54.5
0.38	12.8	54.5	0.517	7.27	54.5	0.355	14.1	54.5	0.51875	6	46
0.39	10.4	46	0.52	7.27	54.5	0.358	14.1	54.5	0.5156	7.4	54.5
0.385	10.4	46	0.5225	5.9	46	0.359	14.1	54.5	0.5172	6	46
0.382	12.8	54.5	0.5212	5.9	46	0.3595	14.1	54.5	0.5164	7.4	54.5
0.383	10.4	46	0.5206	7.27	54.5	0.3598	14.1	54.5	0.5168	7.4	54.5
0.3825	10.4	46	0.5209	7.27	54.5	0.3599	11.4	46	0.517	6	46
0.3827	10.4	46	0.5211	7.27	54.5	0.35985	14.1	54.5	0.5169	7.4	54.5

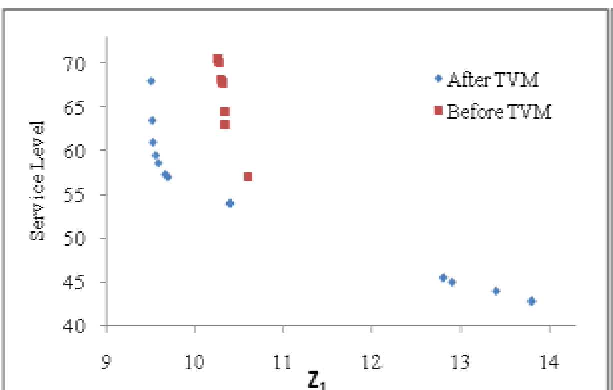


Figure 1. life cycle=20, rate=10%

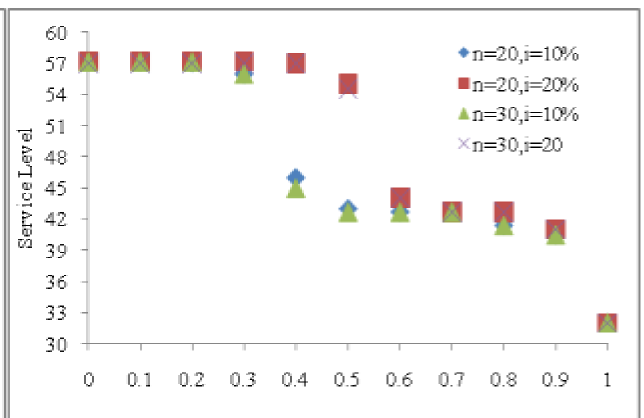


Figure 2. Effect of rate and life cycle

4. Conclusions

In this paper, we present a new mixed integer programming formulation for multi-capacity multi level location distribution problem. Regarding, location problem is a long term, so we consider time value of money in period of using SCM system. We consider different cost of installment for each size of warehouses and stocks according to real world assumptions. Computational results show effect of TVM in objective function. As future research, we suggest to present a multi capacity multi period location distribution problem in which we have a different demand in each period. We show Pareto set of solution the model both before and after TVM (See Figure 2) and we show effect of rate and life cycle in the service level (Fig. 3).

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