INVENTORY MANAGEMENT THROUGH EXTENDED STAR-RING SUPPLY CHAIN NETWORK

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ABSTRACT

Objectives: The production-distribution inventory problem has two main sectors namely production and distribution. In this paper, the nonlinear mathematical model of extended star-ring supply chain network is developed.

Methods: Planning a distribution network plays a vital role in minimizing the total expenditure of the project; to prove this, a ring network topology is taken to supply goods to the SWs and extended star network topology to supply goods to the selling stores. However, setting up separate SWs for each and every selling store will be highly expensive. Hence, keeping the minimum number of SWs is very important. Selection of SWs from the available SWs is done by replacing diverse values based on the distance limitation.

Results: The suggested model is validated with the mathematical problem, and the optimum set of SWs is identified from the result. The result has been substantiated using analytic hierarchy process.

Conclusion: The system of optimum number of SWs is obtained from the result.

Keywords: Inventory model, Facility location model, Secondary warehouse, Analytic hierarchy process.

INTRODUCTION

The operative choice of secondary warehouses (SWs) is the key factor for the achievement of supply chain networks [1,3]. The curiosity in estimating the role of supply network in previous shows the requirement for the progress of complex optimization models capable of replying unanswered questions in the manufacture supply network. Implementations of a supply chain system have decisive effects on organization's economic routine. The general act of a supply network is affected meaningfully by the decisions taken in its manufacture-supply plan integrating the decisions in production, transport, and warehousing as well as inventory management. Thus, one main problem in the act valuation of supply networks is the formulating and optimization of manufacture-supply plan considering its actual difficulty. By placing the system of SWs for filling the necessities of all SSs, the total expenses will be reduced [4].

Based on the combination of the production plan and distribution plan, a nonlinear mathematical model of extended star-ring supply chain network is established. A production-distribution inventory model with possible constraints is developed for the optimization of lot size, unit cost, shortage level, percentage of utilization of warehouse space, and the number of SWs [6,7]. In multicriteria decision-making problem, to substantiate the best decision, analytic hierarchy process (AHP) can be used. In the numerical example, substituting different values for the distance parameter will give some different optimum results. Hence, to substantiate the best optimum result, AHP [8] is used.

METHODS

Mathematical model

The proposed mathematical model is developed under the following assumptions and notations.

A. Notations

n - Number of items
C_i - Scaling constant
S_i - Setup cost of the cycle
t - Number of orders per cycle
H_i - Holding cost
v_i - Volume of unit item
V - Volume of storage space
δ_i - Shortage cost
I - Total investment cost of production
α - Number of SSs
β - Number of planned SWs
m - Number of production plant
d - Maximum allowed distance between SWs and selling stores
t_{ikj} - Transporting cost of the unit item between SW k and SS j
$t_{i\gamma k}$ - Transporting cost of the unit item between production plant γ and SW k
p_i - Unit price of the item
μ_{pi} - Membership value of the unit price of the item
Q_i - Lot size
M_i - Shortage level
V_w - Utilization percentage of storage in the SS
S_{ck} - Setup cost of SW k
A_{jk} - Distance from SWs to SSs
c_{lm} - Distance between SWs.

B. Assumptions

i. The replenishment is infinite
ii. The backorders are allowed
iii. Producing quantity is taken as a required goods for the SS from the SW
iv. Unit price is taken as triangular fuzzy number
v. Demand is taken as $D_i = \dfrac{C_i}{p_i^{e_i}}$ [2,5].

C. Objective Function

$$MinZ = \left\{ \alpha \sum_{i=1}^{n} \left[C_i \tilde{p}_i^{1-e_i} + \frac{C_i S_i}{\tilde{p}_i^{e_i} Q_i} + \frac{H_i (Q_i - M_i)^2}{2Q_i} + \frac{\delta_i M_i^2}{2Q_i} \right] + \right.$$

$$\sum_{i=1}^{n}\sum_{j=1}^{\alpha}\sum_{k=1}^{\beta} (A_{jk} \times Q_i \times x_{ijk} \times t_{ikj}) + \sum_{k=1}^{\beta} (S_{c_k} \times y_k) +$$

$$\left. \sum_{i=1}^{n}\sum_{\gamma=1}^{m}\sum_{k=1}^{\beta} (y_k \times t_{i\gamma k} \times Q_i) + \sum_{l=1}^{\beta}\sum_{m=1}^{\beta} c_{lm} u_{lm} \right\}$$

D. Constraints

i. Warehouse space limitation, $\sum_{i=1}^{n} v_i Q_i \leq V$

ii. Budget limitation, $\sum_{i=1}^{n} \tilde{p}_i Q_i \leq I$

iii. Number of orders per cycle, $\sum_{i=1}^{n} \frac{C_i}{\tilde{p}_i^{e_i} Q_i} \leq t$

iv. Restriction on number of SWs assigned, $\sum_{k=1}^{\beta} y_k \leq \varepsilon$

v. Restriction on SS is served by exactly one SW,

$$\sum_{i=1}^{n}\sum_{k=1}^{\beta} x_{ijk} = 1, \, j=1,2,3,...,\alpha \, .$$

For the constraints vi-viii the value of k=1,2,3,..., β,

vi. Restriction on SS to be served by at least one SW, $\sum_{i=1}^{n}\sum_{j=1}^{\alpha} x_{ijk} - y_k \geq 0$

vii. Restriction on no SS is served by unassigned SW, $\sum_{i=1}^{n}\sum_{j=1}^{\alpha} x_{ijk} - \alpha y_k \leq 0$

viii. Restriction on distance from SW to SS, $\sum_{i=1}^{n}\sum_{j=1}^{\alpha} A_{jk} x_{ijk} \leq d$

ix. Stipulate that only one city can be visited from city 1 and that only one city visited at each stage of travel, $\sum_{l=1}^{\beta} u_{lm} = 1, \, m=1,2,3,...,\beta$

x. Ensures that a given city is visited exactly one stage of travel,

$$\sum_{m=1}^{\beta} u_{lm} = 1, \, l=1,2,3,...,\beta$$

Restriction given in (vi) will not execute when the restriction given in (vii) is executing. Likewise, restriction given in (vii) will not execute when the restriction given in (vi) is executing.

Where $x_{ijk} = \begin{cases} 1, & \text{if a SW k is assigned to SS j for unit item i} \\ 0, & \text{otherwise} \end{cases}$

$y_k = \begin{cases} 1, & \text{if a SW k is assigned} \\ 0, & \text{otherwise} \end{cases}$, $u_{lm} = \begin{cases} 1, & \text{if there is a path from l to m} \\ 0, & \text{otherwise} \end{cases}$

and $\tilde{p}_i \geq 0$ and $Q_i^3 0$ (i=1,2,3,...,n) and $0 < V_W \leq 100$. Unit cost taken as a triangular fuzzy number. The pictorial representation of the proposed configuration of supply network is presented in Fig. 1.

RESULTS

A manufacturing company has single production plant (m = 1) produces single item (i = 1). The company has five selling stores

(α = 5) and five proposed SWs (β = 5). The company decided to select the system of optimum number of SWs to satisfy the supplies of the SSs which are available in various main marketplaces. The volume of the unit item and the storage space available in the SS are given by $v_1 = 8 \, m^3$ and $V = 3600 \, m^3$, respectively. The holding cost, setup cost, and shortage cost of the item are given by \$1, \$100, and \$3, respectively. Total investment cost for production is I = \$1400, and number of orders per cycle is 4. The unit cost of the item is $\tilde{p}_1 = \$(10,15,20)$. Maximum allowed distance between the SWs and selling stores is d = 12 km. The unit transporting cost of single item 1 from production plant γ to SWs k is given by $t_{1\gamma k} = \$2$ and the unit transporting cost of single item 1 from SW k to SS j is given by $t_{1kj} = \$2$. The scaling constant value for the unit item 1 is $C_1 = 113$. The setup cost of SWs and the distance between the selling stores and the SWs are given in Table 1. The distances among the SWs are given in Table 2.

The values of e_1 lie between 0 and 1. The most suitable values of e_1 for the given example are obtained by trial and error method. The above suitable values of e_1 are said to be selected values of e_1. Only the selected values of e_1 are substituted in the problem for obtaining the optimum result. Hence, the optimum values of the decision variables and the respective total expenditures are available in Table 3.

From Table 2, it is observed that for diverse values of the distance d, the diverse optimum result is obtained. To find out the best optimum result among the available optimum results, the AHP can be used. The AHP-based output is given in Table 4.
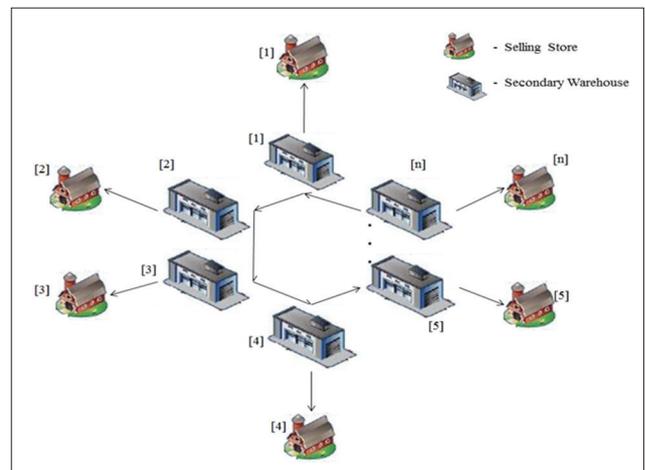
Fig. 1: Pictorial representation of the supply network

Table 1: Distance matrix (A_{jk}) in km

Store (j)	Proposed secondary warehouse (k)				
	1	2	3	4	5
1	5	3	7	6	8
2	3	8	10	9	6
3	10	9	6	3	9
4	4	7	3	8	10
5	9	8	10	9	3
Setup cost (S_{ck})	100	120	110	140	150

Table 2: Distance matrix (c_{lm}) in km

	1	2	3	4	5
1	0	93	110	121	3
2	93	0	237	160	152
3	110	237	0	131	86
4	121	160	131	0	97
5	23	152	86	97	0

Table 3: Output of the example (for d=3-6 km, d=7-8 km, d=9-11 km and d≥12 km)

e_1	p_1	Q_1	M_1	Z
0.640,0.640,0.640,0.640	10,10,10,10	18,18,16,17	4.4,4.4,4.1,4.2	3880,3770,3717,3684
0.650,0.650,0.650,0.6457	11,11,11,11	17,17,16,17	4.2,4.2,3.9,4.1	3831,3722,3667,3656
0.665,0.665,0.655,0.660	12,12,12,12	16,16,14,16	4.0,4.0,3.6,3.9	3758,3648,3641,3585
0.670,0.670,0.665,0.668	13,13,13,13	16,16,14,15	3.9,3.9,3.6,3.8	3733,3623,3589,3544
0.680,0.680,0.670,0.6698	14,14,14,14	15,15,14,15	3.7,3.7,3.5,3.8	3682,3572,3561,3464
0.690,0.690,0.680,0.6699	15,15,15,15	14,14,13,13	3.6,3.6,3.4,3.2	3629,3519,3507,3502
0.695,0.695,0.685,0.670	16,16,16,16	14,14,13,13	3.5,3.5,3.1,3.2	3603,3493,3422,3421
0.700,0.700,0.690,0.680	17,17,17,17	14,14,13,12	3.4,3.4,3.2,3.1	3576,3466,3451,3413
0.705,0.705,0.695,0.690	18,18,18,18	13,13,13,12	3.3,3.3,3.1,2.9	3549,3439,3422,3404
0.715,0.715,0.700,0.693	19,19,19,19	13,13,12,12	3.2,3.2,3.1,2.9	3001,2891,2393,2386

Table 4: Decision matrix and solution when the AHP is used

Alternatives	Criterion			Final priority
	Unit cost (0.2305)	Ordering quantity (0.1074)	Total cost (0.6621)	
d=3-6 km	0.2988	0.0555	0.0583	0.1134
d=7-8 km	0.4916	0.1232	0.1147	0.2025
d=9-11 km	0.0521	0.2427	0.3052	0.2401
d = ≥ 12 km	0.1575	0.5787	0.5218	0.4439

AHP: Analytic hierarchy process

DISCUSSION

Therefore, from Table 4, it is observed that the best distance among the optimum distances is d ≥ 12 km followed by the distance d = 9-11 km is followed by the distance d = 7-8 km which is followed by the distance d = 3 to 6 km.

CONCLUSION

Using extended star-ring supply chain network, the system of optimum number of SWs is obtained to satisfy the requirements of all the selling stores. In future, some other variables can be taken as a fuzzy variable.

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