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Inventory Routing and Pricing Problem in a Supply Chain Network Design by a Heuristic Method

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Abstract: In this research work an analytical model has been proposed, for finding new distribution passage from the suppliers to the geographically scattered dealers and to deal with the pricing problem. Since the result for this model is a non-polynomial problem, tabu search that uses various surrounding approaches has been employed to provide gratifying results. Rate fixing and request claiming are neglected and assumed in several inventory routing problem investigation. To obtain maximum interest in the supply chain network, the agreement in rate fixing have to be good since it affects the demand decision and hence the inventory and routing decisions. The suggested heuristic method was distinguished from two other existing methods of inventory routing and pricing problem and it has been found to be better than the other two methods while considering the average profit.

Keywords: Pricing problem, tabu search, inventory and routing decisions, heuristic method, average profit

1 Introduction

The supply chain can be characterized as a chain of systems that are involved in transferring a product from the producer to the ultimate client. The inventory routing problem in a supply chain is to regulate a new distribution passage from the suppliers to the geographically scattered dealers and to fix the price for the dealers. There occur two disagreements in the inventory routing problem namely fixing the price for the dealers and finding way to deliver the product. If there is a fair agreement between the supplier and the dealer for the inventory and routing problems, then the performance of the organization will be better. To obtain maximum profit in the supply chain network, the compromise in the rate fixing have to be good since this affects the demand decision and hence the inventory and routing decisions. The major hindrance for the supply chain network lies in the determination of inventory, routing and pricing.

1.1 Recent related researches: A review

[1] have addressed the multi- stage Supply Chain Network Design (SCND) complications under two circumstances especially (1) when straightforward cargo transportation is granted and (2) when direct cargo transportation is forbidden. For the above pointed circumstances, initially two integer programming representations were combined for multistage sensitive SCND problem. Later to avoid the complications of integer mathematical programming representation, graph theoretical approach has been used to analyze the arrangement of the SCND problems and it has been proven that both the SCND problems could be designed by a bipartite graph. Finally a satisfactory solution method has been developed based on a solution representation technique initiated from graph theoretical outlook to the arrangement of the considered problem. At last to evaluate the performance of the suggested heuristic solution technique, the obtained results have been compared to the original results obtained by a commercial method.

[2,3] have focused on the operational management of composite multi-echelon multi-item scatter networks. The main motive of the N-echelon vehicle routing problem with cross-docking in stock series management was to content the client requirement at reduced transportation expense. A monolithic optimization frame work for a combined integer linear analytical formulation has been

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proposed. The computed results for various examples also have been illustrated.

[4] have addressed few meta- heuristics to detect the best series of incoming and outgoing trucks so as to reduce the entire working time. Besides assessing and analyzing the ability and scope of the specifications, comparison of these meta-heuristics among themselves has been done to figure out their similarities. By this analysis, the fitness of the meta- heuristics was found to be sensitive for cross-docking system with larger incoming or outgoing trucks to deliver the product.

[5,6] provided a detail summary about the Supply Chain Management (SCM) by categorizing the entire problems into three approaches namely resource administration, management unification and supply network arrangement.

[7] introduced a novel prototype to coordinate all the supply chain systems for reliable and efficient operation in manufacturing industries.

[8] discussed the determinants of the Supply Chain System (SCS) that affects its acceptance and also had suggested four different types of responsiveness to enhance the future growth of the SCS.

[9] have suggested various methods such as genetic algorithm, ant colony optimization technique, tabu search approach and particle swam optimization to deal with non-linear polynomial problems. Among them, Tabu search has been suggested to solve the inventory routing and pricing problem.

[10,11] interpreted a novel approach for fuel transportation obstacle that divides the clients based on their product delivery date and amount using combined integer programming and then navigate to the clients by determining the most favorable route. Even though this approach grants various application in location based framework, there is a need for the extension of the analytical model to improve the performance.

[12] illustrated the employment of time windows for location and navigation problems to improve the work nature and to fulfill the client requirements. However, this method could not produce best results for a large scale network.

[13] represented a shipment model with specified number of vehicles and quantity in the view of minimizing the travel cost, lease of the vehicle and stoppages of the vehicle with the feasible reserves. Yet this approach provides good result only if the vehicle cost is in acceptable level.

1.2 Problem definition

It can be seen that the previous research works have made an efficient supply chain management by properly designing and modifying the supply chain network. The literary works perform network design via minimizing an objective function, which includes transportation cost, production cost, opening/closing plant cost, and distribution centers cost. However, the problem occurs when including all these costs in a single objective function because of the fact that when either of the costs gets reduced extremely, the total objective becomes minimal. This is contradicting with the desire of minimizing every cost, which is involved in the SCND. Moreover, the recently proposed inventory routing methods only make use of the traditional supply chain network. The routing method can be considered as effective only if it functions in the environment of temporally modified supply chain network. But lack of such works further weakens the literature. All these problems have motivated me to do the research work in this research field.

1.3 Problem formulation

The problem creation for the inventory tracking and pricing problem is formulated as below.

1.3.1 Nomenclature

Let

p_i denotes the sales price in the planning period for i_{th} retailer.

a_i denotes the intercept value for the demand pattern of i_{th} retailer.

b_i denotes the demand pattern slope of i_{th} dealer.

y_i denotes the i_{th} dealer claim in the planning period.

w denotes the number of working days in the planning phase.

q_i denotes the claim of the i_{th} dealer for each day.

R denotes the number of route.

N denotes the number of retailer.

j denotes the indicator of dealers or suppliers.

l denotes the indicator of dealers or suppliers.

crj1 indicates the distance from j to 1 for route r.

cm denotes the navigation expense per unit distance.

ψ denotes the Routing dispatching cost.

A express the ordering expense per order.

C denotes the capacity of the supplier.

V denotes the Routing capacity.

δ denotes the Production rate per unit.

h denotes the Holding rate per period.

i denotes the index of dealers.

r denotes the index of routes.

T_r denotes the restoration time of route r.

V_r describes the retailer set for route r.

q_{imax} notifies the upper limit for i_{th} dealer requirement per day.

q_{imin} notifies the lower limit for i_{th} dealer requirement per day.

yi max notifies the upper limit for i_{th} dealer requirement in the planning phase.

y_{imin} notifies the lower limit for i_{th} dealer requirement in the planning phase.

Xrjl if point j immediately precedes point 1 on route r; 0 otherwise

1.4 Distribution Center Cost (DCC)

DCC represent the connection between the rate and load requirement. The total time is usually considered as 1 year or half year for a critical plan of the company. The demand creed for the retailer is given by

$$i : p_i = a_i - b_i y_i \tag{1}$$

Since,

$$y_i = w \times q_i \tag{2}$$

The demand function gets transformed into

$$p_i = a_i - b_i w q_i \tag{3}$$

Hence, the return of each day will be

$$p_i q_i = a_{iq_i} - b_i w q_i^2 \tag{4}$$

1.5 Transportation cost

Transportation Cost ψ , denotes the total expense in travelling and dispatching the products.

$$TransportationCostperday = \Sigma R_l \Sigma_{jl}^{N+1} \Sigma_{ll}^{N-1} \frac{crjl \times cm + \psi}{T_r} \tag{5}$$

The inventory routing and pricing problem is formulated as follows:

$$Max \Sigma_{i=1}^{N} (a_i q_i - b_i w q_i^2) - \Sigma_{r-1}^{R} [\Sigma_{j=1}^{N+1} \frac{crjl \times cm + \psi}{T_r} \times Xrjl + \Sigma_{i \in v_r} \delta \times q_i + \frac{A}{T_r} + \Sigma_{i \in v_r} \frac{T_r \times q_i \times h}{2}] \tag{6}$$

such that

$$q_{imin} \leq q_i \leq q_{imax}, i = 1, \ldots, N$$

$$\Sigma_{i=1}^{N} w \times q_i \leq c$$

$$\Sigma_{i \in v_r} q_i \times T_r \leq v, r = 1, \ldots, R$$

$$\Sigma_{R}^{r=1} \Sigma_{l=1}^{N+1} \times rjl = 1, j = 1, \ldots, N+1$$

$$\Sigma_{j \in v_r \cup \{N+1\}} \Sigma_{l \in v_r \cup \{N+1\}} \Sigma_{r=1}^{R} \times rjl \geq 1, \forall (v_r, \bar{v_r})$$

$$\Sigma_{j=1}^{N+1} \times rjl - \Sigma_{j=1}^{N+1} \times rlj = 0, r = 1, \ldots, R.l = 1, \ldots, N+1$$

$$q_i \geq 0, (Nonnegative constraint and integer), i = 1, \ldots, N$$

$$Xrjl \in \{0,1\} \forall j,l \in s, \forall r \in R$$

The main aim is to achieve maximum profit in the supply chain network.

2 Proposed method

In this work, we have intended to solve all the drawbacks that persist in the current literary works. As the first step, the current objective function is modified and is considered as a multi objective problem. The proposed function initially minimizes the transportation cost, production cost, opening/ closing plant cost and distribution centers costs in supply chain network. Unlike conventionally developed objective function, the proposed function offer equal significance to every individual function model. To solve this, a new modified heuristic algorithm is proposed, which design an efficient supply chain network. In the next steps, the course of actions is taken in enhancing the other heuristic algorithm that is engaged in solving general multi objective problems. Subsequently, provisions are added in the proposed heuristic algorithm to design an efficient route for the supply chain by using a routing function. The defined routing function produces a robust performance in both static and dynamic distribution centers in the supply chain management. Later, the objective models and the algorithms will be implemented in the working platform of MATLAB and the performance will be evaluated using a fulfilled validation analysis. This paper suggests a gratifying approach to improve the basic solution through two procedures namely inventory routing improvement procedure and pricing improvement procedure. The former improvement is established by using tabu search involving VLNS and GENI which are surrounding the search approach.

2.1 Layout of inventory routing enhancement

Inventory routing reformation strategy is depicted in Fig. 1. The procedure is as follows

Step 1: Initially a candidate shift (from the initial solution X^0 to the candidate solution X^1) is created by any one of the following surrounding investigation method
(1) VLNS (2) GENI

Step 2: Check whether the constraint for navigation capacity is disrupted or not. If the constraint is violated once again perform step 1else perform step 3.

Step 3: Validate whether there is any shift in the tabu list. If there is a shift in the list implement step 1 else implement the following updation
(1) Update $X^0 = X^1, TP(X^0) = TP(X^1)$,
(2) Update the tabu list.

Step 4: Analyze whether $TP(X^1)$ is greater than $TP(X^*)$. If yes, complete the following
(1) Update $X^* = X^1, TP(X^*) = TP(X^1)$
(2) Generate a candidate move using the last selected neighborhood search approach

(3) Go to step 2.
If no, stop the process.

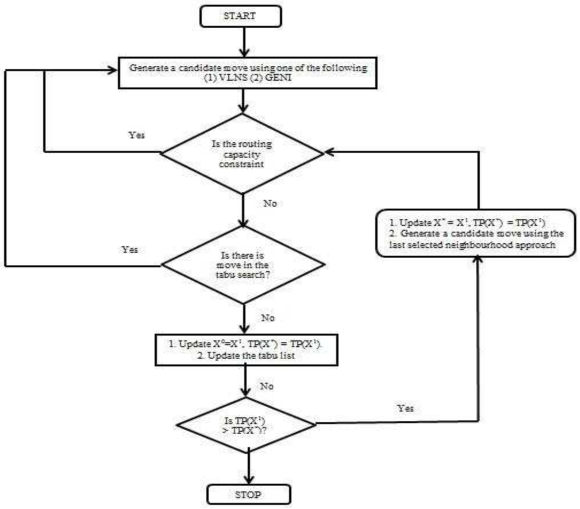

Fig. 1: Flowchart for improving the inventory routing

2.2 Layout for rate correction

The procedure for rate correction is as follows

Step 1: Load K=1

Step 2: Perform the following
(1) Randomly choose $K \times a$ retailers ($a = [N/10]$).
(2)Randomly select an integer Z_i (negative or positive) from $U\left[-\frac{(q_{imax}-q_{imin})}{2}, \frac{(q_{imax}-q_{imin})}{2}\right]$ for each selected dealer i.
(3) Add the number Z_i to the request q_i of each corresponding retailer i.

Step 3: Check whether the constraint for navigation capacity is disrupted or not. If the condition is violated perform step 2 else perform next step.

Step 4: Compute whether there is any shift in the tabu list. If yes move to step 2 else implement the following
(1) Update $X^0 = X^1, TP(X^0) = TP(X^1)$
(2) Update the tabu search.

Step 5: Review whether $TP(X^1)$ is greater than $TP(X^*)$ or not. If $TP(X^1)$ is greater than $TP(X^*)$, perform the following
(1) Update $X^* = X^1, TP(X^*) = TP(X^1)$,
(2) Set k=1, (3) go to step 2.
Else move on to next step.

Step 6: Audit whether the maximum value for K is reached or not. If maximum value is reached stop the process. Otherwise
(1) Set K=K+1.
(2) Go to step 2.

Fig. 2 shows the steps for improving the rate.

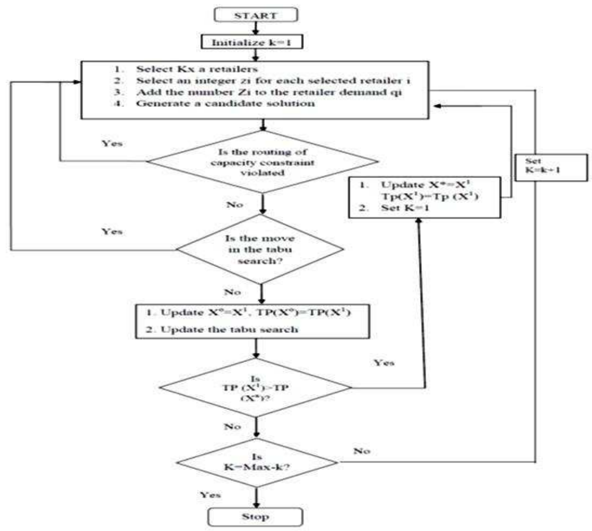

Fig. 2: Layout of rate correction algorithm

3 Results

For the evaluation purpose, the heuristic problems are divided into two types based on the capacity such as small size problems and large size problems.

The specifications for small range problems are listed in Table 1. For small range problems, the intercept value should be chosen from a closed interval value of 18 to 21 and the slope should be in the closed interval of 0.03 to 0.08. Supplier capacity can be of any value but the travelling must be less than or equal to 100.

The output for small range problem based on the proposed method and the existing methods are given in Table 2. Initially, the number of dealers was chosen to 3 and 5 for a claim of products ranging from 1 to 10 and 1 to 20. Subsequently the best solution for the specified range was generated first and then the results for other satisfactory approaches were obtained. The average gain and the processing time for each method were collected and compared.

The analysis of variance for small problems has been done in order to determine the mean difference between the three approaches which is highlighted in Table 3.

Table 1: Specifications for small problems

Parameters	Values
ai	u[18,21]
bi	u[0.03,0.08]
Routing Capacity	100
Supplier Capacity	Infinity
Dispatching Cost	25
Distance Cost	1
Ordering Cost	250

Table 2: Output for small problems

Retailer number	Demand range (q_{imin}, q_{imax})	Optimal solution		H1		H2		H3	
		Average profit	CPU (s)	Average profit	CPU (s)	profit	CPU (s)	Average profit	CPU (s)
3	[1,10]	73.06	2.04	73.06	0.89	64.76	1.56	16.04	0.11
5	[1,10]	143.84	420.24	143.84	1.65	114.49	2.37	28.78	0.17
3	[1,20]	73.16	19.03	73.16	1.72	67.46	1.64	16.98	0.12
5	[1,20]	146.76	30937.41	146.76	2.71	116.48	2.32	29.79	0.19

Different sources such as dependent variable profit, corrected model, intercept, etc. have been considered and their sum of squares and mean square has been computed. Certain number of values can change even after the final evaluation, which is represented as df and f denotes the occurrence of null distribution.

Table 3: ANOVA and various comparisons for small range problems

Source	ANOVA				
	Sum of squares	df	Mean square	f	sig
Dependent variable profit					
Corrected model	149557.984	11	10488.147	25.520	.000
Intercept	806168.035	1	806168.053	1350.657	.000
Method	60302.918	2	35101.909	56.140	.000
Number	80600.427	1	80600.247	152.291	.000
Range	187.463	1	187.643	0381	.547
Method∗number	5467.934	2	2738.247	5.190	.008
Method∗range	19.626	2	9.336	.017	.938
Number∗range	12.995	1	12.995	0.22	.818
Method∗number ∗range	16.204	2	8.201	0.15	.968
Error	67073.624	108	526.843		
Total	1067592.256	120			
Corrected total	215713.275	119			

The mean difference for the three satisfactory methods has been computed for the prescribed number of suppliers and dealers and with the help of mean difference, the standard error has been formulated and provided in Table 4.

Table 4: Determination of standard error

Method (I)	Method (J)	Mean difference (I-J)	Std.error	Sig
H1	H2	18.44715	5.3270205	.002
	H3	55.142263	5.3270205	.000
H2	H1	-18.414175	5.3270205	.002
	H3	36.701988	5.3270205	.000
H2	H1	-55.142236	5.3270205	.000
	H2	-36.701988	5.3270205	.000

Based on the observations, we have found the value of R2 as 0.781.The convincing value of the mean difference is found at 0.05 level.

Similarly the analysis of variance for large problems also have been computed and listed in Table 5.

4 Conclusion

In this research paper a practical satisfactory method for the inventory routing and rate fixing problem has been developed to increase the performance of the supply chain network. It is concluded that when the slope of the requirement pattern decreases, the navigation capacity or the supplier capacity increases thereby increasing the average profit of all the gratifying methods. Similarly when the routing capacity or supplier capacity increases, the middling CPU time decreases. The suggested

Table 5: ANNOVA and various comparisons for larger range problems

Source	ANOVA				
	Sum of squares	df	Mean square	f	sig
Dependent variable profit					
Corrected model	1228876.752	17	7533462.983	718.589	.000
Intercept	384835915.368	1	388345915.386	39258.232	.000
Method	6244230.763	2	3121512.193	322.050	.000
Number	117800062.780	2	59003513.390	6105.611	.000
Range	68725.224	1	68725.224	7.370	.009
Method∗number	32.30447.196	4	818216.551	84.521	.000
Method∗range	20194.035	2	10452.265	1.620	.348
Number∗range	15799.152	2	7989.806	.829	.438
Method∗number ∗range	11411.819	4	2787.547	.288	.885
Error	1533637.790	162	9605.922		
Total	513444551.991	180			
Corrected total	128599095.633	179			

heuristic method is better than two other existing heuristic methods since it make the inventory, routing and pricing judgments separately based on the best average output.

References

[1] M.s Pishvaee and M. Rabbani, Advances in Engineering software **42**, 57-63 (2011).
[2] . Dondo, C.A Mendez and J. cerda, Computers and Chemical Engineering **35**, 3002-3024 (2011).
[3] B. Radhakrishnan, DJ Journal of Engineering and Applied Mathematics **1**, 4-16 (2015).
[4] B. Arabani, Fatemighomi and Zandieh, Expert Systems with Applications **38**, 1964-1979 (2011).
[5] I.J Chen and A. Paulraj, International Journal of Production Research **42**, 131-163 (2004).
[6] M.Y Lmamoglu, Proceedings of European and Mediterranean Conference on Information Systems, Izmir, 1-10 (2009).
[7] J.C.P Cheng and K.H Law, Automation in Construction **19**, 245-260 (2010).
[8] A. Reichhart and M. Holweg, International Journal of operations & production Management **27**, 1144-1172, (2007).
[9] A.K Parvathi, DJ Journal of Excellence in Computer Science and Engineering **1**, 25-33 (2015).
[10] P. Hanczar, Procedia-social and Behavioural Sciences **54**, 726-735 (2012).
[11] A. Yajnik and D. Sharma, DJ Journal of Engineering and Applied Mathematics **1**, 23-29 (2015).
[12] S. Ponboon, A.G Qureshi and E. Taniguchi, Transportation Research Procedia **12**, 213-226 (2015).
[13] M. Hajghasem and A.A shojaie, Procedia Economics and Finance **36**, 353-362 (2015).

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