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Based on the Stock Loss in the Demand Uncertainty of Supply Chain Distribution Network Bi-level Programming Model and Algorithm Implementation

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Abstract: This study introduces opportunity cost into the distribution network, by defining a distribution center which faced shortage of losses and built centralizing supply chain distribution network bi-level programming model which included one manufacturer, more distribution centers and multiple retailers out of stock loss. Combined with the traditional particle swarm designed approximation algorithm to optimize the model and take an example, the effectiveness of the model and algorithm was verified.

Key words: Supply chain, distribution network, uncertainty demand, stock loss, opportunity cost

INTRODUCTION

In order to sale more products in an increasingly competitive market environments, addicted to providing diverse products, more and more companies should increase the distribution centers and retail stores to meet customer demand in different markets. However, increasing distribution centers and retail stores in supply chain distribution can increase the company's invests in the sell market, on the other hand, reducing the distribution centers and retail stores in the distribution network can increase the inventory fee and the loss because of out of stock in the supply chain. Therefore, how to reduce the supply chain distribution network operating costs and improve the operating efficient, this is a case problem. Eppen G and Schrage L research a supplier, a distributor center and multiple retail stores supply chain secondary distribution network model, on the assumption that retail demand follow. supply chain distribution network which demand is a constant and the model is solved by a normal distribution, the early period is a constant in distribution centers and retail stores and proposed the E-S model and get out of the approximate optimal solution (Eppen and Schrage, 1981). After that (Federgruen and Zipkin, 1984) developed the E-S model and proved the optimal solution based on the inventory optimization. Erkip *et al*. (1990) considered the time correlation in the retails' demand and proposed the extended E-S model. Lee (1996) considerded the unfavorable factors in the centralized control and proposed the separately control supply chain distribution network model (Shen *et al*., 2003) establish the centralized control supply chain distribution network model and given the appropriate solution and application examples. ReVelle and Laporte (1996) research the s the simulated annealing algorithm. However, the distribution network inventory cost and shortage cost distribution of the entire supply chain network cost is not considered in the above literature.

CONCEPT

Supply chain distribution network bi-level programming is a two-stage decision problem. It includes the upper decision problem and the underlying decision problem. Bi-level programming model of supply chain distribution network is established as follows.

Supply chain distribution network optimization can be seen as a leader-follower problem. The distribution center is a decision-making department leader; the behavior of the retailer for the distribution center is follower. Product introduction in decision-making departments can be changed through the control and management of a distribution center and its cost, thus affecting the choice of retailers but can not control their choices, the retailer then compare the costs of existing distribution center.They choose what they needs according to their characteristics.

According to this study, it come up with the centralized supply chain distribution network system and distributed supply chain distribution network system, the main issues include build mathematical model need to be addressed in the centralized supply chain distribution network.

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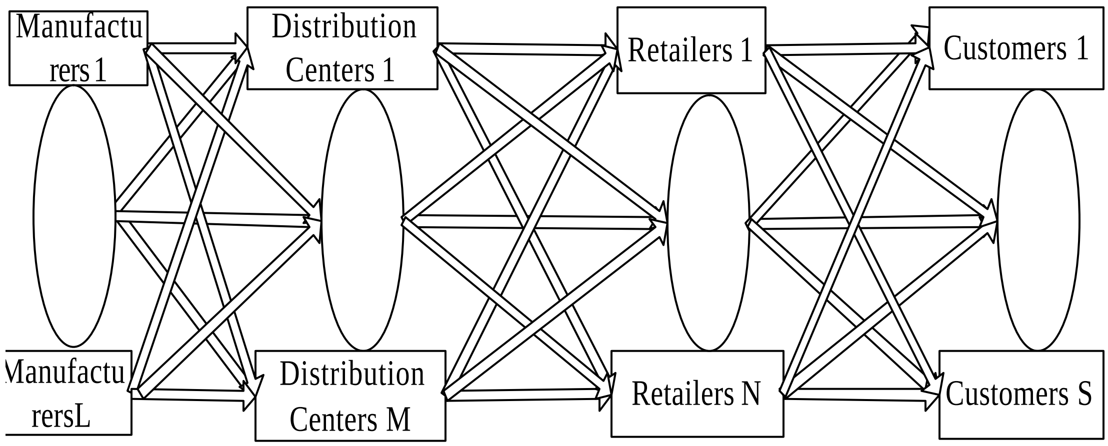

Fig 1: Bi-level programming model of supply chain distribution network

MATHEMATICAL MODEL

Symbol Description: μ_{il} is represented the retail il unit time average demand; δ_{il} is represented unit time in the standard deviation of the retail il demand; $\rho_{il,jl}$ is represented retail il and retail jl demand correlation coefficient; μ_{id} is represented distribution center id within the unit time average demand; δ_{id} is represented the standard deviation of the demand of distribution center id in unit time; $\rho_{il,jl}$ is represented the demand correlation coefficients of distribution center id and distribution center jd; $L_{m,id}$ is represented transport time from the supplier m to the distribution center id; $T_{id,il}$ is represented transport time from the distribution center id to retail store il; $t_{m,id}$ is represented unit cost of transportation from suppliers m to distribution center id; $t_{id,il}$ is represented from the distribution center id to the retail il unit transportation costs; S is represented total inventory of supply chain distribution network; X_{id} is represented the moment distribution center id inventory in $1+L_{m,id}$; X_{il} is represented the moment retail stores il inventory in $L_{m,id}+T_{id,il}$; θ is represented match the coefficient of investment and transportation costs; F_{id} is represented fixed costs of distribution centers id; K_{id} is represented factor of safety stock distribution center id; K_{il} is represented factor of safety stock distribution center il; χ_{id} is represented fixed cost coefficient related to the capacity of the distribution center id; h_{id} is represented distribution center id unit inventory cost per unit time; h_{il} is represented distribution center il unit inventory cost per unit time; p_{id} is represented distribution center id unit shortage cost per unit time; p_{il} is represented distribution center il unit shortage cost per unit time.

$Z_{m,id}$ is represented demand part of the distribution center id portion allocated by the supplier m; $Y_{id,il}$ is represented the part of the distribution of retail il demand in part by the distribution center id; W_{id} is represented transshipment capacity of the distribution center id.

Assumptions of the model:

- Distribution center needs $Y_{i,t}$ to follow a normal distribution and related, $Y_{i,t}\sim N(\mu_i \delta_i^2)$
- Needs of individual retailers $Z_{i,\ t}$ follow a normal distribution and related, $Z_{i,t}\sim N(\mu_i \delta_i^2)$
- Distribution centers in order to make a distribution center inventory from one time to the various suppliers reached, Orders in time$1+L_{m,id}$ to reach the distribution center d, part of the demand of the distribution center d is allocated by the supplier m, $y_{m,id}$, $Y_{i,t}$ demand is allocated by the supplier m, the part reaches the distribution center at $1+L_{m,id}$ moment
- Retailers from$1+L_{m,id}$ time to various distribution centers in order to enable retailer to achieve S_{il} order in $1+L_{m,id}+T_{id,il}$ arrives at retailers l, part of the retailer l demand is allocated by the distribution center d. The demand of $z_{id,il}$ $Z_{i,t}$ is allocated by the distribution center d,the part reach retail stores l in $1+L_{m,id}+T_{id,il}$
- In each cycle L_d, suppliers assigned to various distribution centers ordering makes various distribution centers out of stock of the probability of occurrence of $1+L_{m,id}$ is possible
- In each cycle L_d, distribution center assigned to the ordering of the individual retailer makes various retailers in the probability of the occurrence of out $1+L_{m,id}+T_{id,il}$ cycle is equally possible

Firstly, defining the loss distribution centers out of stock at the 1+ $L_{m,id}$ moment (out of stock costs) in considering the distribution center, the amount of safety stock, distribution center safety stock less than distribution centers of the purchase amount from the supplier and retailers from the purchase amount of the distribution center and distribution center will be out of stock. That the amount of the distribution center's inventory can not meet the demand of the retailer, so that based on the above analysis of the derivation of distribution centers out of stock, the derivation of the distribution centers shortage cost that deduced the following expression:

$$\min_{S}(S,X)=\sum_{i=1}^{m}E[p_{id}(\sum_{i=1}^{n}\sum_{t=1+L_{m,id}}^{1+L_{m,id}+T_{id,il}} z_{id,il}Z_{i,t}-X_{id}-\sum_{i=1}^{L}\sum_{t=1}^{1+L_{m,id}} y_{m,id}Y_{i,t})]] \quad (1)$$

The meaning of the above formulas is that N retailers subtracted from part I of the purchase amount of the distribution center and the first ID distribution center safety stock, minus the first ID distribution center from the difference between the sums of the amount of the purchase of all the M suppliers throughout the distribution center total shortage cost.

So, the whole needs in the system is that:

$$V=\sum_{i=1}^{m}\sum_{t=1}^{1+Lm,id} y_{m,id}Y_{i,t}+\sum_{i=1}^{n}\sum_{t=1+L_{m,id}}^{1+L_{m,id}+T_{id,il}} z_{id,il}Z_{i,t} \quad (2)$$

The meaning of the above formulas is that the system from one moment to the $T_{id,il}$ moment the overall system requirements, so that the system inventory in 1+ $L_{m,id}$+ $T_{id,il}$ moment can be expressed as S-V, it can be seen that the:

$$\sum_{i=1}^{m}x_{id}+\sum_{i=1}^{n}r_{il}=S-V \quad (3)$$

$$\psi(X,R,\lambda)=C(S,X,R)+\lambda(S-V-\sum_{i=1}^{m}x_{id}-\sum_{i=1}^{n}r_{il}) \quad (4)$$

It can be obtained by Lagrange multiplier method:

$$\frac{\partial\psi}{\partial x_{il}}=(h_{id}+p_{id})\Phi(k_{id})-p_{id}-\lambda \quad (5)$$

$$\frac{\partial\psi}{\partial r_{il}}=(h_{il}+p_{il})\Phi(k_{il})-p_{il}-\lambda \quad (6)$$

where, the $\Phi(\bullet)$ is the standard normal distribution function. It can be known from Eq. 6 and 7ifand only if $k_1=k_2=\Lambda=k_n=k$ the system has the best optimal allocation. The H_{id} can be expressed that demand of the distribution center from $1+L_{id}$ moment to $1+L_{id}+T_{id,il}$ moment. The W_{id} can be expressed that the inventory of the distribution center in $1+L_{id}+T_{id,il}$ moment. So that it can be get:

$$v_{il}+W_{id}=(x_{id}-H_{id})=(1+L_{m,id}+T_{id,il})\mu_{id}+[S_{id}-\sum_{i=1}^{m}(1+L_{m,id}+T_{id,il})y_{m,id}\mu_{id}]y_{m,id}\sqrt{T_i+1}(\frac{\delta_{id}}{\delta_1})-[H_{id}+Vy_{m,id}\sqrt{T_{id,il}+L_{m,id}+1}(\frac{\delta_{id}}{\delta_1})] \quad (7)$$

Among that the:

$$\delta_1=\sum_{i=1}^{m}y_{m,id}\delta_{id}\sqrt{T_i+1} \quad (8)$$

The following is that:

$$\varepsilon_{id}=(T_{id,il}+L_{m,id}+1)y_{m,id}\mu_{id}+[Sid-(T_{id,il}+L_{m,if}+1)y_{m,id}\mu_{id}]\sum_{i=1}^{m}\sqrt{T_{id,il}+L_{m,id}+1}\ (\frac{\delta_{id}}{\delta_1}) \quad (9)$$

$$\xi id=y_{m,id}\ Y_{i,1}+L_{m,id}+T_{id,il}+H_{id}+V\sqrt{T_{id,il}+L_{m,id}+1y_{m,id}}\ (\frac{\delta_{id}}{\delta_1}) \quad (10)$$

$$\varepsilon_{il}=(T_{id,il}+L_{m,id}+1)z_{id,il},\mu_{il}+[Sil-\sum_{i=1}^{n}(T_{id,il}+L_{m,id}+1)]z_{id,il}\mu_{il}z_{id,il}\sqrt{T_{id,il}+L_{m,id}+1}(\frac{\delta_{il}}{\delta_2}) \quad (11)$$

$$\xi il=z_{id,il}\ Z_i,1+L_{m,id}+T_{id,il}+D_{il}+V\sqrt{L_{m,id}+T_{id,il}+1z_{id,il}}(\frac{\delta_{il}}{\delta_1}) \quad (12)$$

So that, it can be seen:

$$\min_{S}C(S_{id},S_{il},X)=\sum_{i=1}^{m}E\{Pid[\xi_{id}-\varepsilon_{id}\}^{+}+p_{il}(\xi_{id}-\varepsilon_{id})^{+}]\} \quad (13)$$

$$\frac{\partial C(S,X_{id})}{\partial S}=\sum_{i=1}^{m}\frac{\partial C(S,X_{id})}{\partial\xi_{id}}\frac{\partial\xi_{id}}{\partial S}=p_{id}\Phi(\frac{S-\sum_{i=1}^{m}(L_{m,id}+1)y_{id}\mu_{id}}{\delta_{id}+Ld(\sum_{i=1}^{m}y_{id}^2\delta_{id})+2\sum_{i>j}\rho_{ij}\delta_i\delta_i y_{id}y_{jd}})-p_{id} \quad (14)$$

$$S=\sum_{i=1}^{m}(1+L_{m,id})\mu_{id}+\tau_{id}\sqrt{\delta_{id}+L_{m,id}(\sum_{i=1}^{m}\delta_{id}y_{id}^2+2\sum_{i<j}\rho_{ij\delta_i\delta_j y_{il}y_{jl}})}+\sum_{i=1}^{n}(1+L_{m,id}+T_{id,il})\mu_{il}+\tau_{il}\sqrt{\delta_{il}+T_{id,il}(\sum_{i=1}^{n}\delta_{il}z_{il}^2+2\sum_{i<j}\rho_{ij}\delta_i\delta_j z_{il}z_{jl})} \quad (15)$$

The resulting shortage cost of the distribution center is that:

$$C(S,X) = p_{id}[\phi(\tau_{id}) \sqrt{\delta_{id} + L_{m,id}(\sum_{i=1}^{m} \delta_{id} y_{id}^2 + 2\sum_{i<j} \rho_{ij}\delta_{id}\delta_{jd}y_{id}y_{jd}) + \phi\ \tau_{il})} \sqrt{\delta_{il} + T_{id,il}(\sum_{i=1}^{n} \delta_{il} z_{il}^2 + 2\sum_{i<j} \rho_{ij}\delta_{il}\delta_{jl}z_{il}z_{jl})}] \quad (16)$$

Distribution network bi-level programming mathematical model: The mathematical model of the bi-level programming model can be expressed as follows:

- The objective function of the upper planning of distribution centers is to minimize the cost:

$$\min W = p_{id}[\phi(\tau_{id})\sqrt{\delta_{id} + L_{m,id}(\sum_{i=1}^{m} \delta_{id} y_{id}^2 + \sum_{i<j} \rho_{ij}\delta_{id}\delta_{jd}y_{id}y_{jd})} + \phi(\tau_{il}(\sqrt{\delta_{il} + T_{id,il}(\sum_{i=1}^{n} \delta_{il} z_{il}^2 + 2\sum_{i<j} \rho_{ij}\delta_{il}\delta_{jl}z_{il}z_{jl}}) + \sum_{i=1}^{m} L_{m,id}h_{id}K_{id}X_{id} + \sum_{i=1}^{m}\sum_{i=1}^{1} y_{m,id}(1+L_{m,id})t_{m,id} \quad (17)$$

Transportation costs and the shortage cost plus the distribution center costs equal to the distribution center, distribution center safety stock cost from suppliers to distribution centers and minimum.

- Upper planning constraints:

$$\sum_{i=1}^{m}(X_{ij} + \sum_{t=1}^{1+L_{m,id}}\sum_{i=1}^{L} y_{m,id}) \le W_{id} \quad (18)$$

It can be expressed that distribution center inventory safety stock is equal to the distribution center and distribution center from upstream suppliers the sum of the quantities) the largest transshipment amount of the distribution center is a fixed value

DESIGN ALGORITHM

Design algorithm: Many scholars have discussed bi-level programming model of the solution to problems, due to the non convexity of bi-level programming, bi-level programming problem is referred to as the "NP-Hard problem." This article built bi-level programming model in the distribution network based on the uncertainty of demand. The upper and lower planning are interlinked, the lower level decisions should consider the upper level decisions in the supply chain, in the upper objective function has a lower level of the decision variables, the lower level planning objective function also has the upper decision variables. According to the above analysis, in this study, based on the idea of iterative combined with genetic algorithm and particle swarm algorithm. Firstly, the lower decision variable $z_{id,il}^0$ was given an initial value and then to solve the upper planning, the optimal value of the upper is planning generation again into the lower level programming. Lastly the lower programming was solved. This method can be called a loop iteration algorithm. The step for the loop iteration algorithm is in the follows:

Step 1: Initialize particle swarm (speed and location), inertial factor, accelerating constant, the maximum number of iterations and the algorithm terminates minimum allowed error

Step 2: Evaluate each particle's initial adaptive value

Step 3: To adapt the initial values for the current local optimal value of each particle and the adaptive value corresponding to the position of each particle as a local optimal value

Step 4: Adapt the best initial value as the current global best quality and to adapt the best value corresponding to the location of the position as the global optimal value

Step 5: According to update each particle's current location

Step 6: To limit the flying velocity of each particle, the maximum flight speed of no more than set

Step 7: According to:

$$v_i^d = wv_i^d + c_1r_1(p_i^d - x_i^d) + c_2r_2(p_g^d - x_i^d)$$

update each particle's current location

Step 8: Comparing the fitness of each particle is better than the history local optimal value, if good, will the current particle fitness as the particle's local optimal value, the corresponding position of each particle as a local optimal value

Step 9: In the current group of find the global optimal value and the current global optimal value corresponding to the position as a particle swarm global optimal value position

Step 10: Repeat step 5-9, until meet the set of minimum error or the maximum number of iterations

CONCLUSION

With the development of the integrated in supply chain and increasingly facing uncertainty environment, when the inventory in the distribution center can't meet quantity of the retailer's order, the distribution center will appear out of stock loss. In reality, this phenomenon is often exists, out of stock loss is one of the cost which the distribution center should considered. Therefore, introduce the shortage of loss into the distribution supply chain system is made up of its reasonable and necessity.

With the development of the logistics integration, distribution centers are playing an increasingly important role, how to reduce the stock loss in distribution center, meet the retailer's demand timely; improving the interests of the whole supply chain is a key issue. Through analysis the example, the model built in this article can give a distribution system to provide the decision-making basis.

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