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Wuhan International Conference on e-Business

Summer 6-1-2014

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Liping Lin
School of Management, Guangxi University of Science and Technology, Liuzhou, 545006, China, lipinglin3@163.com

Xiaoqing Zhang
School of Management, Guangxi University of Science and Technology, Liuzhou, 545006, China, 345636945@qq.com

Xigang Yuan
School of Management, Guangxi University of Science and Technology, Liuzhou, 545006, China

Haijun Zhou
School of Management, Guangxi University of Science and Technology, Liuzhou, 545006, China

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Liping Lin [1], Xiaoqing Zhang [1], Xigang Yuan [1], Haijun Zhou [2]
[12]School of Management, Guangxi University of Science and Technology,
Liuzhou, 545006, China

Abstract: This study introduces the opportunity cost of distribution network. The centralized and distributed supply chain distribution network of bi-level programming model were constructed by defining the distribution centers face different stock losses, which include one manufacturer, more distribution centers and multiple retailers. Combined with the traditional genetic algorithm, this study designed approximation algorithm in order to optimize and solve the model, and verify the effectiveness of the model and algorithm through an example

Keywords: stock losses, distribution network, supply chain, approximation algorithm

1. INTRODUCTIONS

With the market economy development continuously, the logistics industry's position as the tertiary industry in the national economy has become increasingly prominent. Generally, scholars believe that the supply chain consists of three phases: procurement, production and distribution. Academic research the relationship between the upstream and downstream supply chain based on the three aspects. Due to the impact of the production decisions consumption theory, most study of the supply chain starts from procurement and production processes. With the continuous development of consumer demand dominated market economy, the supply chain has also become a consumer demand-led chain. Therefore, it is particularly necessary and urgent to study supply chain distribution network.*

Supply chain distribution network is the way and a bi-level programming problem in which the ownership of the product transfers from production areas to the consumer domain, which originated in the economy. In 1934, Stackel berg first proposed a simple model of market economy, which be known as the famous Stackel beg game theory. It was not until 1970s the bi-level programming problem was introduced to optimization field [1]. It is an important way to increase the competitiveness of enterprises by establishing distribution network reasonably, strengthening the management of distribution network [2]. Many literatures set the external environment of supply chain management to analyze the distribution network by choosing different schemes, such as an integer programming model is put forward to describe the decision-making behavior of manufacturing distribution network [3]. Then many foreign scholars study supply chain distribution network. Brown proposed a multi- product distribution network and used mixed integer programming model to solve the problem [4], which includes factories open and close, the distribution of the equipment in the factory and the product's distribution problem from the factory to the customers. Hung - Yi Chen not only discussed how to meet the demand of downstream due to different manufacturers and retailers took alternative strategies in distributed supply chain distribution network, but also discussed the effects of three different alternative strategies on overall profit of supply chain [5]; Hasan Selim et al. maximized the distribution center capacity, at the same time maximum extent to meet the needs of retailers, and proposed the establishment of supply chain distribution network bi-level programming model, and finally proved the solution effectiveness through solving

* Corresponding author. Email: lipinglin3@163.com(Liping Lin), 345636945@qq.com(Xiaoqing Zhang).

the model with fuzzy modeling [6]. Bilge Bilgen established supply chain distribution network bi-level programming model with the fuzzy mathematics method under the dynamic and uncertain environment, and took into account fuzzy capacity limit and the desired cost levels, they also proved applicability and flexibility of the model with different examples [7].

Many domestic scholars also make effort to study supply chain distribution network of bi-level programming model. For example, Sun Hui-jun, Gao Zi-you put forward the supply chain distribution network of bi-level optimization programming model that considering both themselves and the common interests of the network decision-making departments and customers, and designed the heuristic algorithm, and finally validated effectiveness of the model and algorithm through simple examples [8] ;Liu put forward a distribution network optimization model under the demand distribution, and designed the mixed 0-1 integer programming model algorithm based on hybrid genetic algorithm, and at last verified the effectiveness of the algorithm through numerical examples [9]; Zhao Zhi-gang et al. proposed a secondary distribution network model including multiple warehouse and distribution centers, then put forward an algorithm based on particle swarm optimization algorithm and the idea of layered iteration algorithm, and finally proved the algorithm commonality [10].

Currently, there are problems in studying the supply chain distribution network. On the one hand, most programming are single, so that we often fail to consider the mutual influence and interaction of their decision-making between upstream and downstream enterprises, such as we fail to consider the needs and choices of downstream may affect the upstream in decision-making; on the other hand, we did not take into account the impact of stock costs on downstream retailers' profits. In economics, opportunity cost means that before you get one thing, you must give up another thing's most value. By definition we can see that the opportunity cost of a stock shortage cost is equivalent to the loss.

Currently research on supply chain distribution network focused on two aspects: One is a centralized distribution network, a company build distribution network by itself, this distribution network system consists of two subsystems, the upper layer range from manufacturing centers to distribution centers, the lower layer range from distribution centers to the retailers. Distribution centers make major decisions based on their own cost because distribution centers are equivalent to the company's internal transit warehouses in a centralized distribution system; Another is a distributed distribution network, some companies store their products in the warehouse of specialized third-party logistics service companies, and establish their own distribution network through the using of third-party logistics warehousing services company. So that, the special third-party logistics warehousing service companies and downstream retailers are responsible for products storage and sales except for the production of products. In this way, the profit maximization is the only goal for special third-party logistics warehousing service companies, at the same time, the retailers make profit maximization as their goal too.

Whether centralized or distributed supply chain distribution system, it will not only affect the distribution centers' interests and reputation, but also affect retailers' choose as the distribution center out of stock. Therefore, it is of great significance to consider the shortage loss of distribution center for building and running the entire distribution system. In the supply chain distribution system, the shortage loss is different. On the one hand in a centralized supply chain distribution network, when the inventory of an upper distribution center can not meet all the lowers' purchase amounts from the distribution center, the distribution center will be out of stock. There is also another case, which the above situation can not be seen as out of stock loss if the distribution center replenishment from other distribution centers when all the distribution centers are viewed as a whole. On the other hand, when the above distribution centers appear out of stock if it is viewed as a single individual in a distributed supply chain distribution network, the distribution center can replenishment from other distribution centers, in this case, it will cause transportation costs because of the replenishment. So we can treat transportation costs as out of stock loss.

It is prerequisite to consider the mutual influence and interaction of their decision-making between upstream and downstream enterprises. However, in the previous no one research on the influence of the shortage cost of supply chain distribution system. Based on the existing research results, this study put forward supply chain distribution network of bi-level programming model under the stock loss cost restriction.

2. SUPPLY CHAIN DISTRIBUTION NETWORK CONCEPT OF BI- LEVEL PROGRAMMING MODEL

Supply chain distribution system of bi-level programming model is a two-stage decision problem, which includes upper decision problem and the lower decision problem. The supply chain distribution network of bi-level programming model in this study is shown in figure 1:

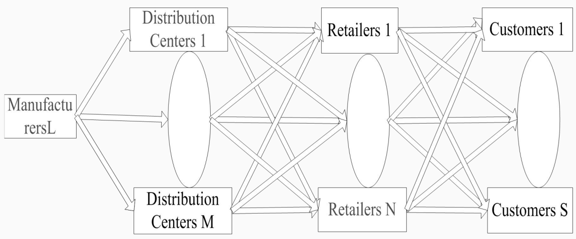

Figure 1. Supply chain distribution network of bi-level programming model

Supply chain distribution network optimization can be seen as a leader - follower (Leader - follower) problem. The decision-making department (Leader) of distribution center is leader, the retail's choice behavior for each distribution center product is a follower (Follower). Decision-making departments can change the product amount and cost of distribution centers through a control and management, thus affecting the retailer's choice of products, but this can not control their choices, retailers compare product costs of each distribution center according to their demand characteristics.

Therefore, the two problems in centralized supply chain distribution network in the bi-level programming model need to be solved are:

(1) Due to the distribution center is only responsible for the distribution of goods to downstream retailers, which make distribution centers a cost center. Therefore, the upper plan can be described as decision-makers determine the order amount of each distribution center to the production sector within the allowable capacity limits, so that minimize total cost of distribution centers, and as much as possible to meet the needs of downstream retailers.

(2) Due to the lower direct-market retailers goal is to sell the product out to gain greater profits. Therefore, the lower plan can be described as the distribution model of each retailer' demand for different distribution center, its goal is to maximize profits for all retailers.

The two problems in distributed supply chain distribution network in the bi-level programming model need to be solved are:

(1) Due to specialized third-party logistics warehousing services company are served as the distribution centers, making the distribution center is a profit center, therefore, the upper plan can be described as decision-makers determine the order amount of each distribution center to the production sector within the allowable capacity limits, its goal is to maximize profits for all distribution centers, and as much as possible to meet the needs of downstream retailers.

(2) Due to the lower direct-market retailers goal is to sell the product out to gain greater profits. Therefore,

the lower plan can be described as the distribution model of each retailer' demand for different distribution center, its goal is to maximize profits for all retailers.

3. BI-LEVEL PROGRAMMING MATHEMATICAL MODEL OF THE SUPPLY CHAIN DISTRIBUTION NETWORK

3.1 Symbolic descriptions

i represents the first i distribution centers; j represents the first j retailers; $K_i(X_i)$ said unit transportation costs of the first i distribution centers; D_{ij} denotes the first j retailers purchase amount from the first i distribution centers or can be interpreted as (the retailer's demand); P_{ij} said product price from the first i distribution center to the first j retailers; H_i said first i distribution center storage unit inventory cost of the product ; X_i represents the total number of products purchased by the first i distribution centers; $C_i(X_i)$ represents the per unit of product function of the first i distribution centers purchase-related costs; A_j represents the total number of products the first j retailers needed; $S_{ij}(D_{ij})$ represents the ordered per unit of product cost function from first j retailers to the first i distribution centers; $T_{ij}(D_{ij})$ denotes transport unit product cost function from the first j retailers to the first i distribution centers ; h_j denotes the first j retailers inventory costs per unit of product; W_i denotes the first i largest distribution centers distribution capability limits.

3.2 Supply chain distribution network of bi-level programming model under the restriction of out of stock loss

3.2.1 The centralized supply chain distribution network of bi-level programming mathematical model under the restriction of out of stock loss

When establish a distribution network within a company, as a transit warehouse, the distribution centers regard their cost minimization as its own goal, when a distribution center can not meet the needs of downstream retailers duo to out of stock, at this time, it is also be seen as a stock loss due to the emergence of goods distribution center losses caused by shortages , when all the distribution centers are in short supply, the entire Out of stock loss is the sum loss of each distribution center in shortage of loss.

Assumptions:

(1) When a distribution center out of stock, it will not transport goods from other distribution centers, as a result this distribution center will be temporarily out of stock. In consideration of its costs minimization, it will consider impact on the total cost of out of stock losses.

(2) The main goal of downstream retailers is to maximize profits.

(3) When the total order quantity from retailers to a distribution center exceeds the maximum distribution center distribution capabilities, more than the quantity of goods as a distribution center of out of stock.

Based on the above analysis, the centralized supply chain distribution system bi-level programming mathematical model are as follows:

①The upper programming model

$$\text{Min}\quad E=\sum_{i=1}^{M}G_i(\sum_{j=1}^{N}D_{ij}-X_i+\sum_{i=1}^{M}C_i(X_i)X_i+\sum_{i=1}^{M}K_i(X_i)X_i \tag{1}$$

$$\text{S. t}\quad X_i \le W_i \tag{2}$$

$$X_i \ge H_i \tag{3}$$

②The lower programming model

$$\text{Max} \quad G=\sum_{j=1}^{n} R_j (D_{ij} - \sum_{i=1}^{m}\sum_{j=1}^{n} S_{ij}(D_{ij})D_{ij} + \sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij}(D_{ij})D_{ij}) \qquad (4)$$

$$\text{S. t} \quad \sum_{j=1}^{n} D_{ij} > X_i \qquad (5)$$

$$\sum_{i=1}^{m} D_{ij} = A_j \qquad (6)$$

The meaning of the above model are as follows: The objective function (1) is the minimum sum of ordering cost ,shortage cost and transportation cost from manufacturer to distribution centers; constraints (2) said that retailer's demand is less than the distribution centers' maximum distribution capabilities; constraints (3) points a little more than its own distribution center lowest traffic objective function; Objective function (4) represents the biggest profit after retailer's total sales revenue minus the total order cost ,retailer's total inventory costs and minus the total transportation costs from the distribution center to the retailer's ;constraints (5) represents that the total amount of the purchase of retailer is more than in stocking distribution center, a distribution center will eventually emerge out of stock and out of stock losses; constraints (6) said that the retailer's purchase and demand is equal, there is no remaining quantity of goods.

3.2.2 The distributed supply chain distribution network of bi-level programming mathematical model

In distributed supply chain distribution network, due to the upstream manufacturers are only responsible for the company's production, the specialized third-party logistics service companies provide warehousing services and then a warehousing logistics service enterprises will distribute the goods to the downstream retailer, and finally there are downstream retailers to sell to customers. In this case, the distribution center is the specialized third-party logistics service enterprise, therefore, not only specialized logistics service companies but also downstream retailers treat the profit maximization as only goals, At the same time, retailers' decision may affect the upstream members' decision, the mutual influence, interaction between upstream and downstream members constitute the distributed supply chain distribution network of bi-level programming.

Assumptions:

(1) the distribution center treat the profit maximization as main goals, at the same time each distribution center is composed of specialized third-party logistics service enterprises, when the storage capacity of distribution center is less than the sum of all downstream retailer's order quantity, the distribution center will appear out of stock.

(2)The retailer also treat the profit maximization as main goals, at the same time, the retailer's decision may affect the decision-making of supply chain upstream members.

Based on the above analysis, the supply chain distribution system of bi-level programming mathematical model are as follows:

①The upper programming model

$$\text{Max} \quad E=\sum_{i=1}^{M} W_i(X_i) - \sum_{i=1}^{M} G_i(\sum_{j=1}^{N} D_{ij} - X_i + \sum_{i=1}^{M} C_i(X_i)X_i + \sum_{i=1}^{M} K_i(X_i)X_i \qquad (7)$$

$$X_i \le W_i \qquad (8)$$

$$X_i \ge H_i \qquad (9)$$

②The lower programming model

$$\text{Max} \quad G = \sum_{j=1}^{n} R_j (D_{ij} - \sum_{i=1}^{m}\sum_{j=1}^{n} S_{ij}(D_{ij}) D_{ij} + \sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij}(D_{ij}) D_{ij} + \sum_{j=1}^{n} h_j \sum_{i=1}^{m} D_{ij} \tag{10}$$

$$\sum_{j=1}^{n} D_{ij} > X_i \tag{11}$$

$$\sum_{i=1}^{m} D_{ij} = A_j \tag{12}$$

The objective function (7) said the distribution center maximize profit by subtracting the total shortage costs and ordering costs and transportation costs from the manufacturer to the distribution center from its income; Constraint (8) said that the distribution center's maximum order quantity is less than its distribution capabilities; Constraints (9) points a little more than its own distribution center lowest traffic objective function; Objective function (10) represents the biggest profit after retailer's total sales revenue minus the total order cost ,retailer's total inventory costs and minus the total transportation costs from the distribution center to the retailer's ;constraints (11) represents that the total amount of the purchase of retailer is more than the distribution center inventory quantity, a distribution center will eventually emerge out of stock and out of stock losses; constraints (12) said that the retailer's purchase and demand is equal, there is no remaining quantity of goods.

4. SOLUTION METHOD FOR MODEL

As the bi-level programming model is a NP-hard problems, and contact between the upper and the lower is very close, so it is difficult to transfer bi-level programming into single programming directly. Top decision-making departments tend to be affected by the lower sector, although this relationship can be expressed in a reaction function, the specific form of response function is hard to get. Therefore, in order to solve the bi-level programming model presented in this study, we can use repeated iterations ideas combined with the genetic algorithm. You can give a definite value X_i , thereby solving the lower programming model, its decision variables D_{ij} and objective function value, and then put D_{ij} into the upper programming model to solve the new X_i value, and then put X_i into the lower programming model to solve in a new D_{ij} value. Thus, it is expected to get the optimal solution of the upper and lower after definite iterations. According to the above iteration idea, the designed algorithm as follows:

Step 1 Set distribution center X_i^0 is the initial value of the quantity, the number of iterations is $N = 0$;

Step 2 To solve the lower programming problem with the given X_i^N , so as to get each retailer's order demand is D_{ij}^{N+1} and the objective function value G_{N+1} of the lower programming model;

Step 3 To solve the upper programming problem with the given D_{ij}^{N+1} , and get the new quantity of goods distribution center X_i^{N+1} , and the objective function value E_{N+1} of upper programming problem;

Step 4 Make $\phi_{E_N} = \left| \dfrac{E_N - E_{N\text{-}1}}{E_N} \right|$, $\phi_{G_N} = \left| \dfrac{G_N - G_{N-1}}{G_N} \right|$

$$\phi_{E_{N+1}} = \left| \frac{E_{N+1} - E_N}{E_{N+1}} \right|, \quad \phi_{G_{N+1}} = \left| \frac{G_{N+1} - G_N}{G_{N+1}} \right|$$

Stop the iteration if the Max (ϕ_E, ϕ_G) $\le \mu$ and Max ($\phi_{E_{N+1}}, \phi_{G_{N+1}}$) $\le \mu$, which, μ as the iteration accuracy; Otherwise, make $N = N + 1$ into step 1;

Step 5 Output the optimal decision variables and the optimal objective function of the upper and the lower programming model respectively;

The basic idea of the algorithm is by giving an initial value firstly to solve the single programming problems, and then repeat iteration between the upper and lower programming model, and finally terminated by setting gradually approximate optimal solution of bi-level programming problem. Therefore, the algorithm can be called bi-level programming iterative approximation optimization algorithm (Bi-level programming iterative approximation optimization algorithm).

5. THE EXAMPLE ANALYSIS

This example assumes that the centralized supply chain distribution system of bi-level programming model is consists of one manufacturer, two distribution centers and two retailers. Known conditions are as follows:

$i=2$, $j=2$, $K_i(D_i)=(10,20)$, $P_{ij}=\begin{bmatrix}2,3\\6,7\end{bmatrix}$, $G_i\ X_i)=(6,8)$, $C_i(X_i)=(6,7)$, $A_j=(50,50)$, $K_i(X_i)=5,7$, $h_j=(6,6)$, $w_i=(100,100)$, $\mu=0.001$, $R_j(D_{ij})=\begin{bmatrix}10,11\\12,13\end{bmatrix}$, $S_{ij}(D_{ij})=\begin{bmatrix}3,4\\2,6\end{bmatrix}$, $T_{ij}(D_{ij})=\begin{bmatrix}4,5\\3,6\end{bmatrix}$, $H_i=(50,50)$

Using Matlab2010 in windows XP, the initial value is $X_1^0=40$ $X_2^0=30$, the model results and analysis are as follows:

Table 1. Bi-level programming operation result

	The upper planning results			The lower planning results				
	$MinE$	X_1	X_2	$MaxG$	D_{11}	D_{12}	D_{21}	D_{22}
The first iteration results	100	0	100	400	0	50	50	0
The second iteration results	90	70	60	400	0	0	50	50
…	…	…	…	…	…	…	…	…
The ninety-ninth iteration results	67.34	32.3	45.8	420.1	34.3	45.3	20.1	0
The one hundredth iteration results	67.21	31.2	34.68	420.098	23.8	36.4	0	38.3

After 100 iterations, the optimal solution of upper planning can be concluded that is 67.21, $X_1=31.2$, $X_2=34.68$ .The optimal solution of upper planning is 420.098, $D_{11}=23.8$ $D_{12}=36.4$ $D_{21}=0$ $D_{22}=38.3$. Therefore, it can be seen that the minimum cost of distribution centre is 67.21, the order quantity from manufacturer of the two distribution centers is 31.2 and 34.68 respectively, the retailer's maximum profit is 420.098, the quantity of goods from the first distribution center of the first retailers is 23.8, the quantity of goods from the second distribution center is 36.4; the quantity of goods from the first distribution center of the second retailers is 0, the quantity of goods from the second distribution centers is 38.3.

6. CONCLUSIONS

This study introduces the concept of "opportunity loss" in economics, puts forward supply chain distribution system of bi-level programming model based on distribution centers appear out of stock. With the development of supply chain integration, distribution centers will be out of stock losses when the distribution center inventory cannot meet the quantity of downstream retailers, loss distribution center will appear out of stock. In reality, out of stock loss should be considered as one cost of the distribution center. Therefore, it is reasonable and necessary to introduce the shortage of loss into supply chain distribution network. With the integrated development of logistics, the role of the distribution center is more and more prominent. It is a critical issue, which includes how to reduce the shortage loss of distribution center, to meet the demand of retailers in time and to enhance the overall interests of the supply chain, while the above model can offer the decision basis for the supply chain distribution system.

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