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Research Article

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Vendor managed inventory coordination strategy of retailer-led supply chain based on genetic algorithm

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ABSTRACT

The paper considered coordinating topic of retailer-led supply chain based on vendor managed inventory under elastic demand. Coordination strategy of common replenishment period and identical price discount was put forward by retailer the leader of the Stackelberg game. The paper established the system profit model based on multiple vendors and one retailer, then Genetic Algorithm was applied to optimize the model and the simulation works are carried out finally. The results showed that both party benefit's Pareto improvement and the superior profits can be realized by coordination strategy.

Key words: Retailer-led, Supply chain coordination, Vendor managed inventory, Elastic demand

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INTRODUCTION

As a new supply chain model, the retailer-led supply chain gets more attention. In the composition of suppliers and retailers of the supply chain, as the leader of the game, whether the retailers could achieved a coordinated and effective cooperation with the partners is related to the operational efficiency of the whole supply chain [1,2]. So the research of supply chain coordination issue has important significance for retailers to consolidate its dominant position in the supply chain and enhance the competitiveness of the supply chain.

At present, according to the environment of supply chain system, the research on coordinating topic supply chain can be divided into deterministic [3] and stochastic [4]; from the optimization model, it can be divided into game optimization [5] and global optimization [6]; making a classification from the coordination mechanism, with the price adjustment, the punishment cost adjustment, the inventory ownership transfer, the sales effort, the number of commitments, the replenishment period coordination and the joint replenishment etc; classify it from the number of both suppliers and buyers, have the situation of one-to-one [7], one-to-many [8] and many-to-one [9, 10]. Research literature on the coordinating topic of retailer-led supply chain is relatively less, Guo Haifeng had considered one-to-one supply chain to establish the VMI supply chain profit model to the bestseller, explored the optimal procurement quantity and profit in VMI model [11]. Toptal had discussed an optimization problem of supplier replenishment quantity in replenishment cost structure conditions and this question is requirement determination, included the fixed cost and internal ladder transportation cost of suppliers [12]. Disney and Towill had discussed the VMI supply chain performance issues that the demand dynamic changes over time [13], Viswanathan and some others had researched and analyzed the problem through the use of common replenishment period strategy coordination supply chain inventory in fixed demand and stochastic demand [14].

In this paper, many-to-one supply chain structure retailers had the characteristics of strong bargaining power to research the coordinating topic of retailer-led supply chain in retailer-led vendor managed inventory. Coordination strategy of common replenishment period and identical price discount was put forward by retailer the leader of the Stackelberg game, the paper established the system profit model based on multiple vendors and one retailer, optimized the model by application of genetic algorithm.

COORDINATION MODEL ESTABLISHMENT

Model hypothesis and parameters

Take the secondary VMI supply chain system that multiple supplier provides a single product to a retailer into consideration, the assumptions: (1) Suppliers obtained products from the external manufacturer or supplier with unit cost of the product remained unchanged; (2) Execute lot-for-lot supply chain ordering strategy; (3) Retailers were in the leadership position in supply chain so that it was fully aware of the various cost of the supplier; (4) The supplier could obtain a large number of products to ensure the needs of retailers at any time, therefore ignore the shortage cost from retailers and suppliers; (5) The retailer sold goods according to a certain profit ratio, that was the retail price is obtained from increasing a certain percentage on the wholesale price. (6) Retailers demanded for commodities have a price elasticity in retail price; (7) multiple vendors had completed information of the market prices, there had no competition between them, that was supplier purchasing price were the same to the wholesale price.

Make the following explanation to the symbol involved:

$D(D')$: the annual demand of customers (piece) before (after) implementing the coordinated strategy;

$D_i(D_i')$: the supply (piece) of the *i*-th supplier before (after) implementing the coordinated strategy;

d : discount rate (%) provided by supplier;

P : selling price of unit product of retailer (Yuan/piece);

W : wholesale price of unit product of supplier (Yuan/piece);

C : the cost of unit product that the supplier-*i* gets (Yuan/piece);

β : the ratio between retailer's retail price of unit product and the supplier's wholesale price of unit product (%), that is the rate of profit, β >1;

r_i : the percentage of annual supply of supplier-*i* in all suppliers (%), $\sum r_i = 1$, r_i remain unchanged;

T_i : supply period of the *i*-th supplier without discount (day);

T_0 : common replenishment period (day);

T_b : the total number of days in a year (365 days);

K_i : costs of each time the retailer orders to suppliers-*i* (yuan/each);

A_i : treatment costs of each time the suppliers-*i* accept the orders of retailer(yuan/each);

A_s : preparatory cost of each supplier processing retailer's one order (yuan/each);

H_i : the percentage of the holding cost of the supplier's unit product average inventory each year in purchasing cost of unit product (%);

$SP(SP')$: supplier's annual profit before (after) implementing the coordinated strategy (yuan/year);

$RP(RP')$: retailer's annual profit before (after) implementing the coordinated strategy (yuan/year);

$TP(TP')$: annual profits of the SC system before (after) implementing the coordinated strategy (yuan/year).

All parties profit model before implementing the coordinated strategy

Before implementing the coordinated strategy, the annual profit model of supplier-*i:*

$$SP_i = (W - C)D_i - \frac{A_s + A_i}{T_i}T_b - \frac{T_i}{2T_b}H_iCD_i \tag{1}$$

The first term was annual gross profit of suppliers, the second was the order preparation and treatment cost (include the transportation cost) of supplier, the third was supplier's average holding cost of annual inventory. From the formula we get the optimal replenishment period of supplier-*i*:

$$T_i^* = T_b\sqrt{\frac{2(A_s + A_i)}{H_iCD_i}} \tag{2}$$

Then, the optimal annual profit model:

$$SP_i^* = (W - C)D_i - \sqrt{2(A_s + A_i)H_i CD_i} \tag{3}$$

Before implementing the coordinated strategy, the annual profit model of retailer:

$$RP = (P - W)D - \sum_{i=1}^{n} \frac{K_i T_b}{T_i} \tag{4}$$

And $T_i^* = T_b \sqrt{\frac{2(A_s + A_i)}{H_i CD_i}}$, we get the optimal annual profit of retailer:

$$RP^* = (P - W)D - \sum_{i=1}^{n} K_i \sqrt{\frac{H_i CD_i}{2(A_s + A_i)}} \tag{5}$$

Before implement the CRE strategy, according to (1) and (4), we get the system annual total profit model:

$$TP = (P - C)D - \sum_{i=1}^{n} \left(\frac{A_s + A_i + K_i}{T_i} T_b + \frac{T_i}{2T_b} H_i CD_i \right) \tag{6}$$

The corresponding optimal annual profit model was:

$$TP^* = (P - C)D - \sum_{i=1}^{n} \left(K_i \sqrt{\frac{H_i CD_i}{2(A_s + A_i)}} + \sqrt{2(A_s + A_i)H_i CD_i} \right) \tag{7}$$

All parties profit model after implementing the coordinated strategy.

When the leader retailer expanded the sales volume in order to improve the profit of themselves and the whole supply chain, they would negotiate the prices discounts volume with supplier, also enable supplier to accept it with no objection, for this it provided that the recharge of the supplier's products could only be carried out at a particular point. As the demand of final customer had price elasticity, get $D_i' = D_i d^{-k}$. After implementing the coordinated strategy, annual profit model of supplier:

$$SP_i' = (dW - C)D_i' - \frac{A_s + A_i}{N_i T_0} T_b - \frac{H_i CD_i'}{2T_b} N_i T_0 \tag{8}$$

Which

$$T_0 \in N \text{ and } T_0 \le 365, 0 < d < 1 \tag{9}$$

From $\frac{\partial^2 SP'}{\partial N_i^{\,2}} = -\frac{2(A_s + A_i)}{N_i^{\,3} T_0} < 0$, that RP' was a concave function on N_i and had maximum, make $\frac{\partial SP'}{\partial N_i} = 0$, get:

$$N_i^* = \frac{T_b}{T_0} \sqrt{\frac{2(A_s + A_i)}{H_i CD_i'}}, \; N_i^{**} = \left[N_i^* \right] \ge 1 \tag{10}$$

The optimal supply cycle of supplier-*i* was:

$$T_i^{**} = N_i^{**} T_0 \tag{11}$$

The optimal annual profit was:

$$SP_i'^{*} = (dW - C)D_i' - \frac{A_s + A_i}{N_i^{**} T_0} T_b - \frac{H_i C D_i'}{2T_b} N_i^{**} T_0 \tag{12}$$

Then the total profit of supplier was $SP'^{*} = \sum_{i=1}^{n} SP_i'^{*}$. For the suppliers, their premise to accept the supply chain coordination strategy put forward by retailer was:

$$SP'^{*} \geq SP^{*} \tag{13}$$

That was $SP_i'^{*} = (dW - C)D_i' - \frac{A_s + A_i}{N_i^{**} T_0} T_b - \frac{H_i C D_i'}{2T_b} N_i^{**} T_0 \geq SP_i^{*} = (W - C)D_i - \sqrt{2(A_s + A_i) H_i C D_i}$

After implementing the coordinated strategy, annual profit model of retailer was:

$$RP' = (P' - dW)D' - \sum_{i=1}^{n} \frac{K_i T_b}{N_i T_0}, \; P' = \beta dW \tag{14}$$

The premise of retailer using coordinated strategy was:

$$RP' \geq RP^{*} \tag{15}$$

So, the annual total profit:

$$TP' = (P' - C)D' - \frac{A_s T_b}{T_0} - \sum_{i=1}^{n} \left(\frac{A_i}{N_i T_0} T_b + \frac{K_i T_b}{N_i T_0} + \frac{H_i C D_i'}{2T_b} N_i T_0 \right) \tag{16}$$

SUPPLY CHAIN OPTIMIZATION MODEL CONSTRUCTION BASED ON GA

According to the characteristics of the supply chain system profit optimal model and the constraints, the paper used the genetic algorithm to find the optimal solution. Basic steps of the algorithm:

Step 1: Initialization. Set the evolution algebra counter n=0; set the maximum evolution algebra N=200, randomly generated individuals with the number K as the initial population. Each individual in every generation represents a strategy.

Step 2: Individual evaluation. Individual evaluation should be compared with fitness function. The paper used penalty function to distinguish the good-bad solution. To transform the constraint problem into an unconstrained problem, according to the constraint condition (9), (10), (13) and the penalty function given from (15) was:

$$F(x) = [f(a) + f(b) + f(c)]^2 \tag{17}$$

Of which, $f(a) = \max\left\{0, SP_i^{*} - SP_i'^{*}\right\}$; $f(b) = \max\left\{0, RP^{*} - RP'\right\}$; $f(c) = \max\left\{0, 1 - N_i^{**}\right\}$

Set TP' as the objective function, the individual fitness function was:

$$f(x) = TP' - \rho F(x) \tag{18}$$

Of which $\rho > 0$ is the punishment strength coefficient. Here is chosen as 1.

Step3: Selecting operation. Use the roulette selection accumulative probability to achieve that the probability being selected had improving of the large fitness value.

Step4: Crossover operation. Randomly set two positions from the first 7 and the last 9 of the selected individual code string, and then used crossover probability P_c=0.8 to make a crossover operation respectively on the first 7 and the last 9 of the two corresponding individuals from the two point, to achieve the operation to generate a new individual through replacing and recombining the part structure of the two parent individuals.

Step5: Mutation operation. Select a gene value respectively from the first 7 and the last 9 of the selected individual series to make 0-1 transformation, here select the mutation probability that Pm = 0.01.

Step6: Judgment of termination condition. If $n \le N$, then $n = n+1$, go to step 2; if $n > N$, then set the individuals with maximum fitness we got from the output evolutionary process as the optimal solution, the calculation ended.

CASE ANALYSIS

The paper selected one retailer and two suppliers as the research object, wholesale price exogenously, the leader retailer knew the cost structure of the supplier and replenishment mode. The annual demanded of retailers' products had price elasticity; provision the rate of discount and common replenishment period in the premise of the supplier profit could achieve the Pareto improvement. The parameters used in the model is shown in Table 1, in which the quantifier of the parameters were *D*- piece, *P* and *C*- ten thousand yuan/piece in turn, K_1, K_2, A_s, A_1, A_2 is ten thousand yuan/once.

Table 1: Model parameters

Symbol	*D*	*W*	*C*	*β*	γ_1	γ_2	H_1	H_2	K_1	K_2	A_s	A_1	A_2	*k*
Number	600	0.3	0.25	1.3	1/3	2/3	0.075	0.1	0.01	0.1	0.02	0.02	0.05	2.5

All parties profit before implementing the coordinated strategy

Obtained by the conditions knew D_1=200(piece), D_2=400(piece), P=β*W=0.39 (ten thousand yuan); before implementing the coordination by the calculation (2) got that T_1=53 (day), T_2=43(day); and from formula (3) got that SP_1^*=9.4532 (ten thousand yuan) , SP_2^*=18.8168 (ten thousand yuan); from formula (5) got that RP*= 53.0864 (ten thousand yuan). Profit of the whole supply chain system was TP*=81.3554 (ten thousand yuan).

All parties profit after implementing the coordinated strategy

The initial condition of genetic algorithm was population size $M = 20$, terminate evolutionary generations MaxGeneration=200, formula (18) was a fitness evaluation function. The result was showed in Figure 1.

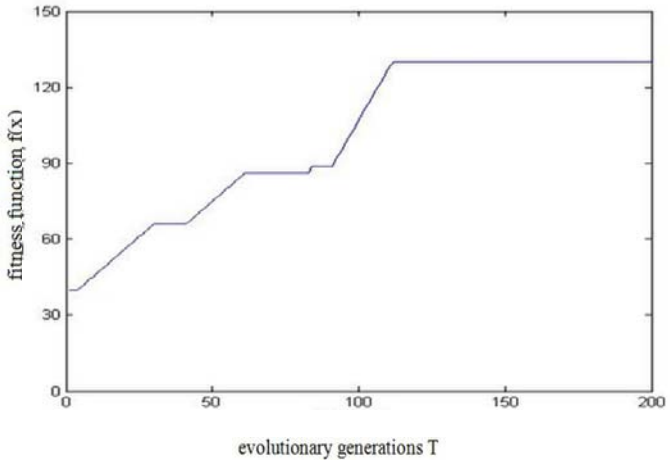

Figure 1: Fitness curve in evolutionary process

According to the simulation results, the optimal strategy was: (d^*, T_0)=(0.73,9), optimal profit of the supply chain was: TP'=112.1322 ten thousand yuan, increased by 37.83% than the profit before the coordination, the profits of supplier were as follows: SP_1'=16.3458 ten thousand yuan, increased by 72.93%; SP_2'=32.9011 ten thousand yuan, increased by 74.85%; the profit of retailer was RP'= 62.8852 ten thousand yuan, increased by 18.46%. The annual demand of retailer was: $D'=600*(0.73)^{-2.5}$=1317(piece), get the annual supply volume of the two suppliers respectively are D_1'=439(piece), D_2'=878(piece), and get that N_i^{**}=(4, 3), that was the replenishment period of the two suppliers were changed into T_1'=36 days and T_2'=27 days, it had showed that replenishment periods were shortened respectively.

CONCLUSIONS

The paper established the system profit model based on multiple vendors and one retailer; used Genetic Algorithm to optimize the model. From the results we can found out a win-win coordination strategy (d, T_0) for retailers and suppliers, got the maximum value of the whole supply chain profits in the premise of the profits of retailers and suppliers could achieve Pareto improvement, the growth of system profit showed the enhanced competitiveness of supply chain; because of price reduction, it also brought tangible benefits to the customer.

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