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NEGOTIATION-BASED COLLABORATION PLANNING MODEL FOR SUPPLY CHAIN MANAGEMENT*

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Abstract: A collaboration planning model (CPM) for co-ordination of supply chain (SC) is established by the sharing of information, based on up and downstream planning models respectively. The factors under internal as well as external situations (price, inventory etc.) are considered in the model. The relationship of cooperating partnership is determined, and the goal of win-win is obtained by negotiation theory. Experiments using realistic data from enterprises have achieved satisfactory results. *Copyright©2002 IFAC*

Keywords: supply chain, upstream, downstream, production planning, negotiation theory, nonlinear programming

1. INTRODUCTION

In recent years considerable emphasis has been placed on supply chain management (SCM). Factors such as increasing globalization and the development of information technology have provided opportunities for companies to become efficient and, at the same time, put competitive pressure on them as their rivals do likewise (Alistair R.Clark 1997). Studies on supply chain management have attached importance to strategic cooperating partners relationship especially. Modern manufacturing philosophies have forced an evolution of the relationships between buyers and suppliers. The supply chain for many successful firms has matured from an adversarial relationship to one of supply chain partnership (Michael J. Maloni 1997). The essence of this relationship is concerned with collaboration between the two participants, and the expected result is a mutually beneficial, win-win partnership that creates a synergistic supply chain in which the entire chain is more effective than some of its individual parts, through reductions in total costs, reductions in inventories throughout the supply chain usually. Rather than themselves (Bowon Kim,2000).

This paper proposes collaboration planning model (CPM), based on the up and downstream planning models respectively, and the trade volume is determined by negotiation between up and down stream in supply chain. Since both up and downstream planning models are nonlinear program -ing models, an approximate algorithm is used to support negotiating in the models.

This paper is organized as follows. Section 2 introduces the relation of up and downstream briefly. In section 3, both up and downstream planning models are described respectively. A collaboration planning model is established and an approximate algorithm is used to support negotiation. The results and comments are included in section 4. Finally, conclusions are given in section 5.

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2.DESCRIPTION

The up and downstream relationship is very representative in SCM. Roughly, it can be described as a kind of principle cooperating partnership. Upstream plant is a primary supplier to downstream. At the same time, downstream enterprise is the primary demander to upstream. However, heavy reliance on one partner can be disastrous if the partner doesn't meet expectation. The competitive ability will be reduced possibly for some reasons, such as losing control of cooperating relation, self-trust excessively, specialization of cooperating partner etc. So selecting proper partner becomes important to the enterprises in the drastic competitive market. Now enterprises are facing to market and have to adjust plan to adapt the variation of market combining their advantage agilely. When an enterprise carries out his plan, the factors under internal situations as well as external situations (price, inventory etc.) should be considered. Both collective benefit and long views of itself should be ensured.

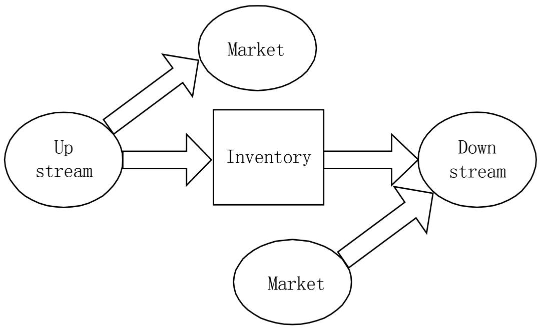

Fig.1. The relation of up-down stream based on market

From Fig. 1, upstream faces the need of market when supplying to downstream, downstream does so. Many strategies can be selected to both sides. According to the characteristics mentioned above, a collaboration planning model is established based on up and downstream planning models respectively, and the trade volume is determined by negotiating between up and downstream in supply chain.

3. MODEL SPECIFICATION AND ALGORITHM

There are many rules in partnership selection, such as price, inventory, services, quality etc. The price and inventory are more representative, and can make both up and downstream plants combined availably. The price is a key factor to get profit, and sensitive to the market. The inventory can coordinate the relation between up and down stream. So the upstream and downstream planning models are integrated in the collaboration planning model (CPM) by price and middle inventory. In the models, many constraints are considered, such as resources, middle stock, and the relation of alliance etc.

3.1 Upstream planning model

Fist, the variables of upstream will be defined as follows:

$x_u(t)$: The output of upstream to downstream. $y_u(t)$: The output of upstream to market. $\hat{x}_u(t)$: The predicted output of upstream to downstream. $\hat{y}_u(t)$: The predicted output of upstream to market. a_u : The bargaining price between up and downstream. $a_u^{mark}(t)$: The price of up to downstream at time t. b_u : The unit cost value. c_u : The unit tax value. h : The unit stock charge. ε_u^1 , ε_u^2 : The permitted limit of upstream trade volume. W : The upper limit of stock. $I(0)$: The initial stock value of upstream. m : The resources quantities of up stream.

$$max \sum_{t=1}^{T} \{(a_u - b_u)x_u(t) + (a_u^{mark}(t) - b_u - c_u)y_u(t) - hI(t)\} \tag{1}$$

$$s.t. \quad I_u(t) \le W \quad (t = 1,2,...T) \tag{2}$$

$$r_{ui}(x_u(t) + y_u(t)) \le R_{ui}(t) \quad (t = 1,2,...T, i = 0,1,...m) \tag{3}$$

$$\varepsilon_u^1 \le x_u(t) - \hat{x}_d(t) \le \varepsilon_u^2 \tag{4}$$

$$x_u(t) \ge 0, y_u(t) \ge 0 \tag{5}$$

Where:

$$I_u(t) = \sum_{\tau=1}^{t} [x_u(\tau) - \hat{x}_d(\tau)] + I(0) \tag{6}$$

Object function（1）means maximum of up stream profit. Constraint（2）means stock constraint of upstream. Constraint (3) means the ith resource (r_{ui}) constraint of upstream. Constraint (4) means alliance relation between up and downstream. Constraint（6）means the stock charge of upstream.

3.2 Downstream planning model

The variables of downstream will be defined as follows:

$x_d(t)$: The input of downstream from upstream. $y_d(t)$: The input of downstream from market.

$\hat{x}_d(t)$: The predicted input of downstream from upstream. $\hat{y}_d(t)$: The predicted input of downstream from market. a_u : The bargaining price between up and downstream. $a_d^{mark}(t)$: The price of downstream from upstream at time t. b_d : The unit cost. c_d : The unit tax value. h : the unit stock charge. ε_d^1, ε_d^2: The permitted limit of downstream trade volume.

$$max \sum_{t=1}^{T} \{\alpha(a_d - b_d - c_d)(x_d(t) + y_d(t)) - a_u x_d(t) - a_d^{mark}(t) y_d(t) - hI(t)\} \quad (7)$$

$$s.t. \quad I_d(t) \le W \; (t = 0,1,...T) \quad (8)$$

$$r_{di}(x_d(t) + y_d(t)) \le R_{di}(t) \quad (t = 0,1...T; i = 1,2,...m) \quad (9)$$

$$\varepsilon_d^1 \le \hat{x}_u(t) - x_d(t) \le \varepsilon_d^2 \quad (10)$$

$$x_d(t) \ge 0, y_d(t) \ge 0 \quad (11)$$

Where:

$$I_d(t) = \sum_{\tau=1}^{t} [\hat{x}_u(\tau) - x_d(\tau)] + I(0) \quad (12)$$

Object function（7）means maximum of down stream profit. Constraint（8）means stock constraint of downstream. Constraint (9) means the ith resource (r_{di}) constraint of downstream. Constraint (10) means alliance relation between up and downstream. Constraint (12) means the stock charge of downstream.

3.3 Collaboration planning model (CPM)

The output $(x_u(t), y_u(t))$ of upstream to down stream and market are calculated by upstream planning model, the input $(x_d(t),\ y_d(t))$ of downstream from upstream and market are calculated by downstream planning model. The output $(x_u(t), y_u(t))$ of upstream are transferred to downstream, the input $(x_d(t), y_d(t))$ of downstream are transferred to upstream. The results calculated by both sides are compared with predicted values, the calculation will not end until results calculated are equal to that predicted (Fig. 2).

The terminating conditions in iteration are：

$$x_u(t) = \hat{x}_u(t), x_d(t) = \hat{x}_d(t) \quad (13)$$

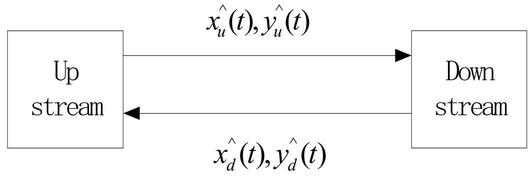

Fig.2. The supply and demand cooperation planning model based on negotiation

The price factor is described via price function curve (Fig. 3).

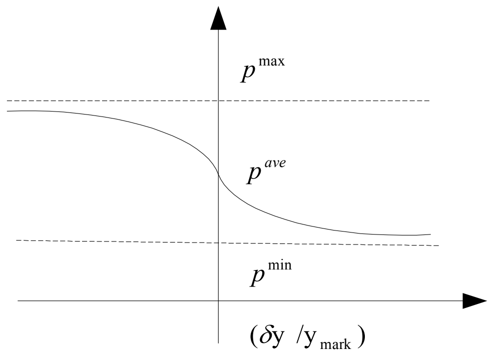

Fig.3. Market price a(t)

The price function of up and downstream to the market can be defined as follows:

$$a^{mark}(t) = -k \; * \mathrm{arctg}(\delta y \; / y_{mark}) + p^{ave} \quad (14)$$

The variables can be defined as follows :

p^{max} : The maximal price of upstream to market (or downstream from market). p^{min} : The minimal price of upstream to market (or downstream from market). p^{ave} : The average price of upstream to market (or downstream from market).

$$k = 2*(p^{max} - p^{min}) / \pi \quad (15)$$

$$p^{ave} = (p^{max} + p^{min}) / 2 \quad (16)$$

y_{mark} : The quantity of market. δy : The deviation between the planning volume of upstream and predicted volume of upstream from downstream.

Where:

$$\delta y_u = y_u(t) - \hat{y}_d(t) \quad (17)$$

$$\delta y_d = \hat{y}_u(t) - y_d(t) \quad (18)$$

3.4 Algorithm

Both upstream and downstream planning models are nonlinear programming models including linear constraints, which are not solved by common mathematic means. In this paper, the complex nonlinear programming model is transformed into linear programming model by approximate means, which can be solved by common mathematic means. The procedure of algorithm is expressed as follows：

Step1). Given mistake $\varepsilon > 0$, $x^{(0)} \in R$; R means feasible area and $\hat{x}(t), \hat{y}(t)$ k:=0.

Step2). if equation（13）can be satisfied, then iteration stop. Otherwise, optimal solutions of up and downstream are got respectively, then go to step 3.

Step3). Calculate optimal solutions $\overline{x}^{(k)} \in R$ by $Min \nabla f(x^{(k)})^T x$, $x \in R$.

Step4). If $|\nabla f(x^{(k)})^T (\overline{x}^{(k)} - x^{(k)})| \le \varepsilon$, then iteration stop, getting $x^{(k)}$ go to step7. Otherwise go to step 5.

Step5). Min $f(x^{(k)} + \lambda(\overline{x}^{(k)} - x^{(k)}))$, $\lambda \in [0,1]$ calculate $\lambda_0^{(k)}$.

Step6).Let $x^{(k+1)} = x^{(k)} + \lambda_0^{(k)} (\overline{x}^{(k)} - x^{(k)})$, k:=k+1, go to step 3.

Step7). Return $\hat{x}(t) = x^{(k+1)}$, do steps 3,4,5,6.

4. COMPUTATIONAL EXAMPLE

We begin this section with plans for quarter of a year in hot-cold rolling plants to illustrate the method. The algorithms for CPM have been implemented in a software package, coded in visual C++6.0. The planning results of hot-cold rolling plants independently can be got in table1 and table2. Where T=3,m=2. Using CPM together with its algorithm to optimize the plan, the respective parameters are modified as in table3 and table 4, where K=57.

From table 1 to table 4, we can observe that the supplying volume of upstream to downstream tend to be in equilibrium with the demanding volume of downstream from upstream. The profit of upstream using CPM is 3.71% upper than that planned independently, the profit of downstream using CPM is upper appreciably than that planned independently. Both up and downstream can make an agreement with the plans.

Table1. The planning trade volume of upstream independently

	Output 0f up to downstream	Output 0f up to market	Profit of upstream
1	6000	4000	5000000
2	6200	3800	5100000
3	6100	3900	5150000

Table2. The planning trade volume of downstream independently

	Input of down from upstream	Input of down from market	Profit of downstream
1	5900	3100	3600000
2	6000	3000	3700000
3	5900	3100	3750000

Table3. The planning trade volume of upstream using CPM

	Output 0f up to downstream	Output 0f up to market	Profit of upstream
1	6553	3447	5043500
2	6617	3383	5144370
3	6601	3399	5194805

Table4. The planning trade volume of downstream using CPM

	Input of down from upstream	Input of down from market	Profit of downstream
1	6417	2583	3733560
2	6578	2422	3837270
3	6512	2488	3889125

Furthermore, in this case, having run CPM several times with data from this example, we find that the difference between the bargaining price of up-downstream and the bargaining price of that with market varies within certain range, the results will converge. Otherwise, they will diverge. Therefore, the negotiating results to some extent depend on the relation between the bargaining price of up – down stream and the bargaining price of that with market.

5. CONCLUSION

Conceptual-based supply chain literature has been extremely optimistic about the promise of win-win supply chain partnerships, however there has been very little rigorous testing of these assertions. In this paper, a collaboration planning model (CPM) for SCM is established by the sharing of information, based on upstream and downstream planning models. According to the internal as well as external situations (price, inventory etc.), the relation of cooperating partnership is determined by negotiating theory, and the goal of win-win is realized. The model has great value implemented in SCM, and great potential for practical application.

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