Optimization Model of Close Supply Chain of Green Agricultural Products

WANG Duo-hong * , **LI Yu**, **ZHAO Hong-xia**, **ZHANG Jiang-quan**

Department of Traffic Transportation, Emei Campus, Southwest Jiaotong University, Emeishan 614202, China

Abstract Close supply chain of green agricultural products is defined, consisting of the supplier, manufacturer, distributor, retailer and consumer (customer). Cost structure of distributor is analyzed, mainly including the order activity-based cost, the inventory cost and the supply transportation cost of agricultural products in upstream and downstream enterprises. Based on this, conceptual model of the close supply chain of green agricultural products is established. According to the idea of dynamic planning, optimization model of close supply chain of green agricultural products at four stages is also set up. In other words, under the constraint condition of supply chain and the uncertainty of sales volume, optimization of the sum of inventory cost, supply transportation cost and order activity-based cost in supply chain at retailer, distributor, manufacturer and suppliers stages is studied, which provides references for the analysis and decision-making of supply chain management.

Key words Close supply chain; Operation optimization; Green agricultural products; China

On the Fifth Plenary Session of the Eleventh Central Committee CPPCC in Tianjin City, China in the year 2008, Yu Wenmei and some other members put forward the issues of agricultural products quality and safety. They suggest to establish close supply chain for agricultural byproducts, ensure food safety, standardize the supply chain of agricultural byproducts by scientific criterion, and implement the close operation of supply chain for agricultural byproducts[1]. Moreover, it is pointed out that we should construct and optimize the close supply chain, implement close operation of supply chain for agricultural byproducts in an all-round way, realize real-time tracking of the supply chain of agricultural products, achieve effective control and overall management, improve the controllability and channel efficiency from structure, and eliminate "Lemon Effect" caused by information asymmetry, in order to create greater value for the entire supply chain, to improve the quality of agricultural products, to reduce the operation cost, and to accelerate the development of green agricultural industrialization.

1 Conceptual model of the close supply chain of green agricultural products

Fig. 1 illustrates the close supply chain of green agricultural products, consisting of the supplier, manufacturer, distributor, retailer and consumer (customer). Assuming that there is only one distributor, that is, the logistics center of green agricultural products, which is the core enterprise of supply chain including the circulation, processing and storage companies and the distribution and delivery companies. The rest nodes in the supply chain are composed of a number of enterprises. And there is certain buyer-seller relationship between the node enterprise and distributor.

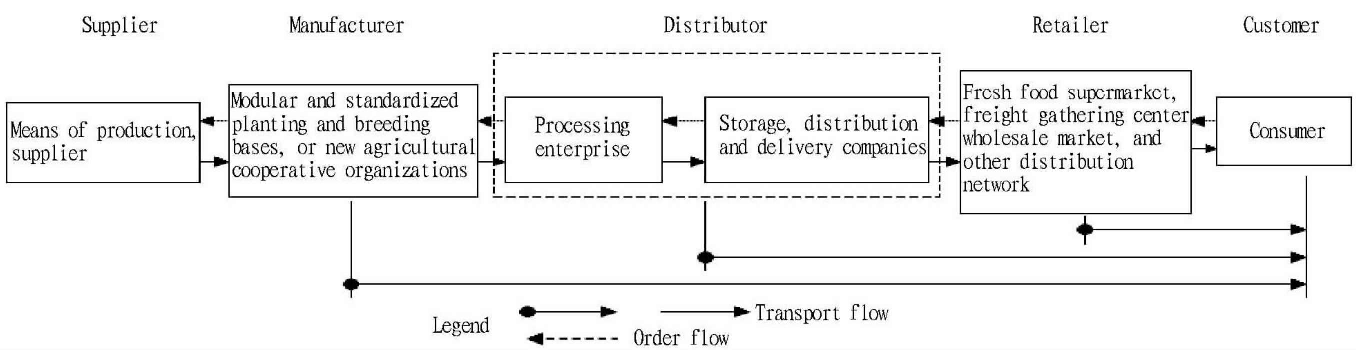

Fig. 1 Conceptual model of the close supply chain of green agricultural products[2-3]

2 Cost model of distributor

2.1 Cost composition of distributor Cost composition is analyzed with distributor as the core enterprise. The distributor sells agricultural products to the downstream retailers and customers. Since distributors sell products to customers and buy products from upstream manufacturer, cost of distributor is mainly the order activity-based cost, inventory cost and supply transportation cost of agricultural products in upstream and downstream enterprises. Among them, order activity-based

Received: September 5, 2009 Accepted: September 18, 2009
* Corresponding author. E-mail: wdh109@163.com

cost basically includes the maintenance cost of customer $Z_{i,1}$, processing cost of customer order $Z_{i,2}$, complete cost of customer order $Z_{i,3}$, maintenance cost of manufacturer $Z_{i,4}$, purchase order cost of distributor $Z_{i,5}$ and complete cost of distributor purchase order $Z_{i,6}$[2]. Inventory cost refers to the cost of distributor produced by the occupation of stocks and funds. Hence, $Z_{i,7}$ is the stock space and capital cost of customer *i*. Supply transportation cost supplied by distributor includes the investment cost of purchasing system $Z_{i,8}$ and the purchasing cost $Z_{i,9}$.

2.2 Cost optimization model of distributor According to the above analyses, distributor takes the total cost as the objective in order to establish the cost optimization model of distributor[4-5]. The equation is:

$$\min_{(Q_{is,1},Q_{is,2})} Z = \sum_{i=1}^{n_1} [Z_{i,1} + Z_{i,2} + Z_{i,3} + Z_{i,4} + Z_{i,5} + Z_{i,6} + Z_{i,7} + Z_{i,8} + Z_{i,9}] \quad (1)$$

Its constraint conditions are as follows:

$$J = \sum_{i=1}^{n_1} [\sum_{S:s \in S_{i\tau}} (P_{is} - C_{is}) (Q_{is,1} + Q_{is,2}) - \sum_{J=1}^{9} Z_{i,j}] \geqslant R, \quad (2)$$

$$Q_{is}^L \leqslant Q_{is,1} = M_1 Q_0 \leqslant Q_{is}^H, \quad (3)$$

$$Q_{is}^L \leqslant Q_{is,2} = M_2 Q_0 \leqslant Q_{is}^H, \quad (4)$$

where P_{is} is agricultural products price charged by distributor for different customers, M_1 and M_2 are the distributive numerics of ordinary order quantity and direct order quantity in the minimum order quantities, respectively, belonging to nonnegative integer, J is rational value of the minimum net profit of distributor ($R>0$), Q_0 is the minimum order quantity. Both ordinary order quantity $Q_{is,1}$ and direct order quantity $Q_{is,2}$ of customers are decision variables. Q_{is}^L and Q_{is}^H are the upper and lower limits of agricultural order quantities of customers, respectively. And their values are calculated based on the historical data of distributor.

3 Overall optimization model of supply chain

3.1 Dynamic system of supply chain

3.1.1 Dynamic system description at supplier stage. Dynamic model at supplier stage is also known as the inventory state equation of supplier:

$$x_{4,k+1} = x_{4,k} + u_{4,k} - v_{4,k}, \quad (5)$$

where $x_{4,k}$ is the inventory of supplier at time k, which is a n_1-dimensional state vector, $u_{4,k}$ is the supply at time k, a n_1-dimensional control vector, $u_{4,k}$ is material quantity of manufacturer provided by supplier at time k, a n_1-dimensional control vector.

3.1.2 Dynamic system description at manufacturer stage. Dynamic model at manufacturer stage is composed of two equations.

One is the neural network equation during production[6]:

$$p_{k+1} = f(p_k, v_{1,k}), \quad (6)$$

where $p_{k+1} = f(\cdot)$ is the output of neural network, which is a n_2-dimensional state vector, p_k is a first order lag of p_{k+1}, as the generalized output of system, $v_{1,k}$ is the control variable in equation (5), as the input of neural network. Since process of production is a complex nonlinear system, we assume that neural network can get close to this unknown nonlinear production system.

The other mode at production stage is production inventory state model[7]:

$$x_{3,k+1} = x_{3,k} + p_{3,k} - v_{3,k}, \quad (7)$$

where $x_{3,k}$ is inventory of manufacturer at time k, which is a n_2-dimensional state vector, $p_{3,k}$ is production output during production in equation (6), and $v_{3,k}$ is target agricultural products for distributor, a n_2-dimensional control vector.

3.1.3 Dynamic system description at distributor stage. Dynamic model at distributor stage is also called the inventory state equation of distributor:

$$x_{2,k+1} = x_{2,k} + v_{3,k} - v_{2,k}, \quad (8)$$

where $x_{3,k}$ is the inventory of distributor, a n_2-dimensional state vector, $v_{3,k}$ is products of distributor provided by manufacturer in equation (7), which is a n_2-dimensional control vector, $v_{2,k}$ is agricultural products quantity of retailer provided by distributor, a n_2-dimensional exogenous vector.

3.1.4 Dynamic system description at retailer stage. Dynamic model at retailer stage is also known as the inventory state equation of retailer:

$$x_{1,k+1} = x_{1,k} + v_{2,k} - d_{1,k}, \quad (9)$$

where $x_{1,k}$ is the inventory of retailer, a n_2-dimensional state vector, $v_{2,k}$ is products of retailer provided by distributor in equation (8), which is a n_2-dimensional control vector, $d_{1,k}$ is agricultural products quantity sold by retailer, a n_2-dimensional exogenous vector.

Sales volume $d_{1,k}$ at retailer stage is an exogenous uncontrolled variable, reflecting the market behavior of customer. It is assumed that there are two different situations of equations (10) and (11):

$$d_{1,k} = \mu + \rho d_{1,k-1} + \varepsilon_t, \quad (10)$$

indicating that the uncertainty in customer demand $d_{1,k}$ is in accordance with the stationary time series of AR(1);

$$d_{1,k} = D_{1,k} + \xi_k, \quad (11)$$

indicating that the uncertainty in customer demand $d_{1,k}$ is the condition of white noise or colored noise. Among them, $D_{1,k}$ is deterministic function, ξ_k is noise function, which might be a white noise or a colored noise.

In a word, equations (5) - (11) have together formed the overall optimization model of supply chain. Change of supply amount at supplier stage in this model has resulted in the fluctuation of supply and demand quantity between manufacturer and retailer, and has promoted the entire supply chain. At the same time, under the exogenous function of sales volume at retail stage, changes of customer demand has led to the supply and demand variation of retailer, distributor, manufacturer and supplier. Thus, it can promote the operation of entire supply chain.

3.2 Objective function of supply chain model Objective function of supply chain model is composed of the inventory cost objective function (Z_1), supply transportation cost objective function (Z_2) and order activity-based cost objective function (Z_3), which is

$$Z = Z_1 + Z_2 + Z_3, \quad (12)$$

3.2.1 Inventory cost objective function. Inventory cost objective function of supply chain system is

$$Z_1 = \sum_{k=0}^{N} (q_{14}^T x_{4,k} + q_{13}^T x_{3,k} + q_{12}^T x_{2,k} + q_{11}^T x_{1,k}), \quad (13)$$

where $q_{11}, q_{12}, q_{13}, q_{14}$, belonging to non-negative numbers, are column vectors of cost corresponding dimensions per unit goods in inventory system at retail, distribution, manufacturing and supply stages, respectively. Inventory cost objective function (Z_1) reflects the requirements of inventory costs at retail, distribution, manufacturing and supply stages, respectively.

3.2.2 Supply transportation cost objective function. Supply transportation cost objective function in supply chain system is

$$Z_2 = \sum_{k=0}^{N} (r_{14}^T u_{4,k} + r_{13}^T v_{4,k} + r_{12}^T v_{3,k} + r_{11}^T v_{2,k}), \quad (14)$$

where $r_{11}, r_{12}, r_{13}, r_{14} > 0$ and $r_{11}, r_{12}, r_{13}, r_{14}$ are the column vectors of corresponding dimensions of supply transportation costs per unit cargo at retail, distribution, manufacturing and supply stages, respectively.

3.2.3 Order activity-based cost objective function. Order activity-based cost objective function in supply chain system is

$$Z_3 = \sum_{k=0}^{N} [\lambda_{14}^T (u_{41,k} + v_{4,k}) + \lambda_{13}^T (v_{4,k} + v_{3,k}) + \lambda_{12}^T (v_{3,k} + v_{2,k}) + \lambda_{11}^T (v_{2,k} + d_{1,k})], \quad (15)$$

where $\lambda_{11}, \lambda_{12}, \lambda_{13}, \lambda_{14} > 0$ and $\lambda_{11}, \lambda_{12}, \lambda_{13}, \lambda_{14}$ are the column vectors of corresponding dimensions of order activity-based cost per unit cargo at retail, distribution, manufacturing and supply stages, respectively.

3.3 Constraint conditions of objective function in supply chain model

3.3.1 Constraint condition of objective function at supplier stage. Supply quantity at supplier stage $u_{4,k}$ belongs to control variable. But it is restricted by certain conditions of suppliers:

$$u_{4,k}^1 \leqslant u_{4,k} \leqslant u_{4,k}^2. \quad (16)$$

3.3.2 Constraint condition of objective function at manufacturer stage. Constraint condition of production level at production stage is

$$p_k \geqslant p^0. \quad (17)$$

It indicates that production should be no less than p^0 according to the planning level at production stage. And p^0 is column vector of corresponding dimension.

3.3.3 Constraint condition of inventory safety in supply chain system. It is

$$\begin{cases} x_{1,k} \geqslant x_1^0 \\ x_{2,k} \geqslant x_2^0 \\ x_{3,k} \geqslant x_3^0 \\ x_{4,k} \geqslant x_4^0 \end{cases}, \quad (18)$$

where $x_1^0, x_2^0, x_3^0, x_4^0$ are column vectors of corresponding dimensions of inventory safety at retail, distribution, manufacturing and supply stages, respectively.

3.4 Overall optimization model of supply chain Based on the references [3] – [6], integration model of supply, manufacturing, distribution and retail in supply chain management should be further studied under the constraint condition of supply chain and the uncertainty of sales volume. Equations (13), (14) and (15) are substituted into equation (12). Hence, we have:

$$\begin{aligned} Z &= Z_1 + Z_2 + Z_3 \\ &= \sum_{k=0}^{N} [q_{11}^T x_{1,k} + r_{12}^T v_{3,k} + \lambda_{11}^T (v_{2,k} + d_{1,k})] \\ &+ \sum_{k=0}^{N} [q_{12}^T x_{2,k} + r_{12}^T v_{3,k} + \lambda_{12}^T (v_{3,k} + v_{2,k})] \\ &+ \sum_{k=0}^{N} [q_{13}^T x_{3,k} + r_{13}^T v_{4,k} + \lambda_{13}^T (v_{4,k} + v_{3,k})] \\ &+ \sum_{k=0}^{N} [q_{14}^T x_{4,k} + r_{14}^T u_{4,k} + \lambda_{14}^T (u_{41,k} + v_{4,k})], \end{aligned} \quad (19)$$

Equation (19) shows the sum of inventory cost, supply transportation cost and order activity-based cost in supply chain at retailer, distributor, manufacturer and suppliers stages. Therefore, overall optimization model of supply chain can be expressed as the optimization issue with dynamic coefficients (5) – (11) and constraint conditions (13) – (18) under the requirement of objective function (12).

4 Conclusion

Integration model of supply, manufacturing, distribution and retail under the constraint condition of supply chain and the uncertainty of sales volume is established, which is also called the overall optimization model of supply chain. However, there is certain difficulty in determining the variables in the model, which is worthy to be further researched.

References

[1] ZHANG XY. Yu Wenmei and some other CPPCC members suggest to establish close supply chain for agricultural by products[EB/OL]. (2007 – 01 – 30). http://news.163.com/07/0130/09/362TDI3H000120GU.html. (in Chinese).

[2] RAKESH N, MAHENDRA G, CHAKRAVARTHI N. Customer profitability in a supply chain[J]. Journal of Marketing, 2001, 65(1):1 – 16.

[3] HUANG XY. Supply chain model and its optimization[M]. Beijing: Science Press, 2004:27 –32. (in Chinese).

[4] LU Z, HUANG XY, LI DS. Application of supply chain model and decision under a condition of supply and distribution[C]//Proceedings of 2001 International Conference on Management Science & Engineering. Harbin: Harbin Institute of 2001 International of Technology Press, 2001: 874 –877.

[5] WANG SG, MA SH. Virtual enterprise based on global supply chain [J]. Journal of Industrial Engineering and Engineering Management, 1999, 13(3):9 –12. (in Chinese).

[6] THOMAS DJ, GRIFFIN PM. Coordinated supply chain management [J]. European Journal of Operation Research, 1996, 94(1): 1 – 15.

[7] LU Z, HUANG XY, LI DS. Application of supply chain model and decision under a condition of supply and distribution[J]. Systems Engineering—Theory Methodology Applications, 2000, 9(4):289 – 295. (in Chinese).

[8] WANG WZ, DING HH. Discussion of green supply chain management and implementation way in China[J]. Journal of Shijiazhuang Railway Institute: Social Sciences, 2009, 3(2):27 – 30. (in Chinese).

[9] XU YX, WANG HB. Development strategy of green agricultural product in Shaanxi Province based on SWOT analysis[J]. Journal of Anhui Agricultural Sciences, 2008, 36(16):6963 – 6965, 7028. (in Chinese).

[10] CHEN GH. Research on TBT forewarning information system's frame in the green primary products supply chain[J]. Agriculture Network Information, 2007(5):25 –27. (in Chinese).

[11] HONG L, LI L. On innovation in circulation system of Beijing fresh and live agriculture & by-product[J]. China Business and Market, 2007, 21(3):33 –35. (in Chinese).

(To page 52)

Since analytic hierarchy process is commonly used in research, weight obtained from analytic hierarchy process is directly given out, as well as the result of consistency check:

$$\eta' = (0.24, 0.14, 0.28, 0.34), CR = \frac{CI}{RI} = 0.08 < 0.1.$$

Hence, the result of final risk assessment is

$$f = \eta' \cdot u = (0.33, 0.23, 0.24, 0.14, 0.06).$$

The final results show that 33%, 23% and 24% experts believe that the risk of this M & A project is low, relatively low and moderate, respectively. Only 20% experts argue that this project has great risk. Therefore, the overall risk of this M & A project is at a relatively low level; and mergers and acquisitions can be implemented.

4 Conclusion

M & A risk is an issue must be taken seriously in China during the process of mergers and acquisitions of agricultural manufacturing enterprises. M & A risk itself is inseparable from the complexity of M & A enterprises and the external environment. Objective assessment of M & A risk not only provides a reference for the merger, but also offers guidance to the further control of risk. In this paper, M & A risk is evaluated through the fuzzy mathematical method; and entropy method is introduced when determining the weight of risk factor, so as to make the risk assessment more objective and to provide a reliable basis for the decision making of agricultural manufacturing enterprises in China.

References

[1] LU QL, LAN QG, HOU ZJ. Study on merger and acquisition behavior of agricultural enterprise based on region[J]. Issues in Agricultural Economy, 2008(4):86-89. (in Chinese).

[2] QIN XJ, CHEN H. Success M&A: the study on how to select the target firms[M]. Beijing: Economic Management Publishing House, 2004. (in Chinese).

[3] ZHANG XY. M&A and integration management[M]. Beijing: China Financial and Economic Publishing House, 2004. (in Chinese).

[4] WESTON JF, MITCHELL ML, MULHERIN JH. Takeovers, restructuring, and corporate governance[M]. Pearson Education Press, 2006.

[5] CAO Y. Study on the risk decision for enterprise merge and acquisition based on AHP[J]. Journal of Central University of Finance & Economics, 2007(8):88-92. (in Chinese).

[6] LIU KD, WU HQ, PANG YJ. Mathematical processing and application of uncertain information[M]. Beijing: Science Press, 1999. (in Chinese).

[7] XU CY. Factors identification and fuzzy measure of enterprise merger and acquisition risk[J]. Commercial Times, 2004(15):22-23. (in Chinese).

[8] LU GX, YI CL. The risk measure method of enterprise merger and acquisition: fuzzy comprehensive analysis method[J]. Statistics and Decision, 2007(9):160-161. (in Chinese).

中国农业生产企业并购风险评价

边宽江,杨卫武* (西北农林科技大学理学院,陕西杨凌 712100)

摘要 分析了中国农业生产企业并购风险的组成,它主要由战略风险、外部环境风险、交易风险和整合风险4类风险组成,其具体的风险来源有16个。介绍了农业生产企业并购风险评价的具体方法:首先,建立首层和第2层风险因素集,并将并购风险划分为5个级别,根据专家小组的评分建立风险评价矩阵;其次,利用信息熵的思想确定各风险因素的权重;最后,求出风险因素的隶属度向量,构建风险度量矩阵,计算出第2级风险度量向量,并作出风险评价。以中国某农产品加工企业为案例,运用模糊数学方法对该企业的并购项目进行了风险评价,结果表明,该并购项目的总体风险较低,可以实施并购。基于模糊数学的并购风险评价方法使评价结果更加客观、可靠,从而能为中国农业生产企业的科学决策提供合理参考。

关键词 并购风险;信息熵;风险控制

(From page 12)

绿色农产品封闭供应链优化模型研究

王多宏,李愈,赵红霞,张江泉 (西南交通大学峨眉校区交通运输系,四川峨眉 614202)

摘要 界定了绿色农产品封闭供应链的定义,它由供应商、生产商、分销商、零售商和消费者(顾客)5方构成。分析了分销商的成本构成,主要包括面向上下游企业的农产品订单作业成本、库存成本和供应运输成本3种,并据此建立了绿色农产品封闭供应链的概念模型。通过动态规划的思想构建了绿色农产品封闭供应链的4阶段优化模型,即在农产品供应链具有约束条件、销售量存在不确定性的情况下,考虑具有动态系统和约束条件的供应、生产、分销、零售4阶段的库存成本、供应运输成本和订单作业成本之和的优化问题,从而为供应链管理中的各项分析和决策活动提供参考。

关键词 封闭供应链;运作优化;绿色农产品