# Supply Chain Model Design and Simulation Analysis for Supply Information Sharing

Xu Wang

{1471075803@qq.com}

School of Management, Tianjin University of Technology, 391 Binshui West Road, Xiqing District, Tianjin 300384, China

**Abstract.** A reasonable and effective supply chain system can largely improve the core competitiveness of enterprises and enhance the operational efficiency of the supply chain. This paper qualitatively and quantitatively analyzes the impact of whether suppliers share supply information on manufacturers' order allocation strategy, considers the decision-making process of suppliers, retailers and manufacturers, and constructs a supply information sharing model on this basis to study the cost and profit changes of manufacturers and suppliers. Then simulations were carried out using matlab software. The results prove that information sharing can optimize the manufacturer's order allocation strategy, reduce the manufacturer's production cost and increase the proportion of profit in sales revenue. Supply information sharing is conducive to optimizing the cost and profit of supply chain node enterprises, and the model can be applied to the supply chain management of other enterprises in order to improve the operational efficiency of enterprises and improve the supply chain management system.

**Keywords:** Sharing of supply information，Order Distribution，Benefits optimization

## 1 Introduction

Market competition in the 21st century is a competition between supply chains of different enterprises, and only by forming a coordinated and effective supply chain can enterprises gain competitive advantages in the market. In order to weaken the negative impact of the "bullwhip effect", the information sharing method between enterprises at the nodes of multilevel supply chain comes into being. Manuj found and pointed out that in the case of non-random checking cycle, retailers make full use of shared information such as suppliers' supply capacity to check goods, which can effectively improve their supplemental ordering decision[1]. Doan T. analyzed how shared inventory data can improve suppliers' ordering decision under the situation of smooth demand of retailers, how shared inventory data can improve suppliers' ordering decisions[2]. Acar argued that information sharing can reduce the fluctuation and amplification of information in the supply chain, and that information sharing is more favourable to the upstream of the supply chain than the downstream, suggesting that the upstream of the supply chain should take incentives to promote information sharing[3]. Doning measured the weakening effect of demand and supply information sharing on the "bullwhip effect", and concluded that information sharing is beneficial to the performance optimization of supply chain members[4-6], and also researched the problems of information sharing in the supply chain[4].

ICEMBDA 2023, October 27-29, Tianjin, People's Republic of China

DOI 10.4108/eai.27-10-2023.2341992

## 2 Modelling studies

Multiple suppliers supplying the same product to a manufacturer at the same time can increase competition among suppliers and reduce the manufacturer's costs[7-[9]. A manufacturer accepting an order from a retailer and allocating the order to two suppliers will have different order allocation strategies depending on whether or not they have access to the supplier's supply information sharing, resulting in a range of changes in order quantities, costs, and profits[10].

Assuming that the supply chain is described as a single-product, multi-cycle system, and that demand external to the system is induced by customer demand, the potential demand in the market faced by the retailer is a simple regression process AR(1).Retailer i orders quantity at the end of cycle t:

$$y_t^i = d + py_{t-1}^i + \frac{1-\rho^{\delta+2}}{1-\rho}\alpha_t + \frac{\rho(1-\rho^{\delta+1})}{1-\rho}\alpha_{t-1} \quad (1)$$

The meaning of the symbols in the text is shown in Table 1.

**Table 1**. Symbol Meaning

| Symbol | Symbol Meaning |
|---|---|
| $\xi$ | Supplier's production in cycle t |
| $pr_1, pr_2$ | Unit product prices of manufacturer and supplier i |
| $c_1, c_2$ | Unit production cost of manufacturer and supplier i |
| $h_1, h_2$ | Unit product inventory storage costs for manufacturer and supplier i |
| $p_1, p_2$ | Unit product warehouse shortage cost for manufacturer and supplier i |
| $R_1, R_2$ | Cost obtained by manufacturer and supplier i in cycle t |
| N | Supplier production capacity constraints |

## 3 Supply Information Sharing Study

### 3.1 Supplier and Manufacturer Decision Making Process

Assuming that the supply chain discussed in this paper is a single-product supply chain, when supply information is not shared, the manufacturer sends orders randomly to two suppliers offering the same parts, and its ordering strategy is based on the criterion of lowest cost for itself. This ordering strategy made by the manufacturer according to its own situation will lead to unreasonable order allocation and out-of-stock cost. Assuming that the cost of ordering from supplier 1 is less than that of supplier 2, the manufacturer will prefer to send orders to supplier 1 under the same circumstances. Assuming that the number of orders sent to suppliers 1 and 2 are x10 and x20 respectively, the manufacturer's cost function is:

$$C^0 = \int_0^{x_1^0}[pr_1.\xi]dF_1(\xi) + p(x_1^0 - \xi) + (\xi) + \int_0^{x_2^0}[pr_2.\xi]dF_2(\xi) + p(x_2^0 - \xi) + \int_{x_2^0}^{\infty}[pr_2.x_2^0]dF_2(\xi) \quad (2)$$

The manufacturer's profit function is:

$$R^0 = \begin{cases} Y_t \times pr - C^0, Y_t \in [0, \xi] \\ \xi \times pr - C^0, Y_t \in [\xi, \infty] \end{cases} \quad (3)$$

By bringing $\mathrm{Y_t} = \mathrm{x}_1^0 + \mathrm{x}_2^0$ in equation (2),and the second order derivative of the function, we get that it is a strictly concave function, which indicates that the manufacturer ordering cost has a very small value, then its first order derivative is 0 when $(\mathrm{x}_1^0, \mathrm{x}_2^0)$ is the optimal allocation scheme for the order. Supplier i (i=1,2) in period i after accepting the manufacturer's order cost is:

$$C_i(x_i^0) = \int_0^{x_i^0} [c_i . \xi] dF_i(\xi) + p_i(x_i^0 - \xi) + c_i \int_{x_i^0}^{\infty} x_i^0 dF_i(\xi) \quad (4)$$

Profits earned are:

$$R_i(x_i^0) = (pr_i - c_i) \int_0^{x_i^0} \xi dF_i(\xi) - p_i(x_i^0 - \xi) + (pr_i - c_i) \int_{x_i^0}^{\infty} x_i^0 dF_i(\xi) \quad (5)$$

In the supply information sharing case, the entire supply chain decision is initiated by the supplier. Supplier 1 determines the optimal order with cost lowest under the production capacity constraint. Its cost structure includes opening inventory cost, production cost, and out-of-stock cost. Suppose the supplier's optimal order supply scheme is ($x_1^0$,$x_2^0$). Then there are under the optimal order supply scheme:

$$C_1(y_1^1) = \int_0^{y_1^1} [c_i . \xi] dF_1(\xi) + p_1(y_1^1 - \xi) + \int_{y_1^1}^{\infty} c . y_1^1 dF_1(\xi) \quad (6)$$

The profit made is:

$$C_1(y_1^1) = \int_0^{y_1^1} [c_i . \xi] dF_1(\xi) + p_1(y_1^1 - \xi) + \int_{y_1^1}^{\infty} c . y_1^1 dF_1(\xi) \quad (7)$$

Then the second order derivative of equation (8) is obtained and its value is greater than 0 for a convex function, indicating that there is a maximum value of the function. At this time the optimal supply is:

$$R_i(y_1^1) = (pr_1 - c_1) \int_0^{y_1^1} \xi dF_1(\xi) - p_1(y_1^1 - \xi) + (pr_1 - c_1) \int_{y_1^1}^{\infty} y_1^1 dF_1(\xi) \quad (8)$$

Similarly, the optimal supply quantity of supplier 2 can be obtained is:

$$y_1^1 = F_1^{-1} \left[ \frac{pr_1 - c_1}{pr_1 - c_1 + p_1} \right] \quad (9)$$

The manufacturer ordering cost function is:

$$y_2^1 = F_2^{-1} \left[ \frac{pr_2 - c_2}{pr_2 - c_2 + p_2} \right] \quad (10)$$

The manufacturer's profit function is:

$$C^1(x_1^1, x_2^1) = \begin{cases} (pr_1 + c) Y_t, Y_t \in [0, y_1^1] \\ (pr_1 + c) y_1^1 + (pr_2 + c)(Y_t - y_1^1), Y_t \in [y_1^1, y_1^1 + y_2^1] \\ (pr_1 + c) y_1^1 + (pr_2 + c) y_2^1 + p(Y_t - y_1^1 - y_2^1), Y_t \in [y_1^1 + y_2^1, \infty] \end{cases} \quad (11)$$

### 3.2 Retailer ordering strategy

The retailer's order quantity is the sum of the market demand it faces directly and the amount of demand forecast to be released, expressed as:

$$y_t^0 = d + \rho y_{t-1}^0 + \frac{1 - \rho^{t+2}}{1 - \rho} \alpha_t + \frac{\rho(1 - \rho^{t+1})}{1 - \rho} \alpha_{t-1} + \beta \quad (12)$$

Since the ordering cost remains unchanged before and after the information sharing, there is no out-of-stock cost because the retailer buys in excess, so the retailer's cost composition only takes into account the storage cost and the ordering cost, and the composition is as follows:

$$C_R^0 = (h + pr)y_t^0 \tag{13}$$

After supply information is shared cascade by cascade, the retailer order quantity is the sum of market demand and demand forecast, expressed as:

$$y_t^1 = d + \rho y_{t-1}^1 + \frac{1-\rho^{t+2}}{1-\rho}\alpha_t + \frac{\rho(1-\rho^{t+1})}{1-\rho}\alpha_{t-1} + \lambda \tag{14}$$

The cost components of the retailer in this case are:

$$C_R^1 = (h + pr)\ y_t^1 \tag{15}$$

When the depth of supply information sharing reaches this level, the supply chain node enterprises can basically reach the degree of complete trust between the retailer in the upstream manufacturer orders are no longer misrepresented demand expansion, the order quantity that it is facing the real market demand, the expression is:

$$y_t^2 = d + \rho y_{t-1}^2 + \frac{1-\rho^{t+2}}{1-\rho}\alpha_t + \frac{\rho(1-\rho^{t+1})}{1-\rho}\alpha_{t-1} \tag{16}$$

The retailer's cost expression is:

$$C_R^2 = (h + pr)\ y_t^2 \tag{17}$$

Poor cost of supply information not being shared versus supply information being shared on a cascading basis:

$$\Delta C_R^{0,1} = C_R^0 - C_R^1 = (h + pr)(\beta - \lambda) \tag{18}$$

Poor cost of supply information not shared versus supply information shared across levels:

$$\Delta C_R^{0,2} = C_R^0 - C_R^2 = (h + pr)\beta \tag{19}$$

Cost differential between sharing supply information cascade by cascade and sharing supply information across cascades:

$$\Delta C_R^{1,2} = C_R^1 - C_R^2 = (h + pr)\lambda \tag{20}$$

Taken together, the above analysis leads to the conclusion that retailers derive benefits from supply information sharing, and that their cost optimization increases further as the level of sharing progresses from purely level-by-level sharing to cross-level sharing.

## 4 Simulation analysis

Since the theoretical study part of the assumption that the manufacturer to supplier 1 order cost is lower than supplier 2, and the manufacturer's product sales price needs to be higher than its production costs, so the manufacturer, supplier 1 and supplier 2 of the product sales price for the value of pr = 14. pr1 = 4. pr2 = 8, respectively, and the cost of production for the value of c = 6, c1 = 2, c2 = 4, respectively. due to the cost of out-of-stock including the loss of sales margins as well as the loss of corporate reputation, the cost of out-of-stock for the manufacturer and the two suppliers is taken to be p=12, p1=6, p2=10, the retailer's order quantity, $Y_t$=1500. it may be useful to assume that the production capacity constraints of the two suppliers are the same, and to take N=1000. assume that their 12-month production volumes are 800,850,800,800, 900,900,900,800,900, 900, 800, 900, 900.Regression analysis of the data yields a supplier yield of ξ~N(854.50[2]).

The results of the simulation operation of the order allocation strategy($x_1^0$,$x_2^0$) when there is no supply information sharing between the supplier and the manufacturer are shown in Table 1.

**Table 2.** Simulation results without supply information sharing between suppliers and manufacturers

| $x_1^0$ | $x_2^0$ | $c_2^0$ | $R_1^0$ | $R_1^0$ | $C^0$ |
|---|---|---|---|---|---|
| 705 | 795 | 3180 | 1410 | 3180 | 18180 |

After the supply information sharing between the supplier and the manufacturer, the supplier gives the optimal supply quantity policy as ($y_1^1$,$y_1^2$)=(811,817), because the price of supplier 1 is lower than that of supplier 2, and the manufacturer learns the optimal supply quantity of supplier 1 through the supply information sharing, so the manufacturer can send the order to the supplier 1 as far as possible until it meets the optimal supply quantity of supplier 1 as 811, and the remaining order quantity is 1500-811=689, which is sent to supplier 2. The remaining order quantity is 689, which is shipped to supplier 2.The remaining order quantity is 689, which is shipped to supplier 2. In this way, the manufacturer obtains the optimal order allocation strategy in the case of supply information sharing based on the supply information and its own actual situation, and the results of the simulation are shown in Table 2.

**Table 3.** Simulation results of supply information sharing between suppliers and manufacturers

| $y_1^1$ | $y_1^2$ | $x_1^1$ | $x_2^1$ | $c_1^1$ | $c_2^1$ | $R_1^1$ | $R_2^1$ | $C^1$ |
|---|---|---|---|---|---|---|---|---|
| 811 | 817 | 811 | 689 | 1622 | 2756 | 1622 | 2756 | 1775<br>6 |

Comparing the data in Table 1 and Table 2, it is found that $C^0$>$C^1$, i.e., the ordering cost of the manufacturer is reduced through the sharing of supply information. Since the production cost of the manufacturer is constant before and after the sharing of supply information, the profit of the manufacturer will be increased after the sharing of supply information.

Clearly, the above experiment is a case of $Y_t \in [y_1^1, y_1^1 + y_2^1]$, when there is no shortage cost incurred due to the order quantity exceeding the supplier's supply capacity. When $Y_t \in [y_1^1 + y_2^1, \infty]$, then there is a shortage of supply capacity. Due to the sharing of supply information, the manufacturer can target the allocation of orders to avoid the generation of out-of-stock costs, so there is still the conclusion that $C^0$>$C^1$, and because the manufacturer's profit can be expressed as 3, so there must be a manufacturer's supply information sharing before and after the relationship between profit $R^1$>$R^0$. Total sales revenue remains unchanged under the premise of sharing supply information makes the manufacturer to reduce the cost of improving profits.

In the simulation study of the retailer's ordering strategy, it is assumed that the retailer's inventory storage cost h=2, the product sales price is higher than its production cost, pr=12, order quantity=1500, and the demand forecast is enlarged by β=500, λ=200. The results of the simulation are shown in Table 3.

**Table 4.** Simulation results of retailer supply information sharing

| $C_R^0$ | $C_R^1$ | $C_R^2$ | $\triangle C_R^{01}$ | $\triangle C_R^{02}$ | $\triangle C_R^{12}$ |
|---|---|---|---|---|---|
| 28000 | 23800 | 21000 | 4200 | 7000 | 2800 |

Table 4 shows the comparison of the values of and reveals that the value of $\triangle C_R^{01}$is much larger than the value of $\triangle C_R^{12}$. This implies that the first step in cost optimization is to engage in supply information sharing. Similar to the manufacturer's case, supply information sharing when total sales revenue is fixed also leads to an increase in the profit gained by the retailer.

## 5 Conclusions

For manufacturers' order allocation strategy, this paper qualitatively analyses the impact of whether suppliers share supply information on manufacturers' order allocation strategy, and constructs mathematical models to study the cost and profit changes of manufacturers and suppliers. The conclusion is that supply information sharing can optimize the manufacturer's order allocation strategy, reduce the manufacturer's production cost, and increase the proportion of profit in sales revenue; for retailers, this paper mainly conducts qualitative and quantitative analyses on the three scenarios of retailers' non-participation in supply information sharing, their participation in level-by-level information sharing, and their participation in cross-level information sharing, and it is concluded that the retailers' improvement of operation process and active participation in supply information sharing will lead to cost reduction. supply information sharing will get cost reduction and profit increase. Participation in information sharing is a key first step towards cost optimization, and the optimization benefits of deepening the sharing of supply information from level to level are greatly increased. Finally, the results from Matlab simulation are analyzed to quantitatively prove the correctness of the qualitative analysis.

## References


[1] Manuj I, Sahin F. A model of supply chain and supply chain decision-making complexity[J]. International Journal of Physical Distribution & Logistics Management, 2011, 41(5): 511-549.

[2] Doan T. Supply chain management drivers and competitive advantage in manufacturing industry[J]. Uncertain Supply Chain Management, 2020, 8(3): 473-480.

[3] Acar A Z, Uzunlar M B. The effects of process development and information technology on time-based supply chain performance[J]. Procedia-Social and Behavioral Sciences, 2014, 150: 744-753.

[4] Soetjipto N, Susilo D E, Riswanto A. Supply chain strategies in mediating the effect of knowledge management on business performance[J]. Humanities & Social Sciences Reviews, 2020, 8(1): 448-455.

[5] Nguegan Nguegan C A, Mafini C. Supply chain management problems in the food processing industry: Implications for business performance[J]. Acta Commercii, 2017, 17(1): 1-15.

[6] Chen X, Shen Z J. An analysis of a supply chain with options contracts and service requirements[J]. Iie Transactions, 2012, 44(10): 805-819.

[7] Ehimwenma K E, Krishnamoorthy S, Liu Z, et al. Optimal recycle price game theory model for second-hand mobile phone recycling[J]. Environmental Science and Pollution Research, 2021: 1-16.

[8] Halati A, He Y. Analysis of supply chains with quantity based fixed incentives[J]. European Journal of Operational Research, 2010, 202(1): 214-222.
[9] Khalilzadeh M, Karami A, Hajikhani A. The multi-objective supplier selection problem with fuzzy parameters and solving the order allocation problem with coverage[J]. Journal of Modelling in Management, 2020, 15(3): 705-725.
[10] Une R P, Sangle S T. Enhancing profitability through efficient supply chain management in fast moving consumer goods industry in India[J]. 2014