International Journal of Multimedia and Ubiquitous Engineering
Vol.11, No.6 (2016), pp.397-410
http://dx.doi.org/10.14257/ijmue.2016.11.6.36

Vendor Managed Inventory Integration on Pharmaceutical Third-party Logistics

Bo Jiang and Lan Teng

School of Management and Economics, Beijing Jiaotong University, Beijing, China
E-mail: tenglan@bjtu.edu.cn

Abstract

VMI can integrate logistics resource more systematically and more efficiently, but pharmaceutical logistics companies rarely consider VMI in inventory management as in the process of implementation, the degree of logistics specialization, information sharing, information technology, and benefit distribution have all become restrict factors of VMI. important role Based on the pharmaceutical logistics theory and logistics system integration theory, the research analyses the pharmaceutical logistics system in China. Aiming at the problem of high inventory, the study uses the method of Vendor Managed Inventory to establish inventory integration model, makes corresponded case study and the sensitivity analysis. The conclusion turns out some important that VMI is advantageous in pharmaceutical inventory integration. The study explores the active role of VMI in pharmaceutical logistics integration theoretically.

Keywords: *Vendor Managed Inventory, Logistics integration, Pharmaceutical logistics, Inventory integration*

1. Introduction

Vendor Managed Inventory (VMI) - a systematic method of inventory management in supply chain, is a method that the upstream enterprises manage and control the inventory of downstream enterprises in supply stream. As the intensify market competition, for some drugs, more and more buyers require Vendor Managed Inventory strategy. Using VMI to integrate inventory resources, third-party logistics enterprises bring their advantages of specialization and scale, so that vendors can use third-party logistics enterprises to integrate pharmaceutical storage and distribution from several downstream demand enterprises. Third-party logistics enterprises can supply specialized facilities & equipment, advanced logistics information platform *etc.* for suppliers to make demand prediction, transport, quality control, delivery, and a full range of services.

As for Pharmaceutical logistics, VMI can reduce logistics burden and improve operational efficiency, address technology shortages and strengthen information sharing, raise the specialization of management and improve customer satisfaction, and enhance risk-sharing and enterprises contacts. Therefore, pharmaceutical logistics integration needs to integrating related upstream and downstream enterprises. Liao [1] came up with this idea in early times. As the mature and widely research of supply chain theory, pharmaceutical logistics joint the party of supply chain management to achieve the efficient operation of pharmaceutical logistics. Rong [2] analyzed pharmaceutical market of China and brought up that JIT (Just In Time) can be used to reduce logistics cost. Wei [3] discussed the request of carrying out supply chain management in pharmaceutical logistics area through the study of modern pharmaceutical logistics concept definition and supply management mode. Karimi [3] researched international drug enterprises finding that for these companies there are some difficulties in realizing global supply chain management, and carried out MILP model which considers the factors of purchase,

ISSN: 1975-0080 IJMUE

product, distribute, and differences in international tax, resulting in that inventory holding cost, drug life cycle, and other factors' after-tax revenue can promote drug supply chain management. Yu *et al* [4] explored the performance and distortions of Chinese drug market based on the literature review and public electronic databases and research information in the official websites of the government, concluding that there are ineffective supervision and other problems in Chinese drug logistics. Narayana *et al* [5] supplied some related advices in pharmaceutical production & sales environment and health care. They considered that drug logistics and supply chain should realize convenient medical purchases. There are scholars managed pharmaceutical logistics. Guerrero [6] used a heuristic algorithm to find out the near-optimal level of orders for each product in the central pharmacy policy, ensuring all other parameters are of optimal policy structure model, which made the hospital reduce about 45% inventory value. At the same time, the service level of the hospital raised. Uthayakumar [7] considered that the shortage and abuse of pharmaceutical medicine would not only bring economic loss, but also produce significant influence, so he carried out an inventory model and integrated continuous feedback supply chain considering the produce and sale of pharmaceutical companies and hospital supply chain, which has made significant influence in drug inventory management.

With the fierce market competition, compared with traditional modes, VMI can integrate logistics resource more systematically and more efficiently. However, the reality is that pharmaceutical logistics companies rarely consider VMI in inventory management as in the process of implementation, the degree of logistics specialization, information sharing, information technology, and benefit distribution have all become restrict factors of VMI. For pharmaceutical logistics, there are strict requirement for inventory management, so companies should improve their competitiveness but also control high inventory costs [8-10].

Based on the pharmaceutical logistics theory and logistics system integration theory, the research analyses the pharmaceutical logistics system in China. Aiming at the problem of high inventory, the study uses the method of Vendor Managed Inventory to establish inventory integration model, makes corresponded case study and the sensitivity analysis. The study is organized as follows: in the following section, we analyze the pharmaceutical third-party logistics, which provide the necessities to implement VMI inventory integration. In Section 3, we introduce the Inventory Management Model, which forms the theoretical foundation of this study. In Section 4, we carry out the analysis of model, as well as the results through which we verify the model. Finally we conclude the whole study.语言

2 Analysis on Pharmaceutical Third-Party Logistics VMI Inventory Integration

Third-party logistics has the following necessities to implement VMI inventory integration.

i. Professional logistics services

Owning advanced information facility and technology, third-party logistics companies focus on specialized logistics service. Facing the constantly changing market, third-party logistics enterprises have better understandings on the features and risk management, and can quickly respond to changes in demand. Using third-party logistics can reduce costs, capital investment to enable enterprises to achieve sophisticated logistics information management service in order to raise customer service level and reduce the uncertainty risk of demand [11-12].

ii. Sophisticated information management system

Third-party logistics have sophisticated information management system, including warehouse management system, customer relationship management system to achieve the effective connection between upstream and downstream customers to have inventory management. Third-party logistics companies involve market prediction through information system from downstream, and they can combine the production capacity of suppliers to issue demand plan, make safe stock, and determine the amount & time of replenishment to ensure information sharing while accurately reflect market demand.

iii. Advanced information technology support

Third-party logistics companies can take advantage of their advanced information technologies, including original technology data acquisition, data storage, data transmission technology, providing technical support for VMI implementation [13]. Figure 1 shows the information technology support which can realize long-distance data exchange, real-time data processing and data exchange between enterprises; realize the synchronize inventory information of upstream and downstream to proceed effective inventory management; supply order processing, billing, inventory information query *etc.*. online business to effectively reduce resource duplication and waste.

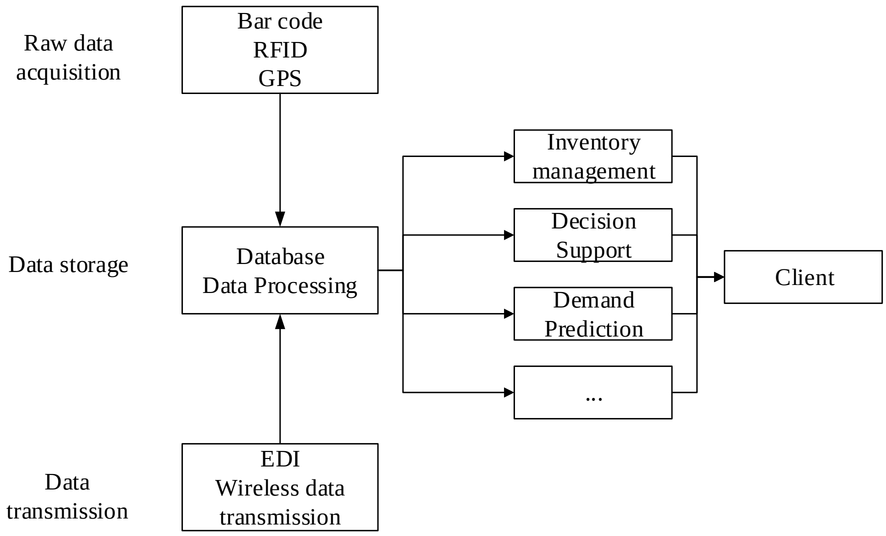

Figure 1. Information Technology Support of Third-Party Logistics

iv. Effective integration of resources

Under VMI model, third-party logistics serve for one supplier and several customers. In pharmaceutical field, there are always multiple supplier serve for one customer [14]. In Figure 2, third-party logistics can use the advantage of specialization and scale to serve multiple suppliers for transport, storage. It is conducive to realize the optimization of overall value.

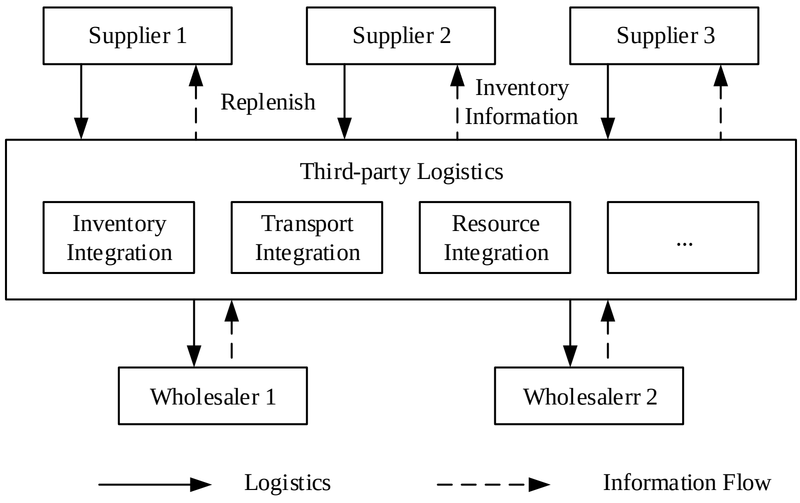

Figure 2. Resource Integration of Third-Party Logistics

3. Inventory Management Model Based on VMI

3.1 Model Assumption and Symptoms

Model assumption

i. The model considers the structure of one supplier and multiple wholesalers.

ii. Before and after integration are both VMI inventory management method. Before is suppliers establish VMI in wholesalers; after is VMI based on third-party logistics

iii. Random Market demand

iv. There are multiple demand circle in wholesalers

v. Considering stock-out cost

vi. Considering safety inventory

vii. Wholesalers require to satisfy certain service level

viii. Temperature cost are considered

iv. Suppliers and third-party logistics company use (s, Q) strategy to have inventory checked constantly, when inventory level is below order point it is time to order, order quantity is Q, which is EOQ

Parameter

M Demand circle

N Number of wholesalers

d_i Demand quantity of wholesaler i

Q_i Amount of replenishment of wholesaler

F_i Inventory cost of goods in unit time per unit of wholesaler i

F_i' Inventory cost of goods in unit time per unit of wholesaler i after integration

$\mathbf{B_i}$ Shortage cost of wholesaler i

$\mathbf{B_i}'$ Shortage cost of wholesaler I after integration

SS_i Safety inventory of wholesaler i

SS_i' Safety inventory of wholesaler i after integration

θ Required service level of wholesaler

C_i Replenishment cost of wholesaler i

$C_i^{'}$ Replenishment cost of wholesaler i after integration

T Temperature control cost

R Transportation cost

TC Total logistics cost of supply chain before integration

$TC^{'}$ Total logistics cost of supply chain after integration

3.2. Inventory Integration Model Based on VMI

Considering random demand, in order to control shortage cost, inventory cost and service level should be taken into account, and also design proper safety stock. Service level is an important factor influencing safety stock, especially for the drug industry. So when considering safety stock level, required service level of wholesalers should be taken into account seriously. Obviously, when service level is high, safety stock is high; service level is low, safety stock is low.

Known that drug wholesaler demand obeys the probability distribution with mean value of d and a standard deviation of σ, the required service level of wholesaler is θ. $p(x < Z_\theta) = \theta$, Z_θ is the percentile point on the probability distribution. If the probability distribution is known, Z_θ can be ensured, so that safety stock level

$$SS = Z_\theta - d \tag{1}$$

Assume that the demand obeys normal distribution, and service level $\theta = 95\%$, so

$$p\left(\frac{x-d}{\sigma} < \frac{Z_\theta - d}{\sigma}\right) = 95\% \tag{2}$$

From normal distribution chat,

$$\frac{Z_\theta - d}{\sigma} = 1.65 \tag{3}$$

So,

$$SS = 1.65\sigma \tag{4}$$

Without considering the involvement of third-party logistics, total inventory cost consists of replenishment cost, inventory holding cost, shortage cost and temperature control cost, which are respectively

$$TC_1 = \sum_{i=1}^{N} C_i \times Md_i / Q_i \tag{5}$$

$$TC_2 = \sum_{i=1}^{N} F_i (Q_i / 2 + SS_i) \tag{6}$$

$$TC_3 = \sum_{i=1}^{N} B_i \times Md_i / Q_i \int_{Q_i+SS_i}^{\infty} (x - Q_i - SS_i) f(x) dx \tag{7}$$

$$TC_4 = T \times \sum_{i=1}^{N} Md_i / Q_i \tag{8}$$

So the total cost of inventory is

$$TC = TC_1 + TC_2 + TC_3 + TC_4$$
$$= \sum_{i=1}^{N}[C_i \times Md_i / Q_i + F_i(Q_i/2 + SS_i) + B_i \times Md_i / Q_i \int_{Q_i+SS_i}^{\infty}(x - Q_i - SS_i) f(x)dx] \quad (9)$$
$$+ T \times \sum_{i=1}^{N} Md_i / Q_i$$

$f(x)$ is demand density function of wholesaler i.

After the involvement of third-party logistics, total inventory cost consists of replenishment cost of third-party logistics, inventory holding cost, storage cost of third-party logistics, and shortage cost of third-party logistics companies. As the involvement of third-party logistics, the transport cost of "supplier to third-party logistics" is added, so transport cost of third-party logistics is added.

Inventory cost of wholesaler is

$$TC_1^{'} = \sum_{i=1}^{N} F_i \times d_i / 2 \quad (10)$$

Inventory cost of third-party logistics is

$$TC_2^{'} = F^{'} \times (Q^{'}/2 + SS^{'}) \quad (11)$$

Replenishment cost of third-party logistics is

$$TC_3^{'} = C^{'} \times M \sum_{i=1}^{N} d_i^{'} / Q^{'} \quad (12)$$

Shortage cost is

$$TC_4^{'} = B^{'} \times M \sum_{i=1}^{N} d_i^{'} / Q^{'} \times \int_{Q_i^{'}+SS_i}^{\infty} (x - Q^{'} - SS) f(y)dy^{'} \quad (13)$$

Temperature control cost is

$$TC_5^{'} = T \times M \sum_{i=1}^{N} d_i^{'} / Q^{'} \quad (14)$$

Transport cost is

$$TC_6^{'} = \sum_{i=1}^{N} M \times R^{'} \quad (15)$$

So,

$$TC^{'} = TC_1^{'} + TC_2^{'} + TC_3^{'} + TC_4^{'} + TC_5^{'} + TC^{'}_6$$
$$= \sum_{i=1}^{N} F_i \times d_i / 2 + F^{'} \times (Q^{'}/2 + SS^{'}) + C^{'} \times M \sum_{i=1}^{N} d_i^{'} / Q^{'}$$
$$+ B^{'} \times M \sum_{i=1}^{N} d_i^{'} / Q^{'} \times \int_{Q_i^{'}+SS_i}^{\infty} (x - Q^{'} - SS) f(y)dy \quad (16)$$
$$+ T \times M \sum_{i=1}^{N} d_i^{'} / Q^{'} + \sum_{i=1}^{N} M \times R^{'}$$

$f(y)$ is demand density function of third-party logistics company.

As (9) and (16) shown, the change of total cost before and after third-party logistics company involves in vendor managed inventory 加上 Equation

$$\Delta C = TC - TC^{'}$$

$$= \sum_{i=1}^{N}[C_i \times Md_i / Q_i + F_i(Q_i/2 + SS_i) + B_i \times Md_i / Q_i \int_{Q_i+SS_i}^{\infty}(x - Q_i - SS_i) f(x)dx]$$

$$\begin{aligned} &+ T \times \sum_{i=1}^{N} M \times d_i / Q_i - [\sum_{i=1}^{N} F_i \times d_i / 2 + F^{'} \times (Q^{'} / 2 \\ &+ SS^{'}) + C^{'} \times M \sum_{i=1}^{N} d_i^{'} / Q^{'} \\ &+ B^{'} \times M \sum_{i=1}^{N} d_i^{'} / Q^{'} \times \int_{Q_i^{'}+SS_i}^{\infty} (x - Q^{'} - SS) f(y)dy \\ &+ T \times M \sum_{i=1}^{N} d_i^{'} / Q^{'} + \sum_{i=1}^{N} M \times R^{'}] \end{aligned} \tag{17}$$

3.3 Model Solution

According to the assumption, demand obeys normal distribution, so assume that required service level of wholesaler is 95%, $\theta = 95\%$, and probability of stock-out is 5%.

First, $\int_{Q_i+SS_i}^{\infty}(x - Q_i - SS_i)f(x)dx$ should be simplified.

Known for probability distribution chart, when $\theta = 99.86\%$, it can be determined not to be out of stock.

$$\rho(\frac{x-d}{\sigma} \prec \frac{Z_\theta - d}{\sigma}) = 99.86\% \tag{18}$$

So,

$$\frac{Z_\theta - d}{\sigma} = 2.99 \tag{19}$$

$$SS = 2.99\sigma \tag{20}$$

When service level is determined as 95%, the maximum amount of stock-out is

$$2.99\sigma - 1.65\sigma = 1.34\sigma \tag{21}$$

Expect of stock-out is

$$1.34\sigma \times 5\% = 0.067\sigma \tag{22}$$

In the course of model solution, EOQ model is selected. The principal of EOQ is keeping the certain amount of storage under the circumstances of several kinds of related cost. In the case of fixed total demand, the smaller the order quantity is, the lower the inventory and storage cost are.

4. Model Analysis

4.1. Method

(1) Demand cycle, number of wholesalers, transport unit cost and temperature control cost unit are given, the related parameter of supply chain members before and after third-party logistics integration are random, including demand cycle, wholesalers' demand, standard deviation of wholesalers' demand, wholesaler inventory storage cost per unit, wholesaler shortage cost per unit, replenishment from suppliers to wholesalers cost, storage cost of third-party logistics per unit, third-party logistics transport cost, third-party logistics replenishment cost, and shortage cost of third-party logistics.

(2) Calculate the total cost difference before and after third-party logistics involve in VMI inventory integration.

(3) Observe the cost variation of one of the parameter increase a fixed amount unit.

The process of solution is as follows.

(1) Initial number

Fixed numbers are given to give the solution. N=10, M=20, T=10, R=10

Wholesalers' demand, demand variance, replenishment cost, storage cost, shortage cost are all random numbers.

(2) Programing

Through Matlab programing, Table1 and Table 2 are the results

Table 1. Parameters Before the Involvement of Third-Party Logistics

Serial	Demand	Standard deviation	Replenishment cost	Storage cost	Shortage cost
1	103.7627	22.90441	10.87965	5.094229	10.65445
2	101.9092	26.17091	10.81776	5.598524	10.40762
3	104.2825	22.65281	10.26073	5.470924	10.81998
4	104.8202	28.24376	10.59436	5.695949	10.71836
5	101.2061	29.82663	10.02251	5.699888	10.96865
6	105.8951	27.30249	10.42526	5.638531	10.53133
7	102.2619	23.43877	10.31272	5.033604	10.32515
8	103.8462	25.84069	10.16148	5.068806	10.10563
9	105.8299	21.07769	10.17877	5.3196	10.61096
10	102.5181	29.06308	10.42289	5.530864	10.7788

Table 2. Parameters After the Involvement of Third-Party Logistics

Serial	Demand	Standard deviation	Replenishment cost	Storage cost	Shortage cost
1	1036.332	81.61796	10.42345	3.090823	10.26647

$TC = 10457$

$TC' = 7803$

$\Delta C = TC - TC' = 2653.9$

From the data above, total logistics cost of supply chain before the involvement of third-party logistics is 10457, after the involvement of third-party logistics the total cost is 7803. So it is concluded that the involvement of third-party logistics in supply chain management inventory integration can lower the total logistics cost.

4.2. Sensitivity Analysis

As shown in expression of (17), cost variation before and after integration is affected by many factors. This part will analysis the sensitivity of parameters to find out the influenced factors of inventory integration in order to supply theory support for third-party logistics integration.

4.2.1. Wholesalers' Inventory Storage Cost

Keeping other parameters still, change wholesaler's inventory storage cost per unit by two units, and observe the cost variation before and after the involvement third-party logistics. Data change and results are shown in Table 3. Figure 4 is based on the simulation data of a line chart, where y is cost variance, abscissa is inventory storage cost per increases of wholesalers.

Table 3. Variation of Inventory Storage Cost of Wholesalers

Added unit of wholesalers' storage cost	TC	TC'	ΔC
2	13036.38	10471.22	2565.162
4	15218.17	11533.61	3684.567
6	17307.26	12595.99	4711.268
8	19333.83	13658.38	5675.45
10	21315.94	14720.76	6595.179
12	23265.19	15783.15	7482.041
14	25189.39	16845.53	8343.855
16	27094.03	17907.92	9186.109
18	28983.08	18970.31	10012.78
20	30859.51	20032.69	10826.82
22	32725.55	21095.08	11630.47

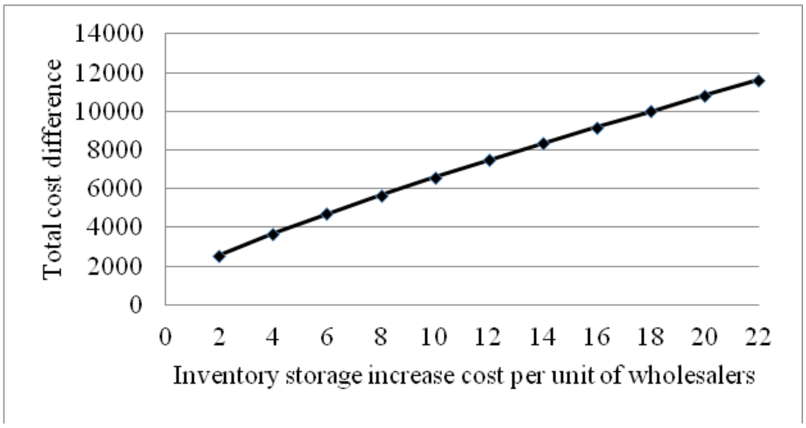

Figure 4. Inventory Storage Cost Variation Tendency of Wholesalers

It can be concluded that as the storage unit cost of wholesaler's raises, total difference becomes bigger and raises steadily.

4.2.2. Inventory Storage Cost of Third-Party Logistics

Keeping other parameters still, change third-party logistics' inventory storage cost per unit by two units, and observe the cost variation before and after the involvement third-party logistics. Data change and results are shown in Table 4. Figure 4 is based on the simulation data of a line chart, where y is cost variance, abscissa is inventory storage cost per increases of third-party logistics.

Table 4. Inventory Storage Cost Variation of Third-Party Logistics

Added unit of third-party logistics storage cost	TC	TC'	ΔC
2	37380.04	31516.2	5863.846
4	37380.04	37502.62	-122.575
6	37380.04	43088.38	-5708.34
8	37380.04	48537.79	-11157.8

10	37380.04	53924.45	-16544.4
12	37380.04	59277.03	-21897
14	37380.04	64609.05	-27229
16	37380.04	69927.7	-32547.7
18	37380.04	75237.18	-37857.1
20	37380.04	80540.09	-43160
22	37380.04	85838.14	-48458.1

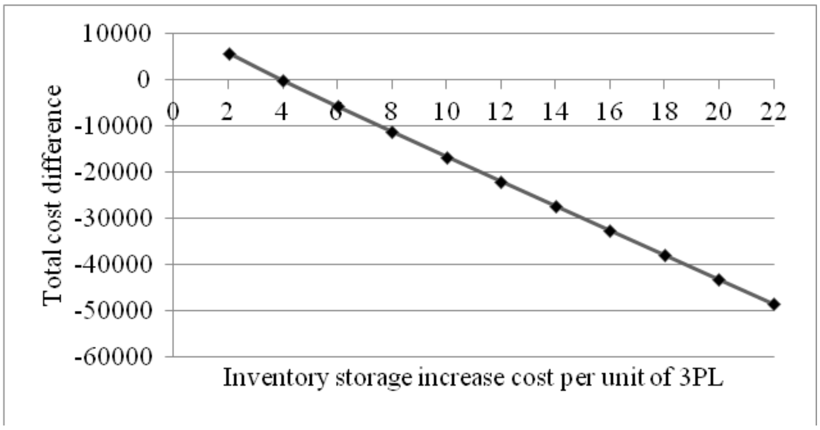

Figure 6. Inventory Storage Cost Variation Tendency of Third-Party Logistics

Known for Figure 6, as the increase of unit cost of inventory storage cost of third-party logistics, total cost becomes smaller. When there is no storage advantages, the total cost after integration is bigger than that of before. So it is essential for third-party logistics to raise the ability of storage, and it is important for suppliers to investigate the storage ability of third-party logistics enterprises.

4.2.3. Wholesaler's Demand Variance

Keeping other parameters still, change wholesaler's demand variance per unit by two units, observe the cost variation before and after the involvement third-party logistics. Data change and results are shown in Table 5. Figure 7 is based on the simulation data of a line chart, where y is cost variance, abscissa is demand variance increases of third-party logistics.

Table 5. Wholesaler's Demand Variance

Added unit of Wholesaler's demand variance	TC	TC'	ΔC
2	11076.21	7091.187	3985.024
4	11446.33	7179.31	4267.018
6	11816.44	7267.426	4549.018
8	12186.56	7355.538	4831.023
10	12556.68	7443.645	5113.032
12	12926.79	7531.748	5395.046
14	13296.91	7619.848	5677.062
16	13667.03	7707.946	5959.081
18	14037.14	7796.04	6241.103
20	14407.26	7884.133	6523.127
22	14777.38	7972.224	6805.153

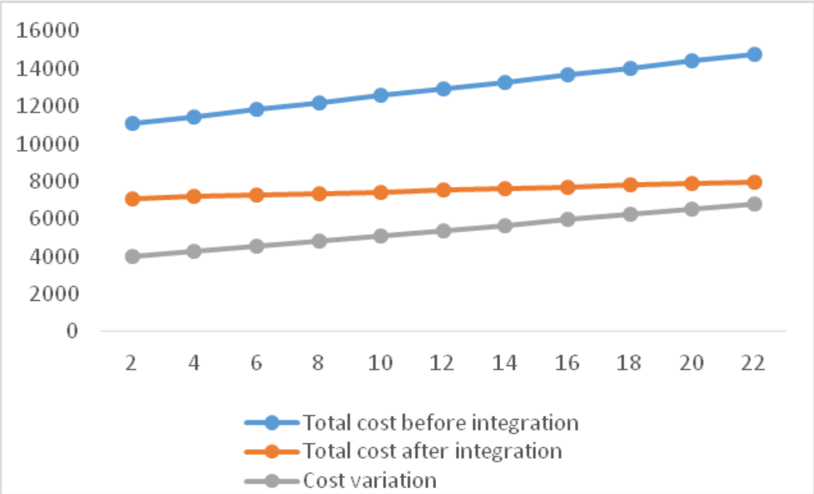

Figure 7. Cost Variation Tendency of Wholesaler when Demand Variance Changes

Demand variation reflects the stability of market demand. Shown in Figure 7, as the increase of wholesalers' demand variance, the cost increases faster before integration, the cost increase steadily after integration, so that the cost variation is becoming bigger. In order to meet the changing market demands, it is necessary for third-party logistics to use the advantage of specialization and standardization to response to instability of the demand. When market demand is uncertain, it is more advantageous to use third-party logistics to control cost.

4.2.4. Demand Cycle

Keep other parameters still, change the demand cycle per unit by thirty units for the sake of study the overall trend, and observe the cost variation before and after the involvement of third-party logistics. Data change and results are shown in Table 6. Figure 8 is based on the simulation data of a line chart, where y is cost variance, abscissa is demand cycle.

Table 6. Data When Demand Cycle Changes

Demand cycle	TC	TC'	ΔC
30	15035.67	8115.83	6919.836
60	19293.44	10658.88	8634.556
90	22584.33	12851.53	9732.799
120	25366.83	14859.93	10506.9
150	27822.21	16749.78	11072.43
180	30044.3	18555.08	11489.21
210	32089.15	20296.15	11792.99
240	33993.42	21986.28	12007.14
270	35782.66	23634.71	12147.95
300	37475.49	25248.21	12227.28
330	39085.99	26831.87	12254.12

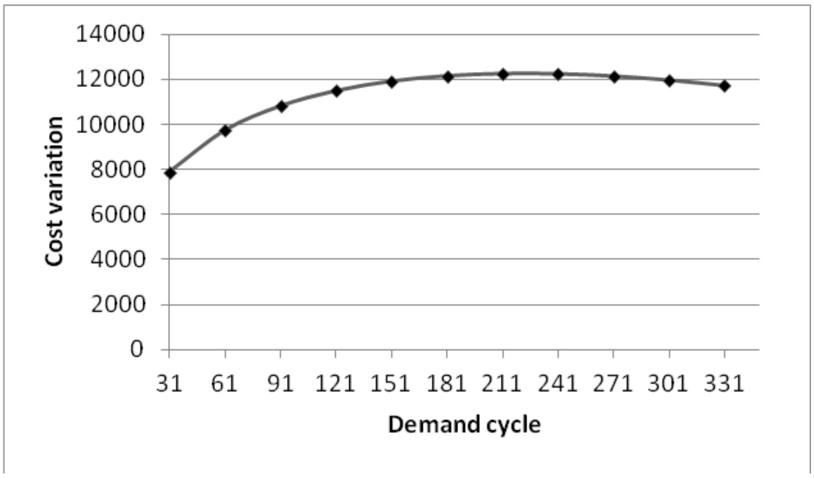

Figure 8. Sensitivity of Demand Cycle

Shown in Figure 8, as the increase of demand cycle, cost variation before and after the involvement of third-party logistics first increases and then diminishes. Obviously, there is optimal demand cycle. When demand cycle is small, cost variance increases; when demand cycle is bigger, cost increase of third-party logistics exceeds that before integration, so that the cost variation before and after integration becomes smaller.

4.2.5. Transport Cost of Third-Party Logistics

Keep other parameters still, change transport cost of third-party logistics per unit by two units, and observe the cost variation before and after the involvement of third-party logistics. Data change and results are shown in Table 7. Figure 9 is based on the simulation data of a line chart, where y is cost variation, abscissa is the increase of demand variance.

Table 7. Transport Cost Variation of Third-Party Logistics

Added unit of wholesalers' demand variance	TC	$TC^{'}$	ΔC
2	41376.21	170164.9	-128789
4	41376.21	174164.9	-132789
6	41376.21	178164.9	-136789
8	41376.21	182164.9	-140789
10	41376.21	186164.9	-144789
12	41376.21	190164.9	-148789
14	41376.21	194164.9	-152789
16	41376.21	198164.9	-156789
18	41376.21	202164.9	-160789
20	41376.21	206164.9	-164789
22	41376.21	210164.9	-168789

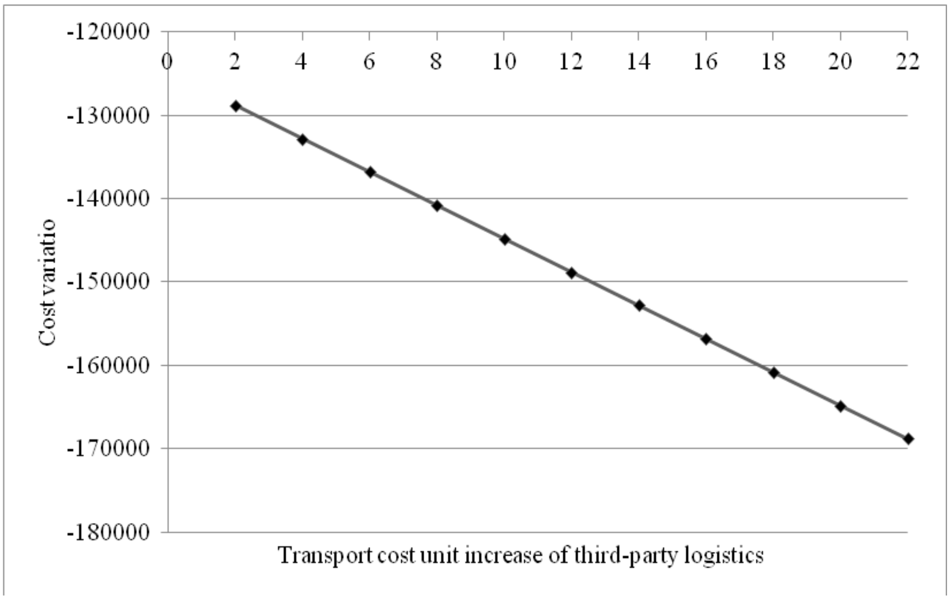

Figure 9. Transport Cost of Third –Party Logistics Sensitivity Analysis

From Figure 9, as the transport cost increases, cost variance becomes smaller and smaller. Therefore, in order to make total cost after integration becomes smaller, it is necessary to control transport cost of third-party logistics. Meanwhile, transport capacity is an important factor when vendors selecting third-party logistics service provider.

5. Conclusion

First the factors that influenced inventory integration with the involvement of third-party logistics are quantitatively analyzed, then for multiple wholesalers and single supplier supply chain structure, considering stochastic demand, shortage, and meet certain service standards, and establish a more realistic inventory consolidation model. Then the sensitivity of the model are respectively analyzed. The results are as follows.

i. The integration of third-party logistics and VMI can effectively reduce total cost of inventory.

ii. The factors that influenced integration effect are comprehensively analyzed from the view of vendor. It can be concluded that once vendor inventory cost are high, demand is unstable, and a higher service level wholesalers, it is necessary for vendors to outsource VMI to third-party logistics, at the same time storage capacity, transport capacity should be focused on intensively.

iii. As third-party logistics serviceproviders, third parties should strengthen the calculation of core competitiveness of logistics, especially in warehousing and transport, *etc.*.

In conclusion, VMI has some advantages in drug logistics, but as the qualification requirement of drug regulatory authorities, the feasibility of VMI needs further exploration and research.

Acknowledgements

This paper is based on major project “City Logistics” of National Natural Science Foundation (Project Number: 71390334), and Laboratory of Logistics Management and Technology.

Reference

[1] Q. Liao, "Drug Logistics Upstream and Downstream Demand Integration", Information and Computer, vol. 10, **(1998)**, pp. 29-30.
[2] D. Rong, "Discussion on Pharmaceutical Logistics Cost Control", Commercial Times, no. 33, **(2006)**.
[3] G. Wei, "Implementation of Drug Logistics and Supply Chain Management in China", Development on Pharmaceutical, vol. 11, **(2008)**, pp. 513-515.
[4] N. Susarla and I. A. Karimi, "Integrated supply chain planning for multinational pharmaceutical enterprises", Computers and Chemical Engineering, no. 42, **(2012)**, pp. 168–177.
[5] X. Yu, C. Li, Y. Shi and M. Yu, "Pharmaceutical supply chain in China: Current issues and implicationsfor health system reform", Health Policy, no. 97, **(2010)**, pp. 8-15.
[6] S. A. Narayana, R. K. Pati and P. Vrat, "Managerial research on the pharmaceutical supply chain–A criticalreview and some insights for future directions", Journal of Purchasing & Supply Management, no. 20, **(2014)**, pp. 18-40.
[7] Jointown Pharmaceutical, "On RFID Tracking System to the Problem of Drug Logistics", Information and Computer, vol. 3, **(2010)**, pp. 52.
[8] W. J. Guerrero, T. G. Yeung and C. Guéret, "Joint-optimization of inventory policies on a multi-productulti-echelon pharmaceutical system with batching and ordering on straints", European Journal of Operational Research, no. 231, **(2013)**, pp. 98-108.
[9] D. Kim, S. John and D. Eric, "Determinants of successful vendor managed inventory relationships in oligopoly industries", International Journal of Physical Distribution & Logistics Management, vol. 36, no. 3, **(2006)**, pp. 176-191.
[10] A. F. De Toni and E. Zamolo, "From a traditional replenishment system to vendor-managed inventory: A case study from the household electrical appliances sector", International Journal of Production Economics, vol. 96, no. 1, **(2005)**, pp. 63-79.
[11] J. K. Jha and K. Shanker, "An integrated inventory problem with transportation in a divergent supply chain under service level constraint", Journal of Manufacturing Systems, vol. 281, **(2014)**, pp. 1-14.
[12] Y. Dong and K. Xu, "A supply chain model of vender managed inventory", Transportation Research Part E, vol. 38, **(2002)**, pp. 75-95.
[13] Y. Yao, P. T. Evers and M. E. Dresner, "Supply chain integration in vendor-managed inventory", Decision Support Systems, vol. 43, **(2007)**, pp. 663-674.
[14] C. K. Huang, D. M. Tsai and J. C. Wu, "An integrated vendor-buyer inventory model with order-processiong cost reduction and permissible delay in payments", European Journal of Operational Research, vol. 202, **(2010)**, pp. 473-478.

