VMI and demand pooling effect in pharmaceutical supply chain

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1. Introduction

Health sector needs sophisticated supply chain optimization techniques, because of the need to balance future capacity with anticipated demands in the face of the important uncertainty resulting from clinical trials and competitors' activity. (Shah, 2004). The pharmaceutical supply chain has recently attracted the attention of academics, researchers, government officials and suppliers as one of the key tools in their effort to manage the costs of care and improve quality at the same time. (Elmuti and al, 2013). Many researchers and experts say that Supply Chain Management (SCM) principles; should be applied to the health sector industries in order to simultaneously; achieve significant, cost savings and improved quality of services. About the advantages of the adaptation of such principles, we can cite (the increase of services and materials availability and reduction of medical errors).

There have been many attempts to improve the hospital supply chain through cooperation between their members (Ford and Scanlon, 2007). Among collaborative health care supply chain techniques, we find the vendor management inventory VMI, which was born in the United States in the 1980s. The first adopters of this strategy were large retailers like Wal-Mart and JC Penney (Bhakoo and Singh, 2012). The VMI is a system where the supplier assumes responsibility for monitoring the retailer's inventory levels and makes periodic replenishment decisions regarding order quantities, delivery method and replenishment date. (Waller, Johnson, and Davis, 1980); (Sahin and Dallery, 2009) and (Robinson, 2002). In other side, supply chain risk management is well mentioned in the literature, since the uncertainty of related factors, has an important effect on inventory management (Schmitt and al, 2014). The most important component of the healthcare-supply-chain management is the demand of drugs, which is a stochastic parameter. In order to tackle the uncertainty of drugs demand, risk-pooling management and especially demand pooling can be a useful technique.

In this paper, we will present a two-echelon health care supply chain composed of the central pharmacy, the regional pharmacies and hospitals. The objective of this work is to show the importance of the collaboration by VMI strategy and the demand pooling to optimize the drug inventory management. For this purpose, a mathematical model is developed to demonstrate the impact of collaboration in reducing inventory management costs. The remainder of the paper is organized as follows: section 2 is dedicated for problem description, the mathematical model is presented in section 3 and section 4 is reserved for numerical results.

2. Problem description

We consider a two-echelon health care supply chain consisting of a central pharmacy, regional pharmacies and hospitals. In this supply chain, the regional pharmacy receives drugs from the central pharmacy and then these drugs will-be-distributed to hospitals according to their needs. The main goal of hospitals is to meet the needs of their patients, with the right amount of medication at the right time with the reduced cost, and the goal of regional pharmacies is to minimize inventory management costs. For this purpose, regional pharmacies and hospitals use inventory management policies (R, Q) and (r, q) based on the continuous inventory, which consist in determining at each period the replenishment points "r" and "R "and the order quantities" q "and" Q ", which help to minimize the inventory management cost. In a traditional supply chain without VMI and without demand pooling, each member (supplier or buyer) is responsible for controlling his inventory level. It also supports all inventory management costs (ordering and storage costs). (Claassen et al 2008) In addition, the requests are processed independently; in this case, the variance of the requests is high and subsequently the safety stock increases, which generates an additional storage cost. (Kang and Kim, 2012) In our case, we are interested by vertical collaboration; which consists of VMI contract between central pharmacy and regional pharmacies, and the consideration of demand pooling between each regional pharmacy and hospitals of the same region.

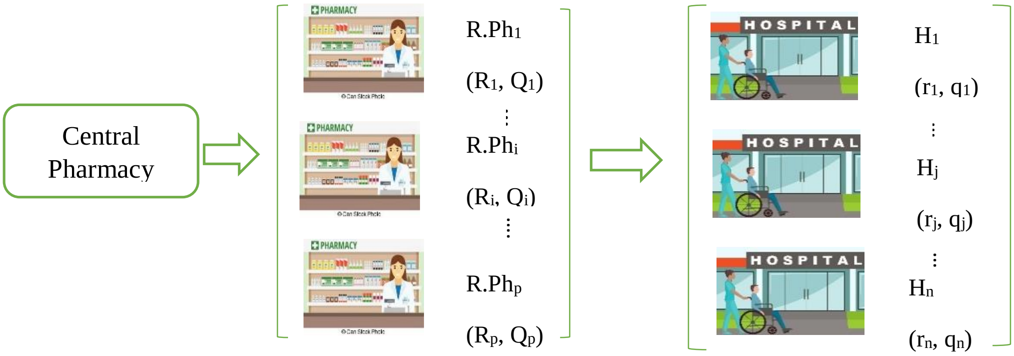

Figure 1. Vertical collaborative health care supply chain.

3. Mathematical Model

The objective of our model is to minimize the inventory management costs for both, regional pharmacies and hospitals of each region, the holding cost and the ordering cost are considered for the two echelons. Therefore, the total cost is the summation of regional pharmacy costs and hospitals costs. With the VMI contract between the central pharmacy and the regional pharmacies, it will be possible for the central pharmacy to monitor inventory levels and variation of demand in regional pharmacies by sharing information on stock levels and uncertainty of request. Consequently, when the stock level in the regional pharmacy reaches the replenishment point "R", an order quantity "Q" will-be-sent by the central pharmacy. Thus, regional pharmacies are no longer obliged to place an order to the central pharmacy; the inventory management cost of regional pharmacies will contains only holding cost and purchasing cost of drugs. On the other hand, by demand pooling effect; regional pharmacies will consider the hospitals demands as one demand by aggregating all demands so the safety stock will decreases, and consequently the holding cost decreases.

Notations:

The sets, indices, parameters, and decision variables used in the model are given as follows:

Set and indices:

P : Number of regional pharmacies, where $i = 1, ..., P$

N : Number of hospitals, where $j = 1, ..., N$

M : Number of kind of drugs, where $j' = 1, ..., M$

Parameters:

$D_{ij'}, d_{jj'}$: Average of demand of drug (j') for regional pharmacy (i) and hospital (j) simultaneously

C_i, c_j : Available storage space for regional pharmacy (i) and hospital (j) simultaneously

$a_{j'}$: Storage space required for a unit of drug (j')

$o_{jj'}$: Ordering cost of drug (j') per replenishment for hospital (j)

$H_{ij'}, h_{jj'}$: Holding cost per unit of drug (j') in regional pharmacy (i) and hospital (j) simultaneously

$b_{j'}$: Purchasing cost per unit of drug (j')

$L_{ij'}$: Lead time required for an order of drug (j') placed to regional pharmacy (i)

$l_{jj'}$: Lead time required for an order of drug (j') placed to hospital (j)

y_{ij} : Binary parameter that equal to 1 if hospital (j) is served by regional pharmacy (i) and 0 else

$S_{ij'}, s_{jj'}$: Safety stock of drug (j') in regional pharmacy (i) and hospital (j) simultaneously

Decision variables:

$Q_{ij'}, q_{jj'}$: Order quantity of drug (j) for regional pharmacy (i) and hospital (j) simultaneously

$R_{ij'}, r_{jj'}$: Reorder point of drug (j') for regional pharmacy (i) and hospital (j) simultaneously

Objective function after VMI and demand pooling effect:

$$Minimize :(holding \cos t + purcha \sin g \cos t)_{regionalpharmacies} + (holding \cos t + ordering \cos t)_{hospitals}$$

- With the VMI effect the , regional pharmacies are no longer obliged to place orders to the central pharmacy, by the way ordering cost will contains only the purchasing cost of drug. With the demand pooling effect, regional pharmacy will consider the hospital's demand as one demand by aggregating all demands so the safety stock will decrease, and consequently the holding cost decreases

Where:

$$(holding \cos t + purcha \sin g \cos t)_{regionalpharmacies} = \sum_{i=1}^{P} \sum_{j'=1}^{M} (H_{ij'}.(\frac{Q_{ij'}}{2} + SS_{ij'}) + b_{j'}.Q_{ij'})$$

$$(holding \cos t + ordering \cos t)_{hospitals} = \sum_{j=1}^{N} \sum_{j'=1}^{M} (h_{jj'}.(\frac{q_{jj'}}{2} + ss_{jj'}) + O_{jj'}.\frac{d_{jj'}}{q_{jj'}})$$

Constraints:

1) $D_{ij'} = \sum_{j=1}^{N} d_{jj'}.y_{ij} \quad i=1,...,P ; j'=1,...,M$

2) $D_{ij'}.L_{ij'} + SS_{ij'} \leq R_{ij'} \quad i=1,....,P; j'=1,....,M$

3) $d_{jj'}.l_{jj'} + ss_{jj'} \leq r_{jj'} \quad j=1,....,N; j'=1,....,M$

4) $\sum_{j'=1}^{M} a_{j'}.(SS_{ij'} + Q_{ij'}) \leq C_i \quad i = 1, ..., P$

5) $\sum_{j'=1}^{M} a_{j'}.(ss_{jj'} + q_{jj'}) \leq c_i \quad j = 1, ..., N$

4. Numerical results

The mathematical model is solved using LINGO 17.0 software, considering randomly generated data. The drug demand is stochastic and follows a normal distribution with mean 'μ' and standard deviation 'σ'. To simplify the mathematical model, we used the average demand of drug which are 'D' and 'd' for regional pharmacies and hospitals respectively. It is worth to note that regional pharmacy demand is equal to the sum of demands of hospitals existing in the same region. Lead times are-fixed in advance, and we neglected the effect of drug shelf life supposing that the kinds of drugs taken in our numerical examples have a big shelf life. Five numerical examples are tested to show the importance of VMI and demand pooling. Corresponding inventory management costs are shown in table1; for considered instances using traditional inventory management technique, VMI technique as well as VMI and demand pooling technique.

	Traditional SC	VMI SC	VMI and Demand Pooling SC
Test1: P= 1,N= 1, M=1	36319.83	15124.90	15124.90
Test2: P= 1, N=2, M=1	61426.06	40231.12	38703.52
Test3: P= 2, N=3, M=3	471356.60	263691.00	257196.50
Test4: P= 3, N= 6, M=3	826205.70	708043.80	689380.50
Test5: P= 4; N= 6; M=5	1131036.00	698727.60	650452.20

Table 1. Instances and related objective values for the three SC techniques

In instance1, we considered one regional pharmacy, one hospital and one kind of drug. In this instance; objective value for the VMI SC decreased by 59% compared with the objective value in traditional SC; on the other hand, demand pooling doesn't have effect because there is only one hospital. In instance 2, instance 3 and instance 4 the objective function values decrease for 35%, 44% and 15% respectively in VMI SC compared with traditional supply chain. When we added the effect of demand pooling to the VMI effect the objective value decrease reaches 46% for instance 3 compared to the traditional SC. In another side, when we augmented the number of kind of drug, the VMI and demand pooling has a very important effect to minimize the total cost, for example in instance 5 with 5 kind of drug the objective function is minimized from 1131036 to 698727.60 by VMI effect and to 650452.20, (about 42%), by VMI demand pooling effect.

5. Conclusion

The purpose of our work is to show the importance of collaboration between supply chain members to optimize their inventory management costs. We have studied vertical collaboration between pharmaceutical supply chain members. The techniques of collaboration used in this paper: are VMI and demand pooling. Numerical examples has shown the importance of these techniques to minimize the inventory management cost. The percentage of minimization varies between 35% and 59%. As future work, we can consider the horizontal collaboration between hospitals for transshipment of drugs. In addition, we can extend our supply chain to three levels by integrating the central pharmacy inventory management costs.

References

Marloes, J.T. Claasen, J., Arjan, J. Van Weele, Eric, M. Van Raij (2008), "Performance outcomes and success factors of vendor managed inventory (VMI)", Supply Chain Management: An International Journal, Vol. 13 Iss 6 pp. 406 - 414.

Bhakoo, V., Singh, P. and Sohal, A. (2012), "Case study Collaborative management of inventory in Australian hospital supply chains : practices and issues",Supply chain management: An international journal,17(2),217-30.

Elmuti, D., Khoury, G., Omran, O., & Abou-, A. S. (2013), "Challenges and Opportunities of Health Care Supply Chain Management in the United States", Vol.128–143.

Ford, E. W., & Scanlon, D. P. (2007). Promise and problems with supply chain management approaches to health care purchasing, (September), 192–202.

Kang, J., and Kim, Y. (2012), "Inventory control in a two-level supply chain with risk pooling effect", Intern. Journal of Production Economics, *135*(1), 116–124.

Robinson, E. P. (2002), "Flow Coordination and Information Sharing in Supply Chains : Review , Implications , and Directions for Future Research", *33*(4).

Sahin, C. K. E. and Dallery, Z. J. Y. (2009), "Consideration of the Undershoot in an (r , Q) Inventory Model for Perishables. IFAC Proceedings" (Vol. 42).

Schmitt, A. J., Sun, S. A., Snyder, L. V. and Shen, Z. M. (2014), "Centralization versus Decentralization : Risk Pooling , Risk Diversification , and Supply Chain Disruptions". Omega 1409.

Shah, N. (2004), "Pharmaceutical supply chains : key issues and strategies for optimisation", *28*, 929–941.

Waller, M., Johnson, M. E. and Davis, T. (1980), "Vendor-managed inventory in the retail supply chain".