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DEVELOPMENT OF A SPREADSHEET BASED VENDOR MANAGED INVENTORY MODEL FOR A SINGLE ECHELON SUPPLY CHAIN: A CASE STUDY

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Abstract

Vendor managed inventory (VMI) is a supply chain initiative where the supplier assumes the responsibility for managing inventories using advanced communication means such as online messaging and data retrieval system. A well collaborated vendor manage inventory system can improve supply chain performance by decreasing the inventory level and increasing the fill rate. This paper investigates the implementation of vendor managed inventory systems in a consumer goods industry. We consider (r, Q) policy for replenishing its inventory. The objective of work is to minimize the inventory across the supply chain and maximize the service level. The major contribution of this work is to develop a spreadsheet model for VMI system, Evaluation of Total inventory cost by using spreadsheet based method and Analytical method, Quantifying inventory reduction, Estimating service efficiency level, and validating the VMI spread sheet model with randomly generated demand. In the application, VMI as an inventory control system is able to reduce the inventory cost without sacrificing the service level. The results further more show that the inventory reduction obtained from analytical method is closer to the spread sheet based approach, which reveals the VMI success. However the VMI success is impacted by the quality of buyer-supplier relationships, the quality of the IT system and the intensity of information sharing, but not by the quality of information shared.

Keywords: spreadsheet, analytical model, vendor managed inventory, random demand, inventory control, service level

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1. INTRODUCTION

The management of inventory by the supplier continues to draw attention in many industries. The coordination of logistics of inventory decisions in a supply chain has a significant effect on the supply chain performance (Lau et al., 2008; Madhusudhana et al., 2008). In vendor managed inventory system vendor or supplier is given the responsibilities of managing the customer's stock. The fundamental change is that the ordering phase of the process is saved, and the supplier is handed the authority and responsibility to take care of entire replenishment process. This integrates operations between suppliers and buyers through information sharing and business process reengineering (Cetinkaya & Lee, 2000). By using information technologies such as electronic data interchange, buyers can share the inventory information with suppliers on a real time basis. Suppliers can then use this information to plan production runs, schedules, deliveries and manage order volumes and inventory levels at the buyer's stock keeping units (Blackhurst, et al. 2006)

There are many advanced models available in literature like single set-up, multiple delivery, vendor managed inventory and 3C (commonality, consume and capacity) as well as advanced methods like fuzzy logic, transfer function and model reference control. However there are plenty of researchers attempting to find answers to supply chain it becomes harder to understand these optimization models when complexity of the problem increases. An analytic solution to a problem may not be available because of a stochastic operating environment, an extremely complex problem or very specific problem (Banks & Malave 1984).In their busy daily business world, inventory managers usually do not have enough time to try and implement such challenging models. Up to now operation research specialists have developed approximately 400 inventory models to replicate inventory strategies and to describe them mathematically. However experience shows that there are very few practical applications (Bona, 2004; Kollurua and Ponnam, 2009). The main reason is that the application of the model is frequently tied to constraints that cannot be met in real stochastic processes. The application of an exact mathematical formula to define the target function required for the optimization is usually very difficult. Analytical solutions using mathematical tools such as probability theory and optimization can be used to obtain the performance level of the inventory system. Unfortunately, the analytical modeling of complex supply chains is limited to underlying mathematical assumptions that make the mathematics tractable. The mathematical formulation for inventory policy is hard to solve analytically, and does not lend itself to analyzing several ordering polices (Ravichandran 2007). Today spreadsheets are used as a programming language. Most researchers have used MS Excel software simulation modeling except Lebal.L (1997). He demonstrated the simulation model for wood yard inventory control. Zhang et al 2001; Gandhi 2003; Sezen et al 2007; Boute etal 2003; Jung et al 2007; Ravichandran 2007; Mahamani et al 2006 and Mahamani et al 2008 used a spreadsheet-based approach for inventory control problems. These simulation software packages require a cost consideration for the program, the time to learn and the appropriateness to the specific needs of a company (Sezen & Kitapci, 2007). Conversely, spreadsheets are simpler, inexpensive and can be developed using available resources (e.g., MS Excel, Quattro Pro and Lotus 123). Simulation models developed on spreadsheets are flexible; the user gains software skills in short period of time, board availability, ease of use, easy validation and low price. This paper investigates the implementation of vendor managed in inventory systems in a consumer goods industry. Once the data were setup in spreadsheet, two axis graphs were used for policy comparison. The planning horizon for system was one calendar year.

2. LITERATURE REVIEW

Vendor Managed Inventory is a system in which the supplier decides on the appropriate inventory levels of each of the products and the appropriate policies to maintain these levels. Yao et al (2007) developed an analytical model that explores how important supply chain parameters affect the cost saving to the realized from collaborative initiatives such as VMI. Result from the model shows that benefits in the form of inventory cost reduction. Mohamed et al (2004) proposed a VMI system, with assumption that the VMI will have to rent storage and shelf spaces in the back room showroom facilities, respectively, to stock and display the items. The VMI has to decide about the timing and sizing of each order for the store and the maximum shelf space to be reserved for each item. . Gronalt et al (2008) demonstrated a case study from wood processing industry by using vendor managed inventory system. The evaluation of VMI implementation against the actual inventory management for three different market sceneries. The application back ground, VMI as an inventory control system is able to reduce overall raw material stock by more than 37% by simultaneously increasing the service level. Claassen et al (2007), presented as an empirical investigation on performance outcome of VMI. The result show that VMI leads to three performance outcomes: higher customer service level, improved inventory planning and a lesser extent, cost reduction. Yao 2004 et al examines the relationship between distributor backorder performance and its inventory levels under Vendor Managed Inventory (VMI) in a supply chain that consists of distributors and manufacturers. We construct a principal-agent model to show that distributors' inventory managed by manufacturers can be used to induce distributor efforts, which are unobservable to the manufacturers, in converting lost sales into backorders in the case of stock outs. We use EDI transaction data collected from the electronic component and truck part industry to test our results from the analytical modeling. The empirical results provide strong supports for the proposition that there is a strong adverse relationship between the inventory level and backorder conversion rate, suggesting that the manufacturer could use a lower distributor inventory as an incentive for the distributors to convert more lost sales into backorders. Portes (2006) attempted to compare the performance of a VMI supply chain with a traditional supply chain with the aim of evaluating the impact of these two alternative structures have on the bullwhip effect generated in the supply chain.

3. PROBLEM DESCRIPTION

The case that is described in this paper is that of a fruit juice manufacturing firm located in India. The firm purchases over 100 items, such as packaging materials. The contribution of the packaging materials in the total inventory value is 83%, out of which 20% have a higher unit cost and a longer lead time. The companies that supply the locally purchasable items are struggling with the frequent rush of orders. The unavailability of packaging materials affects the production line and the fruits go to waste. Therefore, a proper policy to manage the inventory of the packaging items is required. Under the present situation, the firm manager has decided to find a fast, reliable and safe method of ordering the correct quantity for each item, with minimum total inventory costs and maximum service levels. The vendor managed inventory system will avoid formal order process. In vendor managed inventory system vendor or supplier is given the responsibilities of managing the customer's stock. The fundamental change is that the ordering phase of the process is saved, and the supplier is handed the authority and responsibility to take care of entire replenishment process. Therefore reorder point of locally available items reduces 30 % of the existing reorder point. For imported items the reorder level is reduced 60 % in the current re order quantity. This assumption is made by considering transportation time and average delay.

4. SPREADSHEET BASED APPROACH

This section describes the steps used to determine the variables for the vendor managed inventory system that would have the largest impact on the system performance. This was done using a spreadsheet based approach. A screen shot of the spreadsheet model for the VMI policy is shown in Figure 1. The following equations outline the steps involved in calculating the required ordering quantity and reorder point of VMI.

Step 1:

The economic order quantity Q is calculated using following relation. The denotation of each item is given in appendix:

$$G = \sqrt{\frac{2 * D * Co}{Cc}} \tag{1}$$

Step 2:

The reorder point of each item is calculated using following equation:

$$ROP_{VMI} = \{D/Q*C_o + [Z*\sigma_d*\sqrt{LT}\ ]\ \ * C_c\} \tag{2}$$

The lead time for locally purchasable items are 0.3 % of usual lead time and the imported items we considered up to 0.5 % of usual lead time.

Step 3:

Whenever the quantity of items reached in to reorder level, it is refilled with an economic order quantity (Q).

Step 4:

Inventory at the end of each period is calculated using the following relationship:

$$I_F = I_I + Q+D \tag{3}$$

If the inventory is greater than zero, inventory carrying costs are incurred. However, backlog costs only incur when the system faces a stock out. The weekly inventory is assumed to be zero in the case of stock out.

Step 5:

The cost matrix and service efficiency levels are formulated in the spreadsheet by using the following equation:

Total inventory cost (TIC) = Number of shipments $\cdot$ Co+ Inventory quantity $\cdot$ Cc+ Back order quantity $\cdot$ Cb (4)

Service efficiency level = [1- Number of stock outs/ Total period] $\cdot$ 100 (5)

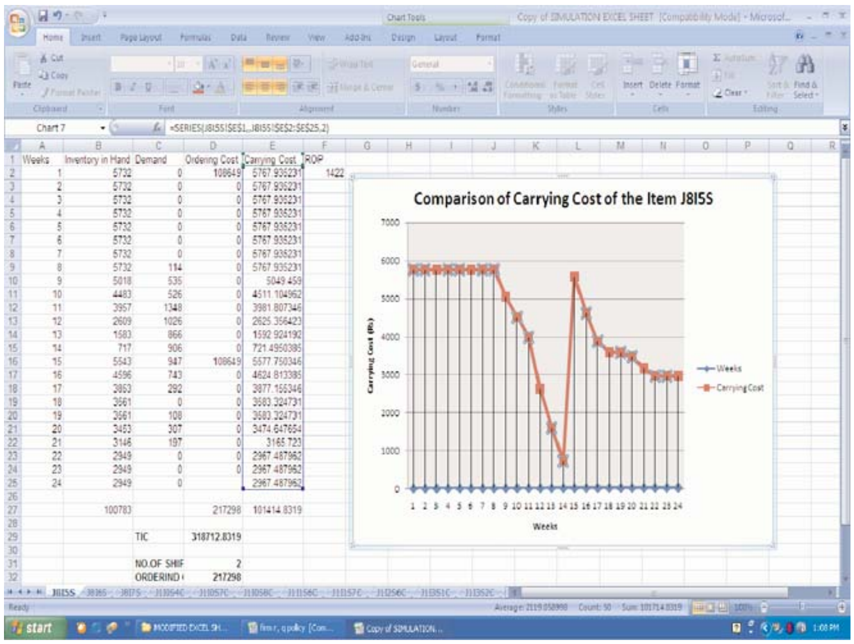

Figure 1. Screen shot of VMI spreadsheet model for item J8I5S

Table 1. Spreadsheet based results of VMI policy

Items/ Inventory measures	Number of Shipments	Ordering Cost (R.s)	Carrying Cost(R.s)	Total Inventory Cost(R.s)	Number of Stock Outs	Service Level (%)
J8I5S	2	217298	101414	318712	0	100
J8I6S	2	217298	116717	334015	0	100
J8I7S	4	434596	313799	748395	0	100
J1I0S4C	6	117894	72522	190416	0	100
J1I0S7C	1	19649	6819	26468	0	100
J1I0S8C	6	117894	89093	206987	0	100
J1I1S6C	2	39298	16569	55867	0	100
J1I1S7C	4	78596	42843	121439	0	100
J1I2S6C	1	19649	8977	28626	0	100
J1I3S1C	1	19649	12213	31862	0	100
J1I3S2C	1	19649	11181	30830	0	100

Table 2. Spreadsheet based results of firm policy

Items/ Inventory measures	Ordering Cost (R.s)	Carrying Cost(R.s)	Back order cost(R.s)	Total Inventory Cost(R.s)	Number of Stock Outs	Service Level (%)
J8I5S	108649	216338	0	324987	0	100
J8I6S	217298	101656	130378	449332	1	95
J8I7S	325947	166422	260757	753127	4	83.3
J1I0S4C	137501	133788	0	271289	0	100
J1I0S7C	19649	115048	0	134697	0	100
J1I0S8C	117894	66831	43227	227953	3	87.5
J1I1S6C	19649	35929	0	55578	0	100
J1I1S7C	19649	207136	0	226785	0	100
J1I2S6C	39298	1623	43227	84149	1	95.8
J1I3S1C	137543	471	259366	397381	3	87.5
J1I3S2C	78596	1287	86455.6	166339	3	87.5

The same steps are followed for all eleven items. Similarly the variables were evaluated for the VMI and existing inventory policies, which are tabulated in Table 1 and 2.

5. ANALYTICAL APPROXIMATION METHOD

In an analytical approximation method the total inventory cost is calculated by summing the ordering and carrying costs.

The system variables of ordering and carrying costs and total inventory cost were evaluated using the following equations shown in Table 3. The system parameters were evaluated for all eleven items and tabulated in Tables 4 and 5. Due to the limitations of this method the service efficiency level could not be evaluated.

6. ANALYSIS OF RESULTS

Fig 2 shows the total inventory cost determined by spread sheet model. Total inventory cost of firm policy is more than the VMI policy. Table 2 represents that few items having back order cost along with ordering cost and carrying cost. Back order cost increase the total inventory cost of the firm policy. There is no back order cost observed in VMI policy (table 1). Fig 3 & 4 shows the benefits of VMI policy over firm policy. Fig 3 shows that it is possible to reduce over 32 % of total inventory cost. The comparison of service efficiency level of VMI and firm policy is presented in figure 4, which reveals that there is a chance of getting 100 % service level when implementing VMI policy. Fig 5.and 6 helps to validate the total inventory cost obtained from spread sheet model. The total inventory cost of VMI policy is evaluated analytically, and illustrated in table 4. Fig 5 shows that total inventory cost evaluated from spread sheet model is very closer to the analytical model. Fig 6 shows the total inventory cost evaluated from spread sheet model is nearer to the analytical model. Fig 5 & 6 reveals the accuracy of spread sheet based approach for estimating total inventory cost.

From the investigation above, it is economical to implement the VMI policy in the present system. In VMI policy the inventory levels of these items monitored by supplier, which avoids the formal ordering

Table 3. Equations for calculating total inventory cost

VMI policy	$(N*Co) + [(1/2)*\sqrt{2D} * \sqrt{Co\,Cc} * (1/\sqrt{d+1})]$ ***(Yao et al 2007)***
Existing policy	$D/q*C_o + [Z*\sigma_d* \sqrt{LT}] * C_c$

Table 4. Analytical approximation results of firm policy

Item Code	Ordering cost(R.s)	Carrying cost (R.s)	Total Inventory Cost(R.s)
J8I5S	108649	326514.2	435163.2
J8I6S	325947	145096.7	471043.7
J8I7S	434596	253157.6	687753.6
J1I0S4C	58947	270648	329595
J1I0S7C	19649	128880	148529
J1I0S8C	235788	64440	300228
J1I1S6C	19649	69526.35	89175.35
J1I1S7C	19649	370800	390449
J1I2S6C	58947	2448	61395
J1I3S1C	373331	662.76	373993.8
J1I3S2C	235788	1651.86	237439.9

Table 5. Analytical approximation results of VMI policy

Item Code	Ordering cost(R.s)	Carrying cost (R.s)	Total Inventory Cost(R.s)
J8I5S	217298	118573	335871
J8I6S	217298	148613	365911
J8I7S	325947	248184	574131
J1I0S4C	117894	100961	218855
J1I0S7C	19649	10208	29857
J1I0S8C	117894	104737	222631
J1I1S6C	39298	28396	67694
J1I1S7C	78596	67615	146211
J1I2S6C	19649	9670	29319
J1I3S1C	19649	13602	33251
J1I3S2C	19649	17214	36863

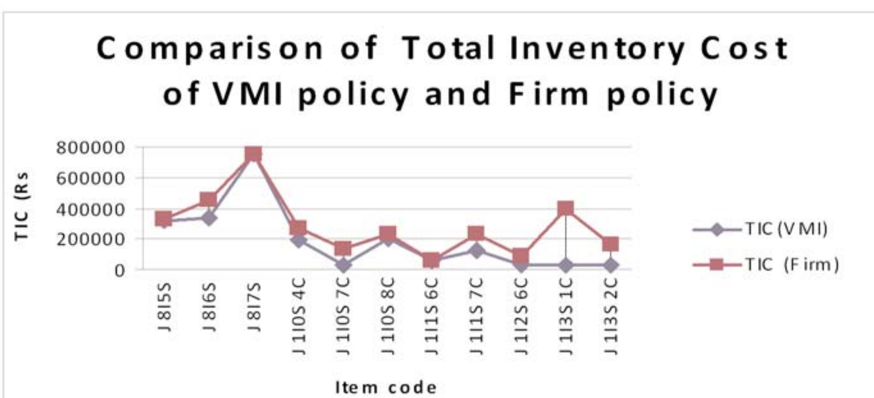

Figure 2. Comparison of Total inventory cost of VMI policy and firm policy

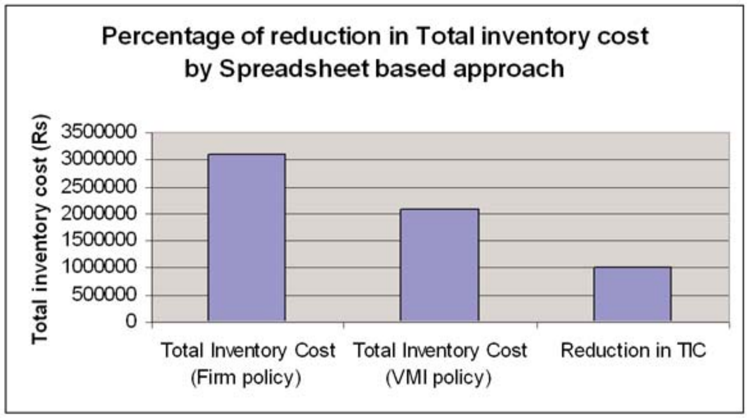

Figure 3. Percentage of reduction in total inventory cost by Spreadsheet based approach

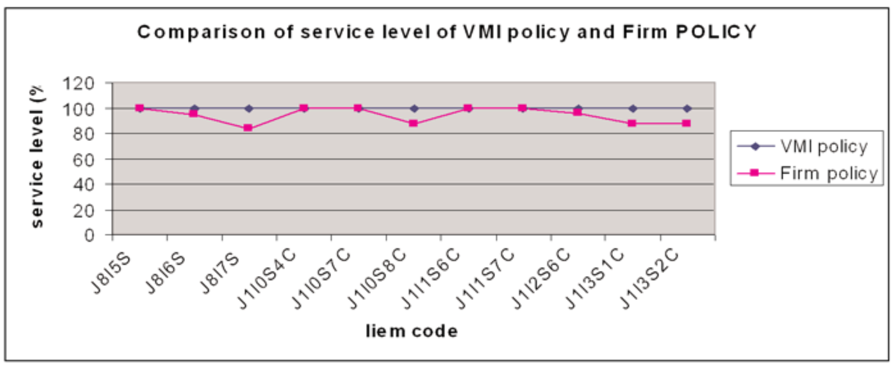

Figure 4. Comparison of service level of VMI policy and Firm policy

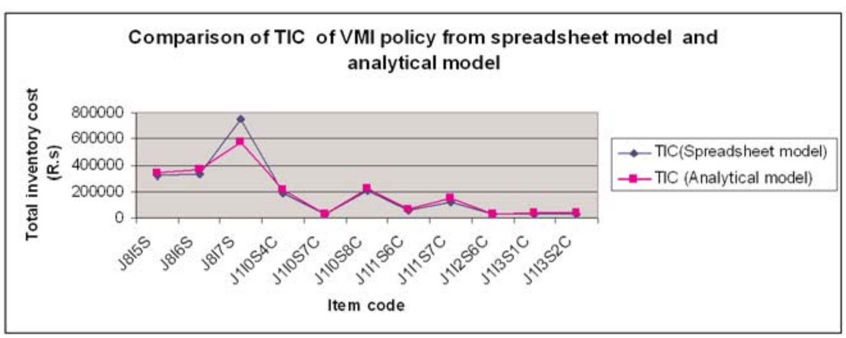

Figure 5. Comparison of total inventory cost of VMI policy from spreadsheet based approach and analytical method

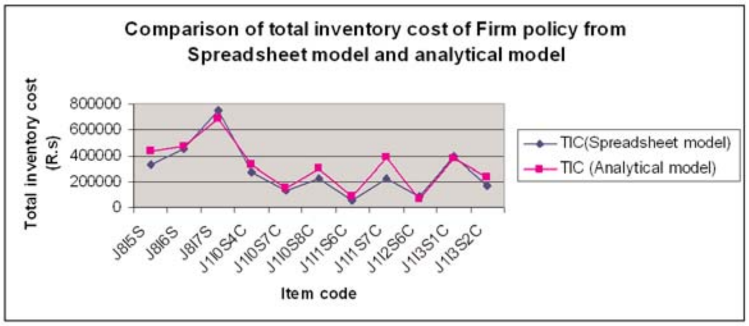

Figure 6. Comparison of total inventory cost of Firm policy from spreadsheet based approach and analytical method

procedure. Therefore the lead time of the item will be reduced. The lead time reduction will minimize the reorder point of each item. Hence we can get considerable savings in inventory across the supply chain. This will be major source of inventory reduction. However the service level of each item highly depends on the transportation delay and excessive rejection of the items. Therefore VMI policy is alternate for the present system.

7. OUTPUT DATA ANALYSIS

The flexibility of the VMI policy was evaluated by means of randomly generated demand values. A spreadsheet was modeled with following variables; random demand values, inventory levels at the end of the period, re-order point indicators, number of shipments, stock out occurrence and back order quantity. The random number was generated through a random number generation option available with the spreadsheet. The screen shot of output data analysis spreadsheet is shown Figure 7. Table 6 shows the result of the output data analysis. This shows that 100 % of service efficiency level can be achieved with randomly generated demand.

8. COCLUSION

Spread sheet based approach can be successfully applied to the VMI policy of a

Table 6. summary of output data analysis

Items	No. of Shipments	Ordering Cost (R.s)	Carrying Cost (R.s)	Total Inventory Cost (R.s)	No. Of Stock Outs	Service Level (%)
J8I5S	2	217298	94368	93781	0	100
J8I6S	3	325947	144705	470652	0	100
J8I7S	4	434596	256781	691377	0	100
J1I0S4C	8	157192	60322	217514	0	100
J1I0S7C	1	19649	7043	26692	0	100
J1I0S8C	7	137543	71631	209174	0	100
J1I1S6C	3	58947	16317	75264	0	100
J1I1S7C	4	78596	38695	117291	0	100
J1I2S6C	1	19649	7315	26964	0	100
J1I3S1C	1	19649	8403	28052	0	100
J1I3S2C	1	19649	10078	29727	0	100

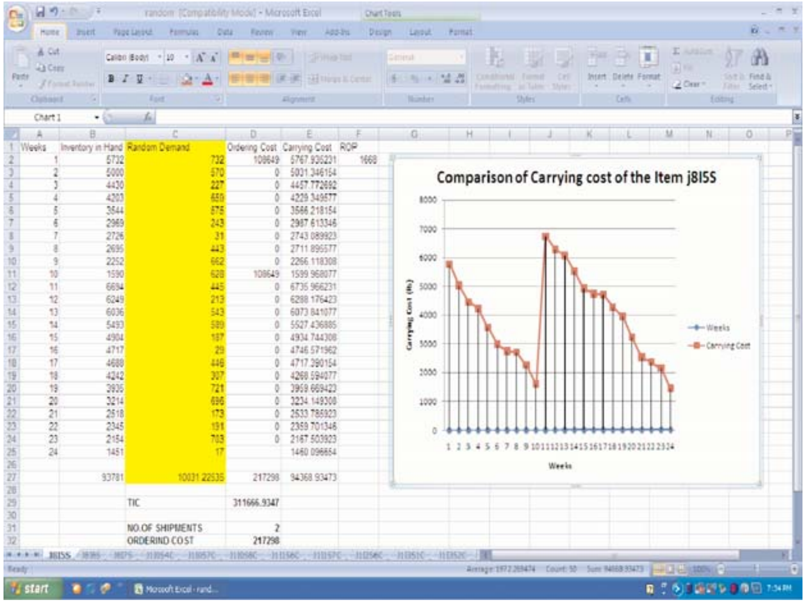

Figure 7. screen shot of output data analysis of VMI policy with random demand

single echelon supply chain. The result analysis shows that the implementation of the VMI policy brings considerable reduction in inventory cost and provides a good service efficiency level. The total inventory cost from spread sheet model is very closer to the analytical model, which reveals the accuracy of the spread sheet. The flexibility of VMI policy was evaluated with randomly generated demand, which reveal that the performance of VMI policy was good with stochastic environment. This research will help to develop the inventory policy for a supply chain. The spreadsheet method is each to learn, easy to scenario analysis and low cost. The major limitation of this approach spread sheet error which can be rectified by means of cell protection. However the VMI success impacted by the quality of buyer-supplier relationships, the quality of the IT system and the intensity of information sharing, but not by the quality of information shared. The major barriers of VMI system are willingness to share data, ability to share data and ability to use the shared information properly.

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РАЗВОЈ МОДЕЛА УПРАВЉАЊА ЗАЛИХАМА, У ОКВИРУ МЕНАЏМЕНТА ЛАНАЦА СНАБДЕВАЊА, КОРИШЋЕЊЕМ РАДНИХ ЛИСТОВА: СТУДИЈА СЛУЧАЈА

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Извод

Управљање залихама засновано на поруџбини је иницијатива ланца снабдевања у којој снабдевач преузима на себе одговорност за контролу и управљање залихама, употребом адекватног комуникационог средства заснованог на интернету. Уколико је добро управљан, овај систем може побољшати показатаље ланаца снабдевања смањењем нивоа залиха и повећањем брзине попуне. Овај рад се бави примењивошћу оваквог начина управљања залихама у индустрији робе широке потрошње.У прорачуну је коришћен (r, Q) модел за допуну залиха. Циљ рада је да се минимизирају залихе кроз ланац снабдевања а да се максимизира ниво услуге. Основни допринос овог рада је развој модела заснованог на радним листовима и процена укупних трошкова залиха употребом метода засниваних на радним листовима и аналитичким методима. Резултати овог рада се огледају и у успешном квантификовању смањења залиха, процени нивоа ефикасности услуга, и валидацији модела управљања залихама са генерисањем захтева за залихама по принципу случајних бројева. Како је показано, модел развијен у овом раду је у стању да смањује трошкове залиха без умањења нивоа квалитета услуге. Ипак, успех модела је у великој мери заснован на квалитету односа купац-снабдевач, квалитету ИТ система и интензитету размене информација.

Кључне речи: радни лист, аналитички метод, залихе управљане снабдевачем, случајна потражња, ниво услуга

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Appendix

r Static re order point
Q Economic order quantity
T Review period in weeks
D Annual demand
Z Service level
q Existing ordering quantity
Co Ordering cost per order
Cc Carrying cost per week
Cb Back ordering cost per order
LT Lead time
II Initial inventory level
FI Final inventory level
σd Standard deviation of the annual demand value
N Number of Orders
d Ratio of the supplier's carrying charge to the buyer's.