PERFORMANCE ANALYSIS OF A CONTRACT MANUFACTURING SYSTEM

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Abstract: This paper develops a simulation model to analyze the performance of a contract manufacturer with information sharing and space constraints. Proper information sharing with a Contract Manufacturer (CM) would benefit both the suppliers and the customer to have a smooth supply chain. The model aims at optimizing the inventory levels at both supplier and contract manufacturer ends and at the same time increases the operating efficiency and service levels. Four suppliers are considered in this model and they follow different types of order to delivery processes with the CM. The paper discusses the contract manufacturing concept, information sharing, space constraint problem, the simulation model, results, and the analysis. The results show the impact of both information sharing and space minimization in a CM's hub in terms of fill rate, inventory level optimization and inventory storage in terms of accumulation of inventory.

Keywords: information sharing, demand forecast, fill rate, lead-time.

1. INTRODUCTION

In today's global business arena, competition is marked by volatile demand, decreased customer loyalty, shorter product life cycles, and mass customization. It is important for businesses to gather vital information and act quickly on it. When a number of companies are in alliance, there is a need for collecting accurate, comprehensive and timely information and sharing with the partners [Viswanadham .N, 2000]. This will enable the partners to make decisions based on global information that benefits the entire process. "Space in square footage" is the buzzword in today's logistics and warehouse scenario. The utility of space available in a warehouse in an efficient way leads to lesser warehouse cost and minimum inventory levels over a period of time. Minimum space usage with maximum service levels benefits the partners of the supply chain. Most of the activities along a supply chain will have an effect on the delivery time of the end product, the important one being the supply of the components by the supplier before assembly.

Advancements and innovations in the area of information technology have created huge impact on the supply chain partners. Proper use of these IT resources would achieve a tight coordination of activities along the supply chain. One such basic enabler for tight coordination using information technology is information sharing. The model described in this paper shows how the shared information is used at the warehouse (CM's hub) to coordinate the inbound logistics, to avoid delivery uncertainties, and to maintain optimum inventory levels for the components in the CM's hub. Particularly in electronics supply chain where the product life cycle is very less, non-delivery of components at right time and keeping more inventories will result in financial loss to the partners along the supply chain. In other words a contract-manufacturing model, which works towards "delivery to promise". The concept of information sharing pattern evaluation and space constraint for all suppliers in a contract-manufacturing scenario is modeled with a continuous simulation model developed in simulation software "ITHINK".

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2. PROBLEM FORMULATION

2.1 Contract Manufacturing

The primary aim of any manufacturing company (OEM) is to reduce inventory at its production site, ensuring maximum production efficiency. The concept of “Contract Manufacturing” is to provide manufacturing support and supply chain solutions to the OEMs. In this case, a CM is considered who provides logistics support to the customer, aiming at optimizing the inventory storage with increased service levels.

Under this CM operation, responsibility for inventory management shifts from the manufacturer to the supplier. The suppliers conceptually maintain the ownership of the production materials of the manufacturer. The ownership gets transferred from supplier to manufacturer once the latter receives the goods physically for production. The suppliers supply goods based on the advanced forecast and the updated version of the demand, received from the manufacturer. The CM operator serves as an intermediator, manager, and facilitator of the storage of goods, inventory levels, managing multiple supplies for the customer.

With the CM, the required materials for the future production would be delivered, stored and maintained at a place “CM hub” close to the manufacturing site. The customer has to deal with only one supplier, the owner of the CM hub who in turn deals with various suppliers of the customer. While goods are stored in the CM hub, the ownership all materials would remain with the respective suppliers [Laura Rock Kopczak, 1998]. The supplier owned inventory program is that a CM hub, which will provide a single source material, provision for the customer. The streamlining in the supply chain is achieved by the close partnership between the customer, supplier and the contract manufacturer.

2.2 Information Sharing

Lots of literatures have shown the key benefits of sharing potential information in a supply chain. Production schedule, demand forecast, inventory levels, point of sales are some types of information that could be shared [Lee Hau and Seungjin Whang, 1998]. In this model, the demand forecast of the end customer is shared with the suppliers and CM on a fortnight basis. Every time the supplier receives an order from the customer, he also receives updated and initial forecast demand values for the future weeks. For instance, the first day of the first week the supplier receives the following through EDI or Internet. The firm orders for 3rd and 4th week, Updated demand forecast for 5th and 6th week, Initial demand forecast for 7th and 8th week. On receiving these forecast details, the supplier works on his production schedule for the first two weeks. This is a process performed two weeks once upon receiving the forecast values from the customer. The production schedule would be made visible to the suppliers’ suppliers who also become a part of the supply chain.

2.3 Suppliers of the Contract Manufacturer

In the model, four suppliers are considered supplying to the customer through CM. To analyze the model in a more detailed manner, the suppliers are considered to have different types of delivery processes. The first supplier is considered to be an overseas supplier and keeps two weeks inventory at the CM hub. The production schedule of the first supplier is done by the demand forecast and firm order values received in advance from the customer. Supplier two follows the traditional re-order level for receiving orders from hub [Nahmias Steven, 1997]. This supplier could be situated either overseas or locally placed closer to the CM hub. Supplier three is a local supplier and follows a Just in time supply to the CM hub. The local transport time is very less and delivery is made twice a day. Supplier four follows a maximum order up to quantity process and receives orders from the CM hub at regular intervals [Simchi-Levi David et al, 1999]. This supplier is considered as a local supplier. The production schedule is based on the order delivered and every time one order is satisfied, the inventory level comes down and before the next order is received the inventory level is filled by the new production. The inventory level is maintained so that during receiving orders, it should be able to fulfill the orders.

3. PROBLEM SOLUTION

3.1 Supplier Hub Model

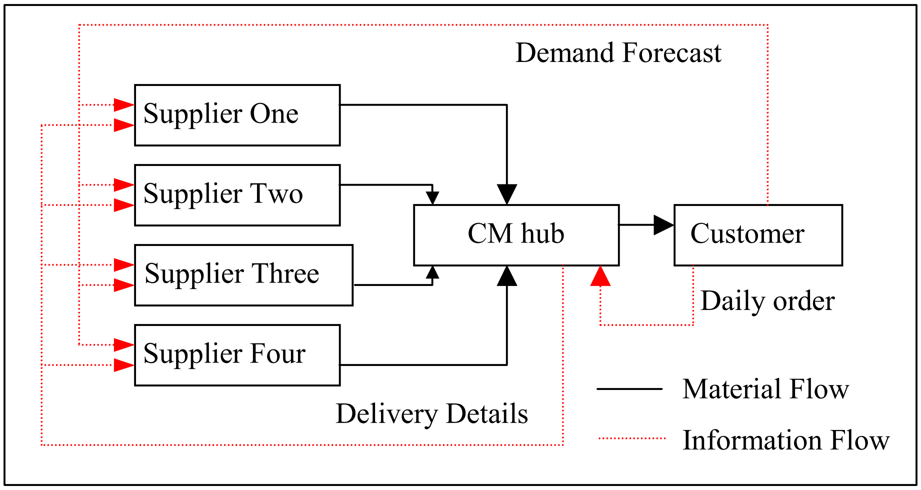


Figure-01: Line diagram of the supplier hub model

The supplier hub model was developed in the software Ithink. The model is as shown in the figure 01. As shown in the model diagram above, the suppliers receive the demand forecast, and delivery details from the supplier hub. In the same way the hub receives the daily orders from the customer. The concept of lead-time is formulated in a detailed manner for the supplier one, taking the following logistics model into consideration. For supplier one, the lead-time would be the sum of the time that each operation that take place in the logistics operations as shown in the figure 02.

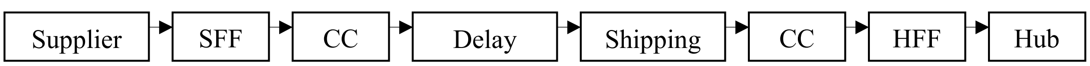


Figure-02: Line diagram to show the logistics model

SFF- Supplier Freight Forwarding; HFF- Hub Freight Forwarding

CC- Customs Clearance at supplier and hub end

The customer sends the demand forecast and firm orders in advance to the suppliers. Based on these forecast values, the material requirement planning and production schedule are charted out at the suppliers end. This production schedule of supplier one and two are made visible to suppliers' suppliers as the model considers two suppliers each for supplier one and supplier two. Based on the production schedule, the suppliers' suppliers plan their raw materials, production and shipment. Supplier three follows the kanban production system by which each time it receives a production card from the CM hub, it produces the same number of components. Supplier four charts the production based on the order quantity shipped every time the CM hub places an order.

The CM receives the components on various days of a month and upon receiving, the components are stored in separate places in the hub. The hub places orders to the four suppliers following the various ordering procedures discussed earlier. Based on the lead-times, the components reach the hub. The customer places order daily twice and it is delivered from the hub depending upon the availability of the four components. Kitting takes place at the hub by which the components from the four suppliers are assembled before being delivered to the customer. Hence to satisfy each unit of customer's need, the hub needs one component each from all the suppliers to do the kitting process and deliver one unit to the customer.

4. MODEL RESULTS AND ANALYSES

4.1 Hockey Stick demand

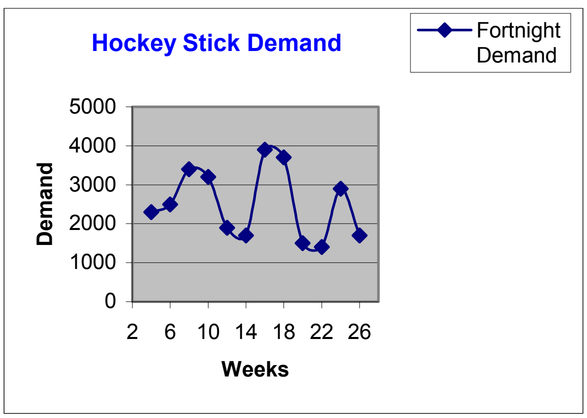
The model is run for five months (5 * 28 (4 weeks) days with two time steps per day). Initially to start the simulation, the inventory levels at each supplier and the CM hub are assumed. The demand forecast values and firm orders are inputted to the model and various results are arrived with. Hundred percent service levels are targeted between CM and customer. The demand values (both the forecast and firm orders) are shown in the table 01. The values are shown in different colors. The supplier, from the customer receives each set of colored values at 15 days interval.

Table 01 Demand forecast and firm order details

Weeks/ Month	Initial forecast	Updated forecast	Firm orders	Recd. weeks
Week3 (1)	-	-	1150	Wk 1
Week4 (1)	-	-	1250	
Week5 (1)	-	1200	1100	Wk 3
Week6 (1)	-	1200	1300	
Week7 (2)	1800	1700	1700	Wk 5
Week8 (2)	1700	1600	1700	
Week9 (2)	1700	1600	1600	Wk 7
Week10 (2)	1650	1700	1600	
Week11 (3)	900	800	900	Wk 9
Week12 (3)	1150	1000	1000	
Week13 (3)	900	900	900	Wk 11

Week14 (3)	900	800	800	
Week15 (4)	1800	1700	1900	Wk 13
Week16 (4)	2000	2000	2000	
Week17 (4)	1900	1900	1800	Wk 15
Week18 (4)	1900	1900	1900	
Week19 (5)	600	550	700	Wk 17
Week20 (5)	850	800	800	
Week21 (5)	800	900	800	Wk 19
Week22 (5)	750	700	700	
Week23 (6)	1400	1300	-	-
Week24 (6)	1500	1500	-	-
Week25 (6)	900	-	-	-
Week26 (6)	950	-	-	-

Graph: 01 Hockey Stick demand pattern distributed over the weeks



Each row in the table shows the initial updated and final orders received from the customer by the suppliers. From table 01, it is clear that the suppliers, on the first day of the first week, will have an idea of what customer needs up-to 8th week. With the help of these demand forecast and firm order values, the suppliers' material requirement planning and production schedule are charted out. Graph 01 shows the demand firm order values over the period of 24 weeks. It is a hockey stick demand pattern, which was considered to run the model as it closely matched with the present demand patterns of electronic industry. Each point in the inventory graph shows customer demand for two weeks.

4.2 Lead-time Analyses

Table 02 Lead-time details for Supplier One (Overseas)

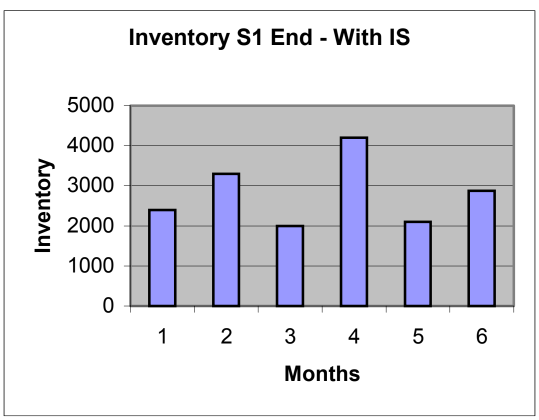
Months	1	2	3	4	5
Lead-time*	10/11/11	5/8/8	5/7/7	3/6/9	8/9/9

Ideal LT/ Actual for Order1/ Actual for Order2

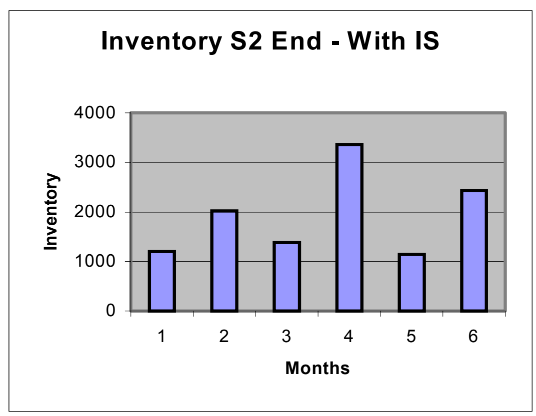
The inbound logistics to the CM hub varies between the suppliers. Referring to table 02, for month 2, the values show that even though the components were ready for shipping, at the S1 end, with a lead-time of 5 time steps (2 and 1/2 days), there was a delay in both the deliveries because of the non - availability of the ship cargo/air cargo. The availability of cargo space was assumed to be only on certain days. For suppliers two and four, randomly distributed lead-time was considered with the range given as input. Supplier three is local delivery with negligible lead-time.

4.3 Inventory levels and Inventory Accumulations at the Hub

Graph: 02 Supplier One End inventory levels With IS



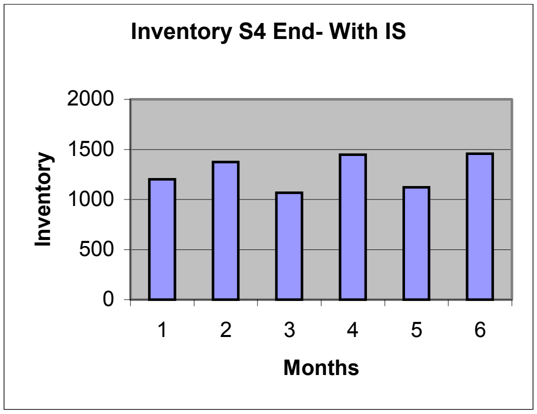
Graph: 03 Supplier Two End inventory levels – With IS



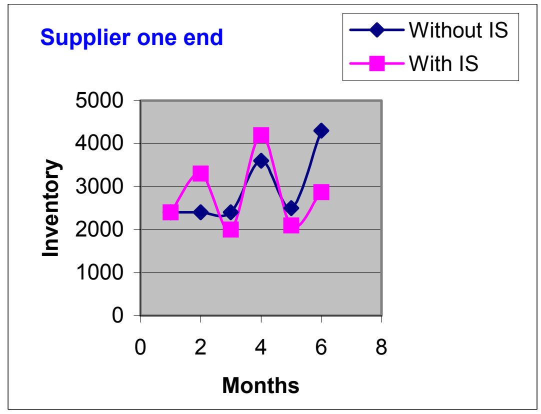
Referring to Graphs 02, 03 and 04, if the inventory values at the beginning of each month are taken into consideration, depending upon the future requirement (demand), the levels of the inventories at the suppliers' end changes. For instance, the requirement from weeks 07 to 10 (month 2), table 01 is well above the average demand of 1200. If the corresponding inventories are seen in the graphs below, inventory levels follow the demand. Similarly the requirement from weeks 11 to 14 (month 3) is well below the average demand. Corresponding to this period, the inventory levels dip for all suppliers, which could be seen in the graphs. This advantage is leveraged through the possible sharing of demand forecast information from customer to the suppliers well before the actual requirement period.

Graphs 05, 06 and 07 show the variation of inventories at the suppliers' ends with and without information sharing at the beginning of each month. Comparing the inventory graphs with the demand values shown in graph 01, it could be seen that the inventory levels at the end of each month is sufficient to satisfy the following month's demand in case of Information Sharing. Moreover it is easy to appreciate these graphs, which show the inventory curves with information sharing follow the demand graph 01. (IS in the graph legends indicate Information Sharing and Space Constraints).

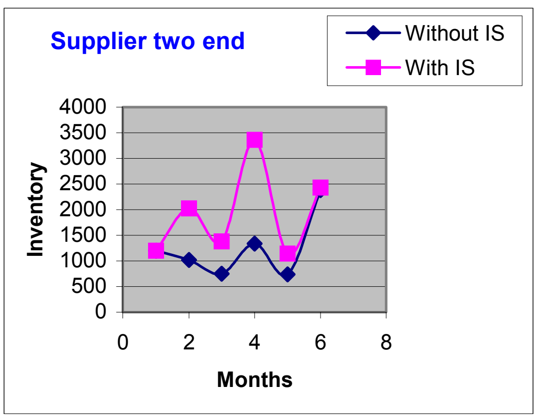
Graph: 04 Supplier Four End inventory levels – With IS



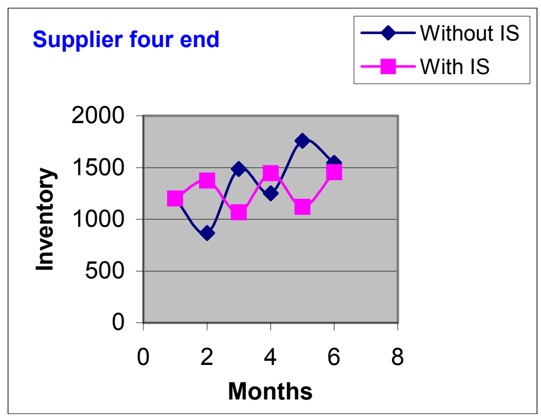
Graph: 05 Supplier One end inventory level



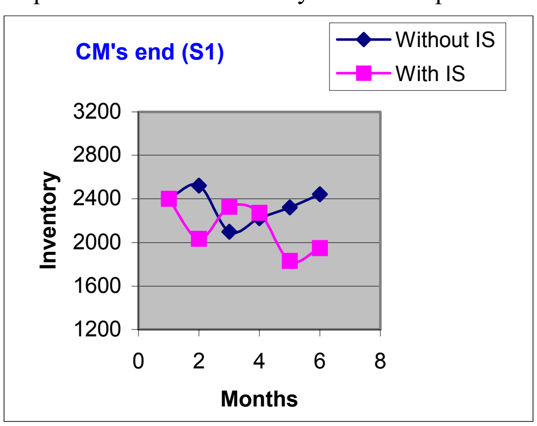
Graph: 06 Supplier Two end inventory levels



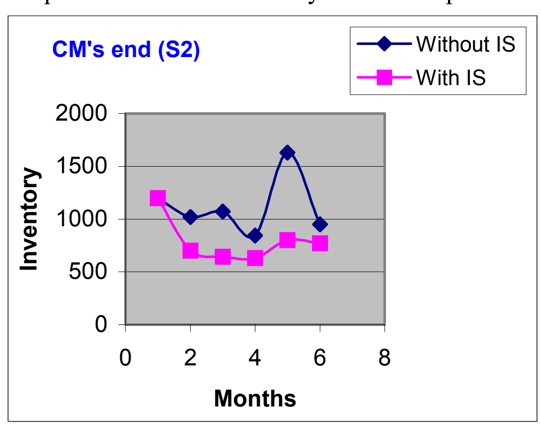
Graph: 07 Supplier Four end inventory levels



Graph: 08 CM Hub inventory for S1 components



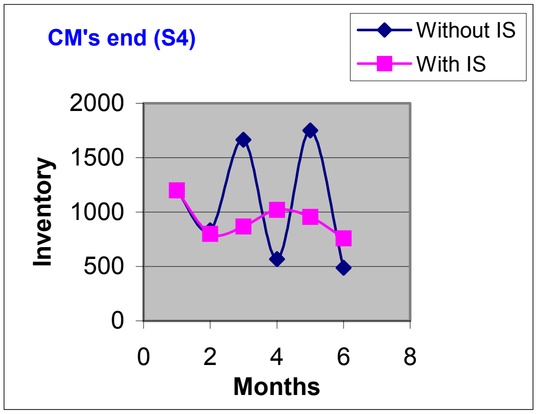
Graph: 09 CM Hub inventory for S2 components



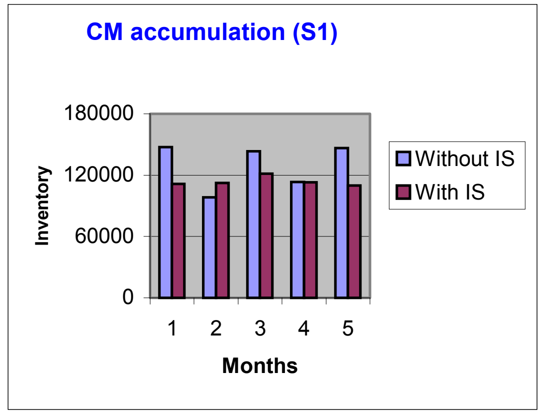
4.4 Minimum Utilization of Space at the Supplier Hub

The CM fixes the maximum space available for each component for each time period depending upon the future demand. The contract manufacturer maintains the inventory level for all the components such that it never crosses the maximum limit neither did it falls below the minimum limit. Graphs 08, 09 and 10 show the inventories for the respective suppliers' components at the CM end with and without information sharing and space constraint. From the graphs it could be inferred that the levels are always less with space constraint taken into consideration.

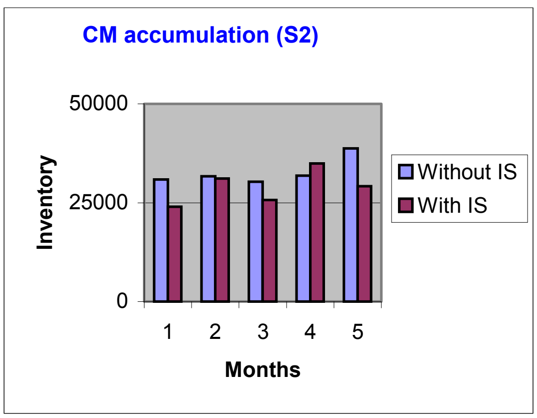
Graph: 10 CM Hub inventory for S4 components



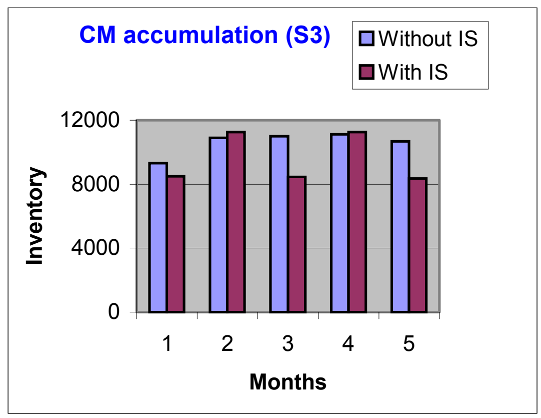
Graph: 11 CM Hub inventory accumulation – S1



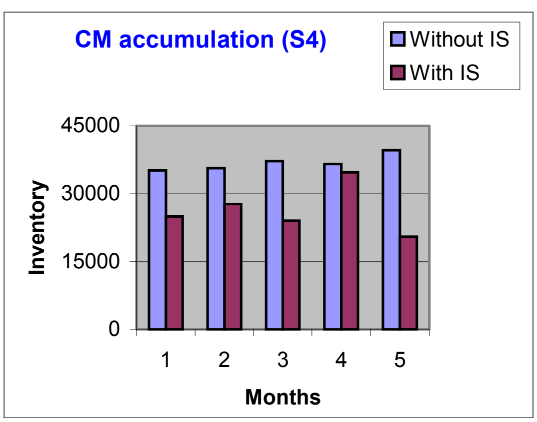
Graph: 12 CM Hub inventory accumulation – S2



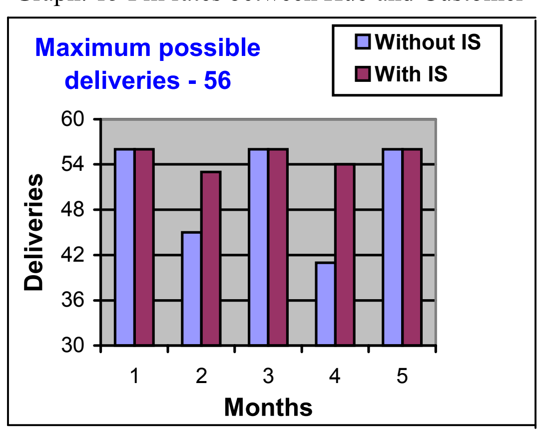
Graph: 13 CM Hub inventory accumulation – S3



Graph: 14 CM Hub inventory accumulation – S4



Graph: 15 Fill rates between Hub and Customer



Graphs 11 – 14 show the accumulation of inventory for all suppliers' components at the CM hub. In all the graphs it was clear that with space constraints, the inventory accumulation for all the months except 2 and 4 were well below the values of the same without space constraints. During the months 2 and 4, the demand itself was very high and hence the inventory accumulation for those two months was more. These graphs clearly indicate the savings by the CM in space, which in turn benefits the suppliers who are responsible for the goods until it is transferred to the customer and also pay for the storage cost.

The implications of space constraints would be the following. For overseas suppliers, the main issues would be the lead-time and transportation constraints. Due to more uncertainty in lead-time and transportation cost, overseas suppliers are forced to supply more than the need for a particular time period and hence the inventory at the CM hub rises. Overseas suppliers could set up a local storage near the CM hub to deliver according to the demand of the customer and space availability at the hub. For local suppliers the main issues are capacity and storage constraints. Local suppliers could work on optimizing the capacity resources to satisfy the daily requirements of the customer thus avoiding accumulation of more inventories at suppliers' end and CM end.

Graph 15 compares the fill rates achieved between the CM and the customer with and without information sharing. Every month was considered with 28 days and with two deliveries per day from CM hub to customer. Hence 56 deliveries would be the maximum deliveries possible if the customer orders twice on all days. Due to the sudden rise in the demand in two places (2^{nd} month and 4^{th} month), there was a drastic fall in the fill rate on those two months without proper sharing of information. This graph consolidates the effort of the value of information sharing pattern in terms of the delivery service level, in a contract-manufacturing scenario.

5. CONCLUSIONS

The objectives of this work are to conduct a performance analysis on contract manufacturer to clearly show the benefits of information sharing and the efficient working of minimum space utilization at the CM hub for the suppliers' components. The variability in demand increases as it moves up the supply chain. This increase in variability causes significant operational inefficiencies, for example mainly stocking of more inventory. In modern supply chains, information replaces inventory. It is shown that by using the information available at different ends of the chain, one can design and operate the supply chain much more efficiently and effectively at high service levels.

There is always a threat associated with sharing of valuable information between supply chain partners. This is especially when information is shared from customer to suppliers. But it is basically the trust, the customer has on the supplier and the type of relationship between the customer, suppliers and the contract manufacturer and the efficient coordination of the supply chain by the contract manufacturer, which play important roles. It could be concluded that information is the key enabler of integrating different stages of a supply chain. This paper would be able to put the reader in a position to think about the quantitative and qualitative aspects of supply chain concepts analyzed.

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