International Journal of Research and Development in Applied Science and Engineering (IJRDASE)
ISSN: 2454-6844

Performance Evaluation of Flexible Supply Chain

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Abstract: Sourcing flexibility's related to the company's ability to find another supplier for each specific component. This paper describes the study of the impact of sourcing flexibility on performance of a proposed flexible supply chain model. The performance measured considered are total ordering cost, total inventory holding cost and total backorder cost. Flexible supply chain models (SCM) developed under two inventory control policies. These are constant demand inventory policy and (s, S) inventory policy. The proposed supply chain models are developed in ARENA simulation software. After conducting simulation experiments results are generated and then for result analysis a statistical tool ANOVA is used. It is observed that (s, S) inventory policy is better than constant demand policy in case of average of total inventory holding cost and constant demand inventory policy is better in case of average of total backorder cost at sourcing flexibility level = 1. For sourcing flexibility level = 2, in case of average of total ordering cost constant demand policy is better and in case of average of total inventory holding cost (s, S) inventory policy is better.

Keywords: Supply chain model, sourcing flexibility, ARENA, ANOVA

1. Introduction:

A supply chain is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. A typical supply chain consist of suppliers, manufacturers, warehouses, wholesalers, retailers and customers. Supply chain management spans all movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption. Supply chain performance measures can be classified broadly into two categories qualitative measures (such as customer satisfaction and product quality) and quantitative measures (such as order-to-delivery lead time, supply chain response time, flexibility, resource utilization, delivery performance, etc.). Quantitative metrics of supply chain performance can be classified into two broad categories: Non-financial and financial. The non-financial performance measures used in supply chain are cycle time or lead time, Customer service level in a supply chain, inventory carrying costs, resources of various kinds: manufacturing resources ,storage resources , logistics resources, human and financial. financial performance measures used in supply chain are cost of raw material, revenue from goods sold, activity-based costs such as material handling, manufacturing, assembling, etc., inventory holding costs, transportation costs etc. The magnification of demand fluctuations is very crucial factor and known as bullwhip effect. The essence of the bullwhip effect is that orders to suppliers tend to have larger variance than sales to the buyer. The more chains in the supply chain the more complex this issue becomes. To compensate the losses of such effects flexibility is highly needed. Flexibility is defined as ability of the supply chain to deliver different types of products to the customers with a wide range of volume at an acceptable cost and time. Supply chain flexibility should be examined from an integrative, customer-oriented perspective. There are many dimensions of supply chain flexibility for example product flexibility [3], Trans-shipment, Postponement, logistics, responsiveness and sourcing [4,5]. In this paper work a study of the impact of sourcing flexibility and different inventory policies on performance of supply chain is performed first develop a simple supply chain model having single provider at each node then we have incorporated sourcing flexibility by increment of service providers. We intend to see that if we increase the level of sourcing flexibility i.e. increment of the service providers at each node of supply chain then what will be the effect on supply chain performance.

2. Methodology:

In the present work first of all the gap between current challenges and previous efforts made for improving the performance of supply chain by adding flexibility in it are found. After this the development of conceptual models is performed. Then conceptual models are converted to simulation models with help of ARENA simulation software package. With the help of simulation models series of experiments are conducted to generate the results. The results are further analyzed in ANOVA to measure effect of input variables on flexible supply chain's performance measures. The model is first developed for supply chain with no sourcing flexibility and then for sourcing flexibility focused supply chain. The models of supply chain with no sourcing flexibility, sourcing flexibility level 1 and sourcing flexibility level 2 are shown in Figure 1, 2 and 3 respectively.

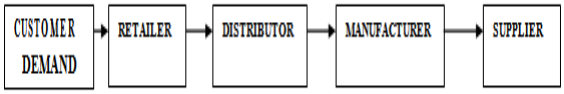


Fig. 1: Supply chain model with sourcing flexibility level=0

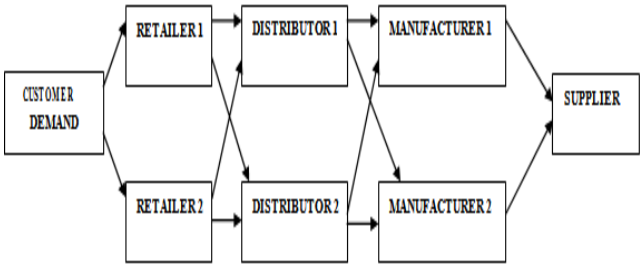


Fig. 2: Flexible supply chain model with sourcing flexibility level=1

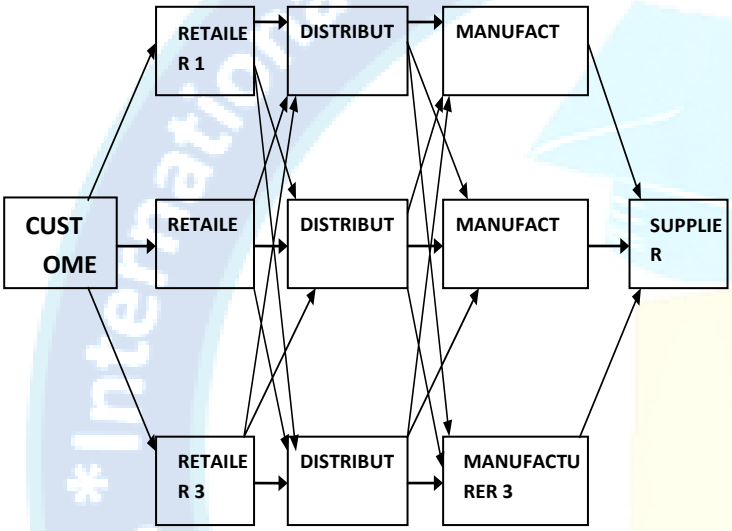


Fig. 3: Flexible supply chain with sourcing flexibility level=2

In Figure 3 there are more options for fulfillment of demand so, in this model sourcing flexibility is more in comparison to model 1. These three models are developed under both inventory control policies i.e. constant demand policy and (s, S) inventory policy. The input parameters are setup cost, incremental cost, unit holding cost, unit shortage cost, inventory level, reorder level (s), order up to level (S) and sourcing flexibility level. The supply chain model is evaluated under following three performance measures – Total ordering cost, total backorder cost and total inventory holding cost. Two inventory control policy constant demand policy demand and inventory policy demand varying at each node and order will be given when inventory level will be less than reorder levels. Replication length is taken as 365 days. Warm up period is taken as 2 days and number of replications is taken as 10.

Setup cost: fixed cost of ordering and its value is taken as Rs.440 [6].

Incremental cost: variable ordering cost per unit per day and its value is taken as Rs.100.

Unit shortage cost: cost of having one unit in backlog for one day and its value is taken as Rs.110.

Unit holding cost: cost of holding one unit in inventory for one day and its value is taken as Rs.1.1

Inventory level: for retailer 1, distributor 1, manufacturer 1 inventory level is taken as 300. For retailer 2,distributor 2, manufacturer 2 inventory level is taken as 200. For retailer 3, distributor 3, manufacturer 3 inventory level is taken as 100.

Reorder level (s): It is the minimum amount of an item which a company holds in stock. For retailer 1, distributor 1, manufacturer 1 reorder level is taken as 80. For retailer 2, distributor 2, manufacturer 2 reorder level is taken as 75. For retailer 3, distributor 3, manufacturer 3 reorder level is taken as 70.

Order up to level (S): Stock levels are periodically reviewed and an amount of the item is ordered to return stock levels to the target level. This target level is called order up to level. For retailer 1, distributor 1, manufacturer 1 order up to level is taken as 300. For retailer 2, distributor 2, manufacturer 2 order up to level is taken as 200. For retailer 3, distributor 3, manufacturer 3 order up to level is taken as 100.

Sourcing flexibility level: It is related to the company‘s ability to find different service provider at each nodes of the supply chain. In figure 1 sourcing flexibility level is zero. In figure 2 it is one due to two retailers, two distributors and two manufacturers and in figure 3 it is two due to three retailers, three distributors and three manufacturers.

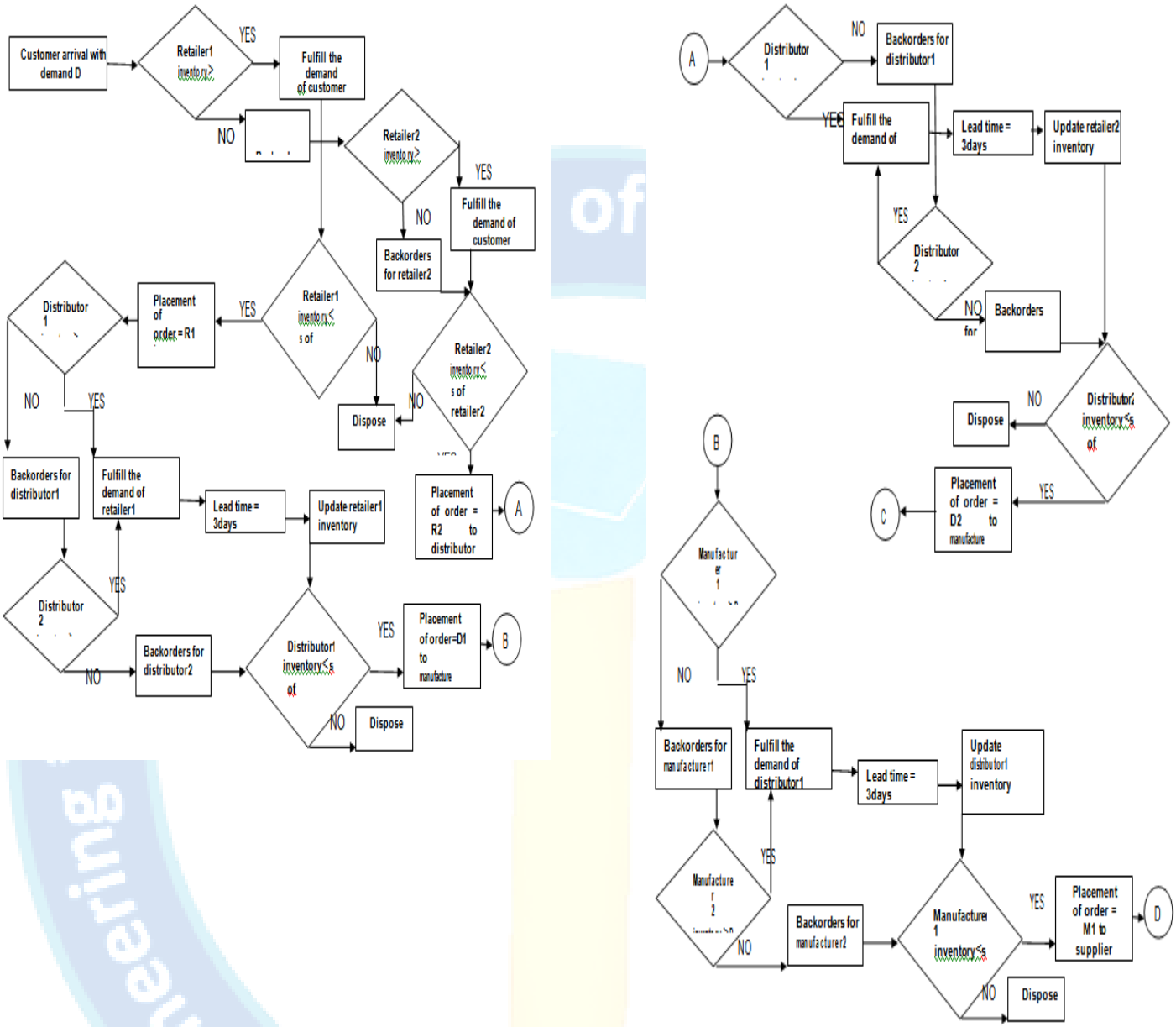
Total ordering cost: It is taken as performance measure to which all ordering cost is added. Total ordering cost = set up cost + incremental cost*order quantity

Total backorder cost: It is the total cost of all backorders. Total backorder cost = unit shortage cost*backorders

Total inventory holding cost: Total inventory holding cost = unit holding cost*inventory.

In this work simulation models are developed using Arena software. In this simulation experiment model is built by placing modules (boxes of different shapes) that represent processes or logic. Connector lines are used to join these modules together and specify the flow of entities. While modules have specific actions relative to entities, flow, and timing, the precise representation of each module and entity relative to real-life objects is subject to the modeler.

Flowchart of simple supply chain with zero sourcing flexibility level for inventory policy having constant demand is simulated in this software. The demand follows the normal distribution with mean = 100 and standard deviation = 15 [7,8]. In constant demand inventory policy, if the demand of customer is not fulfilled by the retailer, then the retailer will order the same amount of demand to distributor. If distributor is unable to fulfill the demand, then it will order the same amount to manufacturer and so on. Lead time is taken as 3 days for retailer, distributor, manufacturer and supplier.



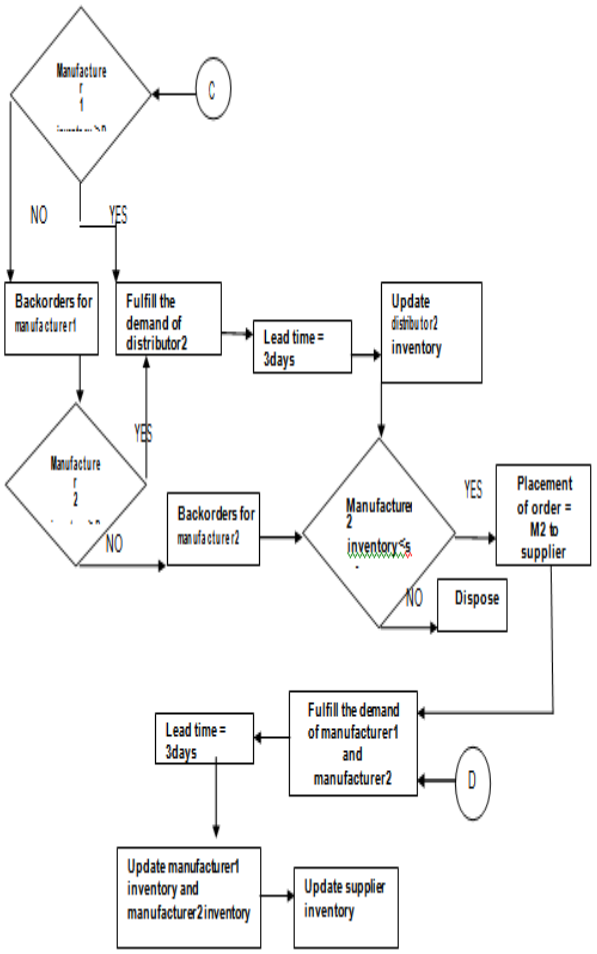


Figure 4: Flow chart of supply chain with flexibility level=1 for (s, S) inventory policy

Figure 4 shows the flowchart of flexible supply chain with sourcing flexibility level = 1 for (s,S) inventory policy. Orders from first retailer will go to first distributor. If it does not fulfill the orders then first retailer will go to second distributor. Like this second retailer will go to first distributor. If it does not fulfill the orders then second retailer will go to second distributor. Orders will be given at each node when reorder level will become more than inventory level. Lead time is also taken as 3 days as in case of inventory policy having constant demand. This process will be continued at each node. Like this we can make flowchart for flexible supply chain with sourcing flexibility level = 2.

3. Result and Discussion:

On the basis of the conceptual and simulation models discussed in previous section we have generated results by executing the models in ARENA simulation software. We have evaluated the performance of supply chain by increasing the service providers at each node of a supply chain when there are three retailers, three distributors and three manufacturers at each node of a supply chain. Hence, there are more options for fulfilling the demand as compared to supply chain having service providers = 2 (figure 5a) at each node. In figure 5 b we can see that when service providers = 3 at each node of a supply chain then, among three retailers, third retailer (R3) has more total ordering cost. Among three distributors, third distributor (D3) has more total ordering cost and among three manufacturers third manufacturer (M3) has more total ordering cost than other two manufacturers

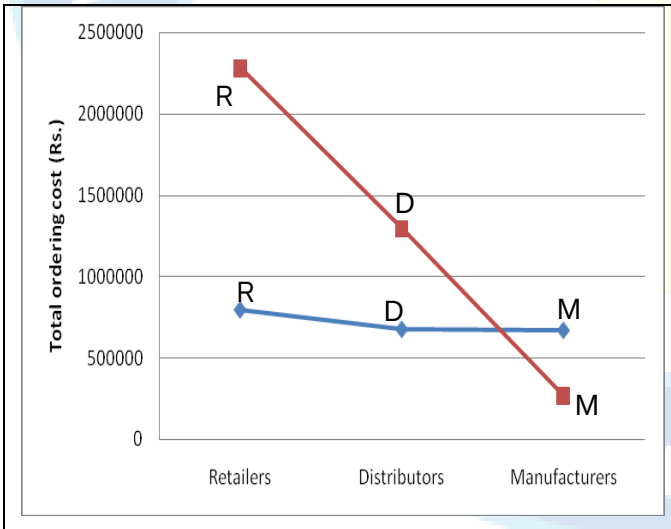


Figure 5 a: Total ordering cost when service providers = 2 at each node

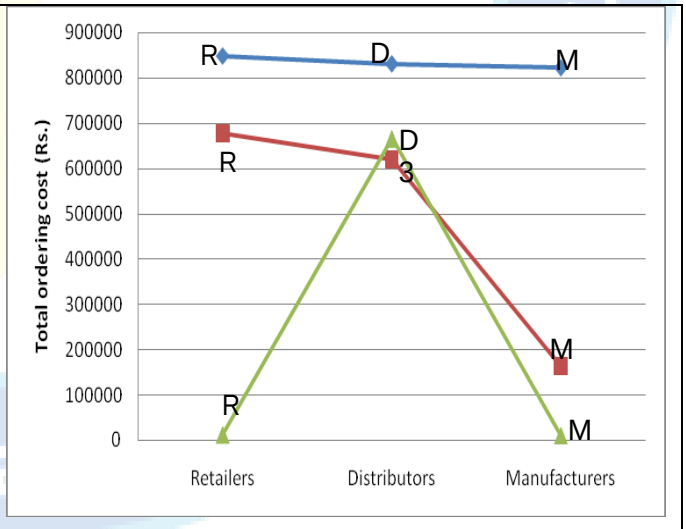


Figure 5 b: Total ordering cost when service providers = 3 at each node

Similarly it observed that when service providers = 3 at each node of a supply chain then first retailer (R1) has more total inventory

holding cost as compared to others two retailers (R2 and R3) but second distributor (D2) and second manufacturer (M2) have more total inventory holding cost as compared to others two distributors (D1 and D3) and two manufacturers (M1 and M3).

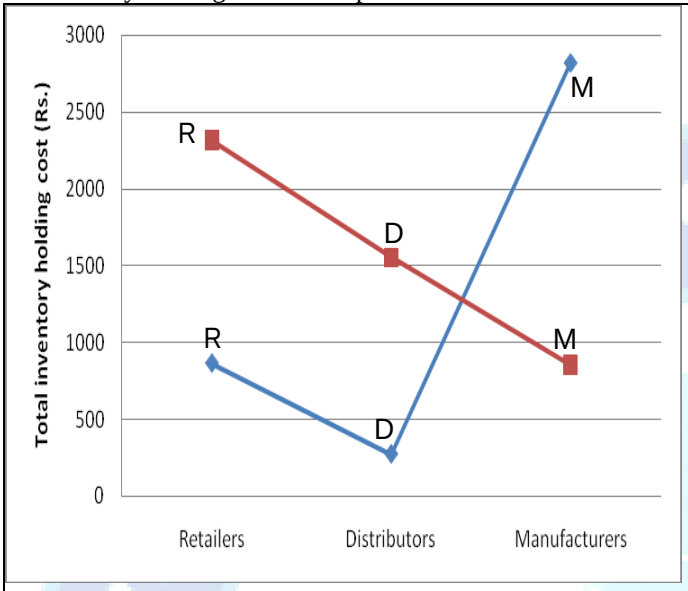


Figure 6 a: Total inventory holding cost when service providers = 2 at each node

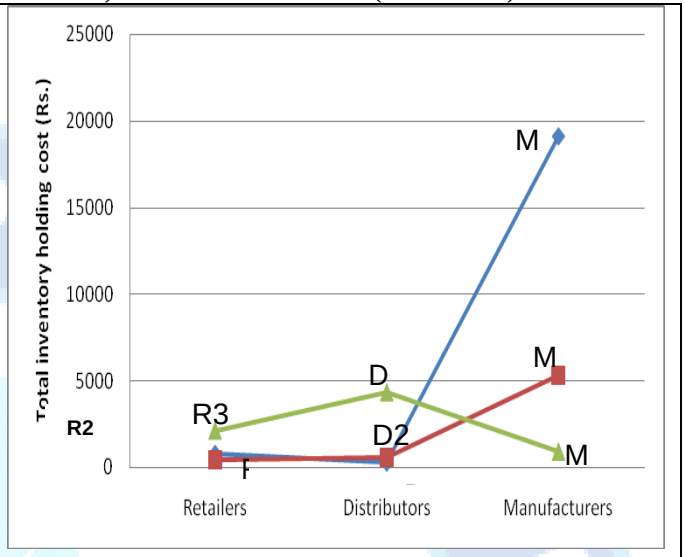


Figure 6 b: Total inventory holding cost when service providers = 3 at each node

In figure 6 a and b we can see the variation of total inventory holding cost at different nodes of supply chain when there is 2 or 3 service provider at each node. When service providers = 2 (fig 6a) then second retailer (R2) and second distributor (D2) have more total inventory holding cost than first retailer (R1) and first distributor (D1). But first manufacturer (M1) has more total inventory holding cost than second manufacturer (M2).When service providers = 3 at each node of supply chain (figure 6 b) then (R3) and (D3) have greater total inventory holding cost than other (R1 and R2) and (D1 and D2). But, (M1) has greater total inventory holding cost than (M2 and M3).

The variation of average of total backorder cost at different sourcing flexibility levels for (s, S) inventory policy is determined. Figure 7 a shows the variation of average of total ordering cost for constant demand policy (blue) and (s, S) inventory policy (red) at sourcing flexibility level = 1. Graph for distributor and manufacturer average of total ordering cost is more for constant demand policy as compared to (s, S) inventory policy but for retailer this cost is more in case of (s, S) inventory policy. Hence, constant demand inventory policy is better than (s, S) inventory policy in case of average of total ordering cost for distributor and manufacturer, because they are giving more orders which govern the good performance of supplychain.

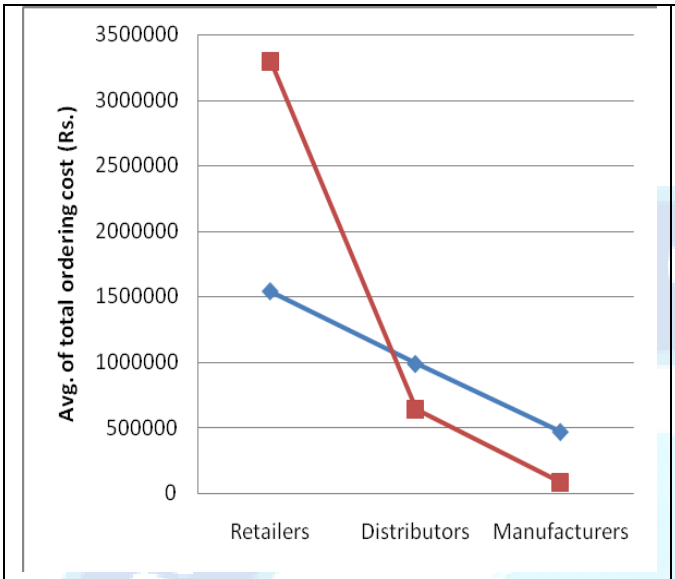


Figure 7 a: Avg. of total ordering cost at sourcing flexibility level = 1

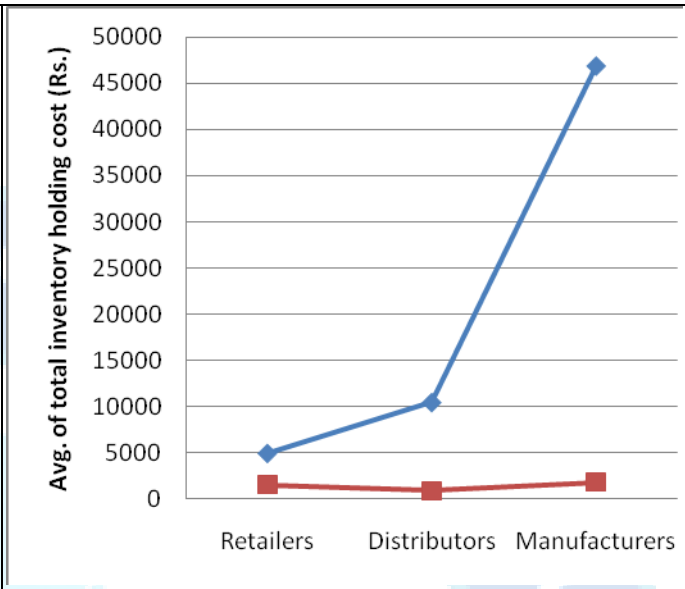


Figure 7 b: Avg. of total inventory holding cost at sourcing flexibility level = 1

Figure 7 b shows the variation of average of total ordering cost for constant demand policy and (s, S) inventory policy at sourcing flexibility level = 1.Here total inventory holding cost is less for retailer, distributor and manufacturer for (s, S) inventory policy as compared to constant demand inventory policy. If, average of total inventory holding cost is less it means good performance of supply chain, hence (s, S) inventory policy is better than constant demand policy in case of this cost.The variation of average of total ordering cost for constant demand policy and (s, S) inventory policy at sourcing flexibility level = 2 shows that average of total ordering cost is more for retailer, distributor and manufacturer in case of constant demand policy. So, in case of (s, S) inventory policy retailer, distributor and manufacturer are giving more orders than in constant demand inventory policy, which shows the better performance of supply chain. Hence, in case of this cost constant demand inventory policy is better at sourcing flexibility level = 2. The average of total inventory holding cost is more for retailer, distributor and manufacturer in case of constant demand policy. So, in case of (s, S) inventory policy retailer, distributor and manufacturer are holding less inventory than in constant demand inventory policy, which shows the better performance of supply chain. Hence, in case of average of total inventory holding cost (s, S) inventory policy is better at sourcing flexibility level = 2.

ANOVA is used to find the significant impact of flexibility level and inventory policies on total ordering cost, total inventory holding cost, total backorder cost for retailer, distributor and manufacturer. ANOVA is carried out using SPSS-10 statistical package. ANOVA is conducted at 95% confidence interval.

		ANOVA analysis of avg. of total ordering cost as performance measure					**ANOVA analysis avg. of total inventory holding cost as performance measure**				
Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	**R**	50148589768728.500(a)	3	16716196589576.190	2.354	.312	29574108.324(a)	3	9858036.10	203.901	.005
	D	7563009610320.980(a)	3	2521003203440.330	3.615	.224	181665233.494(a)	3	60555077.831	6.463	.137
	M	92979832640,2.153(a)	3	30993277546,7.385	2.420	.306	2327588287613(a)	3	775862762.53	20.484	.047
Intercept	**R**	55660989033883.200	1	55660989033883.200	7.839	.107	94792302.346	1	94792302.346	1960.662	.001
	D	12145747740457.960	1	12145747740457.960	17.417	.053	258708017.669	1	258708017.66	27.614	.034
	M	97525432882,2.06	1	97525432882,2.0	7.616	.11	3189660188934	1	318966018	84.211	.012

		9		69		0			8.9		
Flexibility level	**R**	38915401256865.420	2	19457700628432.710	2.740	.267	14862102.007	2	7431051.004	153.702	.006
	D	34980334490,5.368	2	17490167245,2.684	1.366	.423	17018549.842	2	8509274.921	.908	.524
	M	92979832640,2.153(a)	3	30993277546,7.385	2.420	.306	167277706.608	2	83638853.304	2.208	.312
Inventory policy	**R**	11233188511863.150	1	11233188511863.150	1.582	.335	14712006.317	1	14712006.317	304.300	.003
	D	111478696309.588	1	111478696309.588	.160	.728	164646683.652	1	164646683.65	17.574	.052
	M	57999498149,6.785	1	57999498149,6.785	4.529	.167	2160310581006	1	2160310581.0	57.035	.017
Error	**R**	14201492461462.720	2	7100746230731.360			96694.196	2	48347.098		
	D	1394682253350.756	2	697341126675.378			18737714.480	2	9368857.240		
	M	25612276830,6.407	2	12806138415,3.204			75753616.444	2	37876808.222		
Total	**R**	120011071264074.500	6				124463104.866	6			
	D	21103439604129.710	6				459110965.644	6			
	M	21611754235,30.628	6				5593002092.991	6			
Corrected Total	**R**	64350082230191.300	5				29670802.520	3			
	D	8957691863671.740	5				200402947.975	5			
	M	11859210947,08.559	5				2403341904.057	5			

4 Conclusion:

The study conducted in this dissertation work is on hypothetical model of a supply chain with different levels of sourcing flexibility. ARENA simulation software is used to develop the models and generate the results. These three supply chain models under two inventory control policies are developed which are constant demand inventory policy and (s, S) inventory control policy. The performance of these supply chain models are measured in terms of total ordering cost, total inventory holding cost and total backorder cost. From series of obtained results, it is observed that average of total ordering cost is decreasing for retailer, distributor and manufacturer with increase in sourcing flexibility level for constant demand inventory policy and average of total inventory holding cost is increasing for manufacturer when sourcing flexibility level is increasing. But, for distributor and retailer this cost is decreasing with increase in sourcing flexibility level. Average of total backorder cost is increasing for distributor and retailer from SF = 0 to SF = 1, but this cost is decreasing from SF = 1 to SF = 2. For (s, S) inventory policy average of total ordering cost is decreasing for retailer, distributor and manufacturer with increase in sourcing flexibility level and average of total inventory holding cost is decreasing for retailer with increase in sourcing flexibility level. With increase in sourcing flexibility, average of total backorder cost is decreasing for distributor and manufacturer for this inventory policy. (s, S) inventory policy is better than constant demand policy in case of average of total inventory holding cost and constant demand inventory policy is better in case of average of total backorder cost at sourcing flexibility level = 1. For sourcing flexibility level = 2, in case of average of total ordering cost constant demand policy is better and in case of average of total inventory holding cost (s, S) inventory policy is better.

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