Operations and Supply Chain Management
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Lecture - 41
Value of Information

In this lecture, we look at the Value of Information in the context of supply chain. Earlier when we looked at five aspects of supply chain, we had categorized them into location and location based decisions. Production, production based decisions, transportation distribution based decisions, inventory, inventory based decisions. And we also mentioned at that point, that information, and information based decisions become the fifth decision making aspect in supply chain management. In fact, the whole idea of supply chain management is centered around getting good information, and the impact and role of information, information systems, decision support systems, ERP systems etcetera, in the supply chain decision making process.

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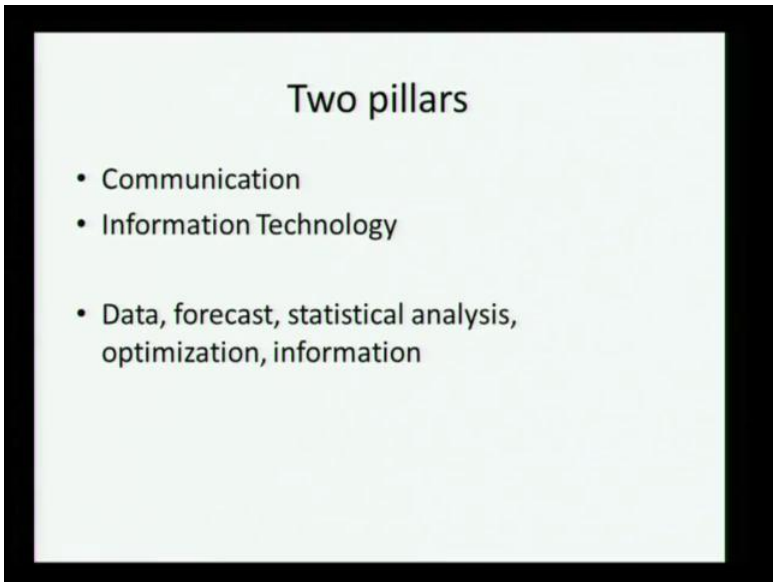

It is not uncommon or it is nor incorrect, if we say that the two important pillars in supply chain management, are communication and information technology. If we look at what separates supply chain management, from traditional way of looking at it through procurement, manufacturing, operations management, and distribution is the speed. The

speed is the one that distinguishes supply chain management, from traditional way of looking at these aspects.

And that speed is essentially given through communication, as well as through Information Technology. There are additional advantages, other than speed we also have some other advantages, which we will see as we move along, but the most important aspect is the speed with which data is obtained. Speed with which, we are able to communicate either through the net or through telephones, and other media of communication.

So, the two pillars are essentially communication and information technology. Information technology also helps us in the following: which is data, forecast, statistical analysis, optimization and information. One of the advantages of Information Technology is the fact that we can get data, and we can get very good data and we can also get recent data, data that is far more important. Simply because, it is the most recent data, now this data helps us in good forecasts.

And we have already seen that good forecasting systems are essential. Good forecasting systems ensure that we are able to produce what is demanded. Particularly either if we produced demand, and demand comes from good data or we produce a little bit to forecast, and the forecast is made on good and recent data. Once we are able to build good forecasting models that forecast the demand, we are able to produce what we can sell, and sell what we can produce which essentially reduces the inventory in the system, as well as reduces the total cost in this system.

Data also helps in statistical analysis, data also helps us in being able to fit trends, data also helps in customizing products, and making known to the customer, products, which suit his or her buying as well as thinking preferences. All these are carried out through statistical analysis, in a separate upcoming field of analytics or data analytics as it is called, where we have large scope for Information Technology, data, forecasting, optimization, and statistical analysis.

Optimization helps in trying to get the best decisions from a given situation; once again the success of an optimization would depend on the success of the numbers or data that go into the optimization process or optimization program. So, once again it boils down to getting good data, and good data can be obtained through good information systems, and

Information Technology. Therefore, contributes extensively to the success of a supply chain.

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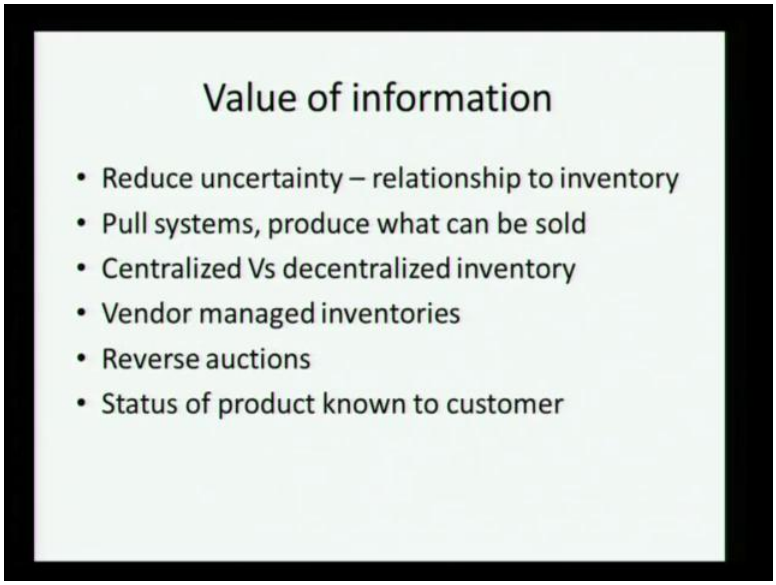

Now, we look at further detail on what is the value of information, and what we can get through good data and good information. First one is the reduction of uncertainty, uncertainty is reduced because, correct information is available at the right time. We have already seen that uncertainty relates to inventory. Wherever there is uncertainty there is excess inventory, and inventory is one of the ways and most commonly used way to reduce uncertainty in manufacturing systems.

More the uncertainty higher the inventory, and if we are able to reduce the uncertainty through good information systems that are able to provide information and data, then the inventory holding will come down. We have already seen that inventory can be measured in terms of units, in terms of money and in terms of time, and all the three are important. And if we are able to reduce the cost or reduce the time to deliver, we automatically improve the performance.

So, the first value of information is to reduce uncertainty in the system, by providing good data and information at the right time, and this helps us in reducing the inventory. Data also helps us to produce to demand rather than produce to forecast. Now when production systems were designed to produce to forecast, invariably there was excess production. Because, there was a forecast error which is the difference between what is

the actual demand is, and what the estimated is the forecast is an estimated demand, while the actual demand would be different from the forecast.

Now, when we start using pull systems which means we produce to demand, which also means that we are able to sell whatever we produce. When we produce to forecast, if there is a change in demand then two things would happen, fact that we would not be able to meet the actual demand. Because, we would have produced something else or produced in some other quantity, and then the excess that has been produced we would not be able to sell or we would be able to sell in subsequent periods, which result in higher cost of inventory or cost of shortage.

So, manufacturing systems move towards pull systems which means the demand will pull the manufacturing, and the production. So, we end up producing what can be sold rather than trying to sell what has been produced, manufacturing always has a lead time. Therefore, if we have to produce what can be sold and if the demand is known at a certain time period, the product is realized or made after a certain time period, which is the manufacturing lead time, and we will be able to sell what has been produced.

Therefore, it is necessary to capture the actual demand and not capture the estimate of the demand. So, information systems help us in getting actual demand and help in implementing pull systems, and sell what has been produced. Information also helps in centralized versus decentralized inventory. We have already seen earlier in the course, that if we centralize the inventory or keeping it in one place, the buffer inventory or the additional inventory will come down. But, the transportation cost will increase because the customers will be located far away.

If on the other hand, we locate the inventory close to the customer, the cost of transportation will reduce, but the cost of holding extra inventory or excess inventory will now be increased. Now, we could through information system we can try and get the best of both, now we will be able to physically locate the inventories close to the customer points. Reduce the excess inventory or the safety inventory which is there, and in the event of the demand being higher than, the available stock in the warehouses that are closed to the customer.

We will be able to pull stock from other warehouses, which have excess stock there will be a slight increase in the transportation cost. But, information systems and Information

Technology would help us quickly understand and know, where how much of stock is available. And therefore, it will be able to get the stock in time and give to the customer, the fourth aspect is what is called vendor managed inventories. Now traditionally each of these manufacturing systems, they maintain their own inventory.

They have their own EOQ computations; they find their order quantities and the reorder levels. And when the stock reach the reorder level, they place orders with the suppliers, now vendor manage inventory is a very interesting concept, now if you imagine a super market or a retail store which sells a variety of products. Now, they will traditionally they will be maintaining their own inventory, so they would know their reorder levels and the points at which they will have to place the order.

In a vendor managed inventory, the retail store does not mange the inventory or does not worry about the reorder level. Now, the reorder level is communicated to the vendor. Now how does the vendor or the supplier know that the reorder level is reached? Now the information system in the store will now talk to the information system with the vendor. So, whenever there is a sale happening in the store, the stock is updated in the store and it gets reflected and the vendor is able to track it.

Now, through Information Technology when the stock reaches the reorder level at the store, the vendor understands that the stock has reached the reorder level in the store. And the vendor automatically generates an order or the information system at the vendor, generates the order resulting in vendor managed inventories. Now, the store does not worry about the inventory positions, the responsibility of managing it is with the vendor. And such a thing is enabled through Information Technology.

The next thing that we can see is what are called reverse auctions, now reverse auctions is like our tendering. So, when we tender for something we will choose the person, who, actually, reverse action is the opposite of in an action, we try and sell the product and whoever bids maximum for that gets the product, pays the money and gets the product. In a reverse action we would, it is like tendering, so we would like to put forth our requirements, and then people bid for those requirements online through information systems, and the person who actually has the lowest bid now gets it.

So, reverse auctions also help in procuring or buying material because, we try to pick the one who has the lowest bid for it, from home we can buy at the lowest cost. Now, this is

also enabled through information systems, and technology and through online processes. Last, but not the least the status of the product or status of the order is now known to the customer, so when customer places an order with an organization for a product, now the organization triggers the work order, and manufacturing executes the work order.

Now, the customer through Information Technology, through internet be being able to login to some systems is now able to understand or view the status of the order. And that helps in the customer knowing exactly, how much more time is needed for the order to be finished and for the product to be delivered. Now, all these also put extra responsibility and owners on the manufacturing system, to gear up and produce and deliver in time.

So, in essence the information system is able to capture and provide the right kind of data to the right kind of person so that uncertainties in the system are reduced, and the organization is able to produce and deliver things in time, and essentially make profits through this process. Therefore, Information Technology is an important component of supply chain management.

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Now, how do organizations maintain or create information systems and Information Technology. Traditionally, we have had MRP systems and MRP II systems within manufacturing. MRP systems were called Materials Requirement Planning systems, and MRP 2 systems were called Manufacturing Resources Planning systems. Now, both

these systems essentially were restricted to the scope of manufacturing, MRP or materials requirement planning talked about the bill of materials.

And the level of each bought out item or component or manufactured item in the product, and through the bill of material it was able to generate, how many quantity or in what quantity each item has to be bought, to meet the demand of the product. And then the output of the MRP systems, were used to identify the vendors, and sometimes used through lot sizing algorithms and methods, to try and bunch or combine orders to a vendor, and increase the order quantity so that certain other benefits can be accrued.

MRP 2 systems also called Manufacturing Resources Planning systems were seen as systems that were one level above the MRP systems. And also handled additional information on availability and on little bit of human aspects of manufacturing, so MRP and MRP 2 systems were essentially created, to act as information systems within the scope of manufacturing.

Now, ERP systems or Enterprise Resource Planning systems came much later, and started looking at the entire organization and ERP systems could map the various functions within the organization or within the organization as a whole. Some of the ERP modules, one could think of are finance modules, logistics modules, order fulfillment modules, manufacturing modules, human resources modules, and supplier management modules. Each of these modules could also have sub modules such as maintenance, quality and, so on.

Now, the advantage of this large system is it is ability to capture the linkages amongst all of these. For example, procurement is largely related to the finance, logistics is largely related to manufacturing because, the finished goods that come out of manufacturing, will now have to be distributed or sent to the customer. Procurement also is related to manufacturing, as well as to marketing, so that the demand of the products are known, as well as the capacities and availabilities from the manufacturing are also known.

Similarly, human resources and manufacturing are equally important, so that the human resources available or known to manufacturing through these systems. So, if we carefully look at the organization as a whole, with it is multiple functions there is a strong relationship among each one of these functions, each of these functions within itself carries out a whole lot of activities. But, importantly there is a strong relationship among

these functions, and a lot of data and information has to move from one system to another.

Now, all these are done through the enterprise resources planning systems or ERP systems as they are called. Now, there are two ways of looking at ERP systems, one approach is to look at ERP as a logical extension of MRP and MRP 2, while the other approach looks at ERP as a completely different system. Different from the scope of ERP as well as MRP, then whatever way we look at essentially what we try to do, is to understand and importantly capture the relationships, among these different functions of management of an organization and use the right kind of data from each one of these functions to make decisions on other functions that would impact the performance of the supply chain.

Now, we spend a little more time on information system and supply chain management, now we classify information systems into three, one is called within firm information systems, inter firm information systems and supply chain information systems.

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Now, this kind of classification is only indicative it is not exhaustive, and we will see some aspects of this classification. Now, within firm we could think in terms of MIS, DSS and ERP. MIS stands for Management Information Systems, DSS stands for Decision Support Systems, and ERP stands for Enterprise Resources Planning systems.

MIS started off a little early. Management Information Systems, started little early and they had cretin limited scope within the organization.

DSS also called Decision Support Systems also had limited scope, and DSS would essentially help the organization in decision making, while MIS provided the information that is necessary for decision making. Now, DSS modules also could incorporate some optimization kind of modules, so that some decisions could come out of these computer systems. Just as mentioned just now ERP systems are, systems that link and integrate the various functions of management, functions within an organization and try and use data from one function to help make decisions in other functions.

So, these three are good examples of within firm information systems, but supply chain management is about a network of facilities or a network of organizations, and it is spreads across organizations. Therefore, we will look at inter firm information systems and it is role, now some of these aspects are EDI Electronic Data Interchange, the use of the internet just in time manufacturing systems, and cross docking systems. We will look at each of these very briefly, electronic data interchange is the ability transfer data from one organization through the other, and it is used extensively.

Internet is well known, and is a way to see and view information public can view information, as well as organizations can view information that is available in a different place. Now, these two help in supply chain management extensively. We did speak about vendor managed inventory that where the supplier manages the inventory of the customer. Now, that is possible either when data comes from the customer to the supplier, through EDI systems or through internet where the supplier is able to view the data that is present in the customer.

So, that is the way by which these two enabling mechanisms help in vendor managed inventory, and other aspects of supply chain management. The other two are applications, where we have inter firm information systems, the role of inter firm information systems, in effective implementation. Now, JIT stands for just in time manufacturing, and one of the important aspects of just in time manufacturing is also just in time purchasing, which means the organizations purchase the items or the products from their suppliers.

And purchase in quantities that are just in time, which means the quantity that is purchased is enough to meet the requirements of a very short period, predetermined period which could be a day, which could be a shift, which could be a week which is predetermined by the system. Now, if we assume that we are going to buy daily, so for an organization to make the product typically today manufacturing organizations talk about, make daily, sell daily we also look at buy daily.

So, let us assume that the organization buys daily, converts them into product and sells them daily. Now, in order to buy daily, the supplier should be in a position to deliver or to provide the items that the organization can buy daily, now in order to do that the information system of the supplier, should talk to the information system of the organization or the customer or someone who is going to buy from the supplier. Therefore, we see the role of interactions between information systems of different firms.

In a cross docking environment which we explained earlier, there is a space in which warehouses send trucks to come to that place. And these trucks are there, and the cross docking area has additional trucks, and the inventory is shifted from one set of trucks to another set of trucks. Inventory does not stay physically in the cross talking area, and then the stock is sent to the customers, once again the timing, the quantities that have to be shifted all of these can now be exchanged through information systems.

And there is enormous scope for inter firm information systems to help in effective supply chain implementation. Now, in addition we have what are called supply chain information systems, where we talk about decision making for the supply chain for the entire supply chain, which means a chain of manufacturing organizations, chain of organizations that act the supplier customer etcetera.

So, effective decisions forecasting for the product that would be useful to the entire supply chain, and effective decision making in planning that would be useful to the entire supply chain. So, we will need software that would do that, information systems to support, create, maintain, and execute such software also have to be created. And then we talk about supply chain information systems, which take which uses ideas from inter firm as well as within firm.

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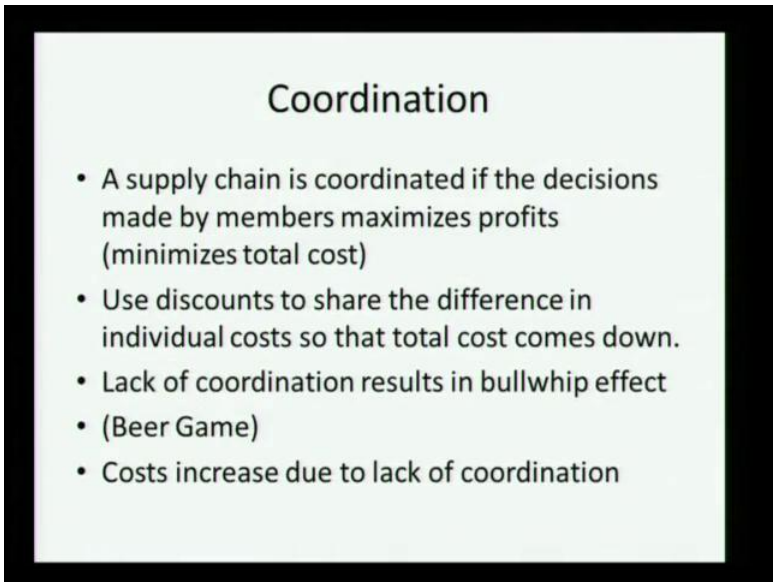

Now, we spend a little bit of time on coordination. Coordination generally means people work together, they coordinate and work together towards a common task. Now, coordination is an important concept in supply chain, supply chain is coordinated if the decisions made by the members of the supply chain, maximizes the total profit of the supply chain or minimizes the total cost in the supply chain. A good way of explaining coordination is like this.

Now, suppose there is a organization which orders for a certain item to a supplier. Now let us assume that this supplier is ordering it and getting it from another person. So, now, we will call these as A, B and C. Now A is the organization which is going order to B, B is the supplier, and B orders from C. Now, A can independently workout the economic order quantity, and the total cost associated with the order, now B will also have to order to C and therefore, B will separately workout the economic order quantity.

Because B's ordering cost may be higher and B's inventory holding cost may be different, now if both A and B work on their economic order quantities, the total cost will be the total cost for A and the total cost for B put together. It is always possible for A and B to come together such that they order a common quantity, so that the total cost for a plus B put together can come down. Now, such a thing is called coordination, now when we do this coordination two things can happen.

Now, through this coordination the cost for A can come down as well as cost for B can come down and the total cost can come down. There can be a situation where, the cost for one of them may increase and the cost for other may come down and therefore, that organization which is A or B, for whom the cost after the coordination increases, while the total cost comes down. Now, that organization will be hesitant to implement it because, its cost would increase.

In such cases organizations should come together to absorb the increased cost of one person in the interest of both the organizations coming together. So, that the total cost reduces. Now such a thing can be done through discounts to share the difference in individual cost, so that the total cost comes down. Now, lack of coordination results in what is called the bullwhip effect, now we have already seen what is bullwhip effect very briefly.

Bullwhip effect is the result of increased inventory in the supply chain, as we move from right to left, which means as we move from customer to supplier there is the average inventory in the system would increase if there is no coordination. The average inventory in the system increases simply because, of the uncertainty that is communicated in the ordering. So, every entity will actually order a little more than what is required, and therefore, the variation in the order increases.

And therefore, the total inventory in the system increases, as we move from right to left or as we move from customer to manufacturer. Now, that is called bullwhip effect, and the effect of bullwhip is that there is total increased total inventory in the system that results in increased total cost of the system, and this cost increases due to lack of coordination. Now, there is an important thing in supply chain called the beer game, which is usually played to help people understand the effect or the role of bullwhip effect, and the increased cost of the supply chain if there is no coordination.

We would spend a little bit of time on the beer game in this lecture after a few slides, now we also have to understand obstacles to coordination. Now, while we know that if organizations come together, and make decisions together that can bring down the total cost of the supply chain, then why do organizations are why are they not doing it? Now, today there is a conscious effort for organizations to come together.

Traditionally they were not being they were unable to do it for multiple reasons, one of which was that information was not available. And information was not shared; there was hesitation in sharing information among organizations. Now, today organizations do not hesitate to share a lot of data, and the means of sharing the data which is through IT has also advanced considerably. So, there is a lot of data sharing and there is a lot of joint decision making, which result in increased coordination.

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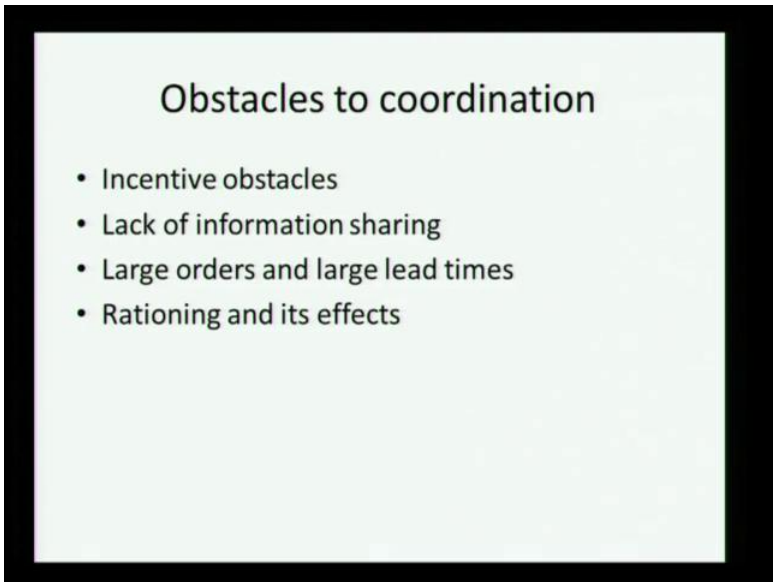

But, in spite of that there can be some obstacles to coordination and organizations have to understand that, and make sure that they do not fall into the trap of these obstacles. Now, four obstacles to coordination are listed here, one is incentive obstacles. Many times through discounts or through other incentives when we make purchasing decisions we end up buying large quantity, much more than what is required simply because, of certain incentives and discounts that we would get.

Now, these things increase the cash that is being spent or the money that is being locked up in the inventory and therefore, it increases the total cost in the system. So, when we stock a lot of items in the system, we are going to make fewer orders per year and therefore, the orders cannot be synchronized or coordinated. Sometimes, organizations also are joined together, place orders together, either organizations themselves place orders together or within an organization orders for different items are placed together so that there can be a saving of transportation or truck cost. In this course we have seen

such models when we studied inventory. Now, if we have discounts and incentives for either certain items or if certain organizations wish to avail and benefit from these discounts, then joint ordering becomes extremely difficult. In a similar manner many obstacles happen through these incentives. Second is lack of information sharing. We have already seen that information sharing and good information helps in reducing uncertainty and therefore, reduces inventory.

Now, organizations have to come together shun their inhibitions, shun their fear and start sharing data. So, that they work in a coordinated manner and the total cost comes down. Large orders and large lead time; large lead times are also obstacles because, whenever there is a lead time there is an inventory, there is an uncertainty and there is an inventory. We have also seen the effect of lead time, in when we studied inventory through some examples.

We not only studied the effect of large lead time, we also studied the effect of variation in the lead time. If the lead time shows variation or if there is a standard deviation of lead time, then we found out through our computations that the total inventory in the system is very high. Now, organizations have to be coordinated to reduce lead times, reduce variation in the lead times work together, share information and data bring down the lead times, so that the total cost comes down.

The last one is called rationing and the effect of rationing, now rationing happens when total demand for a product is more than the supply. So, if we assume a single supplier and let us say four customers, who demand this product and if the total demand is higher than the total supply, then certainly all of them will not get their demand. Then rationing policies come into the picture. Now, the common thing that one would think of is to proportionately reduce the quantity that is transported.

Many times that does not happen largely because, of the importance of the customer, because of the quantities ordered and, so many other factors. Rationing is a very separate area of importance from both theory as well as practice, one of the problems that happen when somebody knows that there is going to be rationing and particularly when we know that the proportion we are going to get will depend on the demand that is being ordered, organizations will deliberately hike up the demand.

So, that a certain proportion of the increased demand would come, which would mean the organization would get more items from the supplier. Now, such a thing also reduces or prevents coordination from happening and organizations suffer through this, so these are some of the aspects of coordination and obstacles to coordination.

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Now, it is also important that coordination is carried out through Information Technology, and there is a strong role for Information Technology in coordination. Now, we have listed three points which are - sharing point of sale data, the important aspect is when we share point of sale data with the suppliers in particular, the vendor can manage the inventory. The vendor knows exactly when the re order point is going to be reached, and the vendor can also plan, so that the reorder point can effectively be reduced by proper coordination.

Collaborative forecasting and planning: Organizations come together, and instead of individually doing forecasting and planning, come together and do the forecasting planning and other systems in a collaborative manner. And the third one is to look at vendor managed inventories, we did speak about vendor managed inventories where the organization does not worry about the ordering, through coordination, through information sharing, through sharing point of sale data. The supplier is able to keep track of the inventory position of the various products of the customer.

And as and when the reorder level reached for these products, the customer will trigger or will create an order and will deliver the item to the customer. Now, this is called vendor managed inventories, there are several examples in the literature for vendor managed inventories, between very famous super markets, and very famous manufacturing organizations.

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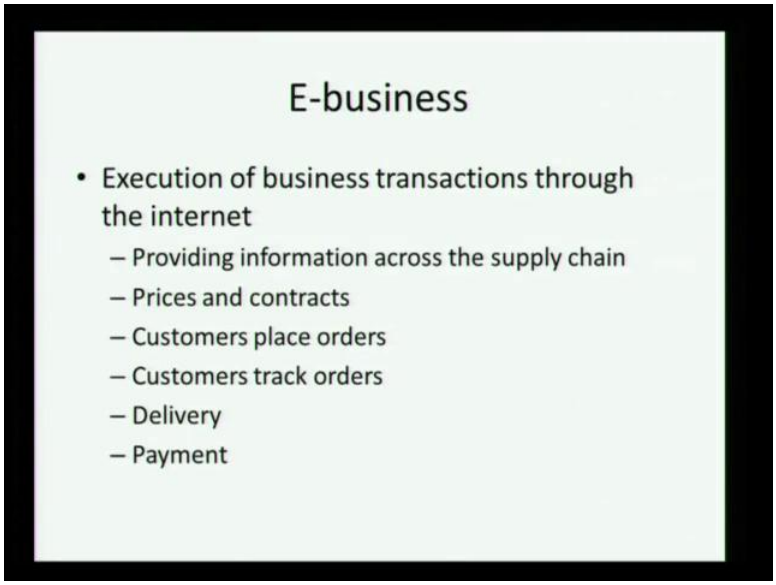

Now, we also talk about E business which is called Electronic business. Now E business is the execution of business transactions through the internet. Now, this is a phenomenon that has been in existence for about 20 years or more. Now, one could say comparatively recent but, extremely important and flourishing. Each one of us would have used E business in many ways today, using E business to order books, today using E business to buy items, today using E business and E portals to book tickets. These are all extremely popular and famous examples of using electronic business.

Some of the aspects are providing information across the supply chain, prices and contracts amongst prices of the products, telling the customers about the prices, so that the buy price changes contracts. Customer can place orders; customers can track orders. Now, the delivery aspect as well as the payment aspect can be ensured through E business strategies. Payments are also famous today we are able to pay most of our bills electronically, so there is a very large role for E business and E commerce in the supply chain.

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Some other things that E business systems can do are direct sales to customers. Examples of computer sale which happen directly to the customer. Another important aspect is a 24 hour access, where these systems are available right through and not restricted by timings. E businesses provides personalized services by keeping track of the buying patterns of the customers, so when you place an order for a certain book immediately the website will show other similar books or books by the same author and, so on.

E business systems also help us in flexible pricing, depending on the stock positions of the books, depending on other interest and, so on. Particularly airline pricing - to be able to track the prices of air tickets, all these are possible through E business systems, lots of examples in PC industry, book industry and, so on. But, E business also has an important aspect in the supply chain management.

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Now, we spend a few minutes on this beer game. The beer game is a game that was created somewhere in the 1960's by a university. Where they made people understand the effect of a supply chain by modeling the supply chain through a classroom game. Now, over the years this game which started off as the classroom game, also has had it is electronic version, and several versions of this game is also available. The beer game can be played in many ways.

It started off with the beer game because, the first time the game was played the product that was used for illustrative purposes, was beer. And therefore, the name beer game has stayed for well over 50 years. This game essentially captures or through a game it explains the various aspects in a supply chain, and also helps in understanding the basic principles of the supply chain, including the bullwhip effect. Now, what we are going to see are results from beer game that have been played in classroom on two consecutive batches of students. Now, in a class containing about 60 students one could divide them, into 7 or 8 groups you see 8 groups which are here.

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Now, each group will have about 8 students and each group will represent an organization. And these students will now be divided - some of them will be customers, some of them will be warehouses or distribution points, and some of them will be manufacturing points. Now, if there are 9 students in a group or 9 people in a group we would divide them into 3 groups of 3 each, and each of these the 3 will act as a customer the other 3 will act as a distribution and the third will act as manufacturer.

Sometimes, we could even have 4 levels in the supply chain or 4 entities in the supply chain resulting in 3 levels, and it can be manufacturing, warehouse, distribution and customer. So, what we do is one of them acts as the customer or as the retailer and then the end customer comes in. So the demands are generated for the classroom. There is a single product that is assumed, and demands are generated. So, this slide would tell us the demands for each of these groups.

So, the demand 100 plus minus 20 would mean that we generate a random number uniformly distributed between 80 and 120. So, you would see 100 plus minus 20 and you will see 100 plus minus 100, so you realize that the demand shows more variance for groups 5, 6, 7 and 8 and lesser variance from 1, 2, 3 and 4. Now, what we also do in this case is that somebody represents the market, and they come and give the demand to the retailer. The retailer has some initial stock, and the retailer will meet that demand from that stock, and place an order with the warehouse or the distributor.

Now, when the lead time is zero, the warehouse or distributor immediately gives the order, and then the warehouse places an order with manufacturing and, so on. And notionally the product is made from the manufacturer given to the warehouse, and then to the retailer, and then to the customer. So, each of these persons updates their beginning inventory demand, what is supplied as well as their ending inventory. Now, for each of them there is an inventory carrying cost, which is taken as one unit or one rupee and there is a shortage cost which is taken as 20 units or 20 rupees.

Now, we also give different lead times sometimes the lead time zero means that when the retailer comes to the warehouse, the warehouse immediately tries to give the item that is available in the warehouse. If the lead time is 1, it means the warehouse will take one more week to deliver. The third dimension that we bring into this game is for groups 1 to 6, we do not have information sharing, for group 7 and 8 we have information sharing. So, for group 7 and 8 when the customer demand is told, the customer demand is told to everybody.

And they can also discuss it, and then they can make their own decisions with respect to how much they wish to buy, so that is how information sharing in modeled. So, if you see the beer game setting that I have described, there is a variation in demand which you can see the mean demand or the average demand is the same. There is a variation in lead time, and then structurally there is a variation where some groups play without information sharing, which means the customer demand is not known to other stages in the supply chain, but it is known only to the retailer. And only the retailer demand is known to the warehouse, and the warehouse demand is known to the manufacturer.

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Group No.	Periods	Average EI	Average Cost
1R	15	206	1030
1D		208	274
1P		306	365
2R	14	84	404
2D		350	350
2P		256	256
3R	18	200	442
3D		206	1100
3P		333	555
4R	10	325	325
4D		1341	4000
4P		1445	1600
5R	14	276	548
5D		306	673
5P		911	1891
6R	15	384	981
6D		154	272
6P		401	401
7R	7	207	1286
7D		155	1336
7P		172	1229
8R	15	262	485
8D		295	295
8P		270	270

We now show some of the results of the beer game that is played in class, and the results of the 8 groups are shown here. The column 1 talks about the 8 groups, the retailers, the distributors, and the manufacturer or the producer, column 2 simply talks about number of periods for which they played, it is observed that one group is a little slow and played only for about 7 periods. Column is 3 and 4 are important from the point of view of understanding the supply chain.

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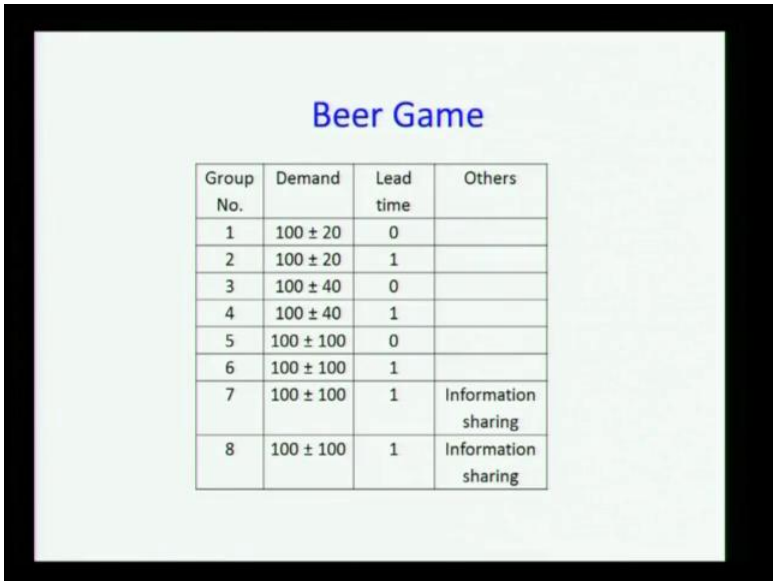

Group No.	Demand	Lead time	Others
1	100 ± 20	0	
2	100 ± 20	1	
3	100 ± 40	0	
4	100 ± 40	1	
5	100 ± 100	0	
6	100 ± 100	1	
7	100 ± 100	1	Information sharing
8	100 ± 100	1	Information sharing

Now, we realize that groups 1 to 6 did not have information sharing while group 7 and 8 had information sharing.

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Group No.	Periods	Average EI	Average Cost
1R	15	206	1030
1D		208	274
1P		306	365
2R	14	84	404
2D		350	350
2P		256	256
3R	18	200	442
3D		206	1100
3P		333	555
4R	10	325	325
4D		1341	4000
4P		1445	1600
5R	14	276	548
5D		306	673
5P		911	1891
6R	15	384	981
6D		154	272
6P		401	401
7R	7	207	1286
7D		155	1336
7P		172	1229
8R	15	262	485
8D		295	295
8P		270	270

And now when we come back and see that the average inventory in the system particularly when we look at group number 7 which is here, 207, 155, 172 we look at group number 7, we observe that the average inventory in the system is far less than the one that is in group 4 or that is in group 5 and, so on. Now, we realize that information sharing helps us in reducing or understanding that the average inventory in the system comes down.

Now, we should also keep in mind that since this is a game that is played in classroom, one cannot make lot of accurate comparisons. But, one can only try and understand some meaningful inferences that come out which I will try to do right now. So, I am trying to explain that the average inventory in the system comes down when we have information sharing. Where even between group 7 and group 8, there is no difference in the problem setting, but then we realized that there are differences, in the numbers that they have, largely because, of the way they have played the game.

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Now, if we look at other groups for example, if we look at group 1 and 2, demand patterns are the same, but lead times are different.

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Now, one could understand that when the demand patterns are the same, but the lead times are different, the way the inventories behave is very, very different. Now, you see that group 2, the inventories are not comparable, the average inventories are not comparable, the average inventory is very high here, little low here, and much lower here

which shows some kind of bullwhip effect that is happening. Here in group 1 the average inventories are reasonably comparable.

For example, if you look at group 3, group 3 has the higher variation then groups 1 and 2, and now we see that the average inventory in group 4 is much higher than that of groups 1 and 2. So, more variation in the system increases the average inventory, now lead time would the variation in demand is not very high, but there is a lead time and the lead time distributes the inventory unevenly in the supply chain, which can be seen in group number 2's performance.

So, at the end we could back and summarize the results by saying that when we information sharing, the inventory in the system comes down compared to groups or systems, which had no information sharing. Now, when the product variation is higher we will now see that the total inventory in the system is also higher, and when the variation is higher we would also see that the inventory is higher compared to systems which have lesser variation.

Now, when we have lead times, lead times essentially try and redistribute the inventory among the players in the supply chain, and a combination or variation in lead time as well as variation in demand shows the bullwhip effect. Now, let me show another sample of beer game that is played in a class, where there are 10 groups and then we also look at the similar pattern, where 8 groups have no information sharing and 2 groups have information sharing.

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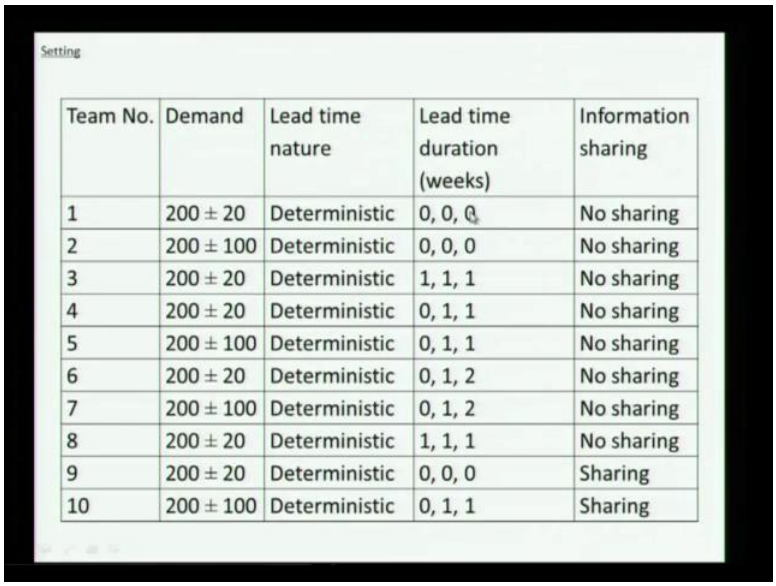

And the lead times are 0, 0, 0 to 1, 1, 0, 1, 2 and, so on, we have deliberately used 2 week lead time. So, that if you place an order you will get that order only after two weeks and, so on and this time we also increase the demand, as well as we change the variation in the demand.

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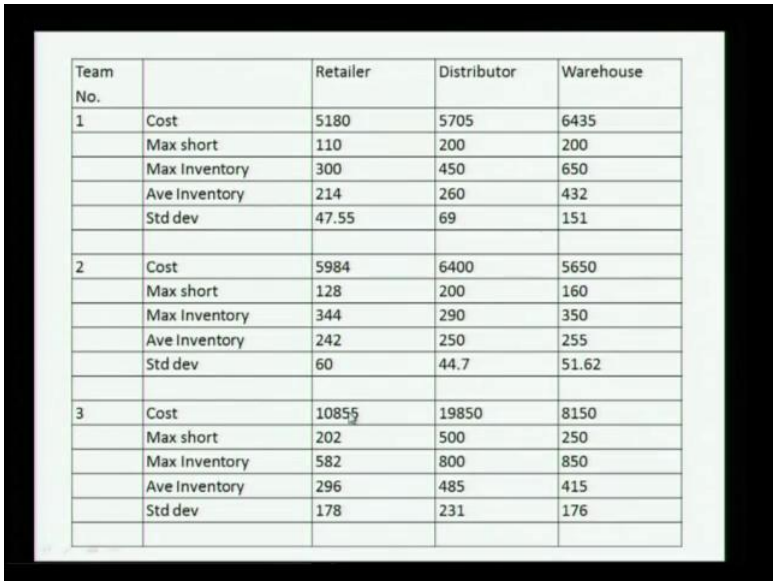

Now, the results of this game is also shown and there are 10 groups, so they are shown over three slides. And then one could understand here, if we look at the inventories here between, we observe that as we move along groups 1 and 2 there is a large variation, so

if we see now that the cost also increases here between 1 and 2. The average inventory in the system here remains increases a little bit. So, with variation we could see that the average inventory increases a little bit. Now, between groups 1 and 3, there is a clear difference in lead time. So when we look at groups 1 and 3 the maximum inventory increases, which is an effect of the difference in lead times. So, when there is increased lead time the maximum inventory in the system will also increase.

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7	Cost	10885	8984.21	15700
	Max short	198	170	420
	Max Inventory	281	480	1150
	Ave Inventory	176.5	277	706
	Std dev	68	165	392
8	Cost	7599	8612.5	6000
	Max short	183	200	200
	Max Inventory	226	520	500
	Ave Inventory	176	361	364
	Std dev	55	155	91
9	Cost	5021	4985	4175
	Max short	110	120	100
	Max Inventory	240	260	300
	Ave Inventory	207	218.5	237.5
	Std dev	44	31.3	33.5
10	Cost	6805	5633	9122
	Max short	188	150	290
	Max Inventory	264	500	500
	Ave Inventory	196	266	303
	Std dev	47	95	127

Now, we will look at groups 9 and 10 we realize that the average inventories 196 which is much lower, than other average inventories in other places without information sharing like 214, 242, 296 and, so on. So, that we are able to show here the total cost in the system also behaves in a certain manner, this is of the order of 5000, 4900, 4100 compared to 7599, 8612 and 6000. And one can see that group 8 did not have information sharing, group 9 have information sharing and therefore, is able to coordinate data. So, what are all things that we have described in theory and practice, we are able to capture it through a classroom game which is called the beer game.

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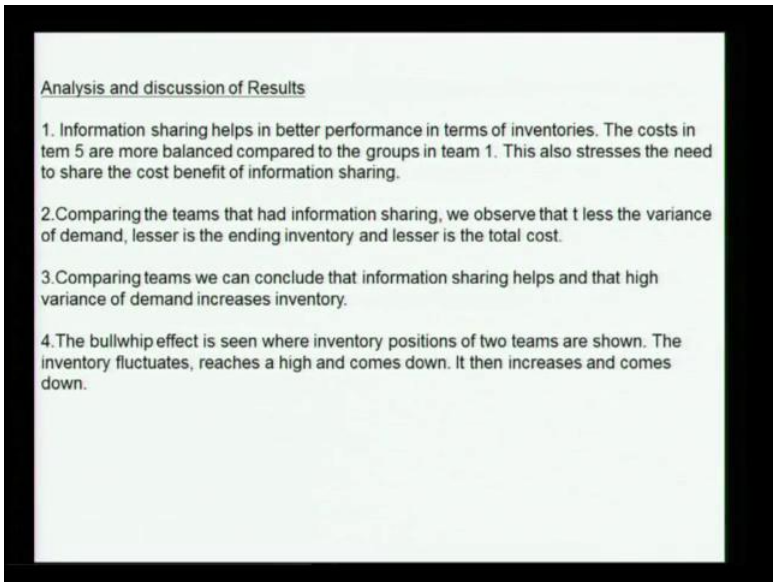

So, the summary of results of the beer game would be - information sharing helps in better performance in terms of inventories. We observe that the less variance of demand less is the ending inventory and less is the total cost. So, variance of demand increases the inventory as well as total cost. Information sharing helps and high variance of demand increases the inventory. Bullwhip effect is seen, where inventory positions of two teams are known, inventory fluctuates, reaches a high and then comes down. The fact that the inventory reaches the high end keeps coming down is the essential component of the bullwhip effect.

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So, this is the this is how we explain or use the beer game in class as well as in other places to make people understand the effect of supply chain, and the importance of coordination and information sharing. Now, with this we come to the end of this session on role of information as well as information sharing. We also come to the end of this course on operations and supply chain management.

Now, there are 41 lectures and in somewhere during the middle of the course, around the end of the 34th lecture, I had given a summary of what we had done, up to the operations management portion. Or looking at it from a supply chain point of view I had given a summary of the important supply chain ideas such as, production decisions and inventory decisions. Now, from lectures 35 to 41 we looked at transportation and distribution, as well as we looked at some aspects of information system.

We also looked at some location decisions, when we did location and layout as well as location and layout in the context of supply chain, and also when we started looking at supply chain in much more detail. So, the earlier lectures in the course concentrate a lot on operations management, things that happen within the firm in terms of managing production, and in terms of managing inventories.

The later lectures talk about the role of distribution, the role of location as well as the role of information. So, with this I would conclude this course on operations and supply chain management. I hope I have covered the various aspects of operations management, and some aspects of supply chain management in this course and I hope that this course is useful to all it is viewers.

Think you.