Economics, Management and Entrepreneurship
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Lecture - 44
Supply Chain

Good morning. Welcome to the 44th Lecture on Economics, Management and Entrepreneurship. In our last lecture, we continued our discussion on Inventory Management. If you recall, we consider different aspects of inventory costs and we took deterministic inventory model. The basic question in inventory control is when to order for replenishment and how much to order.

Assuming deterministic situation, we have developed the Wilson Lot-Size formula. Then we introduced uncertainty in demand and in supply. We said that in addition to keeping the expected amount to fill the demand during the lead time one must have additional material in stock to cater to uncertainty in the demand this we said is buffer stock. We said that at a given service level one can calculate the buffer stock.

This stock should be added to the expected demand during the lead time to find out the reorder level. Then we said that one can find out the expected number of units short and then there are 2 cases. One a lost sales case and the other backorder case. If we can estimate the cost due to backorder or lost sales, then in addition to the 2 usual costs that we had considered earlier namely the ordering cost and the inventory holding cost.

We can also consider the shortage cost. Considering these 3 costs one can then find out the amount that we should ask for reordering. Now we can have fixed quantity model or fixed period model and then towards the end of our lecture in the last class we also introduced materials requirement planning for dependent demand.

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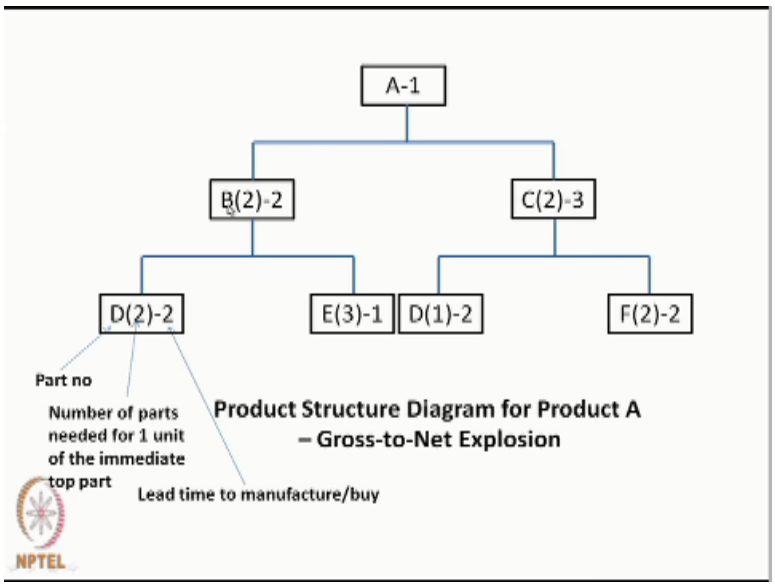

And we took a particular case. This case let us revise once again. The case is illustrated here in the form of a product structure diagram. If suppose that the assembly A requires one day to assemble component B and C and it requires 2 items of B and 2 items of C to make B it requires 2 lead time 2 days and C requires 3 days. B in turn requires 2 items of D and 3 items of E. D requiring 2 days' time, E requiring one-day time and similarly C requires D and F with number of parts of D and F mentioned here and the lead time mentioned here.

This is called a product structure diagram.

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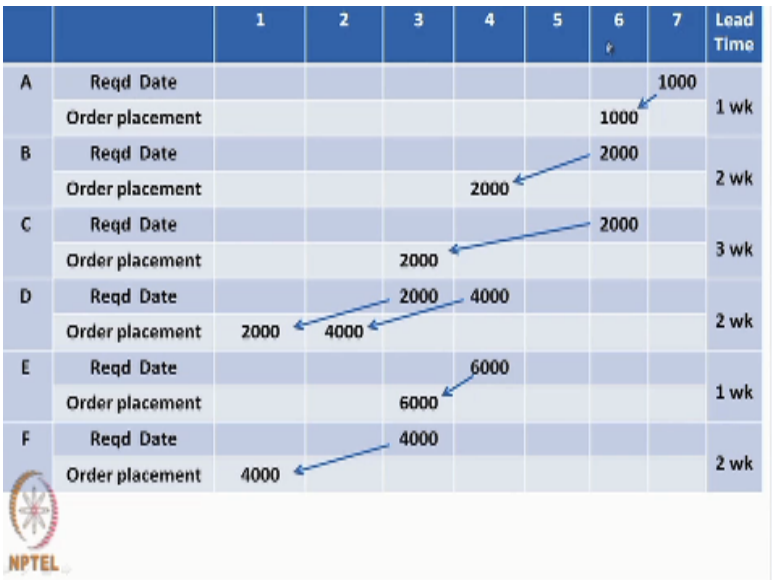

We can use this information in this form. Suppose that we need to get 1000 items of A on August 7 with one-week delay order must be placed for A for 1000 items on the sixth day. Since A requires 2 items of B and 2 items of C then B and C must be available in sufficient

quantity here so that one can manufacture or assemble 1000 items of A. Now to get 2000 items here it requires 2 days' time therefore order must be placed for 2000 items.

And similarly for 2000 items of C 3 weeks' delay therefore order must be placed on the 3rd of August. Now 2000 items of B each items of B requires 2 items of D and 3 items of E. So 4000 items of D and 6000 items of E must be available on day 4 and there is a 2-week delay for D and a one-week delay for E. Therefore, order must be placed for D on the second of August and for E on the third of August and similarly one can calculate here.

So you can see that for materials requirement planning which is good for dependent demand one has to first of all explore from the product structure diagram meaning that we need to have a bill of materials. And we should also have a master production schedule to know when how much of the final product we require. Once we know that using the bill of material one can find out the number of components require.

And from the lead time knowledge we can also find out when to place the order. So these are the basic considerations for material requirement planning. You can see here that the lot size differs from component-to-component and from day-to-day. That is why this is called lot for lot ordering. However, one can also consider lot sizing the way we had been doing in our independent demand case we can also consider safety stock.

And we can also give little more than the lead time expected lead time given there to be on the safer side. So these are various developments on the basic material requirement planning. Now before we end our discussion on inventory control let us consider a concept which has been very popular in recent days and this concept is called just-in-time manufacturing, just-in -time or JIT.

Basically it says that one should not have lot of inventory at stock it should get inventory as and when necessary. Now this has reduced the inventory stock greatly.

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Let us see how this is actually implemented in practice. So JIT manufacturing stands for just-in-time manufacturing. It makes materials available just when it is necessary. It reduces the need for work-in-process, material tracking, and the transactions associated with shop-floor and purchasing systems.

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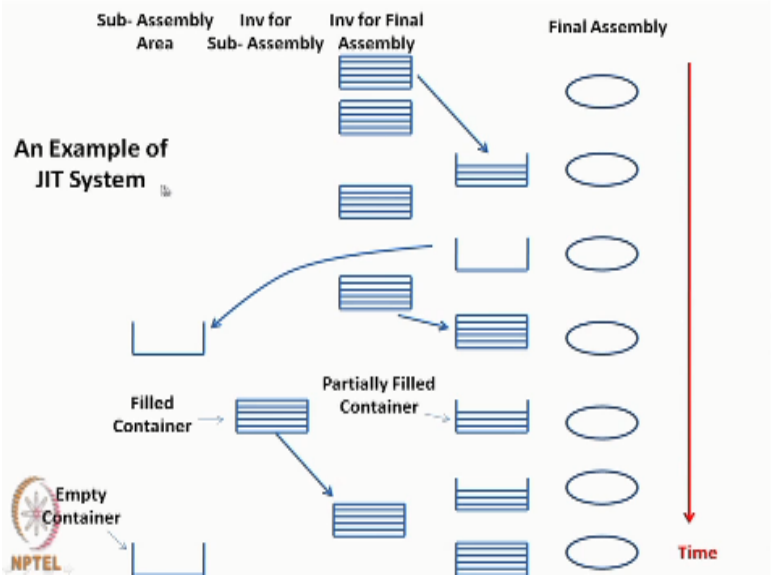

Now this is an example of how just-in-manufacturing system can or operates in practice. Let us assume that we have to assemble a few sub assemblies. Let us say that this is sub assembly area and this is a final assembly area. And let us assume that we have 2 containers (()) (08:14) with these sub-assemblies. So what is done at these 2 are available at the side of the final assembly. Now this axis the vertical axis down way is the flow of time as time passes and measured in terms of minutes.

Now the first container is taken and is assembled as it is assembled then it is this situation after let us say after 15 minutes is the situation when the first container is half filled or partially filled and the second container is intact. Then after 10 minutes, 15 minutes the first container is totally empty and the second container is now free. Second container is full. Now after sometime the second container comes to the final assembly, comes near the final assembly for use after a few minutes one or 2 minutes.

And at the same time this empty container goes to this sub assembly area. As this second container is being used for final assembly it gets partially filled and meanwhile the empty container which comes to the sub assembly area gets filled. And then is passed on to the final assembly area. So this is the case when the second assembly is almost going to be empty and just this one which was empty is filled with the sub assembly and are now available for use at the final assembly side.

Now here is a case after about 10 minutes, 15 minutes this becomes empty and is passed on to this sub assembly area once again and this container this filled container is available for final assembly work. Now this cycle continues. So you will see that at any time there is only one container of sub assemblies that are available near the final assembly and that is the stock So there is no need for much of a work in process inventory.

So this is the concept of just-in-time inventory and it has large number of uses. So in this 2 lectures and 15 minutes or 10 minutes today what we have done we have introduced the concept of inventory, the concept of economic order quantity, safety stock, materials requirement planning and just-in-time inventory. Inventory management however is just not inventory control.

It also includes purchasing, storing, inventory, updating, packing and shipping. So inventory management is much wider term, but we consider only the inventory control aspect in much greater detail because that is the most difficult part and is mathematically sophisticated. The next topic that we just going to discuss today is supply chain management. Supply chain management is quite important subject and it is gaining importance in today's world.

Particularly because the manufacturers should know how to keep contact with the ultimate customers. Gone are the days when the manufacturers used to decide what to send to the

suppliers to the customers how to send, when to send. Now the customers are demanding the type of products they require should reach them as soon as possible and the best quality material should be available to them and at the least price.

Thus supply chain management is becoming more important because the cost of manufacturing gets amplified as it passes through its supply chain to the ultimate customer and therefore price that the customers pays is much higher than the cost of manufacturing. There are different players in a supply chain each player has to get its share of profit. Thus it is very important to design the supply chain in such a manner that the overall supply chain cost is minimized and the overall value of the supply chain generated through the supply chain is the maximum.

Let us see how it can be done. Let me also tell you at this point that supply chain management has become a very, very important topic today and it is sometimes used or taken as a full subject. We wish to only consider in one hour or one lecture the essence of supply chain management without going into any mathematical sophistication. So supply chain management is the topic for today the main topic.

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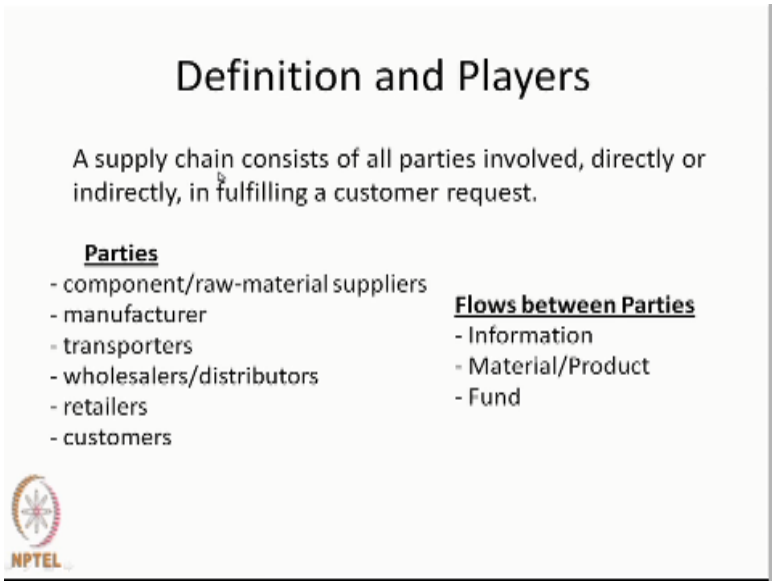

First of all what a supply chain means? A supply chain consists of all parties or players involved directly or indirectly in fulfilling a customer request. So all parties who are the parties? The suppliers of components or raw materials, the manufacturers, the transporters, the wholesalers or distributors, the retailers and the customers and between any 2 parties there are 3 types of flows that take place.

One is the flow of information and here order flow of order is also considered as a flow of information. Flow of material or product and flow of cash or fund. So these are the 3 flows that occur between any 2 parties.

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Now the overall objective of supply chain is to maximize the overall value generated. So I stress the word value and what is value? It is measured by the supply chain profitability and what is supply chain profitability or surplus? It is revenue from sales so the customers pay whatever customer pays that is the revenue from sales-all cost across the supply chain. If we subtract that what you get is the supply chain profitability or surplus and that is the value.

And the objective of a good supply chain is to maximize this overall value.

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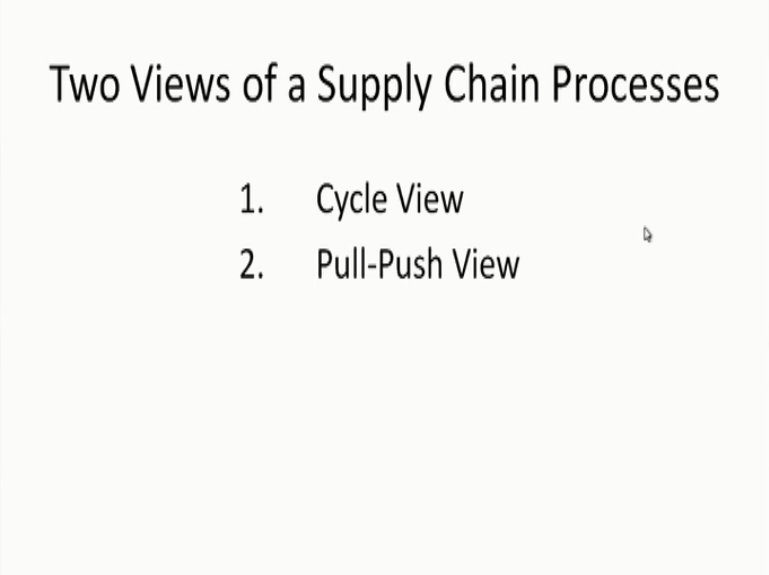

Now one can take 2 views of a supply chain process. The cycle view or a pull-push view.

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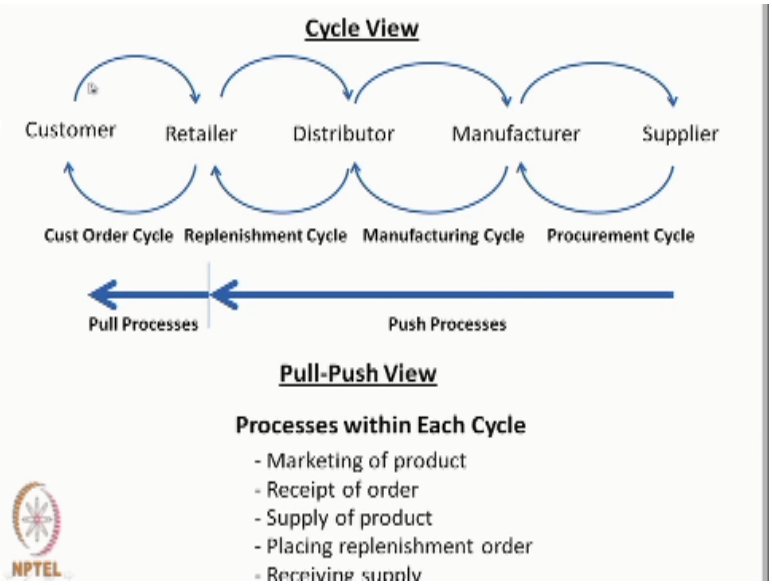

A cycle view is basically this that customer places order with retailer, retailer with supplier makes a supply to customer. Retailer in turn places order for the same goods to the distributor. Distributor replenishes the stock of retailer. Distributors stock comes down it places orders with the manufacturer, manufacturer produces the goods and supplies it to the distributor. Manufacturer requires components and raw materials from the outside vendors and those vendors or suppliers supply the product.

Thus, there are 4 different cycles the customer order cycle, the replenishment cycle, the manufacturing cycle and the procurement cycle. This is the cycle view of a supply chain. Sometimes also people say that there is a pull-push view the customer pulls because it places

a demand customer pulls the product and the manufacturer and the supplier the manufacture and supply is to the market or to the customer so it is a push process.

So sometimes this is also viewed as a pull-push process. Now between each cycle here there are different processes marketing of a product, receipt of order, supply of product, placing replenishment order and receiving the supply. So these are different processes within each cycle.

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Now there are 3 macro processes although there are large number of micro processes, but there are 3 macro processes. One with the customer that is the customer relationship management is gaining ground in marketing when we shall discuss marketing we shall discuss more about customer relationship management (()) (18:44) as CRM. So they are apart from preparing catalog and managing web site, providing after-sales service is also important.

Then the other is supplier relationship management, supplier selection and negotiation of supply terms. And then inside the supply chain which is the internal supply chain management where the warehouse should be located, how big should be the warehouse, how the inventory should be managed, how the item should be packed and shipped. These are concerns of the internal supply chain management.

So these are the 3 different macro processes. Customer relationship management, internal supply chain management and supplier relationship management. Now when we design a supply chain one has first of all to think of what the competitive strategy of the enterprise is.

Sometimes the enterprise wants to minimize the price that is the first objective. Sometimes because the enterprise may say that the main objective should be to make the product available with the customer as quickly as possible.

Sometimes the manufacturer may have a strategy or policy of making a designing new products and make it available as soon as possible. It should be as responsive to the customer demand as possible. So different competitive strategies a manufacturer may use. So whatever supply chain strategy has to be decided has to be aligned with the organizations competitive strategy.

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So that is what is known as Strategic Fit. Customer willingness to tolerate response time, the variety of products needed, service level required, product price, novelty of product design, what exactly the customer needs and what competitive strategy the organization should have, if that is decided in advance the supply chain strategy should fit with this organizational competitive strategy.

So supply chain strategy then will be made with respect to the nature of procurements of raw materials, the transport of materials to and from the enterprise, manufacture of the product, distribution of the product to customer and follow up service. We shall discuss some of these in more detail just now.

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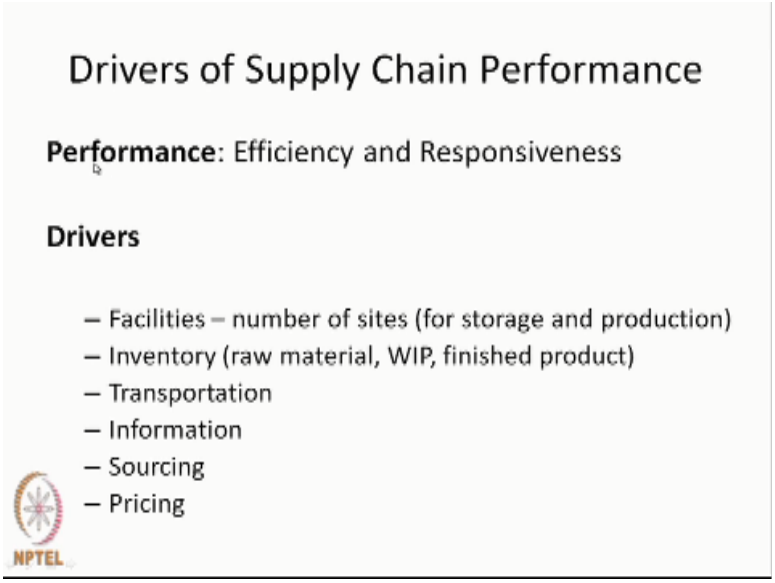

But before we do that let us find out the drivers of supply chain performance. So what we mean by performance? By performance we mean basically 2 things. One is responsiveness how quickly we respond to the customer requirements and how with less cost we are able to make the supply that is efficiency in terms of time and cost particularly cost here. If these are the performance criteria, then the drivers are 6 of them.

One the number of facilities or the number of sites for storage and production how many we shall we have, where to store materials and where to produce, the amount of inventory raw materials components, work in process and finished products, transportation, information flow where from we are getting the materials that is sourcing and then finally pricing. So these are different drivers of supply chain performance.

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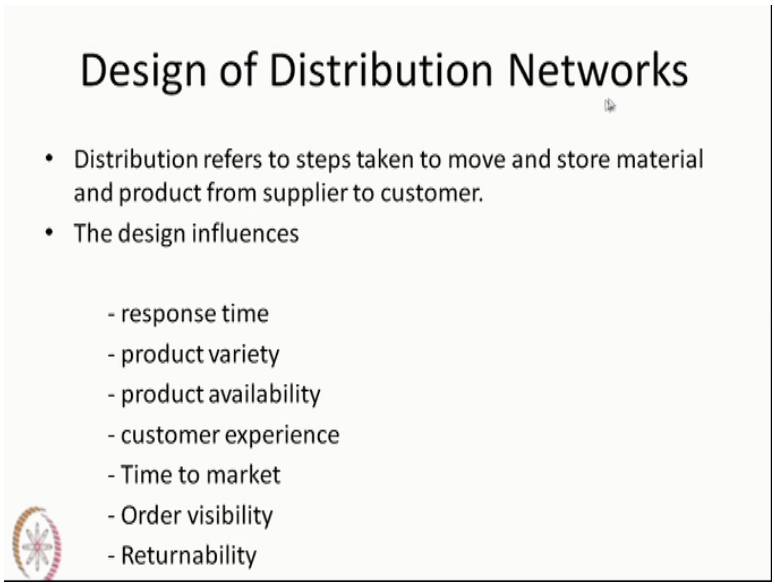

Now let us consider how to design the distribution networks. Firstly, what is the meaning of distribution? Distribution refers to steps taken to move and store material and product from supplier to customer. So all the steps that are taken to move material from the supplier to the customer is known as the distribution. And what are the various considerations when we design the distribution network the response time.

How quickly we are responding to the customer requirement, product variety, product availability it should not be out of stock, customer experience, time to market, order visibility means the orders that are received by different players should be visible to the manufacturer and returnability if customer wants to return certain items or if different parties because of a negotiation with them certain parties in the supply chain they return their product.

If that facility is there that is also another consideration to design the distribution network.

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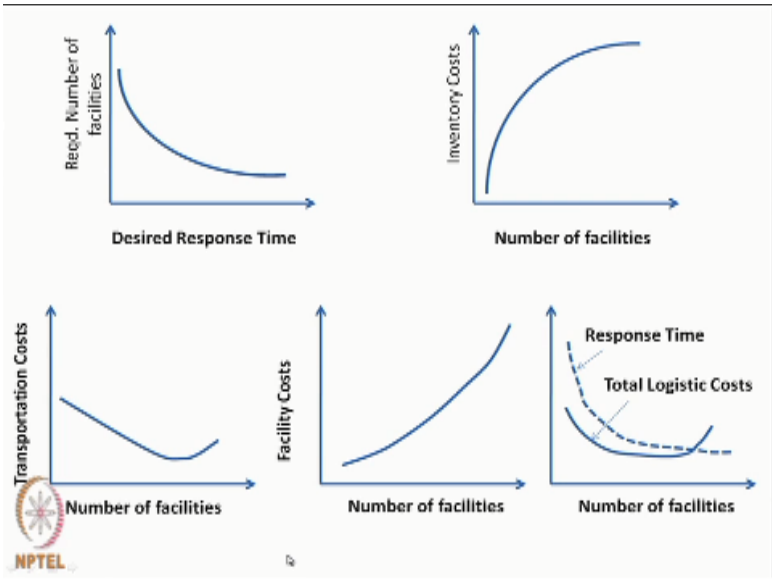

Now these 5 graphs indicate how the different cost change with the requirements, desired response time if the customers require quickly that is less time they need to get the material then naturally there should be a number of sites, a large number of sites in the supply chain so that customers by and large get the supply, but if the customers are ready to wait then the supply chain can have less number of sites so the curve is something like this.

However, if the response time is less and then number of facilities is more than the inventory cost is more because every facility will have some inventory with them. So there will be large number of inventory, large amount of inventory. Therefore, inventory holding cost and other

associated cost will be high if the number of facilities is high. Similarly, if the number of facilities is high at sometime the transportation cost will be low.

But after sometime the transportation cost will rise because the fixed cost will rise, the number of trips to make will also rise. Now as the number of facilities is more the cost of the site the plant cost and other fixed cost will also go up. So on the whole if we add these costs inventory cost, transportation cost and facility cost we shall see that the total logistic cost is something like a bathtub curve for a number of facilities.

That means number of facility the optimal value of the number of facilities is somewhere here. However, the response time declines as the number of facilities rise and response time declines, but to be able to give the services to the customers at a short time the cost associated is pretty high. Therefore, the number of facilities can be optimized so that the cost is minimum while at the same time the response time is within reasonable limit.

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Now a distribution network there are different types of design options. Let us consider how the customer gets the material. One is that retail has the material customer pickup Second manufacturer directly supplies through the customer. Third manufacture storage with direct shipping and in-transit merge that means from different manufacturers products come to one point and then they are supplied to the customer.

Different parts of the final product come to one place and then the final product is merged and supplied to the customers or the distributor may supply small packets through different

carriers or the distributor can supply to different customers or the manufacture of the distributors stores at a point and the customer picks up. So there are 6 different options for distributing goods to the customer.

Now let us show them in the graphical or in figures so that the idea becomes more clear.

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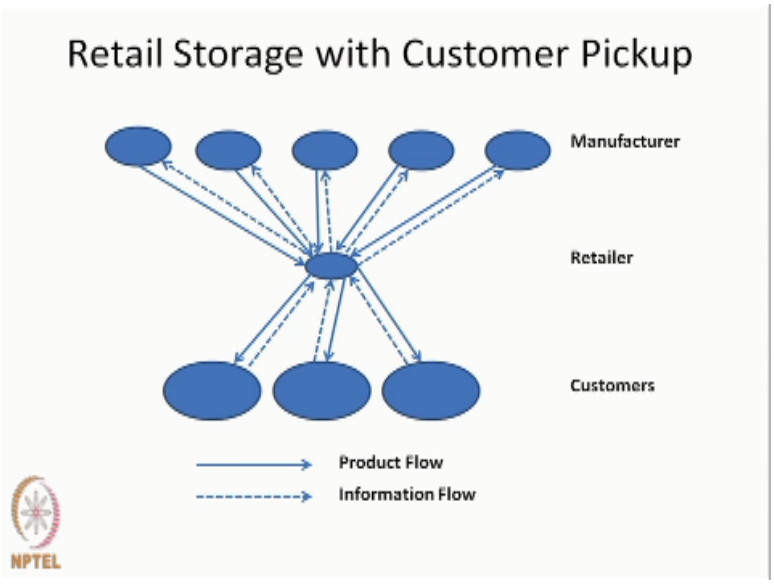

This is the case of retail storage with customer pickup. Here the customers are here and this is the retailer the customers are placing the order with the retail. The retail has the items collected from the manufacturers so it supplies the product directly to the customers this is the product flow the (()) (29:08) line, the order flow is the dotted line and then retailer then places orders with the different manufacturers and get the supply.

So this is manufacturers, this is the retailers and these are the customers. So this retail has the storage and customers picks up their desired goods from the retailer.

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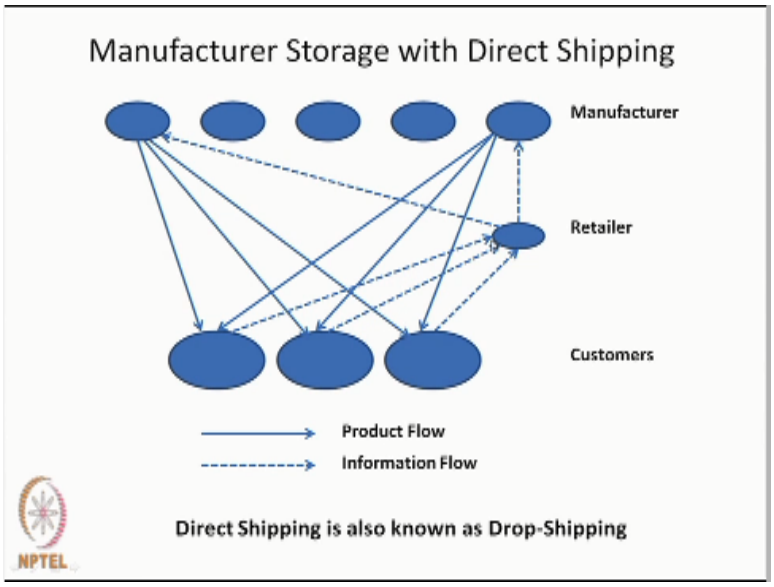

Now this is the second option where the manufacturer has the main storage. So what is the retail work? Retails work is only to pass on the information to the manufacturers. So customers place their order with the retail because retailer is close to the customers. So this is the flow of orders dotted line and retailers in turn pass up depending on the type of requirement by the customers.

It informs the manufacturers either this or that and then manufacturer directly makes a supply to the customer. This direct shipping is also known as Drop-Shipping. Direct Shipping is also known Drop Shipping.

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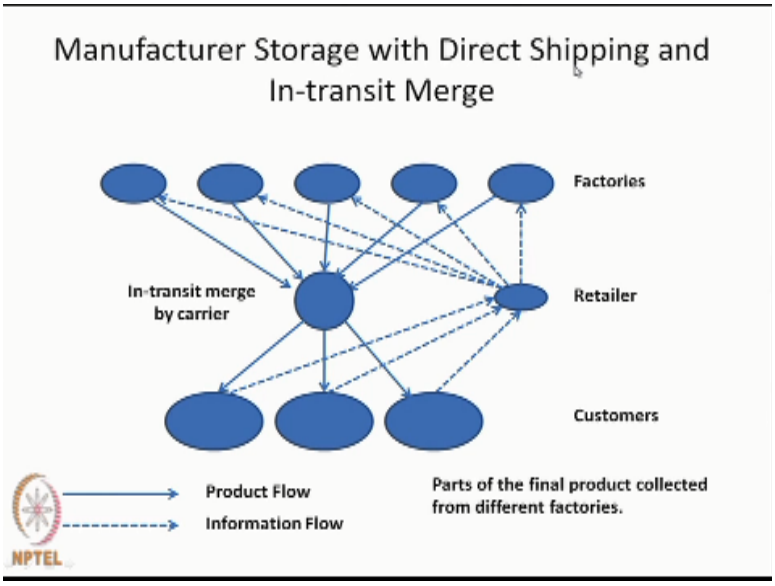

Now manufacturer storage with direct shipping and in-transit merge. Here the customers place their orders with the retail as in the previous options. The retailer in turn informs the

factories of the manufacturer these are the different factories of the manufacturer. Each factory produces a particular part so parts of the final product are then collected from different factories.

And they get merged in another site and then by carrier they are sent to different customers to the designated customers. So here there is in-transit merge by carrier. So each factory of their manufacturer produces separate part that are required for the final product. This is the third option manufacturer storage with direct shipping and in-transit merge. So this is basically in transit merge is the additional thing.

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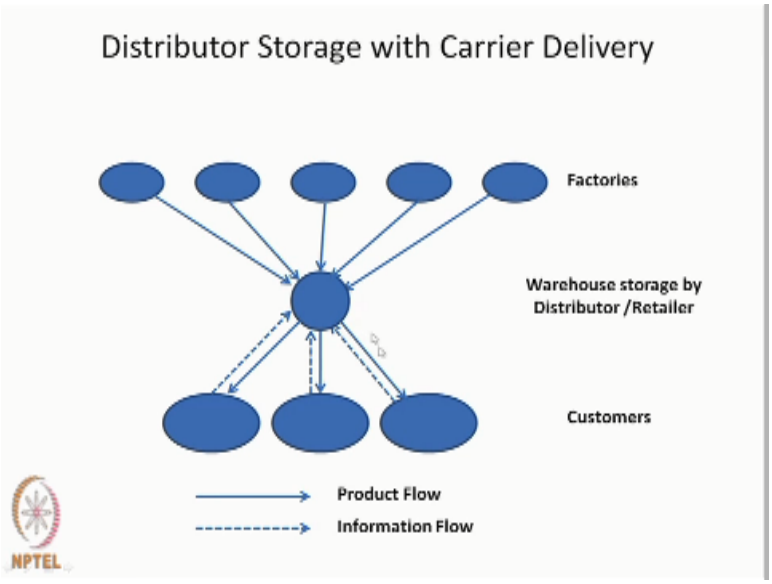

This option is the distributor storage with carrier delivery means that the distributor has the storage facility. The customer places their order with the distributor because they have the warehouse distributor or retailer they have the warehouse where the material or product is stored and as they get the order the orders are filled by shipping the materials through small carrier.

Carriers are basically small packet carriers so they are supplied and the different factories of the manufacturer produce different parts or different components that are put here supply to this place to the warehouse and from the warehouse the supply is made. So this is distributor storage with carrier delivery.

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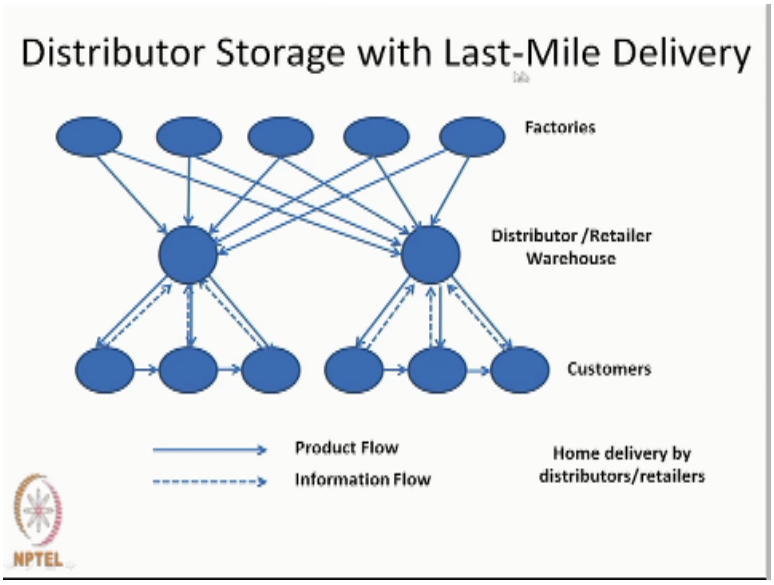

Distributor storage with Last-Mile Delivery. Now here these are the factories of the manufacturer and these are the distributor warehouse or the retailer warehouse where the material is stored materials are supplied from the factory to the distributor the retailer and when the customers place their orders with the distributor or the retailer the supply is made, but the supply is made as you can see with last-mile delivery.

That means it is door-to-door home delivery by distributors or retailers. So what they do they aggregate all orders and they make the supplier to this customer first then after this customer order is supplied they go to the second customer and then to the third customer and then comes back. So these are the facilities of the distributor storage with last-mile delivery. Similar thing is done here also.

So this flow from one customer to customer another to another is basically the last-mile delivery.

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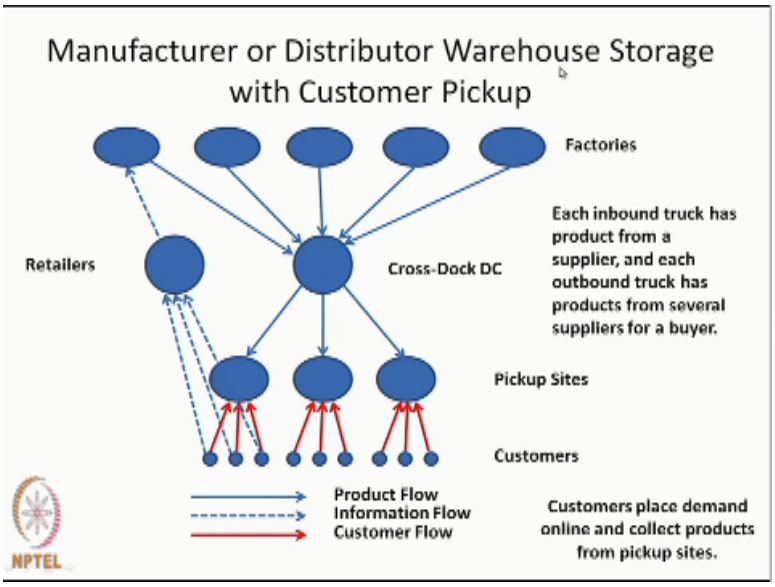

Then we have manufacturer or distributor warehouse storage with customer pickup. So once again this storing facility here the manufacturer has got different factories as shown here these are the factories. They supply products through trucks to a place to the retailers. Now here each inbound truck has product from a supplier. So this supplier uses a truck to supply its product this supplier or factory sends here and each outbound truck has products from several suppliers for a buyer.

Now this outbound truck when it is supplied to this customer it gets material or components from each of them put together in one truck and then it is carried to the pickup sites. So this is why this is called Cross-Dock distribution center. DC stands for distribution center. So in the Cross-Dock distribution center what is happening from every factory different components are coming and so each truck contains large number of components from one factory.

So here another truck contains large number of components from this factory whereas the customer wants a particular product that might read 2 components here, 2 components here, one component here etcetera. So with that the outbound truck meant for the customer is filled and sent to this site this is called a pickup site. And the customers come physically to the pickup site and picks up the material and go. So this red arrow upward flow is basically the customer flow.

Product flow as before downwards shown here and the information flow takes place upwards. The customer places order with the retail and the retail places the order with the manufacturer, but the manufacturer has got different factories. They supply products with

Cross-Docks, and then sends it to the pickup sites the customers pick them up. So customers here place demand online. The customers are placing the demand online and collect products from the pickup sites.

This is the manufacturer or the distributor warehouse storage with customer pickup.

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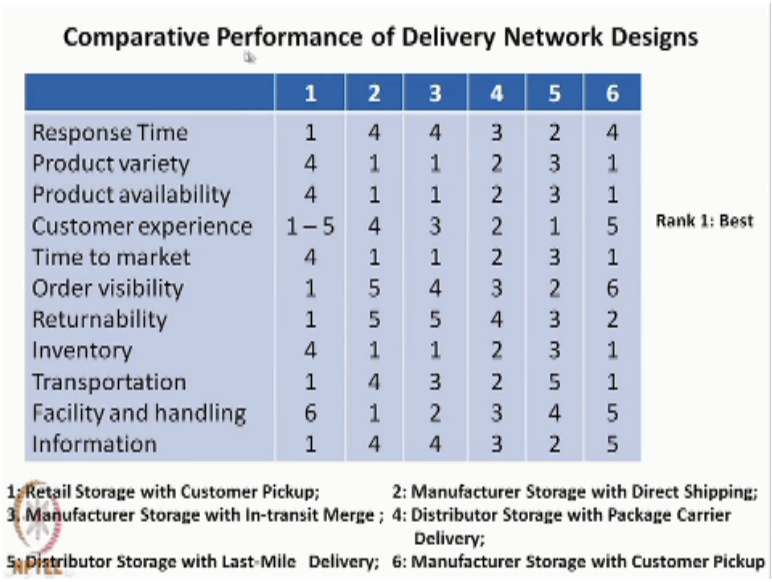

	1	2	3	4	5	6
Response Time	1	4	4	3	2	4
Product variety	4	1	1	2	3	1
Product availability	4	1	1	2	3	1
Customer experience	1 – 5	4	3	2	1	5
Time to market	4	1	1	2	3	1
Order visibility	1	5	4	3	2	6
Returnability	1	5	5	4	3	2
Inventory	4	1	1	2	3	1
Transportation	1	4	3	2	5	1
Facility and handling	6	1	2	3	4	5
Information	1	4	4	3	2	5

Rank 1: Best

Now different their performance of the different design has been compare or ranked basically this is of course almost subjectively they have been ranked. So this 1, 2, 3, 4, 5, 6 are the 6 options 1 retail storage with customer pickup and the last one 6 is the manufacturer storage with customer pickup. So all this 6 options that we just now discussed they are in this columns and with regard to different dimensions such as response time etcetera they have been each ranked.

For example, retail storage is ranked number one as far as the response time is concerned whereas 2, 3 and 6 direct shipping, in-transit merge and customer pickup are ranked 4th. Rank 1 is the best. So like that for each of this ranking has been done almost subjectively. So this once that are appearing they are the best the highest rank the best. Now let us consider

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We have so long considered the distribution aspects. Now let us consider the transportation aspects. In transportation aspects there are 4 types of parties involved. One those who decide how to move the product to the customer to achieve the desired level of responsiveness at the lowest cost. So it can be manufactures when the manufacturer ship, it maybe retailer when they ship it may be distributor when they ship. So they are the shippers.

But who are the carriers? They are basically the transporters who move the product. And owners of transportation equipment and infrastructure this is the third party. So transportation equipment owners or infrastructure meaning rail let say railways so they are the third party and forth part is the operator sub transportation equipment, the drivers, the helpers etcetera the loaders they are the operators. So these are 4 different types of parties involved in transportation.

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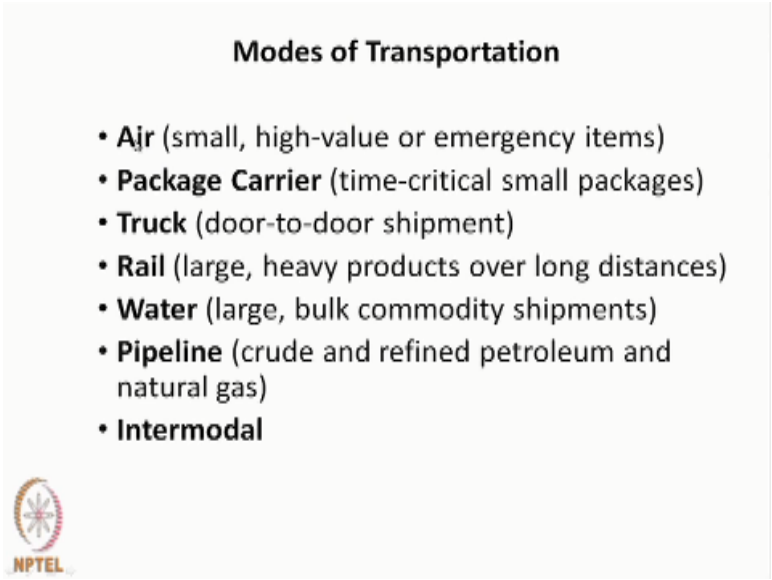

Now there are different modes of transportation. Air, package carrier, truck, rail, water, pipeline and intermodal. Air naturally is the costliest and water it is said is the least cost mode of transport. Naturally you will prefer air when the item is small, but of high value or emergency item. One can use package carriers that means small packages if time is critical. One can use truck because it has high mobility it can serve door-to-door.

One should go for rail when the volume is large and the product is heavy and it is to be transported over long distance and water being the least expensive very large volume bulk and commodity shipments are usually made through water transport. Apart from this there is a fifth type of transport, mode of transport which is called the pipeline where crude and refine petroleum and natural gas is transported or are transported.

And finally there can be mix air followed by truck or by air followed by package carrier etcetera.

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Now there are different design options for transportation network. Direct shipment network, direct shipping with milk runs, all shipment via central distribution center, shipping via distribution center using milk runs and tailored network. So there are 5 different options for a transportation network. Let us see one by one.

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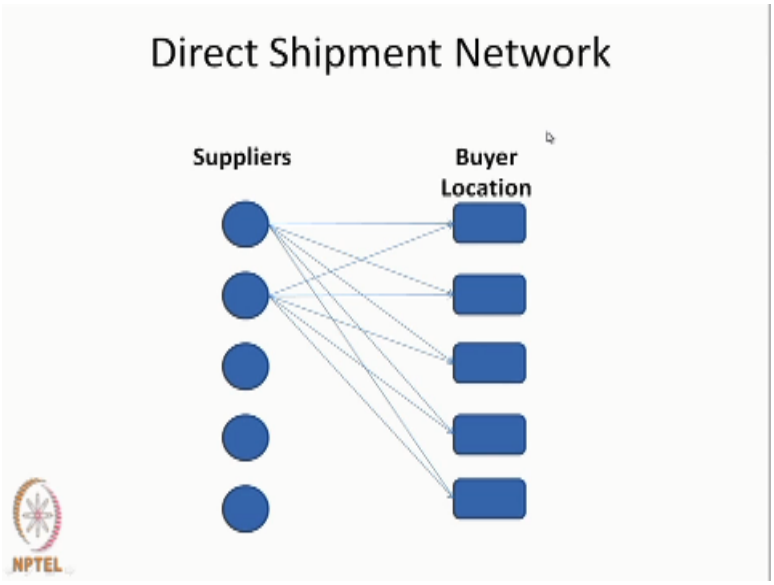

Direct shipment network. Here these are the different suppliers and these are the places where the buyer is located. So therefore the shipment is made directly from the supplier to the buyers. So as you can see this is the easiest form of shipment.

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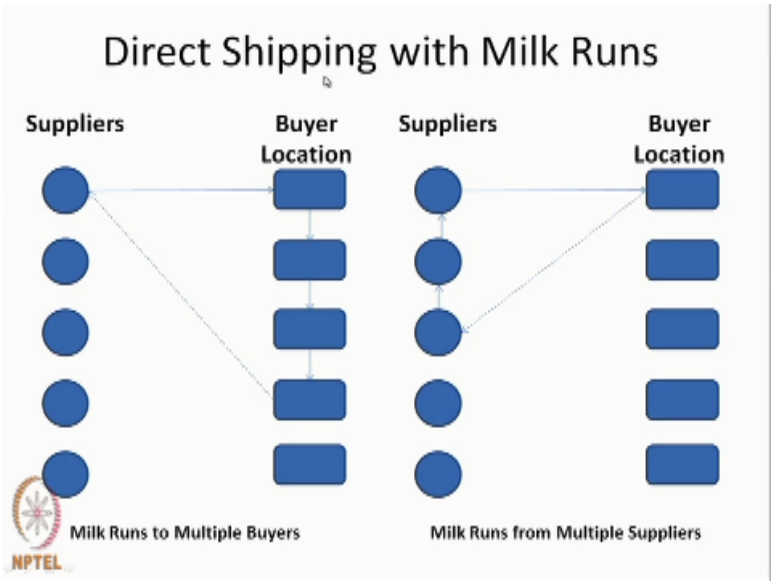

However, it is also possible to ship goods from the suppliers to the buyers with milk runs. So this is the case particularly from the supplier to the buyer. So the truck moves from the supplier with products to be delivered to different buyers. So it goes first to this buyer then delivers the good then goes to the second delivers the good, then to the third, then to the 4th and then it comes back.

So this is the direct shipping, but with milk runs from door-to-door. So these are milk runs to multiple buyers. Also this is the case when the truck can collect materials from different supplier and then serve it to a particular buyer. If a buyer requires large number of goods of different types that are manufactured are supplied by different suppliers, then this is good there is a milk run for multiple suppliers and then once the truck is full it goes to the required buyer. So this possibility also exists.

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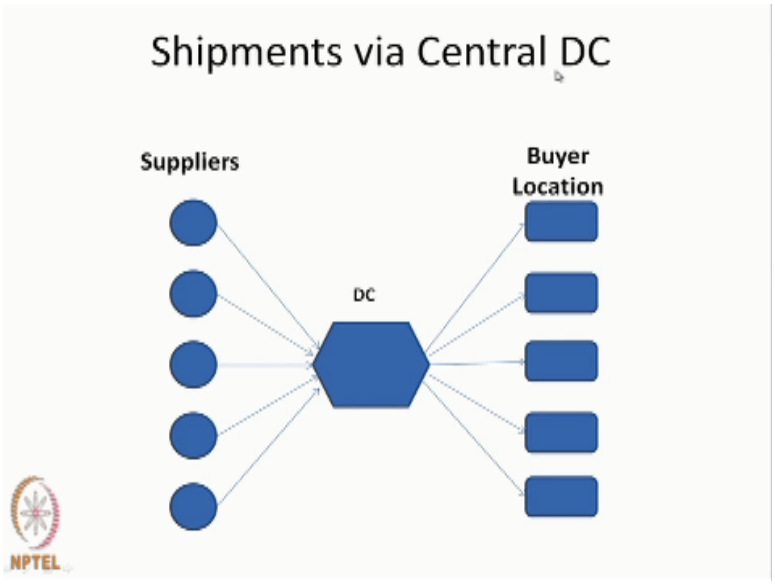

Then shipments via central distribution center. So it is possible that the different suppliers send their products to a particular location the distribution center and from there trucks carry to each buyer location different supplier's products in each truck. So this is still another option.

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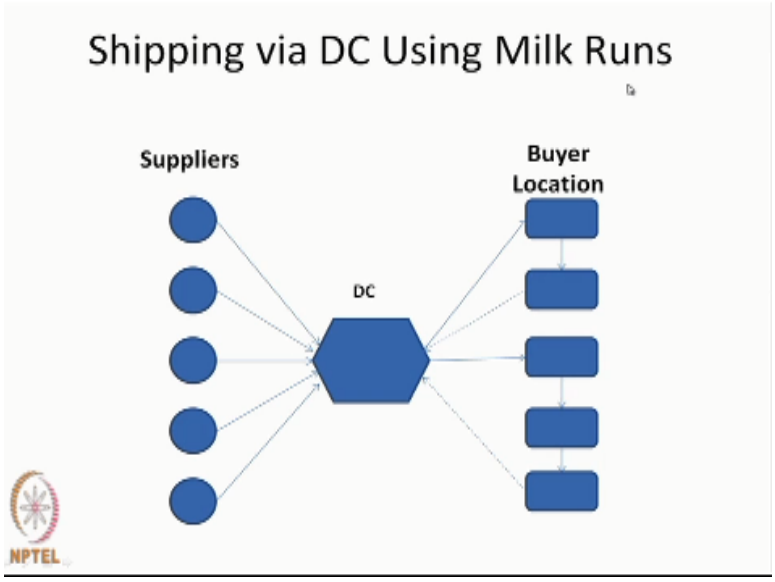

Then this is shipping via distribution center using milk runs. So here what happens as you can see there is a distribution center supplier's product are delivered to the distribution center then depending on the buyer's request for goods and their proximity the trucks carry goods to the first buyer and then second buyer and then comes back in this particular case. Another truck carries materials to this buyer then goes to the another buyer delivers the product then to the third buyer delivers the product and then comes back.

So this is the case of shipping via distribution center using milk runs.

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	Lot Inv	Safety Inv	In-Transit Cost	Transportation Time	Transportation
Rail	5	5	5	2	5
Truck	3-4	3-4	3-4	3-4	3-4
Package	1	1	1	6	1
Air	2	2	2	5	2
Water	6	6	6	1	6

Now once again their performance has been ranked. Here rank 1 means the lowest in terms of these criteria say for example the transportation time water is the lowest. And overall package is the lowest water is the highest. So according to different criteria once again subjectively each has been ranked. Rank 1 here showing the lowest value rank 5 or 6 the highest value.

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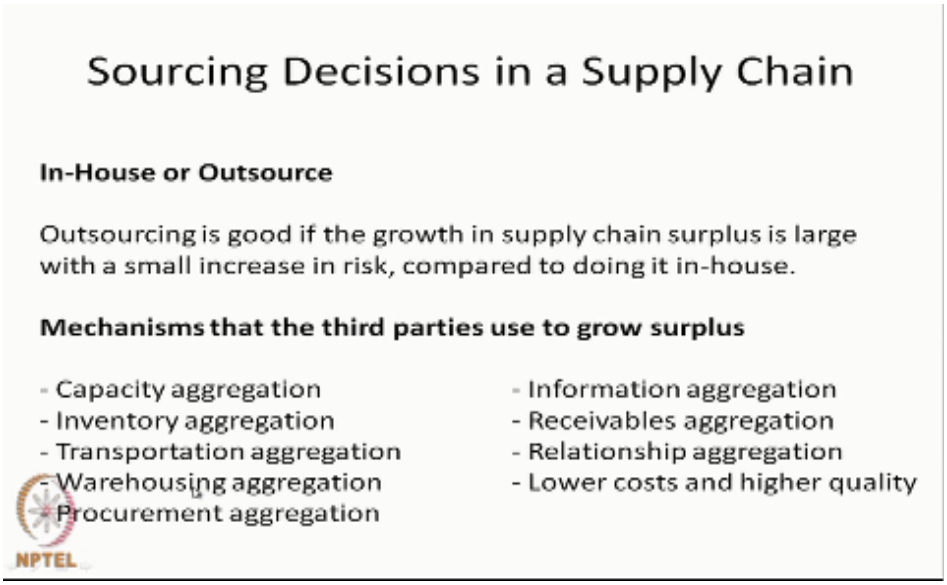

Now the second aspect that we would like to study in supply chain management is sourcing decisions meaning from whom to get our components or raw material. First thing is if the components whether to buy it from outside that is outsource or to make it in-house. So make or buy decision. Already we have studied in engineering economics how to decide whether to buy in from outside or to make it in-house similar principles are first of all applied here.

Basically outsourcing is good if the growth in supply chain surplus we have already defined profitability is large with a small increase in risk compared to doing it in-house. Now there are many reasons why the outsourcing is done. Outsourcing is done because the third party to whom the work is it is outsourced they have larger capacity, they have larger inventory, they have larger transportation system, they have larger warehousing, they can procure goods because they have larger needs so on and so forth.

Therefore, they result in lower cost and higher quality compared to what you can do because a third party is specialized in those components. So these are the reasons why third parties can be useful to improve the supply chain surplus.

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Now there are various aspects or various processes in sourcing. Assessment of a supplier, selection of a supplier, negotiating with the supplier, using him or collaborating him in the design of the product, procure the products and then plan ahead for next year. These are different processes we shall consider only a few that are important.

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First of all, assessment of a supplier is to be done on the basis of different criteria supply lead time how long he takes whether he gives it in time, whether we can change the orders, how frequently he gives only once in a lot or partially first after sometime and then fully after some other time, quality, cost etcetera, etcetera, etcetera. So these are different criteria against which the supplier's performance is judged.

So if there are 10 different suppliers who are eligible then their performance can be judged on the basis of these criteria.

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Then to actually decide there are different ways. One way that is gaining ground today is auctions. There are different types of auctions, but only a few are written down here. Sealed-bid auction this is prevalent in governments where every bidder or every potential supplier

writes the bid in an envelope in a closed fashion or it can be English auction where the party who makes the auction it fixes the price.

And then it asks the bidders to say whether they are interested to supply the products at that price and normally in an English auction because the price will be paid by the manufacturer let say that we are considering a situation where the manufacturer wants to select a supplier on the basis of auction then the manufacturer gives a very low price and then ask who can supply this product.

I think there is not much of a time to discuss this today. So we will take up this auctions and negotiations and other issues of supply chain management in our next class. So what we did today first we introduced the supply chain management issues and in particular we discussed about different auctions that are used for design of distribution network and the modes of transportation. We will discuss in detail sourcing in our next class. Thank you very much.