

Industrial Engineering
Prof. Inderdeep Singh
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 04
Lecture - 06
Capacity Planning-I

A very warm welcome to all of you, in this lecture on Capacity Planning, over last few days, we have been discussing lectures related to various topics of industrial engineering. We have cover topics like, sales fore casting, inventory management and we have discussed certain things related to the network analysis. So, in this topic, we would be discussing the thing related to capacity planning.

Because, capacity planning is one of the important topics, rather I should say, one of the break through topics in the field of industrial engineering, because every now and then we see that in the business environment these days. The demand for the product is changing every now and then, sometimes you have over whelming demand, sometime the demand is very, very less.

So, the economic scenario, the business scenario is changing every now and then, so for in order to adjust for such kind of erratic demand, we have to plan the capacity in such a way. So, that whenever we have demand of huge amount of items or whenever the demands is very, very large, we should have the capacity to adjust to the large amount of demand.

Whenever, the demand is less; then we should have such type of a capacity that we are able use our capacity requirement for some alternative work. So, that our machines, tools equipment, man power or all in all I can say the capacity is not wasted. So, each one of us has certain capacity, we see that this thing is beyond my capacity, I would not be able to do this job, because this requires huge amount of stamina or huge amount of running power or huge amount of physical labor or huge amount of physical strength.

Similarly, each and every machine will have it is rated capacity, that it can turn out may be 500 components per week or certain machines may have a capacity in terms of per day, that this particular machine can make 200 products per day or we can say per week

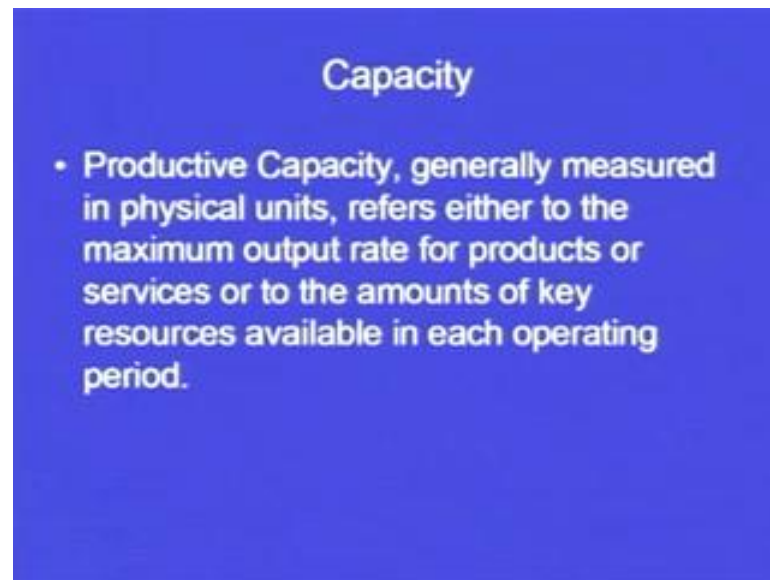
also. Similarly, a train will have a capacity to carry certain amount of or certain number of passengers from one station to another station.

Similarly, a goods train will have its capacity in terms of tonnes of load, it can carry, so even a robot will have capacity to lift the particular component from one place and place it at the other place. So, the capacity is an important point that we need to understand, but as industrial engineers, what is the need of capacity planning and why capacity planning is important for us, that we will be trying to address in this lecture.

So, first of all from industrial engineering point of view or we can say from mechanical engineering or manufacturing engineering point of view, what do we say is the capacity in terms of the productive capacity. So, we will try to understand, how capacity can be defined, what various issues are and various terms related to capacity utilization. Then, we will go forward and discuss economics of scale, diseconomies of scale and finally, we will see certain problems in which the capacity has been utilized.

Some of the examples, I have already told you that each and every system, each and every service sector, each and every manufacturing sector or manufacturing plant has its own capacity. So, all those things, we are going to incorporate in this topic of capacity planning and then we are also going to see the procedure for capacity change. If we want to change the capacity from one stage to another stage, what is the procedure that we should follow, so that the transition from one level of capacity to another level of capacity is very, very smooth.

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Now, productive capacity, we are more concerned with generally measured in physical unit, refers either to the maximum output rate for products or services or to the amounts of key resources available in each operating period. So, it can be defined in two ways, the first way is on your screen, you can see generally measured in physical unit, refers either to the maximum output rate for products or the services or to the amount of key resources available in each operating unit.

So, either we are producing something, we producing certain number of components, so that number of components will dictate the productive capacity or on the other hand, it can be the amounts of key resources available in each operating period. So, for a particular operating period we have certain resources that are available with us, so that productive capacity can also be in terms of those key resources, which are available with us.

So, it can defined in two ways are either in the physical unit is the product that we are producing, the number of products that we are producing for a particular period of time can be called as the productive capacity or the amount of key resources. That, we are holding for a particular operating period can also be called as the productive capacity. Now, strategy capacity planning, so basically strategic capacity planning means, that we have to plan strategically about the capacity.

Initially, we need to understand that, what the requirements are, what is the capacity requirement; that we will see from quantity point of view, from quality point of view, from timing point of view, how demand is going to influence the capacity planning. But, here we need to understand; what is the basic definition of capacity planning or the strategic capacity planning. Now, capacity can also be in previous definition that we have already seen in the previous slide was the productive capacity.

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Strategic Capacity Planning

- **Capacity** is the ability to hold, receive, store, or accommodate raw materials, finished products, customers, etc.
- **Strategic capacity planning** is an approach for determining the overall capacity level of capital intensive resources, including facilities, equipment, and overall labour force size.
- **Capacity used** is the rate of output actually achieved.
- The **best operating level** is nominally the capacity for which the process was designed.

$$\text{Capacity Utilization Rate} = \frac{\text{Capacity Used}}{\text{Best Operating Level}}$$

Now, we are coming on to another aspect of capacity, that is the ability to hold, receive, store or accommodate raw materials, finished products, customers, etcetera, so here we are talking about another facet of capacity. That is in terms of materials management or in terms of man management, so it is the capacity to hold, receive, store or accommodate raw material.

So, we may have a capacity to hold may be certain tones of raw material or the capacity may be less, capacity may be more. Now, depending upon the amount of raw material, that we can hold, that we can receive, that we can store is also a capacity or the ability to hold receive or store the raw materials or the finished goods or the customers can also be termed as capacity.

So, capacity can have large number of definitions, the first definition that we saw was a productive capacity to produce in terms of physical unit. Second definition of capacity that we are seeing here is in terms of holding, receiving, storing, the raw materials or the

finished products or the customers. Now, certainly a service center or a hospital or we can say a rest room may have a certain capacity in terms of the customers, that it can service at a particular movement of time, so that is also a type of a capacity only.

Now, strategic capacity planning is an approach for determining the overall capacity level of capital intensive resources including facilities, equipment and overall labour force size. So, we can say that planning related to all these things that may include the facilities, equipment and overall labour force. So, we can say, we are managing the material, we are managing the man power, we are managing the machines.

So, planning related to all these type of man, machine, material is termed as strategic capacity planning, so once again just to memorize, we will again read the definition. Strategic capacity planning is an approach for determining the overall capacity level of capital intensive resources. Capital intensive, so huge amount of money is involved in this type of resource that is why we need to do the planning activity.

If you do not do the planning activity properly, then the company for which we are working or the company, which is taking care of all these things may also go into huge amount of losses. So, strategic capacity planning is an approach for determining the overall capacity levels, that what should be the capacity level, whether it should be high, it should be low, it should be intermediate of capital intensive resources.

Such as facilities, equipment and overall labour force size, so always we want that we should have adequate amount of labor force size available with us. Adequate amount of machines, adequate amount of capital, adequate amount of equipment that should always be available with us and strategic capacity planning helps us. This is an approach, which helps us to achieve at that optimal level of capacity utilization.

Already, I have told may be in one of the previously classes that always there is a dearth of resources, there is no company which is having unlimited resources available with them. If unlimited resources are available; then there is no need to go for planning activity, there is no need to go for management, but whenever there is a constraint on the resources that the resources are limited then we have to do the planning activity.

So, that the over all process is done in the most cost effective efficient manner and that is why strategic capacity planning gains importance, because we want to know the exact

number of people. Exact number of machine, exact amount of money that would that would be required in order to smoothly follow the process. Like, if you are manufacturing something right from the raw material to the final stage, what we want it, that there should be no hiccups, there should be no breakdown in the smooth flow of the process.

The raw material should enter from one side and it should go from the other side as a finished product. So, for that we need to do the planning activity and we need to understand what is capacity requirement, how many machines will be required, how many man will be require, how many man hours will be required in order to process the raw material into the final form.

So, when we know all these things, we have done adequate planning of all these thing, there will be no breakdown in the process, but if we are not sure about the capacity. Then, there are certain circumstances, where we may have to stop the manufacturing process in lack of the capacity. The capacity can be in terms of money, it can be in terms of machines, it can in terms of a numerous other forms.

So, strategic capacity planning is one of the most important types of planning activity, which has to be carried out by an organization; then capacity used is the rate of output actually achieved. Now, capacity used, the capacity may be more, but we are only using, suppose we have 10 machines, so we can say we have a capacity of 10 machines, which can operate at a time, but we are using only 2 machines at a time.

So, capacity used is on the rate of output actually achieved, so output achieved is that we are only using 2 machines, 8 machines are lying idle and so capacity used is the output actually achieved. Then, the best operating level is nominally the capacity for which the process was design. Always, I will like to give you an example that whenever we are driving a motor bike or whenever we are driving a car, the meter for speed may read from 0 to 220.

But, always there will be a green region in between, it is advise that the you should drive in this zone or at this speed levels, for maximizing the output or for maximizing the efficiency, so that is called the best operating level. So, it is nominally less than the highest rated capacity of that particular machine or that particular system.

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Strategic Capacity Planning

- **Capacity** is the ability to hold, receive, store, or accommodate raw materials, finished products, customers, etc.
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- **Capacity used** is the rate of output actually achieved.
- The **best operating level** is nominally the capacity for which the process was designed.

$$\text{Capacity Utilization Rate} = \frac{\text{Capacity Used}}{\text{Best Operating Level}}$$

So, best operating level is nominally the capacity, for which the process was designed, so nominally this is designed for the process is designed for that level, but certainly we can go beyond that level also. But, the efficiency may not be hundred percent at that level, so best operating is the level for which the process has been design. Also, capacity utilization rate, we can say as the capacity used divided by the best operating level for which the process was designed, so that can be we can call as the capacity utilization rate. Now, what type of capacity decisions we have to take, capacity is the maximum capacity to produce.

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Capacity Decisions

- **Capacity**
 - maximum capability to produce
 - rated capacity is theoretical
 - effective capacity includes efficiency and utilization

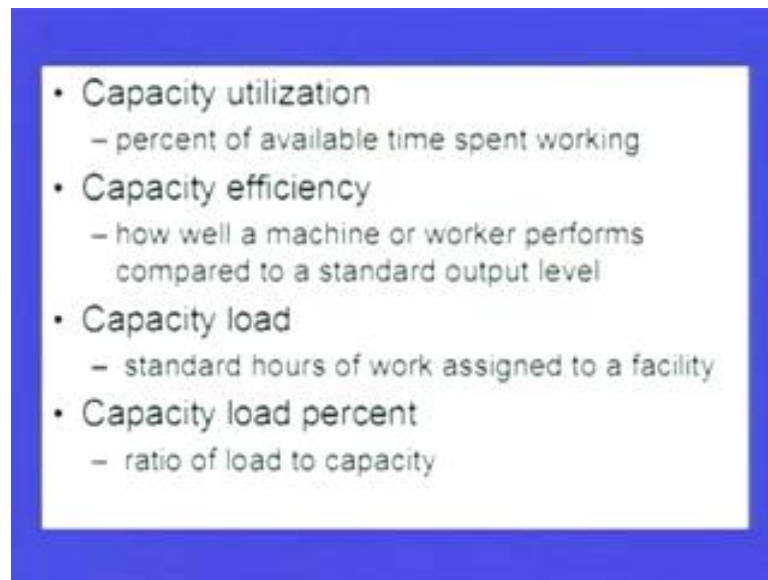
Now, we are talking about the productive capacity, which was shown in the very first slide of this lecture. Now, maximum capacity to produce, rated capacity is theoretical, now rated we can say that this motor will run at this much RPM. So, that is the rated capacity, the RPM or the horsepower, but it may not run at that rated capacity, because that rated capacity is basically the theoretical capacity. But, the actual capacity depends upon the effective and efficient utilization of that particular set up.

So, second point is effective capacity includes efficiency and utilization, so it will the theoretical capacity will be different from the effective capacity and there will be a term called efficiency which will be incorporated. That, how much how much efficient the process is so happen that we have a capacity, but we may not be using the whole of that particular capacity.

For example, if we say we have already taken lectures on inventory management, always we have certain amount of stock, always available with us. We may be having 100 components, but we will always plan according to 80 components only, because 20 we may like to keep as buffer stock. So, that 20 although is there in the capacity, but we are not actually using that 20 per, those 20 articles, because that we are keeping as a buffer.

For any rough day or rainy day, when we are not having the inventory, we will take those 20 and use it, so that our manufacturing process does not stop. So, there is a difference between the rated capacity and the actual capacity or the effective capacity, rated capacity is theoretical in nature and the effective capacity, takes into the count the efficiency and the utilization point.

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- Capacity utilization
 - percent of available time spent working
 - Capacity efficiency
 - how well a machine or worker performs compared to a standard output level
 - Capacity load
 - standard hours of work assigned to a facility
 - Capacity load percent
 - ratio of load to capacity

Now, what is capacity utilization, percentage of available time spent working, now we have a capacity, for how much time we are using the capacity, for example there is a particular manufacturing plant or there is a small scale factory. Now, factory is having 10 machines, now these 10 machines can be operated 20 four hours a day. But, the manufacturer or the entrepreneur or the person, who own that factory, is only running one shift.

That is the morning shift, starting at 9 o clock in the morning till 5 o clock in the evening, so he has the capacity to run the b shift and c shift as well, but he is only running one shift. So, he utilizing a percentage of the total capacity that he is holding, so capacity utilization is the percentage of available time spent working. So, we can find out what is the capacity utilization of that factory, because capacity is there and how much time is using that capacity will give us the capacity utilization.

Similarly, capacity efficiency is given by how well a machine or worker performs compared to a standard output level, very simple at machine has been designed for producing say 500 parts per week and it is only producing 400 parts per week. This may be, because of some breakdown, this may be because of the machine performing at a little bit less rated capacity and this may be, because of host of the other reasons.

But, the efficiency of the machine will be that how well a machine or a worker performance compared to a standard output level; now standard output level has already

been established. We know 500 components per week, this machine should produce, but that machine is not producing according to the standard output level. It is producing certainly certain amount less than that, so that is the capacity efficiency. So, much efficient may be 80 percent efficient, 70 percent efficient; 60 percent efficient.

Then, the capacity load standard hours a work assigned to a facility, now we have a facility and then, we assign certain work to it, depending upon the rated capacity of that machine or service. So, capacity load is the standard hours of work assigned to that facility. Similarly, capacity load percentage is given by ratio of load to capacity, so capacity load already we know that rate standard hours of work assigned to a facility.

And capacity load percentage can be easily found out, when we know the load and we know the capacity, ratio of load to the capacity will give us the capacity load percent. Why, we are discussing all these things is that these things act as the elements of understanding and elements of comparing the different capacity or in terms of machines, in terms of man power, in terms of other equipment, in terms of services. So, these particular items will help us to compare among the various systems.

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<u>Dimension of Demand</u>	<u>Effect on capacity requirements</u>
Quantity	How much capacity is needed?
Timing	When should capacity be available?
Quality	What kind of capacity is needed?
Location	Where should capacity be installed?

Now, we can say that, why capacity planning is very, very important, let us come to a very simple point, dimension of the demand, we can have quantity, timing, quality location. And how this is going to effect the capacity requirements, now the dimension

of the demand, suppose the demand is changing erratically. Already, I have told if you remember in our lecture on sales forecasting, we have seen the business cycles vary.

We can have an increasing trend of business cycle, decreasing trend of business cycle, seasonal trend, cyclic trend or an erratic trend. So, whenever the demand is fluctuating, demand is erratic in nature and in that particular case a quantity is the important point, the demand may be high and demand may be low. So, that reflects the quantity or the quantitative aspect of demand.

So, how much capacity is needed, so from sales forecasting or from demand forecasting we know, that the quantity is going to vary. Suppose, we take an example that most of the employees in India will be getting the arrears in the next year or some of them might have got the arrears in this year. The automobile companies might think that since the people would be getting a chunk of money.

They may plan to buy the automobiles, those who are having the motor cycles may plan to buy the cars and those who have the cars may even try to buy a better car or a bigger car, so they know that the demand for automobiles is going to increase. Now, as the manufacturer, they have to think of their capacity that whether they have the capacity to meet the demand that is going to change over the next year.

So, they have to take a decision, that how much capacity will be needed, whether one plant would be able to make so many number of automobiles as is required in the industry or as is required in the market. So, as the demand is changing, do we have the capacity to meet that demand that is having one? In this way, the demand is having a bearing on our capacity decision.

So, our capacity requirements may change, in this particular case, where I have given you an example, the capacity requirements are increasing, because the demand for automobiles is going to increase may be in the next year. Similarly, coming on to the time timing of the demand, already I have told you that timing may be next year, this year or 2 years later or 5 years later, that the demand will change after 5 years, there is going to be a huge amount of demand for this particular item.

Then, what type of capacity requirement decision will be made, when capacity should be available, so initially in first particular case, when we knew that the quantity of demand

is going to increase. May be next year, we had to take a decision, that how much capacity will be required. Now, we know that next year the demand is going to be more, so timings also we know.

So, when the capacity would be required, because when the demand would be more, certain time before that we should have that capacity, so that we make so many numbers of automobiles. So, timing of the demand is also going to have a bearing on the capacity, increase or decrease, decision that the company has to take. So, if capacity enhancement has to be done, then the company has to take a decision, when it has to be done.

So, from timing of demand point of view, when should the capacity be available, when should the capacity be added, this has to be born in mind. Then from the third point of view is the equality, what kind of capacity is needed, if the quality is very, very high. Suppose, people want a automobile of very high quality, then we need to understand that how much and of what level and of what type of capacity is required.

We cannot increase the capacity not taking into account the quality, suppose already, we have 10 machines and these 10 machines can churn out a product of a particular quality, but now may be next year, next to next year. The quality consideration of the customers may increase; so when the quality considerations will increase at that movement of time, the kind of capacity to produce that kind of quality products should be available with us.

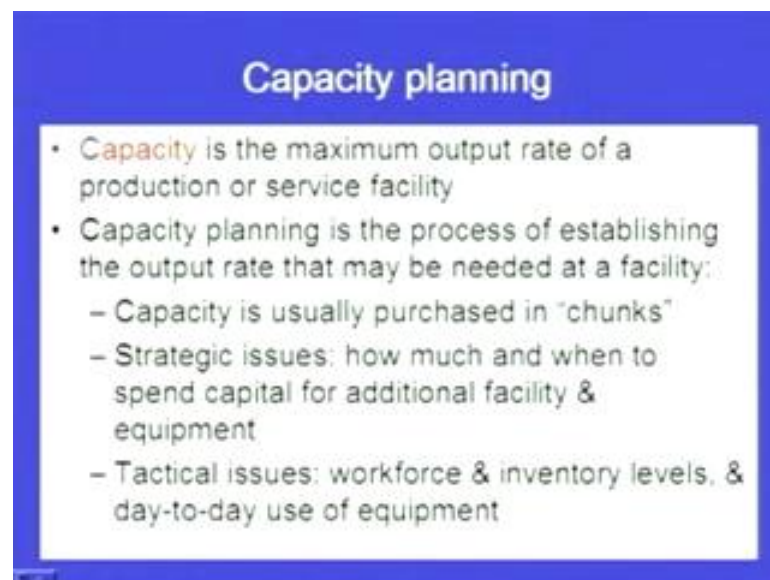
So, from quality point of the demand also, we have to take a decision, whether the capacity has to be of what particular quality level or what type of capacity we have to increase or what kind of capacity is required. Then finally, the location point of view where should capacity we installed, so when the demand is there, we need to understand the where the capacity should be installed.

So, we can say in this particular slide, the sums up the capacity planning, we have seen that the quantity, timing, quality and location, these are the four dimensions of demand which are going to have a bearing on the capacity requirements. Now, capacity we are going to take the decisions we are going to plan the capacity in such a way, in order to take a decision, how much capacity is required. When the capacity would be required, what kind of capacity would be required and where it would be required.

So, how much, when what kind and where if we are able to find out, optimal answers for all these four questions, our capacity problem capacity planning problem is 99 percent solved. We know what type of capacity is required, when it is required, how much capacity is required and at which place it is required. Then, we can just go about installing that capacity at that particular place and our problems will be solved.

So, demand from the customers is going to have a bearing on the capacity requirement decisions that the company has to take. Now, we come on to capacity planning, we have seen that demand from the customers is going to have a bearing on the capacity requirement, decisions that the company has to take. So, planning is nothing but decision making.

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Capacity planning

- **Capacity** is the maximum output rate of a production or service facility
- Capacity planning is the process of establishing the output rate that may be needed at a facility:
 - Capacity is usually purchased in "chunks"
 - Strategic issues: how much and when to spend capital for additional facility & equipment
 - Tactical issues: workforce & inventory levels, & day-to-day use of equipment

So, let us now see capacity is the maximum output rate of a production or service facility, that already we have seen just to memorize, I have put it here. Capacity planning is the process of establishing, the output rate that may be needed at a facility. So, we have to fix a particular output rate that which would be needed at a facility, capacity is usually purchased in chunks, so nobody is going to purchase the whole capacity once and for all.

The capacity will always be purchased in chunks, may be today I have certain capacity I see that, for the next two years, the demand is going to increase, I should add another machine, I should add another group of people, I should add another department in my

organization. So that I am able to meet, the increase in the demand, I should have the capacity to meet that demand, so capacity is usually purchased in chunk.

Strategic issues how much and when to spend capital for additional facility and equipment, so this is what I have already discussed in the last slide, that this is the most important capacity planning issue. That, how much money should be spend, how much capacity is required, when that capacity is required, what kind of capacity is required and where it has to be placed. So, here you can see strategic issues are like; I have you have seen strategic capacity planning.

Now, strategic issues are how much and when to spend capital, to spend the money for additional facility and equipment, so whenever we have already decided that, this much capacity would be required and this much more capacity would be required. Then, we have to take a decision how much money, we should spend. And when, we should spend that money, for purchasing or enhancing our facility and equipment.

Now, tactical issues are also involved that workforce and inventory levels and day to day use of equipment. So, these are certain tactical issues, which also are needed to be addressed as a part of capacity planning. Now, we need to understand that, how we can measure the capacity, I will have to three slides on this, so that we are very easily able to understand that, what capacity actually means and in different contexts, what is the meaning of the capacity.

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Measuring Capacity Examples		
• There is no one best way to measure capacity • Output measures like cars per day are easier to understand • With multiple products, inputs measures work better		
Type of Business	Input Measures of Capacity	Output Measures of Capacity
Car manufacturer	Labor hours	Cars per shift
Hospital	Available beds	Patients per month
Pizza parlor	Labor hours	Pizzas per day
Retail store	Floor space in square feet	Revenue per foot

So, there is no one best way to decide that, how to measure the capacity, so there is no one best way to measure the capacity, but in different sectors, different aspects are there and for those we have different measures of capacity. Now, on your screen, you can see output measures like cars per day are easier to understand. Now, for a manufacturing plant which is having a line type of layout and the raw material is coming from one side and the completely ready to drive car is coming out from the other side.

We can say, if that plant is making 500 cars per week, we can say this plant has a capacity of 500 cars per week, so that becomes a measure of capacity of that manufacturing plant, manufacturing the cars. Similarly, with multiple products input measures the work better, so this particular point is that, a first example that we have taken is that the car, car is the product, but that is a single product.

Only cars are being manufactured in that type of layout, but if there are multiple different types of products available, some products may be produce in more quantity, some products may be produced in less quantity. A large variety of products are being manufactured by a single company. In that scenario, we will say, whatever input is going into the plant that can be termed as the capacity of that plant.

May be, if you take an example of a garment manufacturing company, so many different types of garments, ladies, male members, children, old age people, so many different types of garments are being produced by a single manufacturing plant. So, there we can say whatever is the input of raw materials to that particular company, can be termed as the measure of the capacity of that particular plant.

So, on your screen, you can see a table, where different types of businesses have been shown, I will show you certain more number of slides related to measure of capacity only. So, a type of business is like, car manufacturer, a person who is manufacturing the car, so input measures of capacity. Although, in this case, we can take the output measure of capacity also, but let us see the input measures of capacity is labor hours.

That how many workers have put in efforts for manufacturing the cars in one week or may be one month, for which we want to measure the capacity. Similarly, the output measure here can be the cars manufactured per shift; I think it is very, very clear. An example, already I have told you that, cars per shift or cars manufactured per shift will tell us the output or the plant capacity in terms of output measures.

Similarly, the second example is hospital, so the input measure of the capacity or the available beds, the number of beds available that is the input measure of capacity, but the patients per month is going to tell us the output measure of capacity. That, how many patients have attended that particular hospital may be in a month or may be in a year, so patients per month is an output measure of capacity.

Similarly, a pizza parlor, labor hours again, because the pizza is being manufactured, how many man hours, how many labor hours have gone into the manufacturing of the pizzas that is the input measures of capacity. Similarly, the pizzas per day, how many pizzas they were able to offer to the customers, how many pizzas were sold, we can say is an output measure of capacity.

Similarly, a retail store, floor space in square feet, shows the input measure is how much floor space is available for that retail store or a shopping mall, how many kilo meters of walking distance is available within the shopping mall. We can say that is a input measure of capacity and the revenue per foot, that how much money has been generated per square feet of the floor area, that that shopping mall or the retail store is occupying can be output measure of capacity. Though, these types of input measures and output measures help us to understand the capacity in a much clearer manner.

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<u>Facility</u>	<u>Unit of Measure</u>
<u>Class A Uniform output characteristics</u>	
Steel Mill	Tons of steel produced daily
Shoe factory	Pairs of shoes/shift
Commercial airline	Passenger per route
Bottling plant	gallon

Now, again you see a facility which is like a steel mill shoe factory, we will see how a shoe factory, unit of measure, what can be unit of measure for shoe factory, what can the

unit of measure for steel mill. So, facilities we can classify into two types, now first type is a class A, uniform output characteristics. So, output characteristics are uniform here, we will have another class, where the variable output characteristics are also there.

So, if they have a uniform output characteristics, facility can be steel mill, what can be the unit of measure or capacity measure of this particular type of steel mill, it can be tons of steel produced daily. So, the capacity measure for this type of a uniform output characteristic steel mill is the tons of steel produced daily. Similarly, for a shoe factory, we can say pairs of shoes, produced per shift is a measure of capacity or unit of measure.

Similarly, for a commercial airline, passengers per hour or per miles of distance traveled per hour or may be number of passenger seats; there are so many measures, which can be used to measure the capacity of a commercial airline. Similarly, bottling plant we can have gallons or per gallons of fluid or per gallons of liquid chunk out by that bottling plant.

So, that can be another measure of capacity for a bottling plant, so we can see each and every type of manufacturing plant each and every type of service sector industry will have certain capacity constraints, it will always work under those capacity constraints. So, in this particular slide, we have seen that uniform output characteristics, so uniform output characteristics means that the output is uniform, in the next we will see the variable output characteristics.

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<u>Facility</u>	<u>Unit of Measure</u>
<u>Class A Variable output characteristics</u>	
Hospital (or hotel)	Number of beds
Machine shop	Machine hours daily
Stadium, night club	Seating capacity
Telephone switchboard	Number of trunklines

Now, the facility here is hospital, machine, shop, stadium, telephone, switchboard and variable output characteristics are there. So, unit of measure, in case of hospital or a hotel is a number of beds, this already I have told, in one of the previous examples in which we were seeing the input measures of capacity and the output measures of capacity. So, variable output characteristics in terms of hospital or hotel or the number of beds.

In terms of machine shop, we can say per machine hours daily, so daily how many machine hours have been put in order to convert the raw material into the final product. So, that is giving us the capacity of the machine shop, similarly a stadium or a night club it is capacity can be measured in term of seating capacity, that how much seating capacity is available in that stadium or the night club. And similarly for a telephone switch board, we can say that it is capacity in number of trunk lines, it can accommodate.

So, the capacity of a telephone switchboard can be in terms of the number of the trunk lines available and it can accommodate easily without any failure. So, now we have seen that capacity is a inherent word, which is not only associated with the manufacturing company. It is associated with the all service sector, companies as well as may be different types of machines, different types of infrastructural systems.

Now, we come on to the best operating level, now capacity we have seen, each and every system, each and every place, like a hospital, stadium, each and everything will have certain rated capacity. Now, what is the best operating level, we have seen capacity is inherent to all the systems. Now, what is the best operating level, should we always operate at the maximum operating level or is there certain best operating level.

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So, now we are discussing, what is the best operating level, so example we can take best operating level, as the engineers design engines and assembly lines to operate at an ideal or best operating level to maximize output and minimize wear. So, if they are operating at their best rated capacity, what are going to be the problem areas, there may be certain amount of problem. That is why always, it is advisable to operate the systems or the machines at their best operating level.

Neither, they should be underutilized nor they should be over utilized, so the engineers design engines and assembly lines to operate at an ideal or best operating level to maximize the output and minimize the wear. So, this summarize is up, whatever we are going to discuss, may be in the subsequent slides. So, there is always going to be a best operating level at which we should operate.

It also tells us that, if you operated that level, what are the advantages that we would be able to derive out of operating at that level and what are the problem areas? If you go beyond that level, which is already there on your screen and with the help of certain slides, we would be trying to understand this phenomenon, now what is best operating levels.

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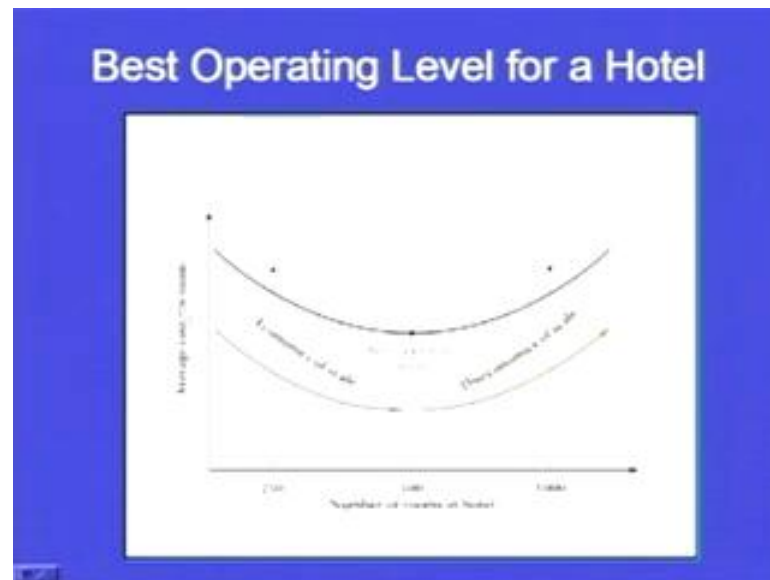


Now, you can see average unit cost of output, this is decreasing and there is a level at which we say this is the best operating level and after that we have the over utilization, before this we are having the under utilization. So, as the volume is increasing the average unit, cost of output, may be output, may be in terms of cars, it may be in terms of shoes, it may be in terms of coat, it may be in terms of trouser.

So, whatever product we are producing as the volume is increasing the average per unit cost is coming down, but it is coming down till a particular level only, when we go beyond that level, the cost again starts to increase. So, the bewildering question is that, why such a phenomenon, why it is not continuously coming down, why it is increasing after a particular level.

So, let us summarize the graph, we are seeing that average unit cost of output, this is decreasing to a particular level, which is called the best operating level and then again it starts to increase. So, as the volume of output is increasing, we are getting a point which we term as the best operating level and after this point, we are saying we are over utilizing the resources. Over utilization of that resources is taking place and the per unit cost or the average unit cost of output or cost of product is increasing, why this is happening, let us try to understand it, with the help of an another example.

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Now, on your screen, you see a best operating level for a hotel, on x axis, it is the number of rooms in hotel and on y axis, we have the average cost per room. So, the average cost per room is decreasing, if 250 rooms are there or 250 rooms are being use the cost is decreasing. And 500 rooms are being used, the cost is minimum, cost per room, but as we go beyond, if 1000 room are being used, then the cost per room is increasing, on your y axis is the average cost per room.

So, the average cost per room is optimum for the number of rooms equal to 500 and beyond 500, we see that the cost is again increasing, so this region till the best operating level, we call as the economics of scale. So, economics of scale is till this level, this dotted line and beyond that we call it as the diseconomics of scale. So, what is the underlying difference between the economics of scale and the diseconomics of scale, that we need to understand.

This is also a very important capacity problem, because the rated capacity in every 1000, but once we go beyond a certain level our economies of scale is not justified. We go into the region that belongs to the diseconomies of scale, so at what level should be operate that is the measure problem and how to decide that level. That at this level, we will be getting the best operating level or we will be getting the minimum average per unit cost of the product.

So, that decision has to be taken, but we need to understand the difference between the economics of scale, that why the cost is decreasing up to a particular level and why after that point the cost starts to increase. So, how much capacity is best, this is a very simple question, the best operating level is the output.

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How Much Capacity Is Best?

- The **Best Operating Level** is the output than results in the lowest average unit cost
- **Economies of Scale:**
 - Where the cost per unit of output drops as volume of output increases
 - Spread the fixed costs of buildings & equipment over multiple units, allow bulk purchasing & handling of material

That results in the lowest or we can say the minimum average unit cost or the cost, so the best operating level is the output, on x axis we have taken the volume, if you say x axis the number of rooms in the hotel, so this is the volume. So, the best operating level is the output or the volume that results in the lowest average unit cost, so for our case 500 rooms was the best operating level.

So, economics of scale, why such a phenomenon happens and first point is, where the cost per unit of output drops as the volume of output increases. So, this is the economics of scale, where is the economics of scale, where the cost per unit of the product or the output drops as the volume of output increases, which was very clearly evident in the last slide.

That, when we are number of rooms is increasing on the x axis, the average per unit cost of the room was decreasing, why this happen, because spreads the fixed cost of buildings and equipment over multiple units. So, as the number of unit is are increasing as the number of products or the volume of the products is increasing, the fixed cost of

buildings and other infrastructural facilities is getting spread over these many number of components.

And when the fixed cost is getting spread over so many numbers of components, the total cost of the product is bound to decrease. Allow bulk purchasing and handling of material, so this will allow and the volume is increasing, this will also help us to place lesser number of orders. We can purchase more material in one go only and handling of material would also become easier.

For example, one truck load can be ordered, when we know the volume is going to be more, when large volume is there, we need to do more manufacturing, we need more raw materials and more raw materials will be ordered at once. So, the ordering cost can be decreased and similarly the handling of material would also become a lot more easily and all these will add up to the reduction in per unit cost of the product as the volume increases.

If you remember in inventory management, we have seen the ordering cost as well as the holding cost, add up to the total inventory cost, so when the volume increases or economic order quantity is there, then the total cost is minimize. Similarly, here also when the volume is increasing, may be less number of orders have to be placed and the handling or the holding cost will also be less for large amount of material.

So, over all when the volume increases the cost per unit of the product will decrease, but till the best operating level. Till the economics of scale range is there, when this range or best operating level is there, beyond that the diseconomics of scale will start and the cost per unit of the product will start to increase. Now, we come on the second range, first range was economics of scale, where the average cost of product per unit was decreasing, till the best operating level and after the best operating level, we another stage starts that is the diseconomics of scale.

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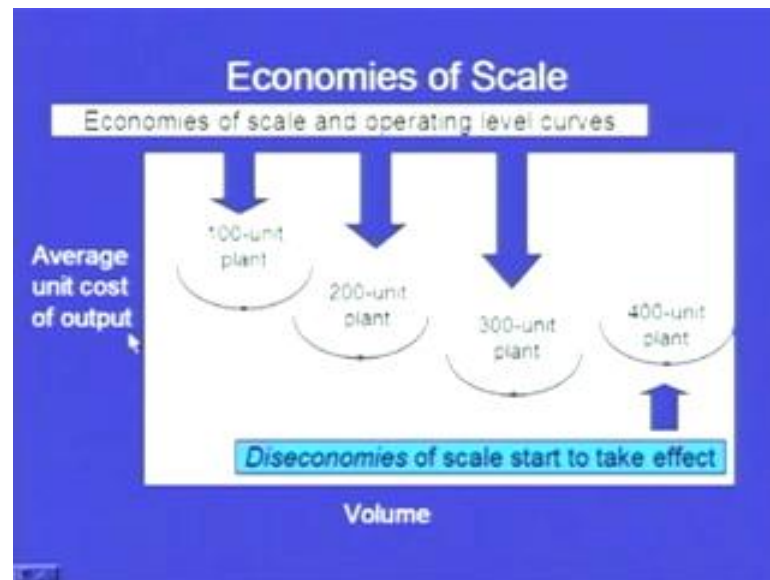
- **Diseconomies of Scale:**
 - Where the cost per unit rises as volume increases
 - Often caused by congestion (overwhelming the process with too much work-in-process) and scheduling complexity

Now, diseconomies of scale, where the cost per unit rises as volume increases, in the previous case cost per unit was decreasing, as the volume was increasing, here the cost per unit is increasing, as the volume is increasing. Why this is so, often caused by congestion, overwhelming the process with too much work in process and scheduling complexity.

So, whenever the volume is too much, the scheduling becomes very, very complex, we are not able to schedule the process properly which may later on result in breakdown of that complete process and it may require more maintenance. So, that will add up to the cost of the product or the cost of the output, therefore the diseconomies of scale will result.

In the previous, first slide if you remember, engineers design engines and assembly lines to operate at best operating level, the last word was minimize wear. So, if we are using the facilities too much, then the maintenance required will also be more. And because of wear and tear, sometimes the failure of machines may also take place, which will fall in the range of diseconomies of scale.

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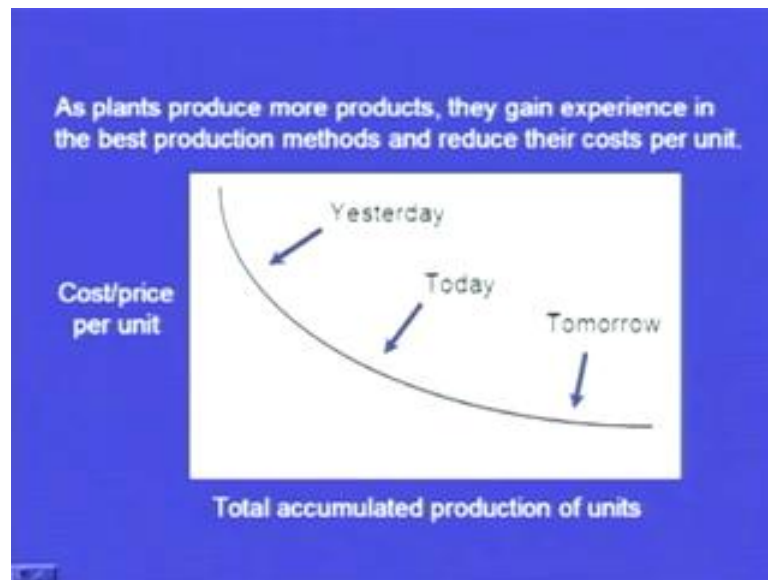


Now, let us see the economics of scale and operating level curves, so this is 100 unit plants, 200 unit plants, 300 unit plants, 400 unit plants. So, average unit cost of output, so average unit cost of output is decreasing, till a particular point may be 300 unit plants and after that it starts to increase. So, if you see here, this is the minimum average unit cost of output and after this at 400 unit plant, it starts to increase, so we can say that 300 unit plants is the best operating level.

So, economics of scale and operating level curves for each, we are seeing and we finally see that 300 unit plants is going to give us the minimum average unit cost of output, so we should go for this point. And diseconomies of scale, start to take effect from this point, so initially when the volume is increasing in x axis, 100 unit, 200 unit, 300 unit. Still, this point economics of scale is there, but just after this point diseconomies of scale starts.

And the 400 unit plant is going to be little bit more complex to manage the scheduling may be difficult, more wear and tear, more maintenance, may be large number of factors would creep in and the average unit cost will tend to increase. Therefore, we should focus on the best operating level in this particular diagram; we can say that, this is the best operating level. After this level or after this volume, the diseconomies of scale starts to creep in.

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Now, as plants produce more products, they gain experience in the best production methods and reduce their costs per unit. This is another example, that why that average unit cost is decreasing, when the volume is increasing or when the time is passing by. Because, with the passage of time, as plants produce more products, they gain experience, they know, what are the bottle necks, they are able to improve on those bottlenecks and then the cost automatically comes down.

The best production methods also are adapted and the reduce cost per unit, so cost per unit you can see here, cost per unit decreases, yesterday, today, tomorrow and total accumulated production of unit. So, accumulated production of unit is increasing on the x axis and the average unit cost is decreasing with the passage of time. So, with this we come to the end of this first lecture on capacity planning 1.

We have seen, what is the definition of capacity, what is productive capacity, what are the units of measuring the capacity, what are the input units or input measures of capacity, what are the output measures of capacity. Then, we have seen a very important topic of best operating level.

We have seen, what is economics of scale, what is diseconomies of scale, why economics of scale take place, why diseconomies of scale take place. Now, in the next lecture, we will see, what type of capacity planning is done and we would try to understand the entry cases of capacity planning with the help of certain problems.

Thank you.