Economics, Management and Entrepreneurship
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Lecture – 37
Capacity Planning

Good afternoon, welcome to the 37th lecture on economics, management and entrepreneurship. In our last few lectures, we had elaborately discussed various methods of forecasting, in that we stressed on forecasting methods for 3 types of futures; one, long term forecasting 2, the medium term forecasting and 3, the short term forecasting methods. For long term forecasting methods, we suggested that one has to use various types of survey brainstorming or similar such methods taking the opinion of informed individuals in the field.

The methods vary from face to face interviews questionnaire survey, committee meetings and Delphi study. The medium term forecasting methods mainly constitute the causal methods and one such causal method, which we had discussed very, very elaborately was regression method or multiple regression method and in our last lecture, we discussed short term forecasting method.

In that we discussed moving average and exponential smoothing methods, they are both time series forecasting methods. We said that there is a much more sophisticated method of time series forecasting, they are known as box Jenkins methods or ARMA or ARIMA methods. We did not discuss that in detail, we just told how the AR model or MA model or ARMA model looked like.

One of the application areas of forecasting is capacity planning. Capacity planning is also one of the first steps in starting a new enterprise. When an entrepreneur decides to start a new enterprise, he first of all thinks of a particular product or service in which the business will be associated with and then comes the question of what did be the forecast of demand for these products; for this product or service.

And then comes the planning for capacity; capacity planning is important from the point of view of an entrepreneur, it is also important from the point of view of an existing business, where additional capacity has to be added in view of the fact that the company of the business man foresees a substantial increase in the business opportunity in the future. Now, there are different methods of adding or observing additional demand for the product.

The company has the option of going for overtime, going for subcontracting the work, going for even new or additional shifts and it also has the other alternative of adding new capacity to its already existing capacity. Therefore, there are various options, in today's lecture we shall discuss first of all what we mean by capacity, how we define capacity and how we plan for capacity, can we have alternative plans for capacity addition.

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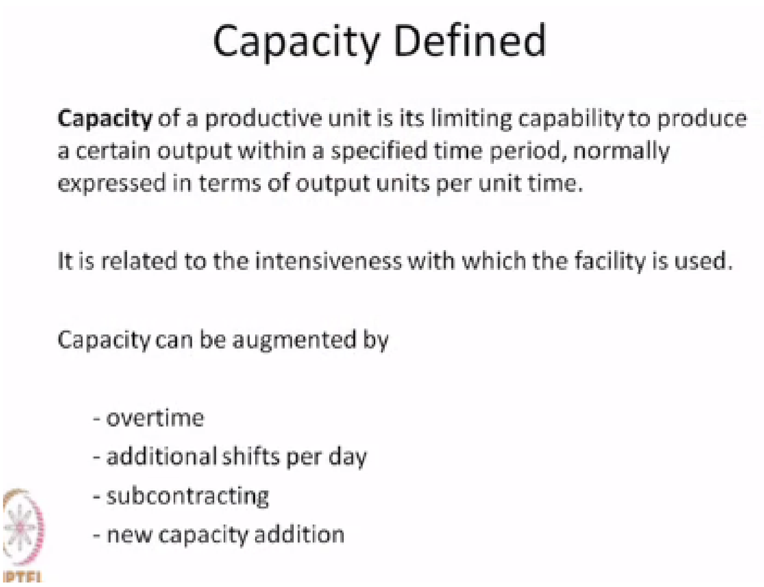

And if so, how to economically evaluate them, so these are the things that we are going to discuss in today's lecture, so the topic for today is capacity planning. First of all, there is a need to define capacity and normally we define capacity of a productive unit has its limiting capability to produce a certain output within a specified time period expressed usually in terms of output units per unit time.

In this definition, therefore 2 things are highlighted; one, the limiting capability in terms of output units in a particular time, so usually in a specified period what is the maximum capacity; maximum output feasible that is the definition of capacity. The limiting capability of a productive unit to produce certain amount of output units in a given or a specified period of time.

Naturally, it is related to the intensiveness with which the facility, the productive unit is being used by means of intensiveness, we mean whether the company is thinking of 2 shifts or 3 shifts or whether 3 shifts per day or whether it is going for overtime etc., etc. that is what we have written next. Capacity can be augmented by various options, the immediate options available is to use overtime.

Normally, when an overtime option is exercised then the payment given to those who work overtime is usually higher than the normal payment that means the cost of over time is usually higher than cost of normal time, so there is an additional cost involved in going for overtime, this must be understood. Also at the same time, we must understand that overtime does not always ensure full efficiency of a person.

Because usually, a person who works instead of 8 hours, let us say 12 hours, working for more hours in addition to his or her normal working hours gets tired, fatigued and therefore his efficiency also comes down. Thus, there are 2 effects; one the productivity of the person goes down because of working overtime and at the same time, the overtime payment per hour given to a worker is usually higher than the normal remuneration or payment given to a worker in normal time.

The second option available to augment capacity is to go for additional shifts provided the company has already not exhausted its 3 shift option per day, if it is working for 1 shift, it can go for 2 shifts, if it is working for 2 shifts, it can go for 3 shifts but again unless, it has additional labour force, the same labour force has to work for one more shift, which naturally reduces the productivity of the worker.

The output will not be hard part with their normal output thus going for overtime if it is done on a temporary fashion, it has to recruit temporary workforce. Temporary workforce is not always very good because they are not as efficient as their permanent workforce. The third option available with the management is subcontracting; subcontracting means that suppose, the orders received by the company is higher than the capacity limit.

And that and if the customer is not interested to wait for a long time and if the other 2 options the company does not want to exercise then it can subcontract this remaining amount meaning, the orders received minus the capacity that it has to produce in a given period of time. This amount it can ask another supplier to produce and give. Normally, this is called subcontracting; here also there is a problem.

The problem is one of the quality of the products although, the work is subcontracted, you have to ensure that the quality of the product that you receive from them is acceptable and therefore some of your own people must be associated with the manufacture of this subcontracted work. Additionally, there must be a certain amount of negotiation between the 2 companies; your company and the company to which the work is subcontracted.

So, that the negotiated price is acceptable to you and of course, the last option is to add new capacity, the first 3 options are basically contingency approaches to meet extra demand that you may be having temporarily but if a company or experiences permanent divine, demand exceeding its capacity for a long time therefore, it understands that it is a case of demand exceeding its capacity for a long time.

In that case, it must plan for new capacity addition in fact, before the situation occurs that the demand is exceeding its capacity, the company should go for new addition; new capacity addition such that it does not lose any sale, loss of potential sell is a cost to the company and the companies should therefore plan much in ahead; much in advance, so that it has sufficient capacity to meet the increased future demands of the market.

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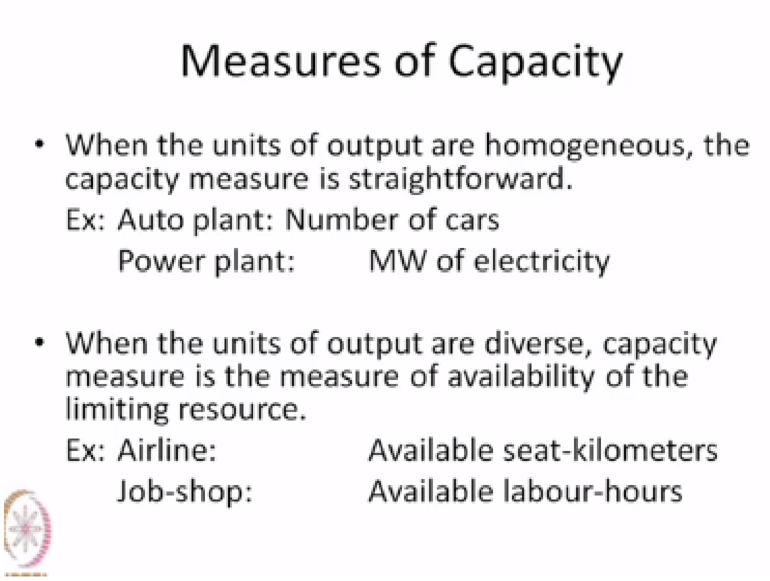

Now, in this slide we are going to discuss how to measure capacity usually, when the units of output are homogeneous, the capacity measure is straightforward in case of auto plant for example, the output is more or less homogeneous is the number of cars produced in a given time. For a power plant, it is a megawatt of electricity however, when the units of output are diverse, capacity measure is the measure of availability of the limiting resource.

So, when there are multiple products or the output is not easily understandable and is diverse then we measure by the availability of the limiting resource. A very good example of this is a job shop; a job shop produces different types of jobs and therefore here one cannot express the number of jobs per unit, every job requiring different types; different amount of effort in terms of machine hours or man hours.

One job may take one month, another job may take only 1 week and each job is very unique, sometimes only 1 item is needed to be fabricated or made and supplied to the customer in such a case, there are large number of products or services being given, the variety is very large, here we go for the limiting resource. In a job shop, the resource could be labour hour; available labour hours in a month or it could be available machine hours.

Depending on whether the job shop is machine intensive or labour intensive, if it is labour intensive requiring, it does more amount of labour oriented work, then it is labour hours. Say for example, a civil contractor; the work is mostly labour oriented and therefore, for such a contractor, if the contractor has 400 workforce, the size of work force is 400 and if they work for 7 hours a day in a month and they work for 25 days in a month.

Then the capacity of the contractor will be 25 days * 7 days; 7 hours a day * 400 size of the workforce that is the capacity in terms of labour hours. In terms of machine hours, it would be how many machine hours in a month the company has, similarly for an airline, it is the number of seats and how many kilometres, the airline will fly in a month therefore, for an airline the capacity is available seat kilometre.

So, both are used in practice, also you can see here that we are not necessarily considering only manufacturing plants or manufacturing systems, we are also considering service systems. Airline provides a service whereas; auto plant, power plant and jobs shop are manufacturing units.

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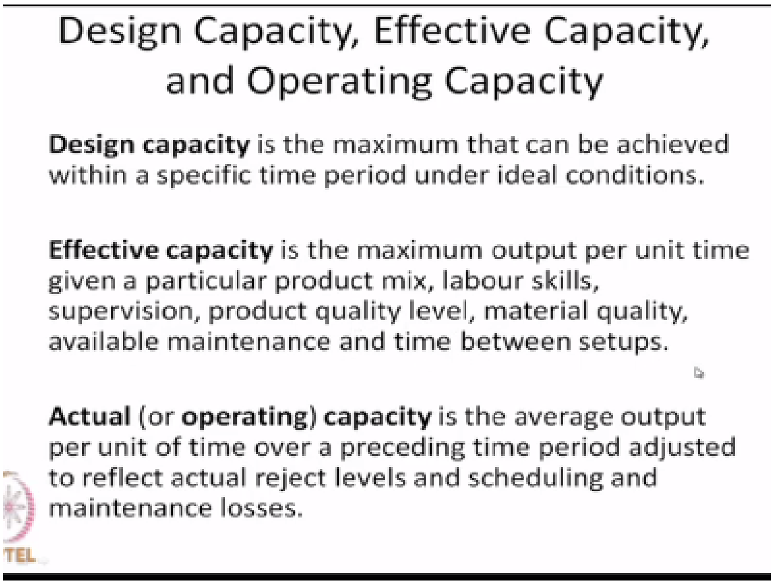

In this context, we can define 3 forms of capacity; one, the design capacity; 2, the effective capacity and 3, the actual or the operating capacity. We define design capacity as the maximum that can be achieved within a specific time period under ideal conditions. So, usually when a design is made and capacity is estimated, the conditions are assumed; certain conditions are assumed and they are like the ideal conditions.

Under those conditions, the design of the plant is specified; the capacity of the plant is specified and that capacity is normally called the design capacity whereas, the actual operating capacity is vastly; could be vastly different from the design capacity and that is because of various reasons, the way, the labour skill, the product mix, the managerial practices, the supervision, the maintenance all these are the reasons why the design capacity is usually not achieved in practice.

If one continues to improve upon these management practices then it has a possibility to improve the actual operating conditions to effective capacity that is the definition of effective capacity, it is the maximum output per unit time that means, it is a maximum operating capacity that can be achieved, if things go well given a particular product mix, labour skills, supervision, product quality level, material quality, available maintenance and time between setups and so on and so forth.

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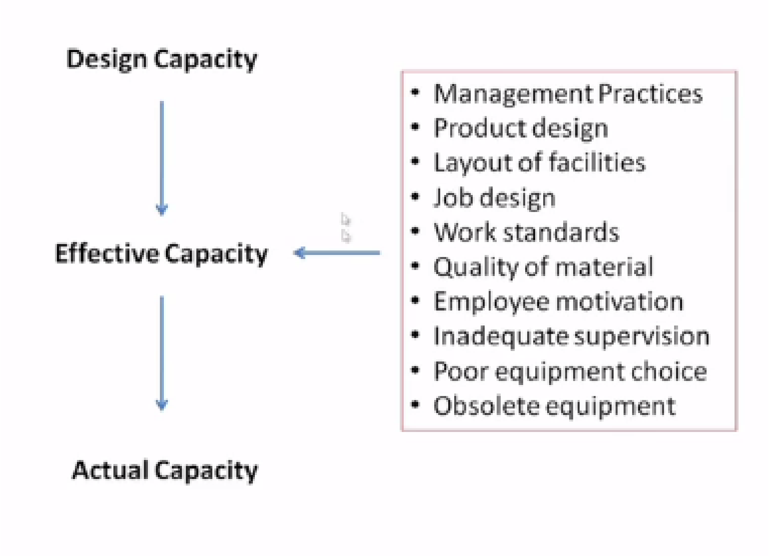

This we are showing here, design capacity and effects of various things lead to effective capacity and the actual capacity, this effective capacity is basically the limit of the actual capacity and these factors are various management practices, product design, layout of the facilities, job design, work standards, quality of product material, employee motivation, inadequate supervision, poor equipment choice, obsolete equipment and so on and so forth.

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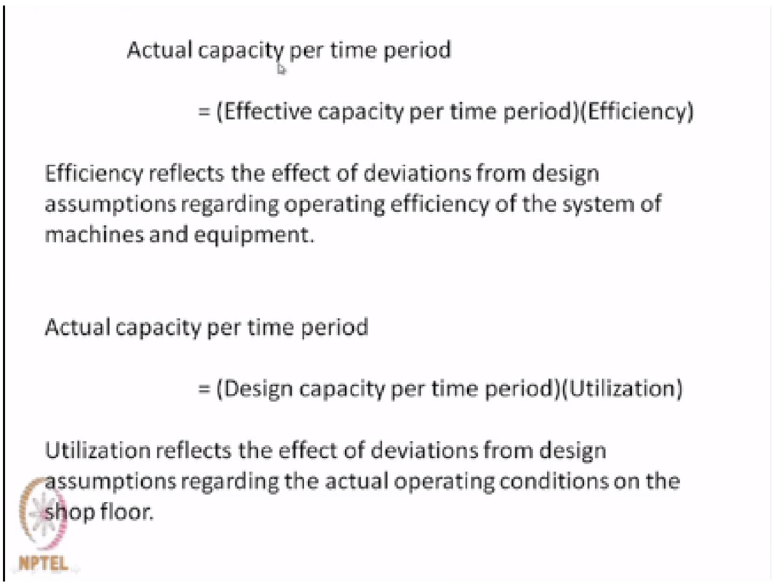

Now, we have defined or tried to find out relationship between the actual and effective and between actual and design capacity by defining 2 terms; efficiency and utilization. Efficiency; multiplicates product of efficiency and effective capacity is actual capacity and product of utilization; plant utilization and design capacity is the actual capacity. Efficiency reflects the effect of deviations from design assumptions regarding operating efficiency of the system of machines and equipment.

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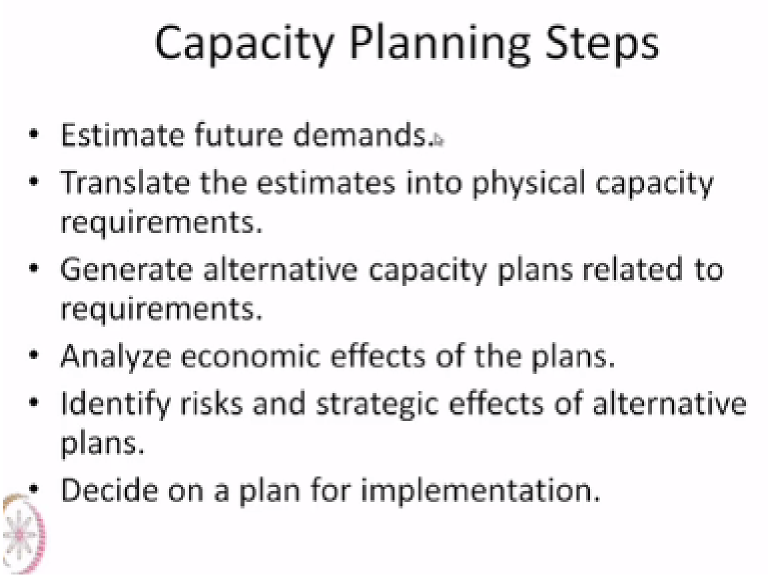

Whereas, utilization reflects the effect of deviations from design assumptions regarding the actual operating conditions on the shop floor. Now, that we have given certain introduction to what is capacity, how it is measured, let us now go to defining the steps that are required to plan capacity. Capacity planning steps are about 6 in number; one estimate future demand, so naturally this is where we have to use our forecasting methods.

But at the time of estimating the future demands, we should make if possible; as far as possible most likely optimistic and pessimistic demand estimates, to translate the estimates into physical capacity requirement, demand is in terms of output, in terms of numbers in the market, customer demand; customer demand has to be converted or translated into capacity of the machines of the assembly section.

And various things like that detailed estimation of physical capacity requirements, then generate alternative capacity plans related to requirements, analyse or evaluate each alternative capacity plan, identify risks and strategic effects and decide on a plan for implementation. Now, these are a few steps that are usually carried out in planning for additional capacity.

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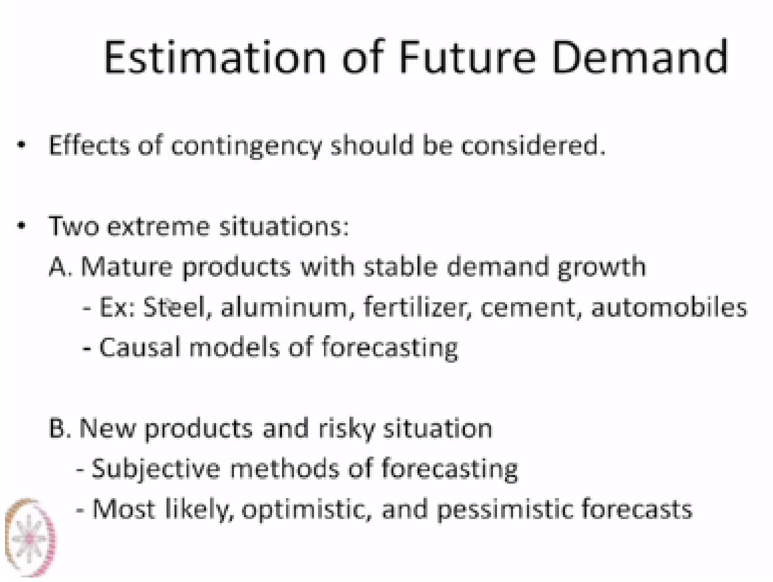

In the estimation of future demand, one should always go for different types of contingencies that can occur. Contingency could be new technology, competitors coming, new technology being introduced or new government rules regarding pollution, regarding environment or alternative products coming, so these are contingencies that can change your demand projections.

Therefore, it is always desirable that you make 3 estimates; the projections that is most likely to occur and optimistic and pessimistic projections however, preparing 3 forms of projections into the future is relevant mostly in risky situations or when the company is thinking to launch a new product. If the company is trying to enter a market in which the product is in its maturity phase of its life cycle, then the risk is much less.

Risk is more, when the product is new being launched or it is in its major growth period and that is where the need for 3 scenarios or 3 forecasts is very high but if as I said the; if the product is in its maturity phase, then 3 scenarios may not be required, just we are writing, there are 2 extreme situations; one, mature products with stable demand growth normally seen in sectors like steel, aluminium, fertilizer, cement, automobiles and so on and so forth.

The growth may be very stable of course, in our country now that it is; we are going through a growth period, automobiles are as in the rise because of construction work, cement demand may also be on the rise and because of construction work still may be on the rise, so one has to consider the fact that they are not strictly stable demand, there is a slow growth in that and there could be another situation, where the product is new or risky.

So, there it is mostly passing through the introduction phase or the major growth phase here, one has to or normally use a subjective method of forecasting and 3 forecasts are made most likely optimistic and pessimistic and in this case, the model usually is causal model of forecasting like regression analysis.

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Example

A company has three departments: Machine, Assembly, and Receiving, shipping, and factory warehouse (RSF). Its present capacities are 12,000, 10,000, and 18,000 units/year. The most-likely, optimistic, and pessimistic demand estimates are given below.

Find the capacity gaps in various departments.

Demand Estimates	Capacity, units/year			
	Current 2012	2014	2016	2018
Most likely	10,000	14,000	17,000	20,000
Optimistic	10,000	15,000	25,000	40,000
Pessimistic	10,000	12,000	15,000	18,000

Now, we give an example; a company has 3 departments; machine, assembly and RSF; RSF standing for receiving, shipping and factory warehouse. The capacities of these 3 departments in terms of final product is 12,000, 10,000 and 18,000 units per year, the most likely optimistic; most likely optimistic and pessimistic demand estimates are given below sorry; are given below. Find the capacity gaps in various departments.

So, the most likely scenario is given here, the present capacity is this is 10,000 for it and the most likely demand growth is 14,000, 17,000, 20,000, most optimistic is 15,000, 25,000, 40,000, most pessimistic is 12,000, 15,000 and 18,000, these are in the years 2014, 2016 and 2018. Currently, year is 2012 and today's demand is standing at 10,000 units per year.

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Demand Estimates	Capacity, units/year			
	Current 2012	2014	2016	2018
Most likely	10,000	14,000	17,000	20,000
Optimistic	10,000	15,000	25,000	40,000
Pessimistic	10,000	12,000	15,000	18,000
Mcg Capacity	12,000			
Assy Capacity	10,000			
RSF Capacity	18,000			
Mcg Cap Gap	2,000	(2,000)	(5,000)	(8,000)
	2,000	(3,000)	(13,000)	(28,000)
	2,000	-	(3,000)	(6,000)
Assy Cap Gap		(4,000)	(7,000)	(10,000)
	-	(5,000)	(15,000)	(30,000)
		(2,000)	(5,000)	(8,000)
RSF Cap Gap	8,000	4,000	1,000	(2,000)
		3,000	(7,000)	(12,000)
		6,000	3,000	-

So, what we have done here is that first of all, we have written down the demand here, this is the capacity required, what we have is; machining capacity is 12,000, assembly capacity is 10,000 and receiving shipping and factory warehouse capacity is 18,000 units per year today in the year 2102. So, first we find out the manufacturing capacity gap, assembly capacity gap and RSF capacity cap.

So, we find that compared to the demand, excess capacity is available in the machining department, in the assembly department it is just matching 10,000 and 10,000, so it is nothing and RSF capacity is 18,000, so 8000 more capacity it is having. Now, what we have done here; we have written 3 numbers under machining capacity gap, considering the 3 scenarios, so in the current; currently, there is no problem, this only 2000 and 8000.

And there is no is exactly matching, now when we consider 2014, we find that the requirement is 14,000, the machining capacity is 12,000, therefore there is a shortfall or gap of 2000, written within parentheses, so this is the additional capacity that is needed following the most likely scenario and if the optimistic demand is taken, the gap is 3000 deficits and if the pessimistic demand is taken, it is exactly matching.

The manufacturing capacity is 12,000 and the pessimistic demand is 12,000, therefore there is no shortfall neither there is in excess capacity. When we go to assembly capacity, it is 10,000 therefore, the gap is 4000, 5000 and 2000, this is the deficit, this is the capacity requirement gap, additional capacity is these and in the RSF; receiving, shipping and factory warehouse, the capacity existing is 18,000.

And in the year 2014, we have less than that in all the demand scenarios and therefore, we have excess capacity of 4000, 3000 or 6000 here, so we are comfortable as far as the RSF capacity goes but whereas, assembly and machining capacity requires new additions. In the year 2016, similarly we consider first of all the machining capacity, we have only 12,000 and the gap is 17,000 – 12,000 is 5000, it is a deficit; 25 – 12 is 13, 15 – 12 is 3.

So, the capacity gap are 5, 13 and 3 similarly, we can calculate for assembly capacity, it is 10,000 at present in the year 2016, we require all this therefore, 7, 15 and 5000 are the capacity deficits or capacity gap considering each of the 3 scenarios and finally RSF capacity is 18,000 required, we only in the optimistic scenario in the demand is 25,000, there is a deficit of 7000 capacity but else it can definitely provide services if the demand is 17,000 or 15,000, excess capacity is 1000 and 3000 respectively.

And in a similar fashion, we can consider 2018 data and we can estimate the gaps; the capacity gaps in manufacturing assembly and RSF. We see here that if the demand is pessimistic at 18,000 units per year, the RSF capacity is just sufficient to cater to the need of this, therefore there is a dash here, else it also needs to be augmented with additional capacity both for most likely and for optimistic scenarios.

So, this gives an example of how to basically translate the final demand into the other departments physical requirements and then compare with the existing capacity of these departments and estimate the or calculate the capacity gaps.

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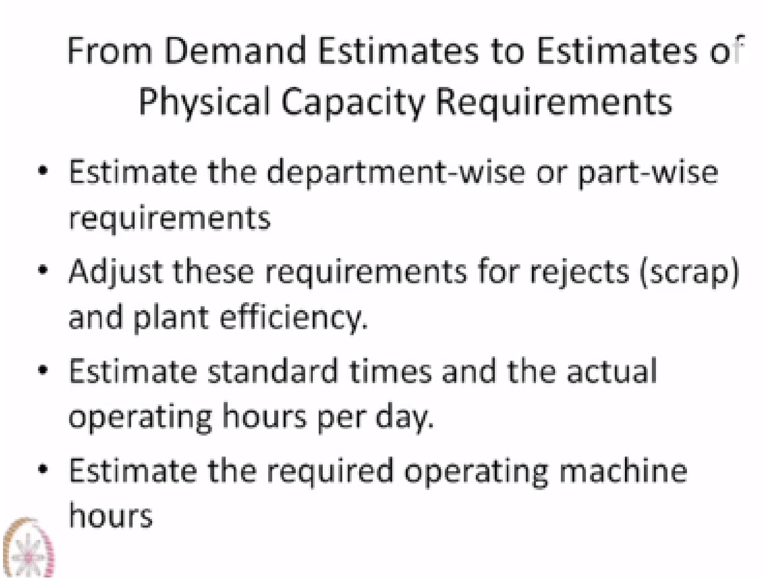

The second step if you recall is demand estimates to estimates of physical capacity requirements. Now, here we estimate the department wise or part wise requirement but adjust these requirements for rejects and plant efficiency. Adjusts these requirements for rejects and plant efficiency, remember that whatever we plan for these products have to meet certain quality specifications.

And quite often, we may come across situations where certain products do not meet these quality checks or specifications in which case 2 options are available; one, it is reworked, certain parts can be reworked but in certain cases, the parts cannot be reworked in which case they will be scrapped. If the scrap level goes to 10% that means, we must produce 10% more to get the desired number of output in a month or in a day.

So, this percentage of the defective items must be estimated, a reasonable value has to be taken that is scrap also, there is a case of plant efficiency. Although, we may have designed a plant to be operating at certain value most likely or certain; at certain speed for various reasons, we are unable to maintain the speed and for that reason, the efficiency of the plant reduces, we sometimes go for calculation of plant efficiency.

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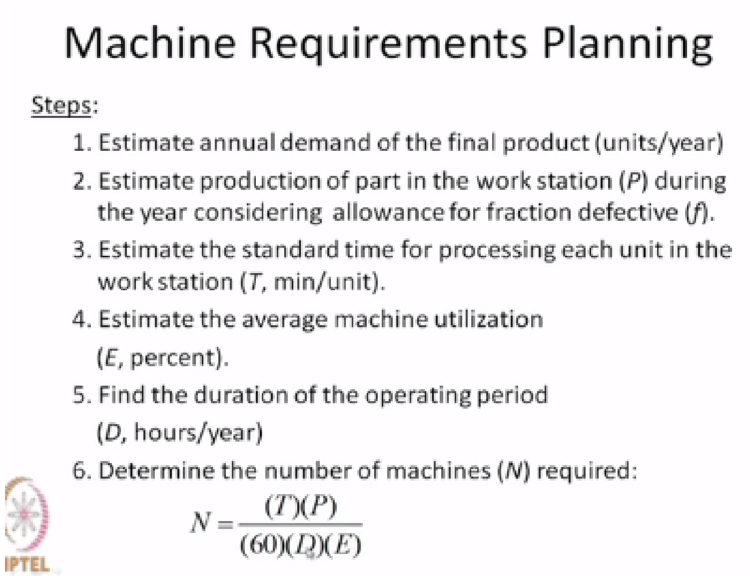

Then we estimate the standard times and the actual operating hours per day and estimate the required operating machine hours. We give an example to illustrate what we are trying to say suppose, that we are interested to calculate the number of machines required to produce certain output, this is machine requirements planning. There are a few steps here, estimate the annual demand of the final product which we have to do anyway.

Estimate the production of part in the work station P; work station in a particular machine during the year considering allowance for fraction defective, this is what I was saying; scrap considering allowance for fraction defective f, let that f be the fraction defective. Estimate standard time for processing each unit in the workstation T minutes per unit. Estimate the average machine utilization, find duration of the operating period.

Determine the number of machines that is nothing but T the minutes into P production of parts divided by E, the efficiency, average machine utilization, D the duration of the operating period in hours and 60 minutes per hour, T is in minutes.

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Example:

Each unit of the final product requires 2 units of part A and 1 unit of part B. Part A is produced in a machine. The annual demand for the product is 20,000 units/year, percent defective *f* is 5 %, average machine utilization (due to breakdown) is 90 %, standard time for part A is 10 min/unit, the shop works for 2 shifts a day, with 8 hours per shift, but the idle time (due to shift hours not being fully utilized) is 20 %.

Find the number of machines required to produce the required number of parts A.

Considering scrap (5 %), the no. of part A required to be produced is

$$P = (20{,}000)(2)/(1 - 0.05) = 40{,}000/0.95 = 42{,}105 \text{ units/year}$$

Now, let us take an example to illustrate what it is, let us say that each unit of the final product requires 2 units of part A and one unit of Part B that is the product consists of 2 parts; A and B, so it is an assembly of 2 parts of A and one part of B. Part A is produced in a machine and that is work station here, the annual demand for the product is 2000 units per year, percent defective is 5% that is 5% goes a corrupt.

Average machine utilization due to breakdown is 90%, it is not 100% because of breakdown, standard time for part A; standard machining time is 10 minutes per unit that is the machine takes 10 minutes to produce part A, the shop works for 2 shifts a day, 8 hours per shift but the shift hours are not fully utilized, only 20%; only 80% of 8 hours is utilized that is 6 hours; 6.4 hours.

The rest time goes for other types of activities by the employee or other things, machine not available, tool not available, worker is not working, parts not available etc., now find the number of machines required to produce the required number of parts A, so we are only talking about part A and at this moment we are not talking about part B, remember that to produce one final product, we require 2 units of part A.

So, if 2000 units of the final product is required in a year, then 2000 * 2; 4000 units of part A are required in a year, so 2000 * 2 that 2 is this; 2 units of part A for one unit of final product and because 5% of the final product is defective, we have to produce more, we divide by 1 – 0.05. There is one mistake, please make a correction here, this is 20,000 not 2000, yes it is 20,000.

So, 20,000 * 2 is 40,000 divided by 0.95 that is 42,105 units minutes per year, so we have to produce therefore 42,105 units of part A in a year to be able to produce 20,000 parts; 20,000 even itself final product.

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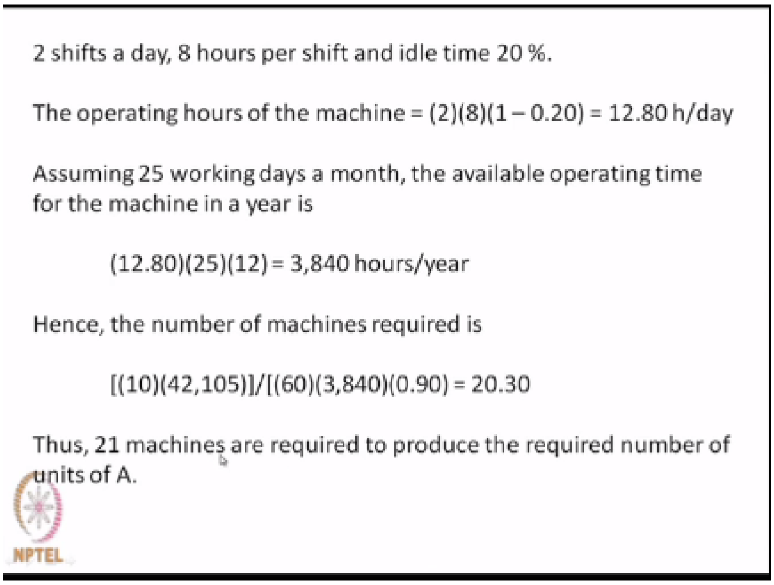

Now, we know that we are working on a 2 shifts basis; 8 hours per shift but the idle time is 20%, therefore the actual operating hours of the machine in a day will be 2 shifts * 8; 16 * 20 % loss, so 1 – 0.2 and that comes to 12.8 hours per day, they may see; actual operating time of the machine and there are 25 working days in a month we are assuming and there are 12 months in a year therefore, the available operating time in hours in a; just one second.

Yeah it should be also in a year not month, so this becomes 3,840 hours in a year is available operating time requirement of the machine. So, how many number of machines are required, we already know that the standard time to produce a part is 10 minutes, so 10 minutes and how many parts are required to be made? We have already estimated that has 42,105, so 10 minutes per unit into 42,105.

This is the total time required and we have 3840 hours * 60, so many minutes but 90% is the machine; average machine utilization therefore, the actual is 0.9, so we require 20.3 number of machines, which means 21 machines are required to produce the required number of units of part A. I think in this example; we have clearly shown how the demand forecasts made can be translated into physical requirements in terms of machines.

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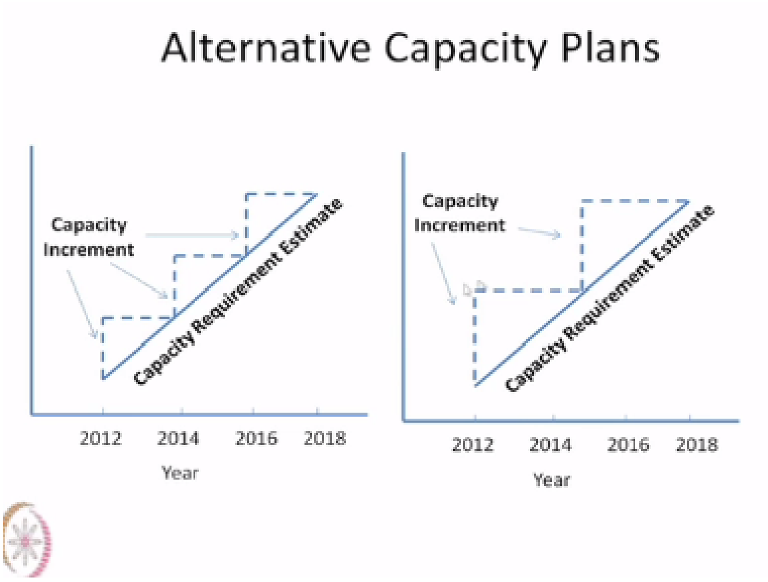

Now, when we actually add capacity, we can add, this is the additional capacity made and the capacity is available here, we place an order here and it comes here, place an order here it comes here, so one possibility of designing capacities every year or every 2 years. The same thing we have plotted here, more capacity and less frequently, this is less capacity more frequently, addition of capacity.

This is how the capacity requirement estimates go up, this is for different years, here we are assuming that every 2 years, certain capacity is being added, we could assume that every 3rd year, it is being added but more capacity addition, there are therefore 2 alternative situations of capacity.

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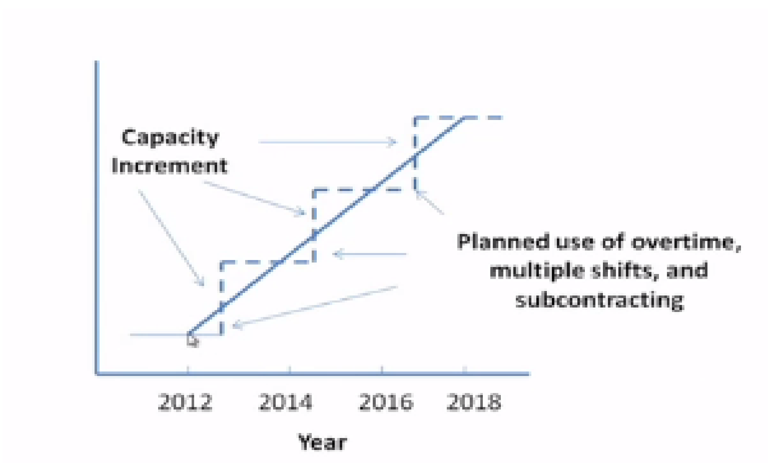

This requires; there is yet a 3rd option, which is that you can; this is your existing capacity and the capacity requirement goes up like this, so what you do; you work under capacity that means your capacity is less than the demand and how do you observe the demand then? You absorb it by planning use of overtime, multiple shifts and even subcontracting that is what we have done here and then the new addition take place.

And once the new addition takes place, it continues to serve the demand till the demand exceeds the new capacity; the total capacity and once again, you get the order later, so you; that time you go for planned use of overtime, multiple shifts and subcontracting. So, basically what I am trying to say is that there are different alternatives of when to add capacity or how much to add capacity and how much of overtime, subcontracting and new shifts to be used; additional shifts to be used.

These are; there can be different alternatives, it is required that for each alternative the cash flows are to be estimated, remember that every when a new capacity is ordered a great amount of money is to be invested, a very good amount of money is to be invested initially and the capacity is not coming at that particular time, when the order is placed, it might take 6 to 8 months' time.

And when the capacity actually arrives it has to be installed, it has to be seen that it is working as per requirement, testing has to be done, all this may take between 6 months to 1-year time or even more sometimes. So, during that time what is to be done and if you have more capacity but less demand or less capacity more demand, then the cost position will change; the fixed costs and the variable costs will also be different.

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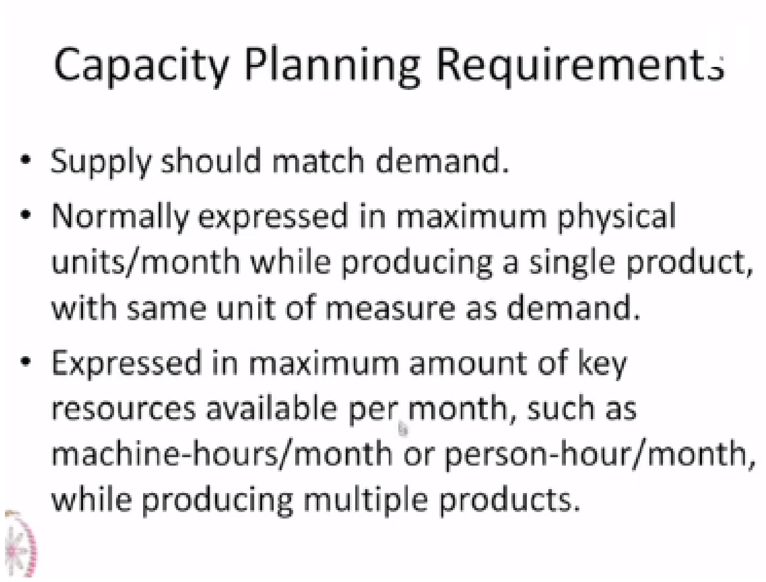

Now we say that supplies would usually match demand, well this thing we have already discussed in a way, so let us not spend more time on this.

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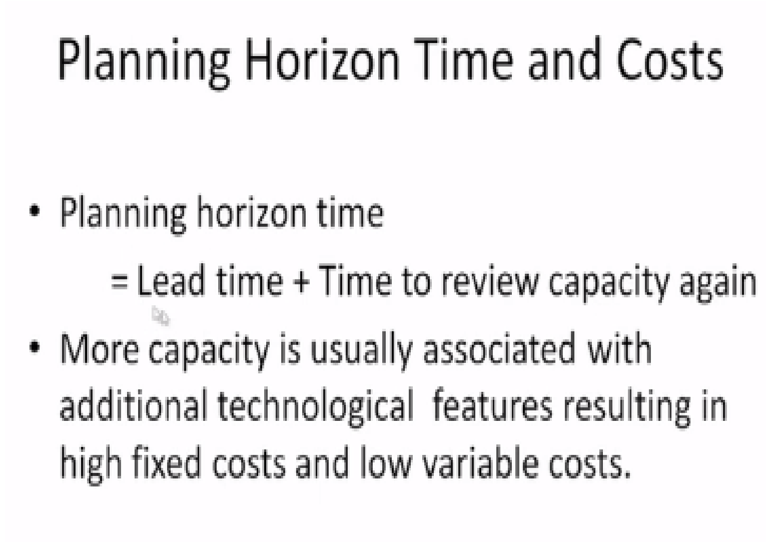

This one; planning horizon time therefore, is a lead time plus the time to review capacity again. Lead time basically the procurement lead time, we place; we decide to place or go for additional capacity and finally, after a year or so, the capacity comes and is installed and is used, that time that separates the point of placing an order or deciding to place an order and the actual receipt of the capacity and the use of the capacity is called the lead time that can be considerable.

And the time to review capacity again for the future, this is the plan; total planning horizon time and more capacity is usually associated with additional technological features. Normally, when a company decides to go for higher capacity, it has the option of choosing a better technology that can have high fixed cost and low variable cost vis a vis, smaller capacity, which has small fixed cost but high variable cost.

Therefore, the cost implications are different for different alternatives, this call for an economic analysis like the way we had been doing, when we considered managerial economics, the cash flow diagram and then evaluation of the cash flow diagram in terms of present worth cost comparison method or other methods to find out which alternative is the best alternative.

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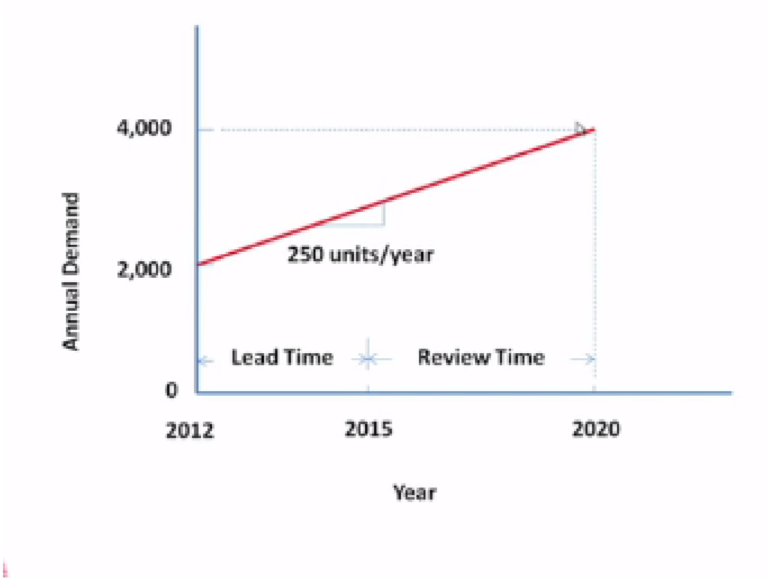

This we are showing here, let us say that the demand today is 2000 and it is projected to be going at a rate of 250 units per year, so it may take in this case a 3 years lead time to get the; whatever we place order here we may get after 3 years, so after 3 years, the demand is this and that capacity which we are ordering that should cater not exactly for the demand at 2015 because very soon, if we; if it is 250 units per year and it is for 3 years.

So, if we are placing an order for only 250 * 3; 750, then at the end of the 3 years, 750 arrives, we are here then very soon we will find that the demand is exceeding our capacity. So, what is normally done is that suppose that we decide to have our next review time for 5 more years then altogether we have to plan for 8 years, it means that 250 units per year into 8, which is 2000, so we should plan for 4000 units and place order for 4000 units.

And the capacity can be added at this point, we may carry certain amount of overcapacity for some time, so which means the capacity will not be utilized fully. We shall continue to discuss the capacity planning problems particularly in risky situation and also for normal situation, when the product is in natural stage, in our next class with the help of a few examples. Thank you very much.