Sustainability Through Green Manufacturing System: An Applied Approach

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Lecture – 18
Productivity and Sustainability

Good morning, welcome to one more lecture of sustainable manufacturing and today we are going to discuss about productivity and sustainability and the mathematical considerations associated with it. So, that in the next lecture of optimization, we can talk about what are the how do we consider different factors that are relevant for optimization of maintaining the productivity, while trying to achieve sustainability, I am talk to Deepu Philip and I am from IIT, Kanpur.

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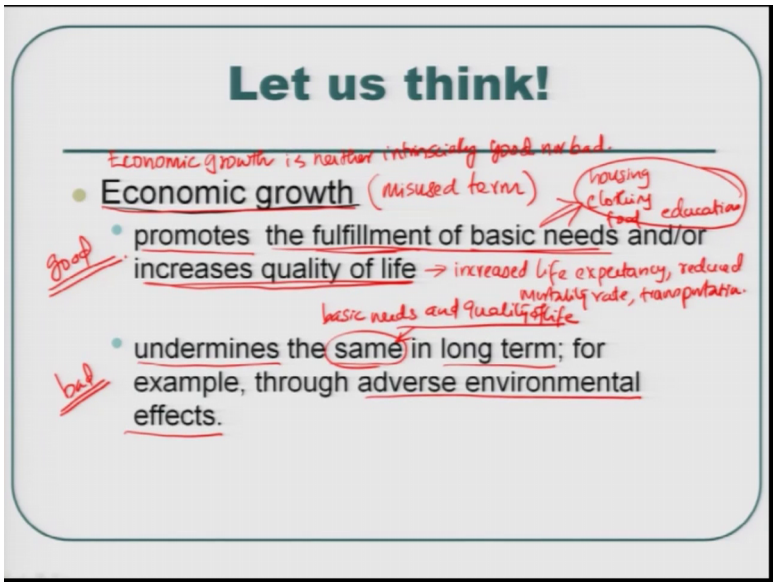

So, let us think first, we all know about the word called economic growth. So, this phrase economic growth is one of very important phrases, because this phrase contains main color got changed.

This phrase contains the lot of this is like I would probably say it is a misused term, because lot of inherent misunderstandings are part of this. So, for the purpose of this course, we need to understand, when we talk about economic growth, what we are

talking about. So, on the contrary to the belief, economic growth is neither intrinsically good nor bad, is not necessarily good or not necessarily bad. So, the most of the time the term that we use in this class, economic growth it is used under. It is something that promotes the fulfillment of basic needs and increases the quality of life.

So, you are supposed to do two things out of this one is fulfill the basic needs the basic needs includes housing, clothing, food, education, like this. So, you would you the economic growth allows you to fulfill of the basic needs of an individual or a human being or a society and also it increases the quality of the life. Quality of life can include, you can think about us increased life expectancy, see reduced mortal reduced mortality rate or transportation. There are lot of things healthcare, many aspects are comes out as a part of the increases of quality of the life. So, it is good that it promotes. So, the good aspect of it is this, the economic growth is good, because it promotes the fulfillment of basic needs and increases the quality of the life.

Now, at the same time since, it is promoting something, it also undermines the same undermines, what the same is basic needs and quality of life. These things, the same in the long term, mostly through adversarial environmental effects. So, this is the bad side of it. It will give you, yes fulfillment of basic needs and quality of life immediately, but in the long term, it undermines the quality of life and basic needs in the adversely environmental impact. So, let me give you an example, big example everybody heard about green revolution, this is in India, it is increase in agricultural productivity.

We all heard about doctor M S Swaminathan, who was champion of this whole thing. So, what we did is we utilized fertilizers high yielding varieties and pesticides to increase food production. So, what are the advantages of this the main advantage of this was you know poverty reduction, elimination off famine etcetera so obviously, the standard of the living and the basic needs of the people, the fooding was fulfilled, but what is the bad side of it. Now, the bad side of it is that polluted land bodies increased diseases, like cancer, then extinction of species of natural species etcetera.

So, that in the long run, it also even though it reduce the famine, it increase the food grain availability in the country. It also is now adversely impacting the life of the people through the environmental or the ecologically impacts it has. So, you have to think about us the economic growth or productivity. So, you always have to think about this way

productivity has two sides, the positive and negative. So, to address the negative sides of it is very use sustainability. So, think about it this way from there further rest of this course. So, that we are using sustainability or we are incorporating sustainability into our course work to actually minimize the effects of the adversely effects, of the in productivity or economic growth.

So, now, there are many definitions of productivity and we have studied quite a lot of definitions also of that.

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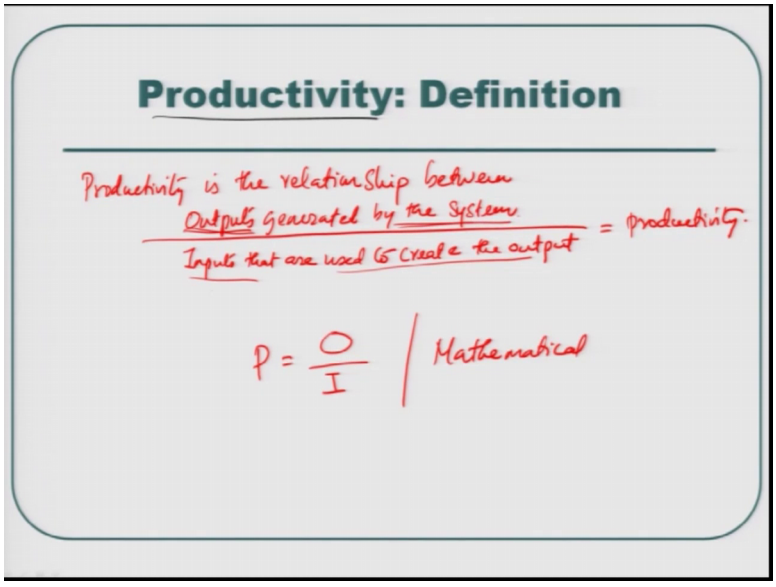

So, the main definition of productivity, if you think about it or how do we define this. So, the productivity is the relationship between what; between outputs generated by the system and inputs that are used to create the output. So, if you take a ratio of both then you can think about this ratio as productivity. So, you have the relationship it is a relationship between the outputs generated by the system. So, system are some outputs has generated and there are inputs, there are used to create that output, this gives you the productivity.

So, P is equal to O over I, this is the simplest way we can write this as in the mathematical form. So, let us keep this at to this level, so that when we go to the rest of the class, we would not have any problem with the definition of productivity. So, it is the outputs that are generated by the system, the ratio of the outputs to that of the inputs, that are used to create that output, it termed that as productivity.

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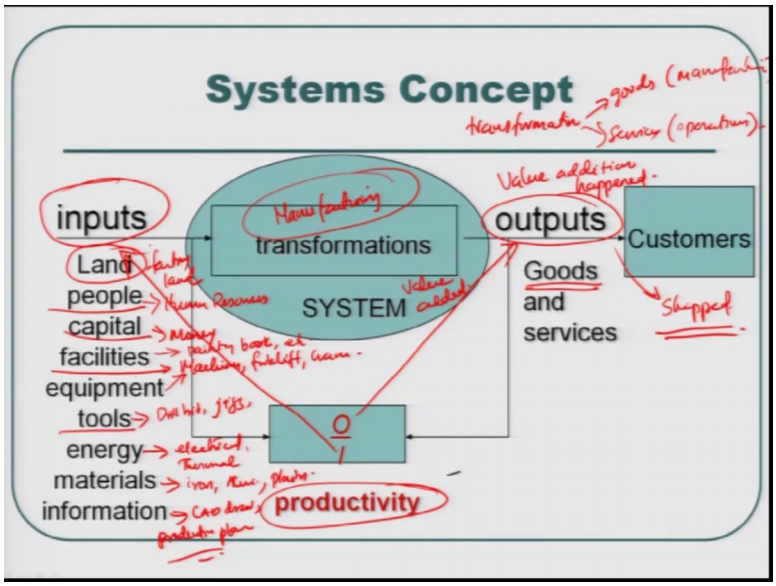

So, if you look into this we have a interesting aspect, the system what are the inputs of this, the inputs of the system includes there are multiple inputs. Land is the land parcel in which a factory is built. So, factory land you can think about it, this way. People, which is human resources, then you have capital which is the money facilities. This includes machines forklift crane etcetera, sorry, equipment involves, facilities involves like painting booth etcetera. I am just giving rough examples, equipment we already said this is what equipments is tools, we can talk about different tools, drill, bed jags, fixtures, energy; this is electrical or it can be also thermal or you use multiple energies to take care of this materials, iron, aluminium, plastics, etcetera.

Information which includes cad, drawing, production plan, these are all inputs, all of these are inputs into the system and if you look at it from a systems, an overall view point. This transformation is typically what we called as the manufacturing. It can be into the transformation process, if it produces transformation, if it produces goods, then we call it as manufacturing. If it produces services then we call it as operations, we have studied this, you might have studied this in different textbooks. So, what we talking about is the manufacturing transformation. So, you transform these inputs, all this inputs into some output. Here is some value addition happens, value addition happened or occurred.

What is the value addition happens. So, the value gets added here. So, system does the value addition or the transformation process gets see value addition or the manufacturing process does the value addition. So, you get into the form of goods and services we are focusing more on goods, because we are in the manufacturing side and these goods gets than shipped to the customer. So, then the productivity, we can measured. This way it is the ratio of this to that of this inputs.

So, that is the systems approach or the systems view of the productivity, in this regard. So, what we will do is we will talk about how can we increase productivity, how do, how productivity can be in increased.

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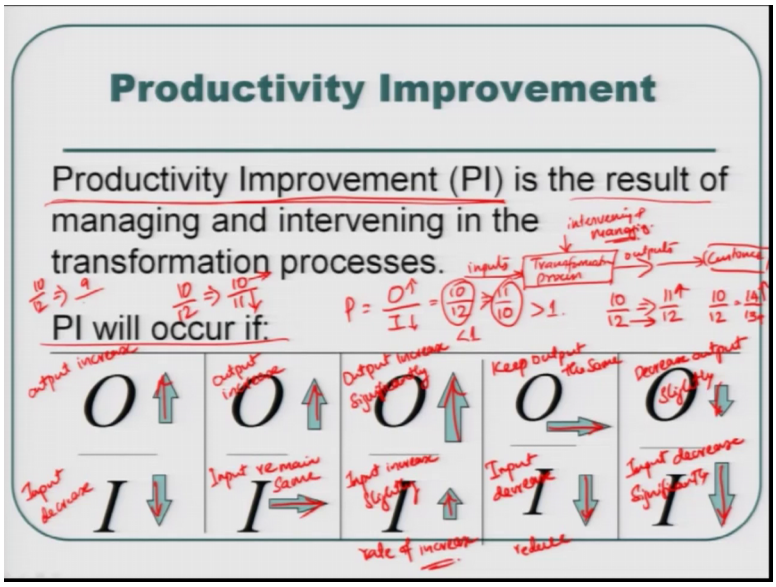

So, the first thing that we need to think about productivity increase is the, it is the result of the productivity improvement typically the PI, we abbreviate this as PI. It is the result of managing and intervening the transformation process. So, if you remember the diagram, here is a transformation process. You had inputs, you had outputs, this outputs were going to the customer.

So, this transformation process, when you are intervening, intervening means your interfering and managing. You are basically trying to manage the transformation process that is where you talk about productivity improvement happens. So, there multiple ways productivity improvement will occur. If this is the output increase, this is the increase sign. It goes up input decrease. So, then your productivity will go up, because P is equal

to O over I. So, if this increases and this decreases your productivity will improve. So, another example is if your output was 10 and your input was 12 and if you change this to output is 11 and input is 10, then you can see the productivity has increased in this case.

So, this is 10 over 12, this a fraction with this is less than 1 and 11 over 10. This is a fraction that is greater than 1. So, you can see that your productivity has improved. So, anyway just numerical example, other option is input, they remain same, you keep the input the same. Do not change the input, but output is increased. You increase the output, if this happens, then also the productivity will increase. So, another example of this would be, your initial was 10 over 12 and you can translate that 11 over 12 then; obviously, you can see there, the input remain the same, where as the output has increased.

So, then also the productivity will improve, other option is output increase significantly. So, is a large increase in output, input increase slightly. So, the rate of change here, the rate of increase, you increase output at a much faster rate compared to input. If that is the case then also your productivity will improve. So, an example of this will be, let us a productivity was 10 over 12, 10 was the output 12 was the input. Then you made it to 14 and the 12 became like say 13, then also your productivity. So, here also your input does improved, but the output has improved at a much faster rate.

So, here also you will get a larger productivity improvement, then another option is keep output the same or output remain the same no change in output. Input decrease or reduce, this strategies typically called as the reduce strategy. You reduce the input. So, here what happens is your productivity, let us say, if you assume that it was 10 over 12 and your output it will translate it, remains the same 10, but you reduce 12 to 11 or 12 to 10 or something like that, then your productivity will increase. So, here the output remain the same whereas, the input has decreased. So, that is the strategy.

Another option is decrease output or reduce output slightly. You reduce output slightly, input decrease significantly at a much faster rate the input reduces. So, here than example of would be, it will be 10 over 12 is the productivity you make it, transform to 9 and this 12 maybe get reduce to 8 or something like that. So, yes this is reduced, but this is reduced at a much faster rate. So, this is like you know the frugal strategy people, sometimes called it as the frugal strategy. So, there are multiple ways, you can deal with

the productivity and you can actually look at how to reduce the productivity in multiple fashions.

So, there are in sustainability, the one aspect that we look into is we sometimes look into. Most of the time people think about sustainability as this aspect, but this is also sustainability producing more for the same level of input and this is also sustainability in that regard and; obviously, yes if you can do this nothing like this, but this is very difficult.

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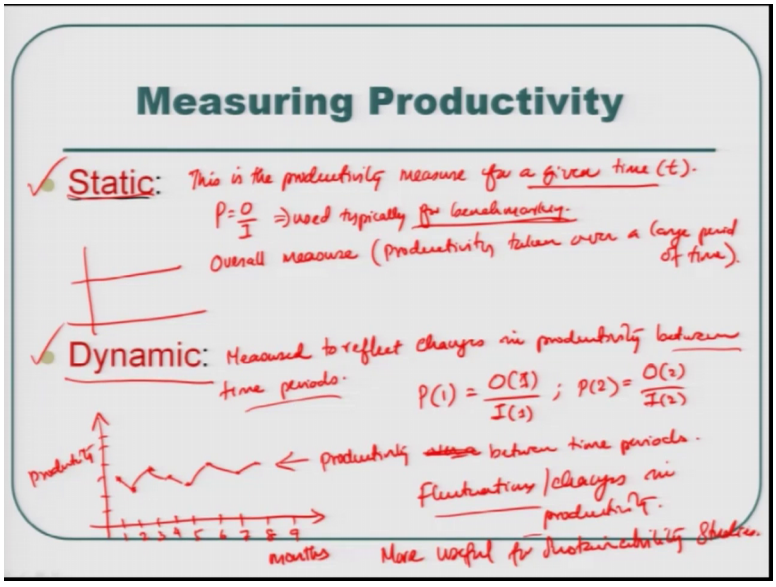

This is not very easy to achieve or obtain increased output by reducing input is not very easily. So, how do we measure productivity that is another aspect, we need to do there are two measures of productivity, one is called the static and the other is called as the dynamic, the static productivity. So, this is the productivity measure, measure for a given time T and. So, this is P equal to O over I.

But this time there is no is for a given time used typically for benchmarking. So, in a simple way, you can think about. This is kind of an overall measure productivity, taken over a large period of time that is, what is the static productivities all about. So, typically, we used for benchmarking processes, the other hand the dynamic productivity, it is measured to reflect changes in productivity between time periods So, if you think about a 12 month time period, you think about it this way. This month is 1 2 3 4 5 6 7 8 9, something like this and your productivity is on the Y axis.

So, here is months, here is productivity and you have for the month of one, the productivity is this 2 is this, 3 is this. So, you have P of 1 will be O of output of 1 over input of 1 P of 2 productivity of the second month will be output of 2 over input of 2 the second month. So, someway like this and. So, system where you have productivity measure, this way and you know, you sometimes programs and those kind of things out of this. So, this is sometimes called as a dynamic productivity. So, you are measuring their productivity, over a time period or it is not over it is between time periods.

So, you are more interested in the fluctuations or changes in productivity. In this case the starting one, the productivity is more like this, it having one average number, whereas, here your measuring it in a different way. I hope that you guess understand the concept of how do you measure productivity. So, we measure it static and as well as in dynamic fashion. So, static is for a given time period, it is for benchmarking dynamic, is between the time periods and it is used for measuring the fluctuations and changes in the productivity. So, this dynamic productivity is more useful for sustainability studies.

We will see how; because when we go to the optimization, then we will find that of right. So, also there is other way to measure productivity which is called as we call it as the partial factor productivity, multifactor productivity and total factor productivity.

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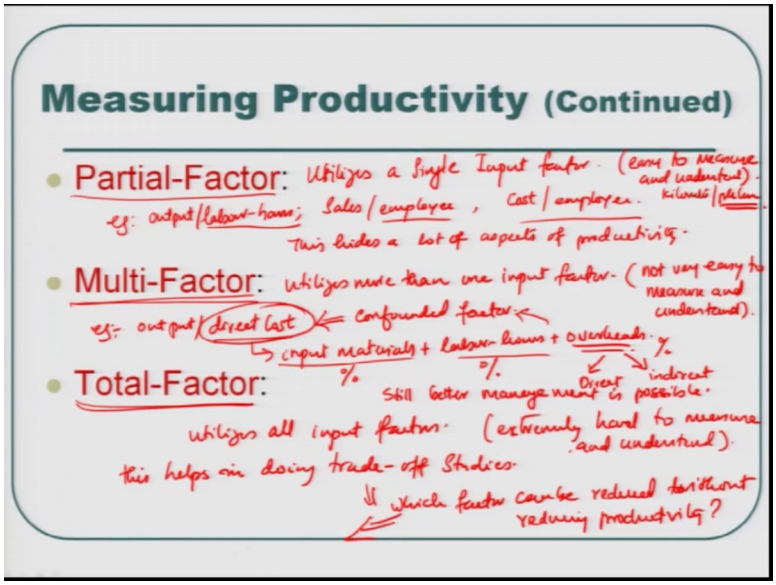

So, let us talk about, what is the partial factor productivity. So, the partial factor is it users or utilizes single input factor. So, here what you are measuring here is some

examples of this is output per labour hours, or we can say, said sales per employee, or you can think about it as cost per employees something like this.

You can measure multiple ways, but here you are using a single input factor, labour hours is one input factor employees, one input factor or you know the you can think about (Refer Time: 22:31) or kilo meters per hour. So, that is one another input factor. So, you have doing a single measure input factor. Here, this is very easy, the advantage of partial factor is they are easy to measure and understand the disadvantage of this is, this heights a lot of aspects of productivity. Now, when we talk about the multi factor productivity, here what happens is we utilizes more than one input factor, why do we utilize more than 1 input factor, because you know these are not very easy to measure and understand.

So, some of the examples of these would be like output per direct cost. So, the direct cost includes what? So, what is now the question is, what is direct cost, you are like what are the things that are part of direct cost? So, then you will have input materials plus labour hours plus you can think about us overheads, then you will say what overheads. So, you will have is it the direct over head or the indirect overhead what is involved in this. So, the problem with the multi factor productivity is that you need to really know what are the underlying factors that is used in this. You know input factor that is which is more than 1.

So, this is usually what we call a confounded factor. So, in this we have to find out what percentage of it is input material, what percentage of it is labour hours, what percentage of it is overheads or what is contribution of these factors, put together to this confounded factor. So, that is why it is sometimes not very conducive for to do that, but still better management is possible, if you have a multifactor productivity, that is note then that last is the total factor productivity, where it utilizes or input factors. So, here this is extremely hard to measure and understand the quantification is quite tough in this case, but this helps in doing trade of studies, trade of studies is important, because this is where you can study, which factor can be reduced to without reducing productivity. This is one question that we always ask, if we can answer this then you are on the raw to sustainability.

So, from the manufacturing stand point, we are more interested in the sustainability aspect. We are looking more towards the total factor productivity, if not, if this is not possible; obviously, then we might look into a multifactor productivity, but definitely not partial factor or definitely not a single factor productivity. So, these are the two aspects that we look into the class to optimize multiple factors, in order to reach sustainability that is what the aim in the few following lectures, to demonstrate to you how that is being done. So, then can we talk about the measurement problem, which is a very interesting problem in this regard, because there is you know, when you have multiple products and services. So, we have like think about it for example, if we take Maruti, Suzuki has an example.

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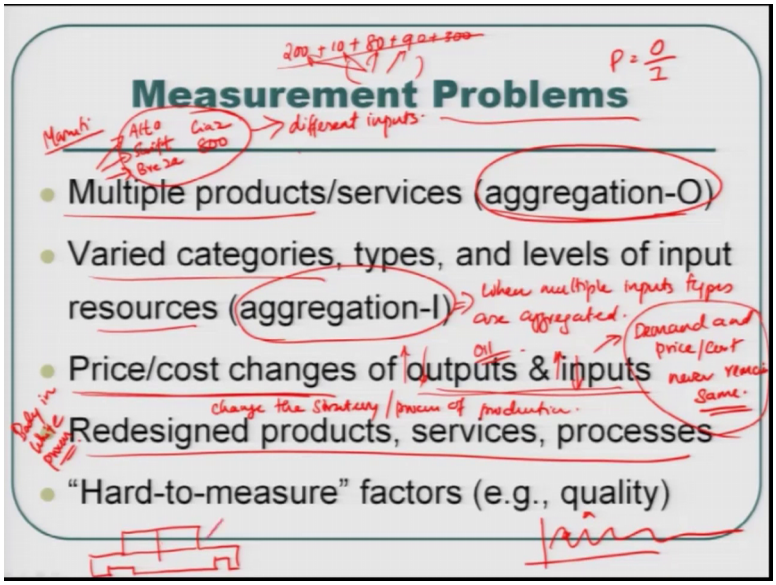

They make many cars, they make, they no longer might Maruti 800, but they have Alto, they have Swift, they have Breza, they have I think Ciaz, quite a lot of models. Let us put one more model, what is a another model of Maruti? Let us put Maruti 800 also just for the time being, assuming that way. So, these products multi, when you have multiple products, then they will have different requirements or different inputs. So, when you multiple production, we want to do the productive measure, because remember productivity is output over input, when you have these once then measuring the productivity that because of the aggregation of the output, it becomes a problem, because you would say that I produced 200 Maruti, 810 Alto, 80 Swift, 90 Breza and 300 Ciaz and then the input, these are the outputs divided by some big value of input.

But then what percentage of their input has gone to this, what is gone to this that classification clarification is not there. So, hence the importance with the case is that, when you have multiple products and you aggregate all this multiple products, then decrease a measurement problems, that is what we call us the aggregation of the output problem, then the second problem that we typically face is the varied categories types and levels of input problem, which were the aggregation of input. So, when multiple inputs, input types are aggregated, when that happens, that also creates a problem which we typically call as the aggregation of the input problem, the aggregated I problem.

Then the changes in price and cost, the main assumption in almost, all the study is that the demand and price slash cost. They never remain same, they are always fluctuating. So, if you draw it in a graph, it will be all over the place like this. So, you will be like what so, but you are, you some value to basically, pick it up and study. So, you will pick up, some value here and then use it to do the study and when you done with the study, you come back and you find the value is not here is now here.

So, your entire optimization has gone for a different thing. So, this fluctuations in the prices and the cost changes of both outputs. It can increase, it can decrease, those kind of things, it can also increase or decrease does not matters, but if there cost of the price or cost of the outputs increases. Now, the input decreases then you are; obviously, in good like if you look at the price of the oil in this country, this is an example of that. So, the price changes also creates an issue to your measurement problem, then we come across something called as the redesign production services. So, when you have the when you change the strategy of production or process of production.

Then you will get into much different input and output. An example of this is the body invite process. So, if you understand automotive manufacturing, one of the things is the shell of the automotive, one reduce to be made and then the primary used to be painted on to this spray painted on to that. Now, what they have is. So, you have the shell of the car, think about it, this way no tires nothing, no door is just the shell of the car, you take this car and the new spray paint. So, you had a sprayer here and then you spray paint everything and that is how the primer was. Now, what happens is you have a big bath tub in which the primaries kind of floating and the car gage dipped in this. So, this process this is called the body in white.

So, by then process got changed, then what happens is the entire energy and everything used for keep on spray painting and everything got changed, because you just dipping it in a paint bath and taking it out and this allowed for better coating and etcetera. So, when you read this and the product or process. So, then you are sustainability has now taken a different time, a stuff then comes this last one which we called as the hard to measure factors like quality sometimes. You are saying that, they say quality, they you say that this restaurants this. So, are, sorry we will say that particular food is of good quality that might be of good quality to the person who said if the food is of a good quality, it need not be of good quality to somebody else.

So, because quality, the issue with quality is that, it is subjective, it is individual dependent or customer dependent. So, it is quite hard to measure in that regard. So, when you have hard to measure factors, also part of this, because you still how to build a quality product, that is the meaning build a right product, for the customer. This is right product, is what we call as the quality product, but how do you measure; this is tough to measure. So, these are the measurement problems that are associated with the productivity side. So, now, let us see, what are the levels at which productivity is can be applied to. So, productivity can be applied to different levels.

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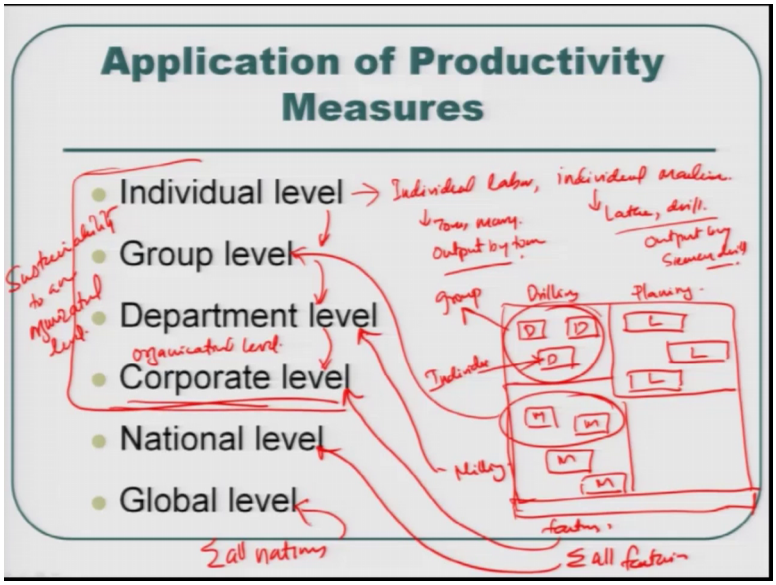

It can be applied to at a individual level, it can be applied at a individual level means we can talk about as a individual labour, individual machine.

So, here we are talking more about Tom or Marry or something like this. Here, we are talking about, the lathe or the drill or something like that. So, we are looking at the individual level, you can measure the productivity, how many parts are Tom produced. So, we can say output by Tom. So, that is the productivity at individual level or output by you know Siemens drill. So, this is an individual level productivity. So, if you think about a factory as such, if you are seeing, this is a factory and you have, you assumed that these are like drilling machines and this is the drilling department and then you have a lathe machines. This is, let us call it us the planning department or machining department, whatever you want, a call it and then, there is some mills milling machines.

And so you can think about the productivity of this. This is the individual, this is the group, this is the group level, because you can think about this group or not completely. Let us say there is let us think about this as the group, this is better way to demonstrate a group. So, this is the group level productivity, same way we want to do the productivity of the milling department, then this is the department level and if you want to think about this entire factory. Let us call this as the factory, then this is the corporate or the organization level, this is also called as the organizational level and you measure for all such factories. Some of all factories, if you do that then there comes at the national level and you do some of all nations, then that comes at the global level. So, that is how you measure productivity in hierarchical level, in our study we are basically, only looking at to up to this level, which is the corporate level.

We try to see sustainability to an organizational level. So, we start from the individual level, we move to group from group to department to corporate and we kind of stop there as part of this course, we do not take it any further, the reason is, because if all the corporates become sustainable then; obviously, you are then this a summation of the sustainability across the national and the global level.

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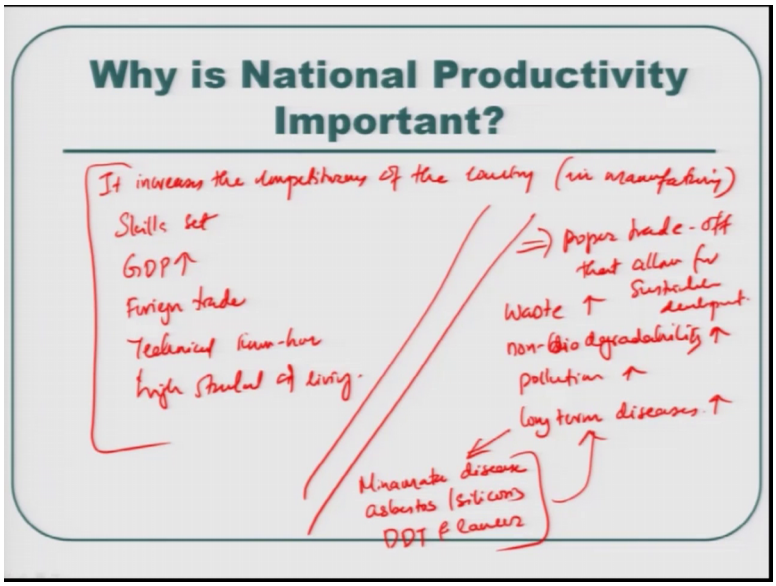

So, this is where we called as a cut off point for us in this course. So, the obvious question is why is national productivity improvement important for us, that is the important question, for us and why is the national productivity is important. So, everybody ask this question and the problem with the national level product productivity, why is it important these.

It first, it increases the competitiveness of the country in manufacturing. Let us just think about it, that way one is it is competitiveness in the country, then skills sets GDP, thing research those kind of things, then also foreign trade technical know how high standard of living, then those kind of things. So, it has lot of advantages in that way, but at the same time, this we have waste increases, then non biodegradability, bio degradability, that increases pollution, that also increases, then long term diseases are that increases, I will request you guys to read something called as minamata disease. It is a phenomenon that happened in Japan then I will ask you to study about, ask the stores and silicosis then D D T and cancer, this kind of stuff.

So, these are aspects, there came out of you know long term disadvantages of doing the national productivity. So, what in this course, we are trying to do is yes, there are benefits and demerits to this, but let us find a proper trade off that allows for sustainable development. So, we are not really harming the, you know the national ecology and other kind of things by do trying to shoot for productivity all right. So, when we think about

this, when you are competing in the national level on productivity, it needs a, it definitely needs a high standard of living. It holds the inflation and check; that means the price of the items increase.

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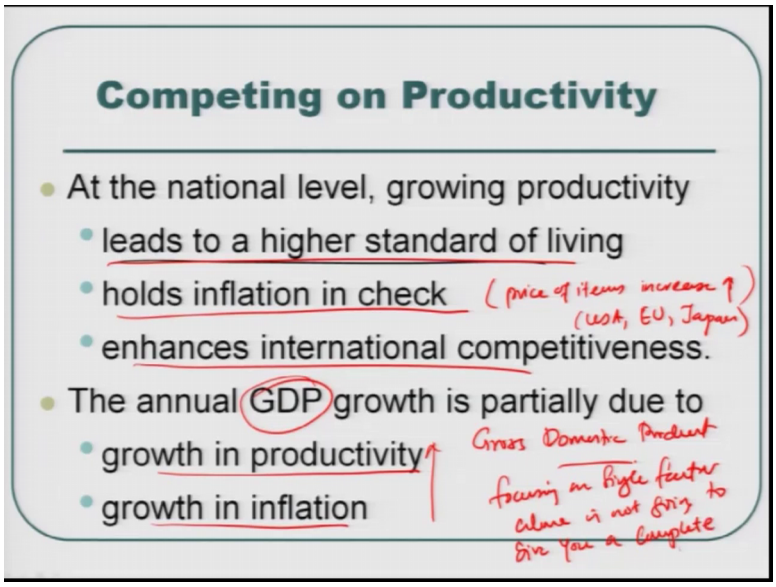

So, this is it does not goes up through the roof. It enhances the international competitiveness of the country, becomes you know like an example of this is USA, European Union, Japan and or how they became quite competitive in the international and the GDP growth is quite a lot. I can give to the growth in productivity and growth in inflation. So, the GDP, which is the gross domestic product, it is if the GDP growth can be, it is partially to the productivity and the growth in inflation impacts this, but what happens is just focusing on GDP, focusing on single factor, single factor alone is not going to give you a complete picture. We have already seen that. So, it is important for us to understand that you know, we how to think about other of aspects of just focusing, rather than just focusing on GDP and what are the typical measures that impacts the measurement of productivity.

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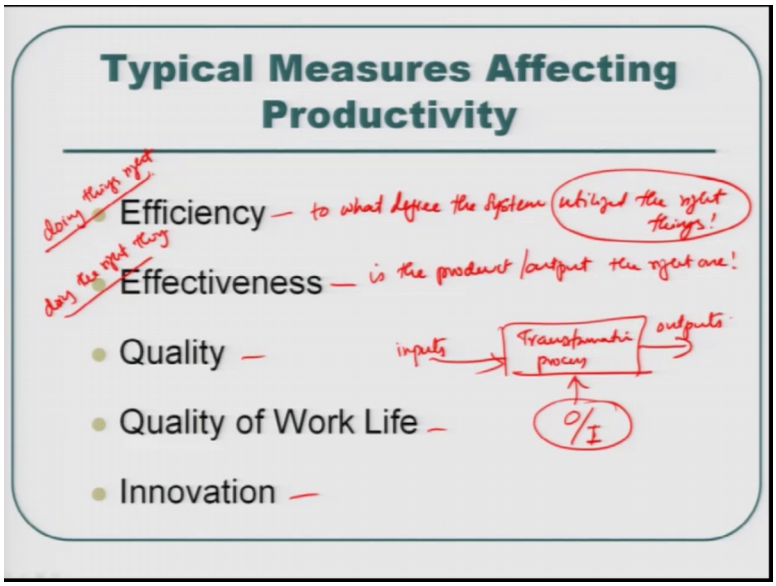

There are few factors that impacts the measurement of productivity; number one is the efficiency, other one is called as the effectiveness quality. Quality of work life and innovation. So, efficiency is typically, you know to extent, we are trying to measure to what degree the system utilized, the right things for the sustainability course rather than the conventional definition of the sustain in a efficiency. We will actually see to what extend the system utilize the right things. The transformation process remember, our system is like this the inputs, then you have a transformation process then you have outputs. So, here you are measuring at this point. We set output or inputs will give you the productivity, but we are trying to check here to what extent of the output we utilize, the right things that is what we will be trying to measure the you know efficiency.

Whereas the case of the effectiveness, what we are trying to say is the product or output, the right one are we making the right product. So, efficiency to a large extent is doing things right for us and this is doing the right thing. So, this is slight difference to this, but that is the way we look into the definitions of efficiency and effectiveness in this class then qualities. So, let us go through this terms one by one. So, efficiency is the measures, the resources expected to be consumed to the resource, actually consumed or as I mentioned earlier, it is to what degree did the system utilizes the right things.

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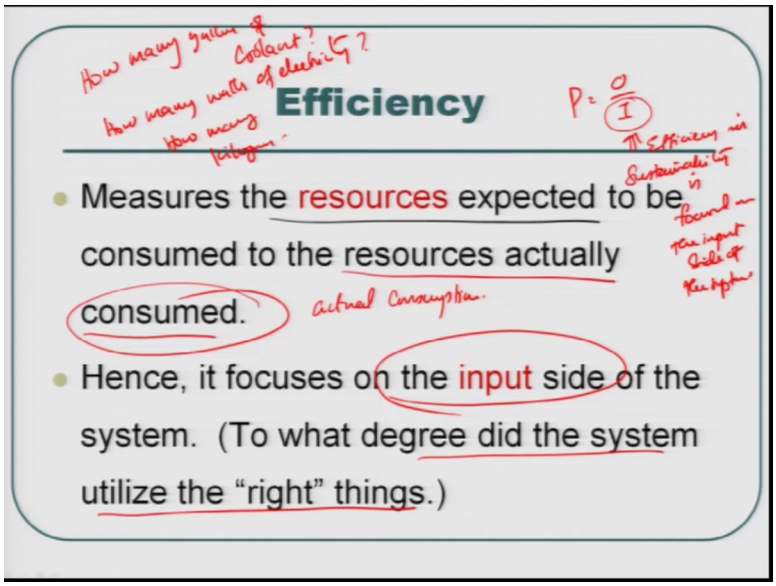

So, that it focuses on the input side of the system. So, for us when we say productivity is equal to output or input, we measure the efficiency when we talk about efficiency in this course, we are focusing on the input side of the system. So, efficiency in sustainability is focused on the input side of the system, remember this. So, what are the resources actually consumed, what was the actual consumption, this actual consumption it includes, how many gallons of coolant when we are measuring how many watts of electricity, so that kind of thing, how many kilograms of iron. So, these are the aspects that we look at the input side, so this measure. So, to a large extent you will see in this course, that we look a, do a lot of efficient efficiency measures, measures to obtain sustainability.

And similarly, the second aspect of this which, what we call as the effectiveness, you know that is the second aspect, which again my in color changed I apologize for this. So, the effectiveness of the system, it measures what the systems such out to accomplish and what it was actually accomplished. So, what you did you actually reach, what you plan to do?

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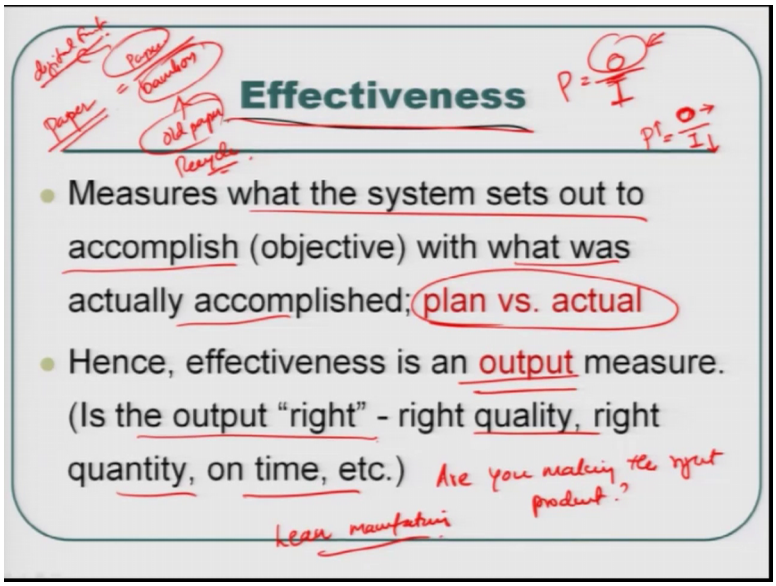

So, the effectiveness is a measure of the output. So, when you have productivity, is equal to output or input, the focus on the output is what we call as an effectiveness, is the output right, as I said earlier is it the right quality, right quantity on time etcetera. So, you are you making the right product this is an important aspect, because to a large extent the lean production, lean manufacturing everything kind of focuses on this aspect as well making the product right and making the right product. So, here the, you just cannot, just focus on the input as well; obviously, if we focus on the input remember, you can drive productivity by maintaining the output, the same and reducing the input, you are mentioned this earlier. So, one option is this you can focus on reducing the input, but also by focusing on the output, you might end up making a better product like for example, paper let us talk about paper as an example.

Earlier paper is a major input was the bamboos and those kind of trees and the, you use to get out, output as the normal paper. So, now, instead of this we started adding old paper also into this, what we called as a concept of recycle. So, then the input we ended up changing here, but the output, still remain the paper. Now, one other way of thinking about is do we really need the paper? Can we convert this into a digital format, this is where you are talking about being effective in a different fashion all together. Usually effectiveness well result in something that is unique or something that is different compared to what is already being, it done. So, we will take a break at this point and we will come back and continue with the rest of the concepts later down with the road.

Thank you.