Design and Optimization of Energy Systems

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Lecture No. # 01

Introduction to Optimization

Good morning, so we will formally introduce the course through this lecture. So, as you know, the title is Design and Optimization of Energy Systems. Now, I will just give a broad overview of what design and optimization are all about and then, in the next class, we will formally start with design workable system, system simulation and so on.

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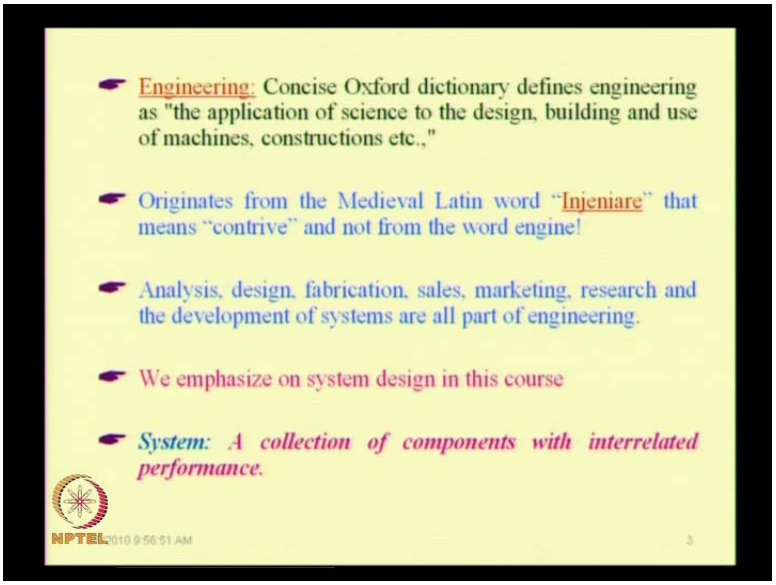

If you look at the concise oxford dictionary, which is called COD, the concise oxford dictionary is a very important reference material, in the sense, that if there is any dispute in the court of law, if there is any dispute in the court of law, lawyers and the judges will always refer to the concise oxford dictionary for final say on the matter.

So, if you look at the concise oxford dictionary, for the definition of engineering, it says, the application of science to design, building and use of machines, constructions etcetera. So, very jocularly you can say that it is an application of science to make us more and

more lazy. You did not want to go to the theatre, we want to see movies at home, so television and then, we did not even want to get up from our seats, so we invented the…

TV is already there… remote and so on. So, we wanted to have the comfort of standard temperature and humidity throughout the year, so we figured out and we invented the… Now, you do not even want to change the temperature, so we invented the remote for the air conditioner and so on.

So, we can say, that engineering sometimes, we can say, it exploits human weakness, I mean, the clamour for more and more comfort. But the positive connotation is, whatever you figure, the new things we figure out in science, you applied the design, building and use of machines, constructions and so on.

Engineering originates from Medieval Latin word 'injeniare'. Unfortunately, it does not originate from the word engine, though as mechanical engineers we would have very much loved to declare, that engineering came from engine, it does not come from engine. It comes from injeniare, which means, contrive or come up with something and it is not from the word engine. If you look at the various activities, which are concerned, which are all part of engineering, some of them are: analysis, design, fabrication, sales, marketing, R and D and so on. So, all these are essentially considered as part of engineering, but we emphasize on system design in this course. So, we are going to emphasize on system design.

As I already told in the last class, so system is a collection of components. So, there should be at least two components, which constitute a system. Just like a cycle, thermodynamic cycle should consist of at least two processers, right. So, you go from one to two and comeback from two to one. So, system by definition is a collection of components with interrelated performance.

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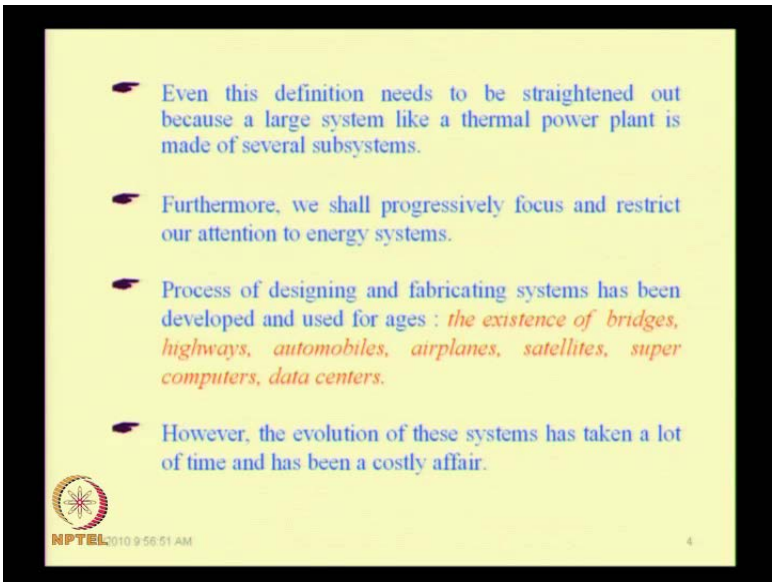

But even this definition needs to be flushed out or it needs to be straightened out because large system, like a thermal power plant, is made up of several subsystems. So, you can, you can immediately recognize, that the modeling, simulation and optimization of a very large system, like a thermal, thermal power plant will be exceedingly complex. Suppose I want to do an optimization of a power plant, are there some ways of doing it? I hope you got the question.

So, I am saying, that a thermal power plant is exceeding the complex. The thermal power plant is itself made up of several subsystems. So, if I enlist all the variables, which are involved in the thermal power plant, and find out the mathematical relations connecting all this, I will die. We want to optimize the power plant, what are the options?

Student: Take the variables for each subsystem.

Take the variables for each subsystem and do what?

And optimize the subsystem under the belief, that…

Student: (( ))

Under the belief, that if you optimize the individual subsystems, the overall system will, it will lead to overall optimum, but that again is questionable. But just because it is questionable, we cannot be an armchair critic and say, that this is not the right way to

optimize and not optimize at all, at least dividing into subsystem. And if one group is not capable of optimizing each of the subsystem, if it is alternator generating, you give to the electrical systems group. If it is a boiler and heat exchanger, give it to the heat transfer group. Then, if it is concerning the ash handling, coal handling, give it to mechanical handling machine design people. So, each of these people, each of these people will come out with modeling, simulation, whatever, optimization, each of these subsystem and integrate all these, we hope to get a, hope to get an overall optimum for the thermal power plant.

So, optimization of thermal plant is not what we are going to do in this course because that will, that will take six month, that will be like a BTP or MTP or whatever, so but you must realize, there it is possible to break down into subsystems and each of this subsystems, you can have a finite number of variables, so that the problem is, tract, tractable or as we say, the problem is handleable, it can be handled, right. Furthermore, we shall progressively focus and restrict our attention to energy systems or thermal systems because the course, the course is called as design on optimization of energy system.

Now, if you look at designing and fabricating, designing and fabricating systems has been developed for ages, right. So, there is ample proof, when you go around, there is ample proof, that people have been designing and fabricating. The existence of bridges, highways, automobiles, airplanes, satellites, super computers, data centers, what have you, all these, all these things when we look around, I mean, there is ample proof, that people have been designing and fabricating systems for ages. So, what it is the big deal? Why are we talking about it?

But if you see, the evolution of these systems has taken a lot of time. For example, the steam engine is only 200 years old, the steam engine is only 200 years old, but civilization has been there for how long? Come take a guess, some millions of years. Now sometimes, if you, sometimes you look back and retrospect, you feel very ashamed, it has taken such a long time. It has taken such a long time to come up with a steam turbine; it has taken such a long time to come out to the jet-plane and all that. But in prospect, we are happy, that at least they are there now. So, it is, it is always like that.

Even when you start learning something, the progress will always be non-linear. Are you getting the point? If you are solving a very complicated problem for your research or a project or whatever, the first part is we will have to learn. For example, you are modeling something (( )). Now, if you report this, I am your advisor, at the end of ten days, I ask you what is the progress, what is the progress, what is the progress? So, if you draw the, if you draw curve of progress versus time, it will be 0 for long time. Assuming, that you are working and you are still learning, then suddenly there will be a, suddenly there will be a non-linear part, that is where you conquered all these things.

You have figured out how to give boundary conditions, you have figured out how to give the properties, you have figured out how to do the solid model or gambit, and then, and then, you will start getting wrong answers. That is good, getting wrong answers better than not getting answers at all. Then you will put fight, you will cry, you will talk to your friend, you will talk to your guide, sometimes guide is not available, but when he is available, and then you sit down and talk and then you figure out, change this, change that and finally, finally you get your results and go to Raja Xerox, take a printout, bind it and then show yourselves, appear before committee, and then land up on July 31, where you go in and get out. I mean that is the way, that is a way science and technology progresses in IIT.

So, to get a long story short, the long and short of it is, it takes a long time for systems to evolve, but you are happy, that at least we have these systems. And now, by looking at all this we should be, we should, the lead time taken for improvements because there is a accumulated knowledge of so many generations. Now, we should not take that longer time to come out, come out with the new development, of course. So, we should try to take on problems, which are more and more challenging.

Do not to be too happy or do not be too upset. Either that, that course is going like this, from the next class onwards, we start solving problem, right. So, there is no other way of teaching this. So, I thought instead of writing all this on the board, I will come up with a PPT. I am going to open an electronic access to this course. I had told you (( )).iitm.ac.in. I had promised that I will do it in two days, I have not done it, but after the class, I will immediately do it. I will host this immediately on this. Tomorrow you can see these. You do not have to copy this, right.

But now, if you see, most of the systems are not working at optimum conditions. We, we, we do not know, whether the pump in your homes, whether you live in apartments or bungalow whatever, did you ever try to figure out optimum? Is it the best pump? Why are you not able to optimize that? Some reasons should be there, no? Say, the electric motor and pump arrangement in your apartment or in your bungalow, why is it not, why have you not thought about it? Yeah, please go ahead.

Student: You know only specific…

You will also come on NPTEL.

Student: Only specific motors are available.

See, you are free to, you are free to write any partial differential equation or ordinary equation, whatever you want to solve, and then you say, the optimum design is 1.3464 kilowatt or something. You go to Velachery, I want a pump 1.34. He will say, get lost, because they are making only in standard sizes. So, you round it after the nearest, to the nearest size, point number 1, and always, we are always not confident. We are all, we are never confident with our design, right, generally. So, therefore, we will choose, we will go for the next higher, we will go for the next higher one.

When it comes to why we are not… One example to prove, that we are not confident is, this physics lab and chemistry lab in your schools, right. You submit records, you used to submit records to the teacher, you used to submit in the beginning or the end, that in biology lab and all that the teacher sits, the records are stacked up. So, where will you summit your record?

Student: (( ))

Who is the hero, who will do that? You will always like to do this, right, and if possible…

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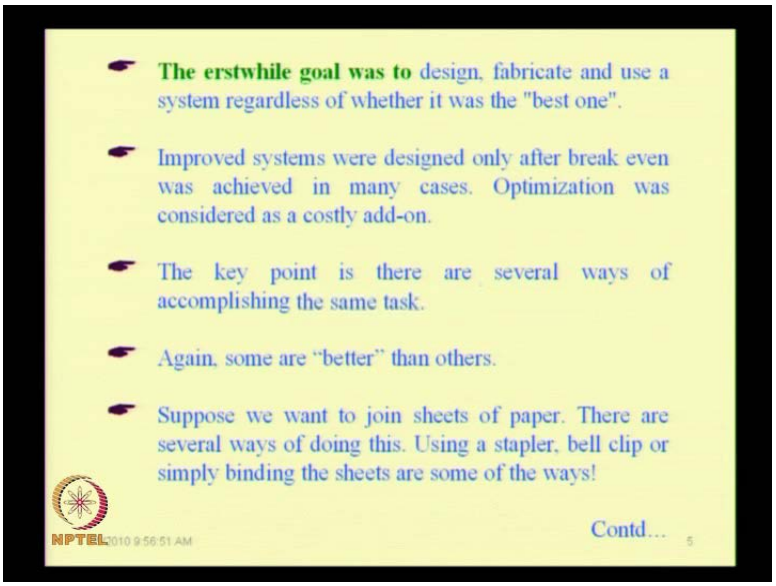

So, the erstwhile goal, erstwhile goal was basically, let it work man, it should not break, it should work. Optimum, optimization is not for us, that was an original goal. But now, because of competitions and there are, there are several competing designs, there are several competing models, which will do these same job and so on.

So, the original British idea of something, something, which is what we call as over-engineered, something it is, everything is a big size, very, very, we call it as a conservative design, which is no longer ok because the costs have gone up and we want to cut down cost, we want to rationalize the cost, so that we get an optimum performance. So, the erstwhile goal was to design, fabricate and use a system regardless of whether it was the best one.

Improved systems were designed only after break even was achieved in many cases. Break-even is, that is, whatever initial investments you had put in, you are able to recover that. Optimization was considered as a costly add-on. Many people did not want to invest the time and effort required for optimizing a system.

Now from what I have discussed thus far, it is clear, that the key point is, there are several ways of accomplishing the same task that is one of the important things. It is the, you have a choice; you have a choice of various designs. It is different from your solution to an integral or find out an integral, where you, where you think that everybody

should get the same answer, but design is not like that. So, I mean, instructed… What was I saying?

Student: (( ))

No, no, I am still not able to get back.

Student: Many ways of accomplishing the…

There are many ways, there are many ways of accomplishing the same task, and you will have to pick and choose, which is the best one for us. Again, some are better than others. I put 'better' in quotes because what is better or not has to be decided by you. You have to tell, just like I told you in the last class, whether it is the specific fuel consumption, or break, or break thermal efficiency for an engine, or cost, or cost of ventilation system, whatever. So, you have to decide on what the objective function is, and accordingly you have to go ahead and optimize that.

So, suppose we want to join sheets of paper. There are several ways of doing this. You can use a stapler, you can use bell clip or simply binding the sheets are some of the ways. So, there are even silly things, like I, you want to join the sheets of paper, there are several ways of accomplishing the same task.

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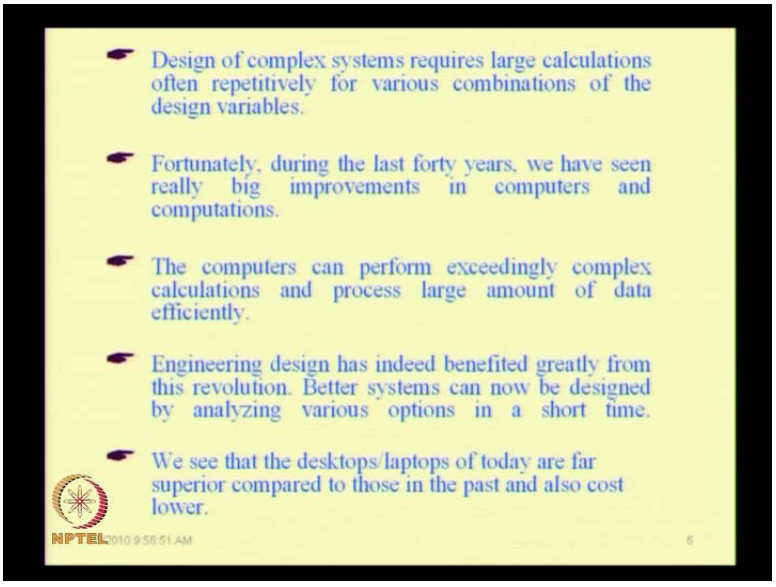

So, first of all, there is, there is a choice available to you. Secondly, the design of complex systems requires large calculations, often repetitively for various combinations of the design variables.

Suppose we want, suppose you, let us take this desktop, we want to arrange all the components of the desktop, so that we get optimal cooling, but it is not like… There you have choice, but it is not like you have infinite choice because there are certain positions, certain positions will be fixed, right. You do not have much leeway, but there are certain things where you still have some, you still have some freedom to play around with the variables. Then, you have a choice where you want to put this (( )) and so on, where you want to put the fans. There are two fans in a desktop, you are all aware of that? There is one fan and heat sink. Heat sink will just sit right at the top of the processor. The other fan is very close to this. Now the second fan, that is, the dedicated, the fan, which is dedicated to the processor, will turn on only after it reaches certain degrees. You can see; you can hear that.

When you initially start working, it will not turn on. After it is, when you are running several programs, when you have, so many windows are active and the outside is also hot, after sometime it will turn on. Now, if you can consider this problem, you can consider, it has a CFD problem. You can model the whole thing in gambit, go to Fluent, and find out the temperature for a particular arrangement of component. Now, if there are ten components, there are millions ways of arranging this. Each time you have to go to, you have to have a solid model, you have to measure it, get the convert solution and look at the temperature, maximum temperature in this system. How many times we will have to do this? Is it possible to, is it possible to optimize like that? So, so, it is not a very complex system, it is only desktop. We are not talking about optimizing a data center or a big cluster of so many computers.

So, design of complex systems requires large calculations for various, repetitively for various combinations, for various combinations of the design variables. But fortunately, during the last 40 years, we are seeing really big improvements in computers and computations. So, in order to give a sneak peak into what I am saying, I can, I can arbitrarily choose a set of combinations of these variables, instead of doing it a million times I will do it only hundred times. I can parallelize it for hundred various combinations of the variables. I will fire job, multiple jobs.

Suppose, I get the results at the end of two months or three months. Now, I will use what is called on artificial neural network, which will give a correlation between the positions of the various, positions of the various components and the maximum temperature. And now, out of the 100 cases, I will use 80 or 90 cases to come up with the neural network, and the remaining 10 cases, I will use, I will use the 10 cases to test, whether my neural network model gives me the right temperature for the chosen set of variable.

Now, if that model is working fine, now I will ditch the fluent model, and then I will repetitively run the neural network model for various positions. Then, I will draw graph and find out where it is maximum and I will, I will finish the job. All these things were not possible 40 years back. First, Fluent was not there, you have to write program for doing this CFD. I wrote one CFD program and got PhD 16 years back. Now, you cannot do that because now it is all standardized, right.

So, now, powerful computers are available, CFD packages are available, neural network is there, and then several optimization tools are available. So, it is possible to do today. Therefore, if you just solve a CFD or a heat transfer problem today, it is no good. If you solve a three-dimensional CFD problem or heat transfer problem 20 years back, you are considered as done. So, that is a state of affairs.

The computers of today can perform exceedingly complex calculations and can process large amounts of data very efficiently. Engineering design has indeed benefited greatly from this revolution. Better systems can now be designed by analyzing various options in a short time. I just gave you a quick example of this how better system can be designed. This is one possible approach, but sometimes a neural network will fail, it will not work. You have to use other option, some other options and so on. But it is possible for you, it is possible for you to attempt and attempt earnestly.

Now, we see, that you can see, the desktops and laptops of today are far superior compared to those in the past and they also cost lower. So, I just read a news item that the sale of desktop in India is dramatically, exponentially falling. Sale of lap, sale of laptops is exponentially increasing because you carry your work, you carry your data, you carry your trash, whatever, you carry, you carry that with you everywhere. So, that possibility is there in a laptop, that possibility does not exist in a desktop. Now, you have

a I5, right? You have I5, I6; my students are running the fluent program on the laptop. It is running pretty fast.

Now, we look at design analysis through flowchart. See, all this, whatever I am teaching is considered as necessary evil, in the sense, that when you go through a course on design and optimization, you have to know all this. But it is not possible for me to ask any questions on what all I am teaching today, but we will have to go through this rigmarole.

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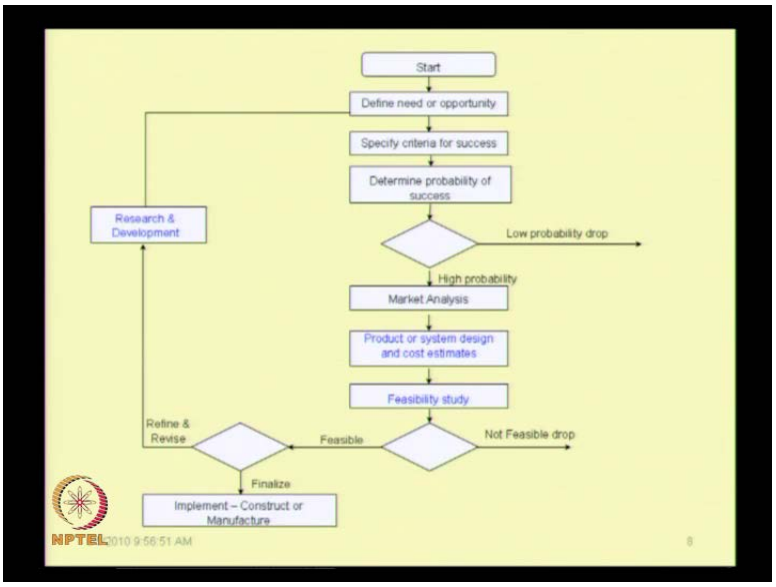

Let us, so, start. You start from somewhere? No, no, you start only from this place. Now, first you have to define a need or an opportunity; you have to define a need or an opportunity. I will explain, explain this to you in a while. Now, you have to specify the, I will explain each of these little later, but now, I want to go through this very quickly.

So, define need or opportunity, specify criteria for success, determine the probability of success. If it is a high probability, you go ahead with other things, otherwise you drop. High probability, you first do what is called a market analysis to find out whether what you are designing and developing will eventually have a market or not. Then, you go through product, PD, product design. PD guys are here? So, product or system design and then, work out the cost estimates. Then, you go through feasibility study. If even at this stage it is not feasible, feasibility study is techno-economic feasibility study. It should be technically feasible and economically viable also. If it is not feasible, you drop

it. If it is feasible, because 20, 30 years back, desalination used to be technically feasible, but economically (( )) unviable for a developing country like ours. But now, we have put up a big plant in Chennai, you know, last week it was inaugurated. Now, India is also becoming rich. We are able to use the technology. Saudi Arabia has been having it for last 30, 40 years, big desalination plants.

Now, if it is feasible, then you can go ahead, you can go ahead and either finalize or if you want to fine tune your design, you go refine and revise. It goes through R and D and this loop gets completed, right.

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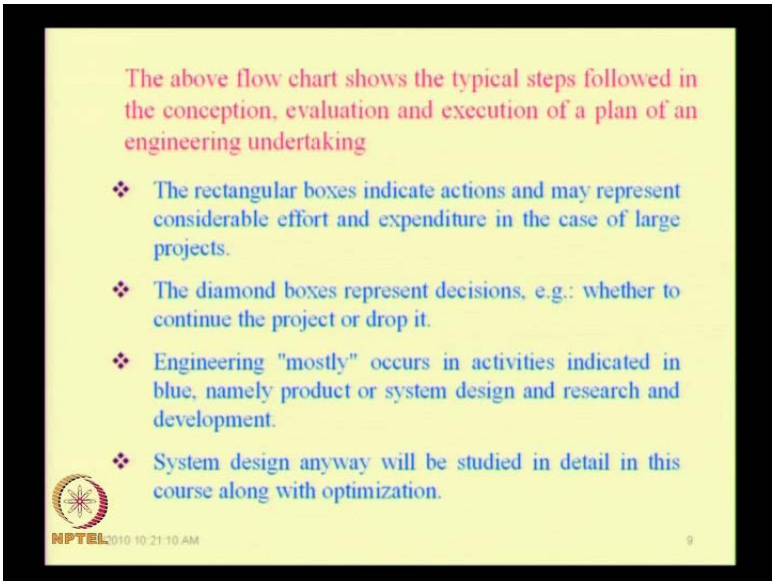

Now, this flow chart typically shows the typical steps followed in the conception, evaluation and execution of a plan of an engineering undertaking. The rectangular boxes indicate actions, and each of these may represent considerable effort, time and expenditure in the case of large projects.

So, the diamond boxes represent decisions, whether to continue. For example, after listening to this lecture, you may want to, whether you want to drop this course or retain this. You still have time till 15th. When it is the last date for dropping?

Student: Monday.

So, that is the decision. Diamond boxes are decision, whether you want, whether you go or no go, or yes or no.

Engineering mostly consists of activities indicated in blue. I think there is a problem in the color. Engineering design means, product or system design, R and D, right. So, most of this, for example, this market analysis and market analysis and other things; all these things are usually not considered part of engineering. So, research and development, here, there should be something else, right. Some problem, I have to go here. So, all these are considered as engineering. These things are not considered, generally, as part of engineering.

System design, anyway, will be studied in detail, along, in this course along with optimization. Therefore, for the next 20 minutes, I will focus on the other things, which are not considered part of engineering because you are not going to consider this again in this course.

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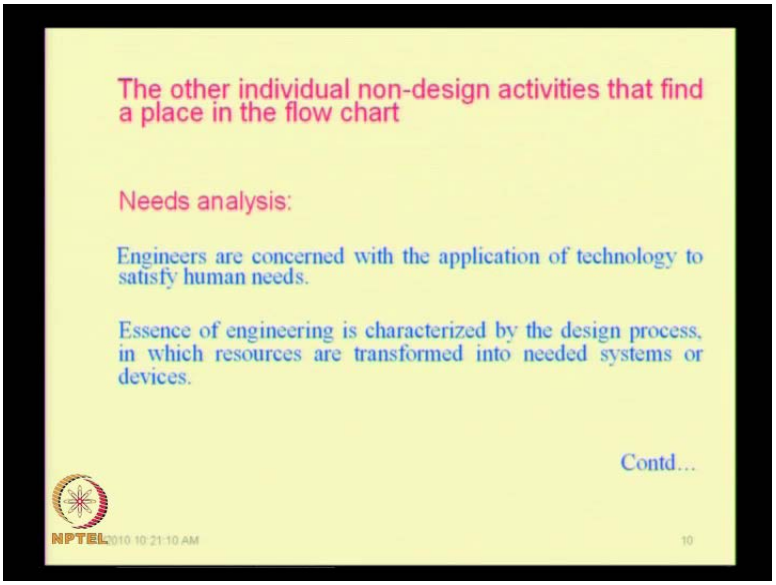

The other individual non-design activities, that find a place in the flow chart, are basically needs analysis. First, you have to do need analysis. Engineers are concerned with the application of technology to satisfy human needs that I have already told you. So, the essence of engineering is characterized by the design process, where resources are transformed into needed systems. Stating the need is not always so straight forward.

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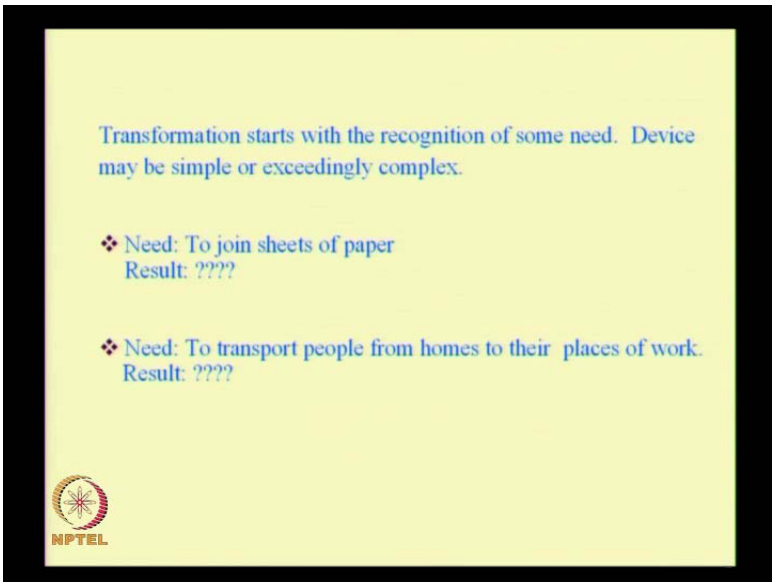

For example, transformation starts with the recognition of some need. First, you have to identify a need. So, this, the device or whatever you have in mind may be simple or exceedingly complex. For example, you want to join sheets of paper. You can come out with the various options, already told you this example. You can have stapler, you can have a punch, you can punch a hole and then put a tag, you can bind, there are various things.

Now, for example, to let us take something exceedingly complex, to transport people from their homes to the places of work, what be, what could be the solution?

Student: (( ))

No, I am not talking about private cars or scooters, whatever. That anyway is… Suppose a government wants a solution, what…

Student: Buses, trains

Metro bus, sky rail, whatever, metro bus, sky rail, so there can be various other, various options, metro bus, metro rail, MRTS, mass rapid transits systems and so on.

So, this is first you have to state the need.

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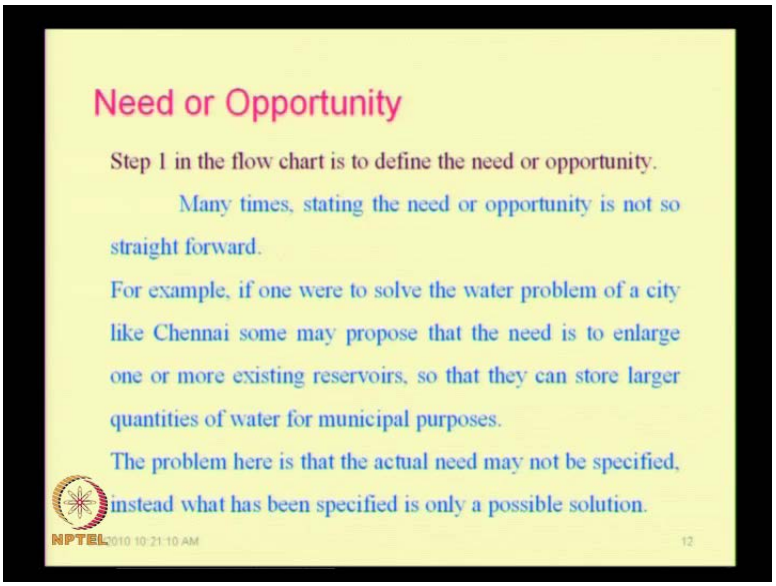

Many times stating the need is not so straight forward. For example, if you want to solve the water problem of city like Chennai, some may propose, that there is a need to enlarge one or more existing reservoirs. You desilt them and make them more deep and let them store more water. So, whenever there is a rain in the northeast monsoon season, during October, November and December, you can store more water and so the need is, so the need is to enlarge the reservoirs.

But unfortunately, the way the need has been stated now is incorrect because that is a solution. Sometimes, if there are various possible solutions, sometimes incorrectly you state one of the solutions as a need. You can still solve the water problem of Chennai without enlarging the reservoir because there are other ways of doing it. You can do desalination. You can put a very high water tax, which is exponentially increasing, so many liters a month. You have water meter for every apartment, so many liters a month, it is this cost. When it increases, next slab, it will go 1.25 times, 1.5 times, 1.75 times, it can keep on increasing, that is one way of doing.

Then you can have, you have Krishna water project right. You can get water from some other state. You can get, you can get water through pipes from some other reservoirs. We had this project (( )) desalination. So, there are various ways of doing it. Therefore, the need has to be stated.

The need has to be stated in such a way, that it is very broad. And the need should not be stated in such a way, that some solutions are already precluded, that is, already closed some options, that is incorrect way of stating the need. The problem here is that actual need is not specified. Indeed, what has been specified is only a possible solution.

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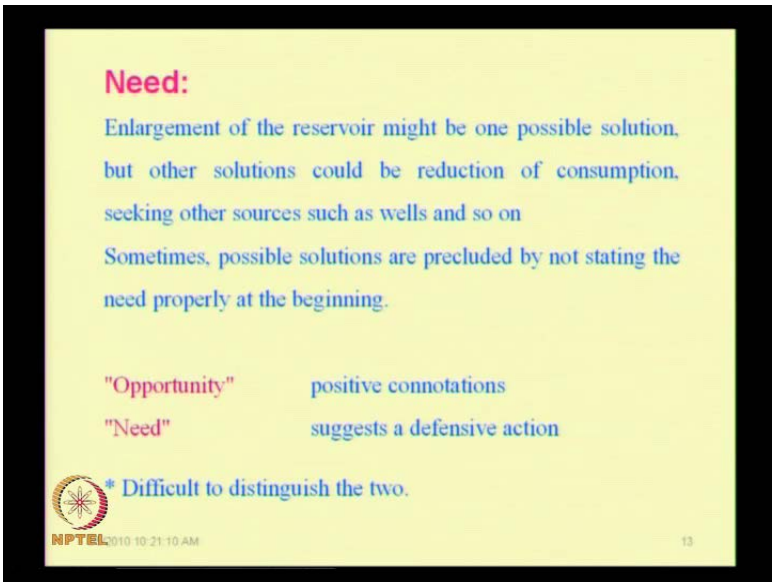

Enlargement of the reservoir is one possible solution, but there could be other solution. Reduction of consumption, seeking other sources, such as wells and so on. Sometimes possible solutions are precluded by not properly stating the need at the beginning. There is a difference between opportunity and need and all that. So, your economic process will teach you all that, principle of economics. Opportunity is positive connotations, need suggests a defensive action and all that. Let us not get into that.

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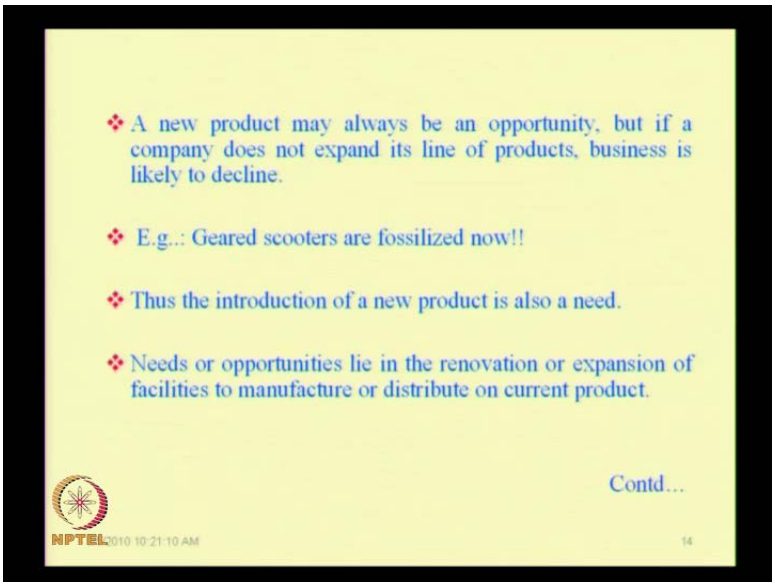

A new product is always considered on opportunity, but if a company does not expand its line of products, business is likely to decline. For example, geared scooters are fossilized now. You have the Bajaj scooters was very famous in the 80s. You had to wait for six month or one year to get a Bajaj scooter. Now, the TVS started investing lots of money into their geared scooter called spectra. Has anybody seen this? This, it came about 10, 15 years back. So, they invested a lot into R and D, and then they built up a division and all that, but geared scooters are vanishing from the market.

Why, why, are you getting the point? They designed the best geared scooter, but by the time the geared scooter came, people did not want geared scooter. Therefore, so, that is called RG, right. You are completely RG. So, we have to keep our eyes and ears open and find out what is going on. Let us not to try to overdo something, which is anyway going away, alright.

So, thus the introduction of a new product is also a need, but you have to be very watchful. Needs or opportunities sometimes lie in the renovation or expansion of facilities to manufacture or distribute on current product also. So, you want, for example, there is heavy waiting time, there is heavy waiting time for design and so on now, right.

Maruti can be very happy, that people are waiting and all, but it could be an opportunity. If somebody is able to make something, which is similar, which is able to give in one or two months, people will go. Maruti cannot bask on its glories and say, “Oh, people are

waiting for one year." We never know when people will ditch us. That is a first lesson you have to learn in life. So, so now, this Manesar plant, they are going to run three shifts or whatever, they will put one more plant and if you watch, if you read the news and all that, they will try to capitalize on this. Now there is a premium on swift desire, swift and swift desire. So, they have to cash, that means, they have to increase the production before people begin to realize, that there are other products, which will do equally well.

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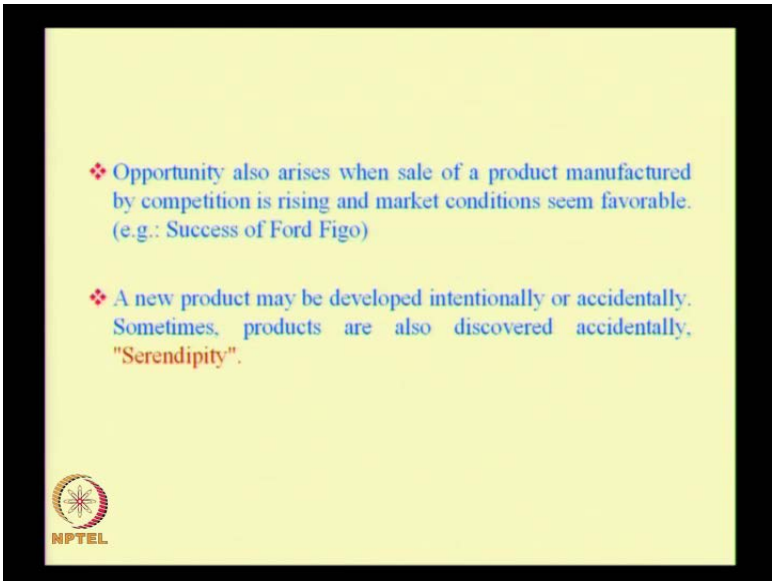

Opportunity also arises when the sale of a product manufactured by competition is increasing and market conditions are favorable. The Ford, the Ford motor company started in big way in Chennai, Maraimalai Nagar. Most of its products were the utter disaster. The Ford Fusion, disaster; then, Ford Escort, Ford Ikon was alright; the Ford, Ford Fiesta was quite alright, but they have, it is, but they realized, that the money is not in those big cars. Money is there in not in the sedans, but in the hatchbacks. Sub 5 lacs, less than 5 lacs. And then, they studied, they had all the time in the world to look at all the models of TATA motors, Maruti, Hyundai and all that and they come with a Ford Figo. Now, it is already started with 25000 bookings, right? It is a, it is just around 4 lacs and it is very successful. The same company, which (( )) 10 years ago is now able to, is now able to turn around and come out with very successful product.

So, you should also look at, you should also look at what? That is what we practice all the time in IIT, right. So, you should also look at what your friends, what others are doing, whether, whether you are abreast, whether you are keeping yourself, whether you are aware of what others are doing and whether you are not losing and all that. So, that is, that is what I stated. Success of Ford Figo is one example.

A new product may be developed intentionally and accidentally. I teach in ID 110, how the velcro was figured out, right, George de Mestral, that insects attached to the jeans to the, when then, and then people figured out this Velcro. Velcro is used everywhere now, right. So, then you have post it, the Art Fry post it, the post it is basically, you know, what I am talking about. The post it, is, is a failed product, that adhesive because it defies all the properties of conventional adhesive. Adhesive means Fevicol, you know, so like this. But somebody figured out, somebody developed an adhesive, which, which does not stick after sometime. And some other scientists figured out, Art Fry figured out, that if does not stick for a long time, it can be used as a bookmark because it can be removed without any trace of having used it. So, it became a very successful office product, 3M, right. This is very successful office product.

So, if you, if you have to figure out something accidentally, it is called serendipities, serendipity, it is there in word list, right.

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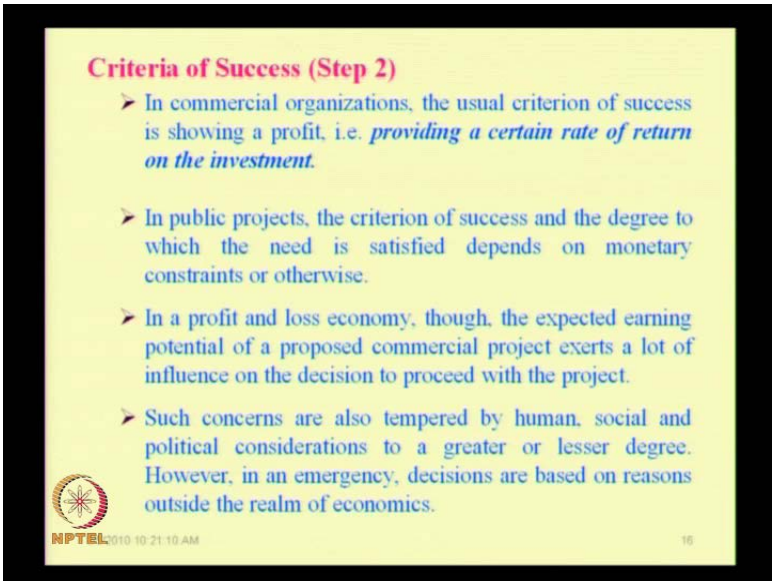

Criteria of success; CGPA is one criterion of success, but CGPA may not be the sole criterion of success. So, in commercial organizations, what is the criteria? The usual criterion of success is showing profit. Commercial enterprise means, that there should be a return on the investment. I am putting in so much of money, 100 rupees money, at the end of the day how much do I get, at the end of the year or whatever?

So, as a fraction of how much I invested, that percentage is called rate of return. It is put as a percentage. They will put various costs, inflation, this and all that. So, the rate of return should be 15-20 percent, whatever, right. But you will not get return on big project. If you are coming out of the power plant, can you start getting returns at the end of the first year? No. It will take time. At the end of five years, it will start breakeven, that is called breakeven point. After you reach the breakeven point, what is your return on the investment? So, that is a, so this is a figure, which all the commercial enterprises will look at, the return of investment, return on the investment, ROI, return on investment.

In public projects, of course, suppose you are building a new terminal, terminal three in Delhi or you are building a new flyover, what is a criterion of success? The criterion of success is the degree to which the need is satisfied, whether the people are happy with that. So, it is, sometimes it can become very subjective and qualitative.

In a profit, however, in a profit and loss economy, the expected earning potential of a proposed commercial project exerts a lot of influence on the decision, whether to go ahead with the project. However, these concerns are also tempered by human, social and political considerations to a greater or lesser degree. Whether you want to have a dam over the Narmada, whether you want to have Tehri-Garhwal project, whether you want to stop the Alakhnanda river in the fragile Utharanchal or Utharakhand?

I mean, there are other, other considerations, which will temper, which act of, which will, which will temper your this thing, your drive to keep the return on investment as only criterion for success. However, in an emergency, decisions are based on reasons outside the realm of economy. So, that is clear to us. We want to declare a war, know economics, whatever.

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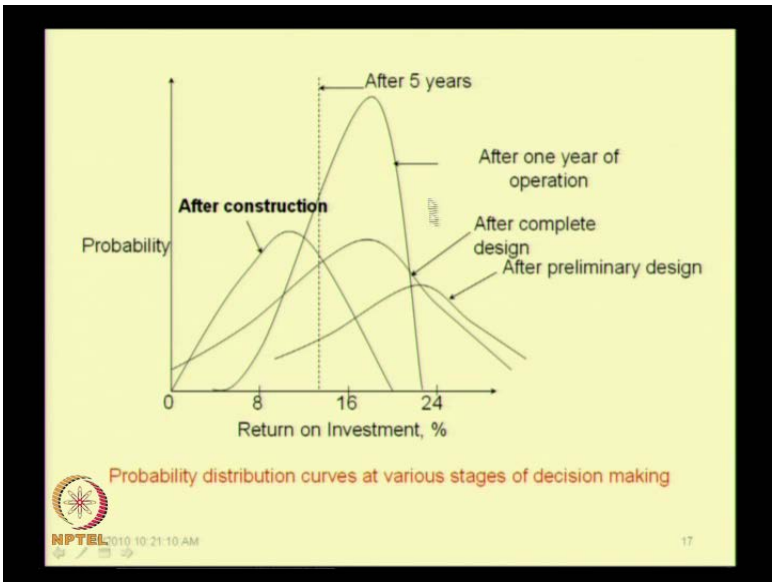

Now, if you look at, so, this is basically return on investment as percentage as a probability, so after preliminary design, you have something like this in a typical qualitative (( )). After complete design, it may go like this, which means, the variance is decreasing. The variance or the standard deviation is decreasing means, is a standard deviation of graph like this, probability versus variable is decreasing, that means, your confidence increases. When you are able to draw something very sharp, that you are absolutely sure, that mean plus or minus 3 sigma, 99 percent of the points are, there is 99 percent chance, that the return on the investment will be x plus or minus 3 sigma.

That is what we are saying. First it was very defused, then after construction it becomes better, after one year it is like this, after five years you have a good idea, assuming that the market does not change dramatically. So, this is basically the probability distribution curve at various stages of decision making.

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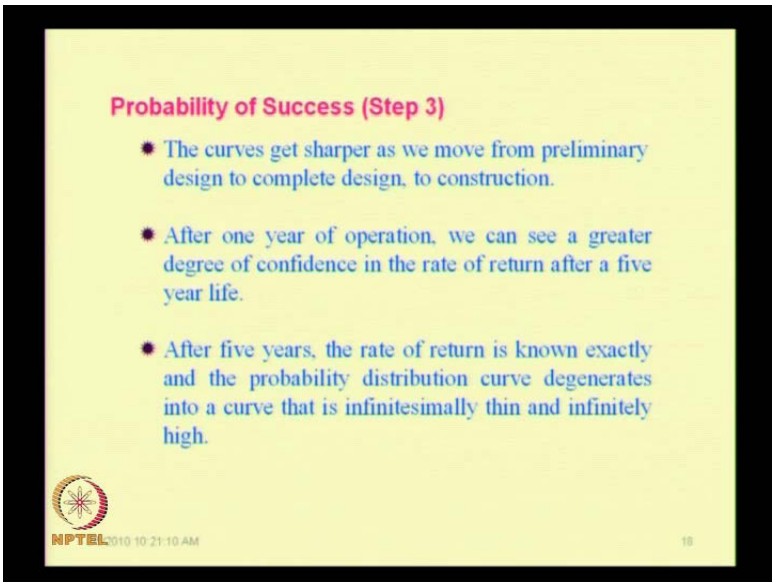

Probability of success, the curves get sharper as we move from preliminary design to complete design to construction. After one year, it is sharper. After five years, the rate of return is known exactly and the probability distribution curve degenerates into a curve that is infinitesimally thin and infinitely high. What is it? It becomes like direct delta.

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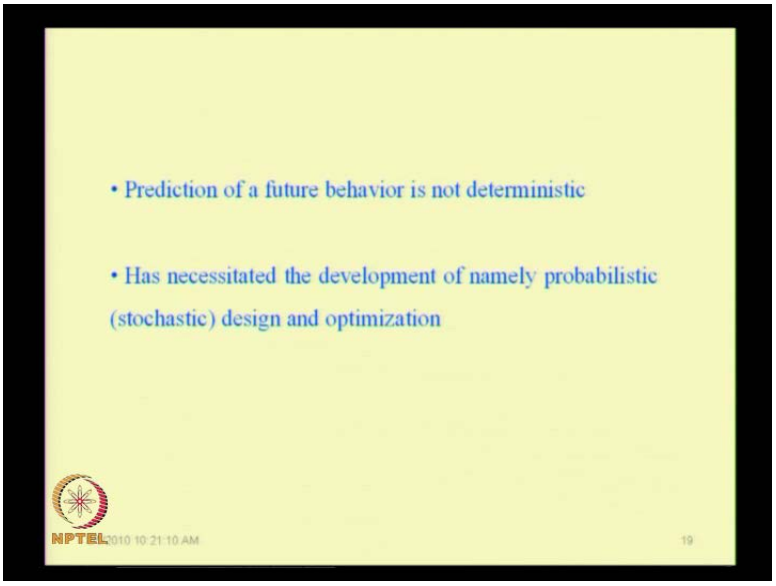

But the prediction of a future behavior is not deterministic. So, you have to factor in various things. Future market conditions, the cost, the inflation associated with this, and

the fluctuation in interest rate and all that. Therefore, you have to... So, the design will change from deterministic design to probabilistic design as stochastic design.

Stochastic design is now very much, stochastic design is very, very popular nowadays. For example, the fluctuations in the stock prices, the fluctuation in stack prices of various companies. If you can take all this fluctuations to be a mean, u is equal to u bar plus u dash, v is equal to v bar plus v dash w, I am taking three velocity components. So, you can modulate along the lines of turbulent flow, and then you can come out with stochastic partial differential equations.

So, if you are (( )) in turbulence, you can get a good job in Wall Street. I am not joking. They want people who are extremely good in partial differential equations, stochastic partial because if you solve this system, if you solve these equations, you will be better equity analyst. You will become a good fund manager or you help fund managers. All this, you know, this business analytics, equity analysis, all those kinds of, all those kinds of job now require mathematical finance, stochastic partial differential equations and all, right. So, there is a new, there is a new trend even in design, stochastic design.

I work a lot, a lot on stochastic optimization, neural network is one, genetic algorithm, (( )) optimization, swarm form behavior, you know, particles swarm optimizations, particles swarm optimization. When a swarm of birds is trying to catch food, then the probability of getting the food for the birds increases if all the birds stay closest to the leader. The leader is the one who is the closest to the food. You can work out all this, you can write equation for each of this and people have modeled all this and they have applied it on a practical Engineering problem. It is called PSO, particle swarm Optimization.

How ants, the foraging behavior of ants, how do ants, the behavior of ants in searching for food? When ants go and search for food and come back, after they figure, after they eat the food and come back, they, they leave a trail of chemical called pheromone; p, h, e, r, o, m, o, n, e. This pheromone concentration, this pheromone concentration will of course, be stronger, if there is more food, which is available from the place where it went, and this concentration will also exponentially decay with time. So, the ants, which follow this, will look at the pheromone trail and wherever the pheromone trail is very, wherever there is a pheromone concentration very weak, it will avoid that path. And

even along the path where there is a pheromone trial, even where there is a, where there is a pheromone trail, if the signal is very feeble, it knows that.

His, his friend, his senior went to that place 2, 3 days back and there is a chance that by this time the food would have already got exhausted. So, they are not taking 6 to 80 or 11 introduction to finding food. They are not taking any course. No 1, no 1, no 110 courses they are doing it all the time. So, this is called Biomimetic, mimicking biology in engineering, biomimetic or Bioengineering.

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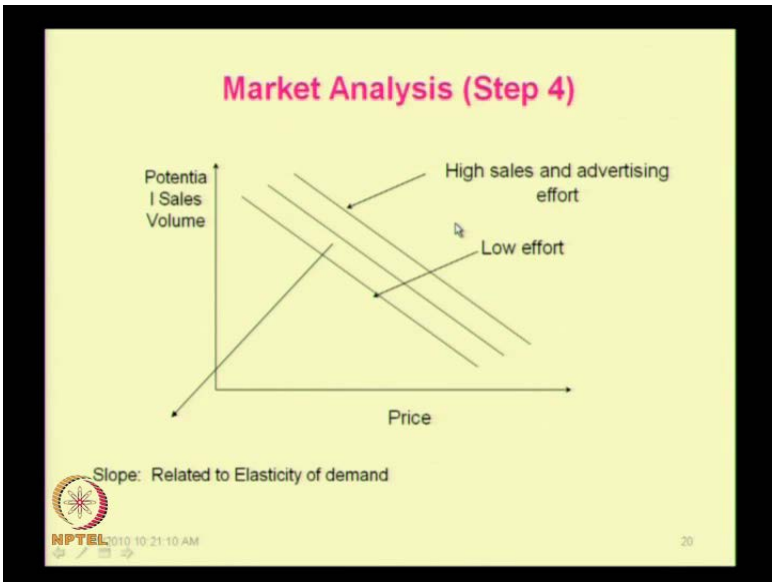

Market analysis, a typical, a typical graph of sales volume versus price will be like this, where this mouse is, will be like this. So, you will expect that as the price, as the price increases, sales will decrease. Is it always true?

Student: (( ))

Can you tell me some, some goods, which will defy this?

Gold, gold will have an opposite trend because when the gold price increases, you get more scared, that it will rise further, and then you will go and buy and then that will cause a demand, that will cause a short supply, and then it will increase. So, vanity goods have that.

Some goods, the Hindu newspaper, coffee, tea, of course, Hindu newspaper, we cannot say, market conditions (( )). Now, Times of India has come, so there will be some disturbance, but morning you want newspaper, morning you want coffee and all. Unless and until the coffee becomes twice as expensive as tea or something, then you will consider switching to... So, there is a possibility, that the, that the consumption of, consumption of tea will increase, when the price of coffee increases. That is called? Nobody has studied economics?

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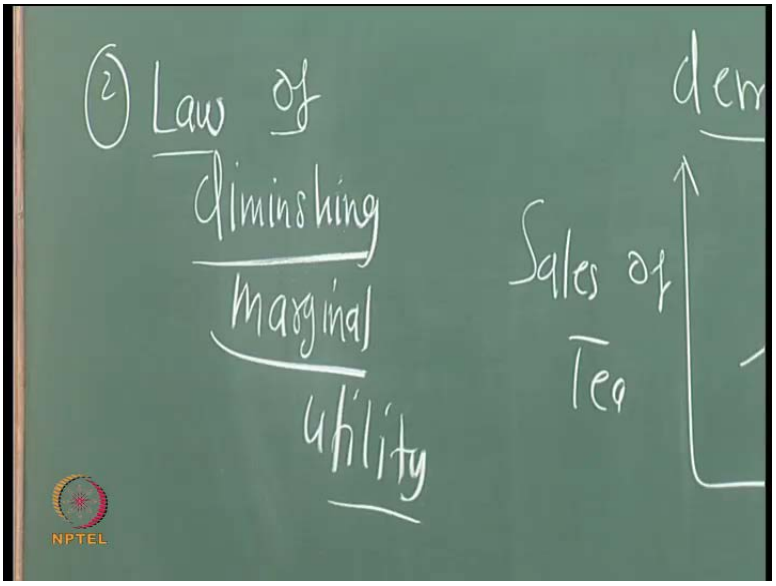

So, that is called cross elasticity of demand. For example, how you draw this? Increasing upwards or... So, this is one possible curve. Now, there, there are, you have got a bunch of lines. Here you have got high sales and advertising affect. So, even if there is a, even if the curve is drawing like this, you can keep on advertising and make people remember you brand and increase it. But after sometime, the return on the, return on the advertising effort will decrease. So, that is called, that is called the law of diminishing marginal utility, that is, what is satisfaction you get by having repeated quantities of the same thing.

For example, you like kaju-katli very much. First you take, very good. Second, third and fourth, fifth, after sometime, then if you take more, you will start vomiting. Or apple, you like apples, first apple, second apple, after sometime, you do not want to go near apple for the next one week. So, that is a law of diminishing marginal utility. It is applicable

for. suppose you get a salary of x rupees, right. If it keeps on increasing, for example, somebody gets, somebody gets 30000 or 40000 a month. The first 10000 rupees will be very critical because it satisfy the basic needs. Then, it satisfies the secondary needs. The last 10000 generally, generally will be spent on general things, which are not important. Suppose 40000, it becomes 70000, the last 20000, 30000 will, will go to completely irrelevant things and so on.

So, the marginal utility in your salary into bunches of 10000s each, the value of the first 10000 is very critical. You will go and buy provision, you will buy, you will pay your electric bill, you will your telephone bill. The value of the first 10000, it has the same 10000, the first 10000 has got a high utility. The last 10000 has got very poor utility. So, the marginal that is called the marginal utility; same 10,000, it depends on the context, alright.

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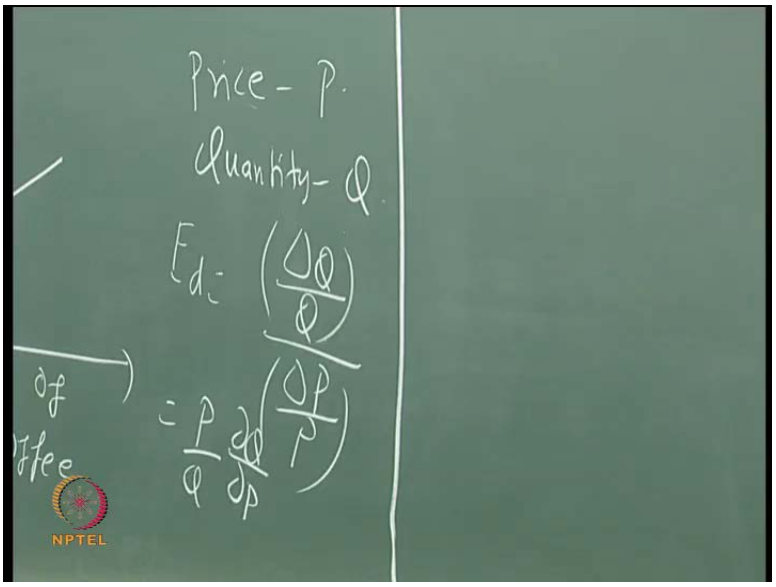

Now, elasticity, elasticity of demand, you can write it like this. If you start using equation in economics, then you are micro economist. There are two bunches of economists, one who do not know equations at all, the other who specialize in equation. The guys whose specialized in equation are the micro, micro economists

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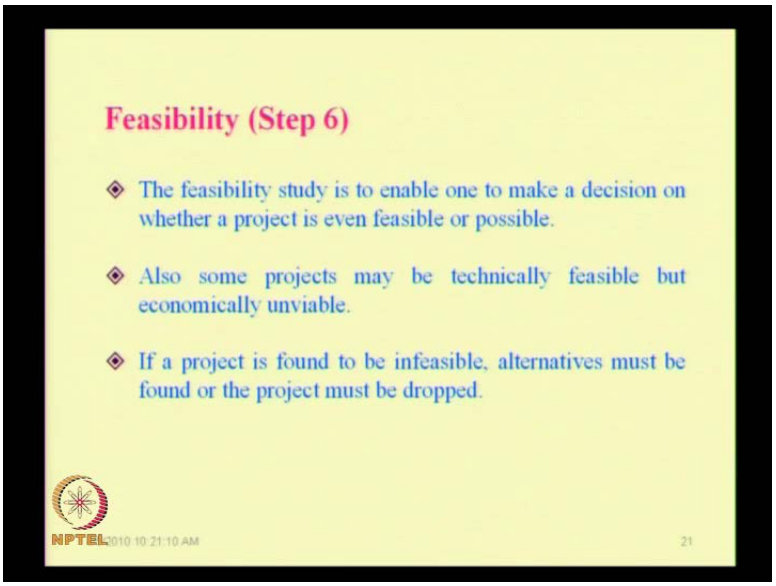

Now, feasibility, the feasibility study. You have got the next class, I will try to finish it. The feasibility study is to enable one to make a decision on whether a project is feasible or not. Also, some projects may be technically feasible, but economically unviable. Even if it is technically feasible, we have to drop it. The concord supersonic flight, it was technically feasible, but now it is economically not viable. No supersonic flights now. All the flights are, even A3 ATs are 0.9 Mac number. It is transonic flight. If a project is found to be infeasible, alternatives must be found or drop the project.

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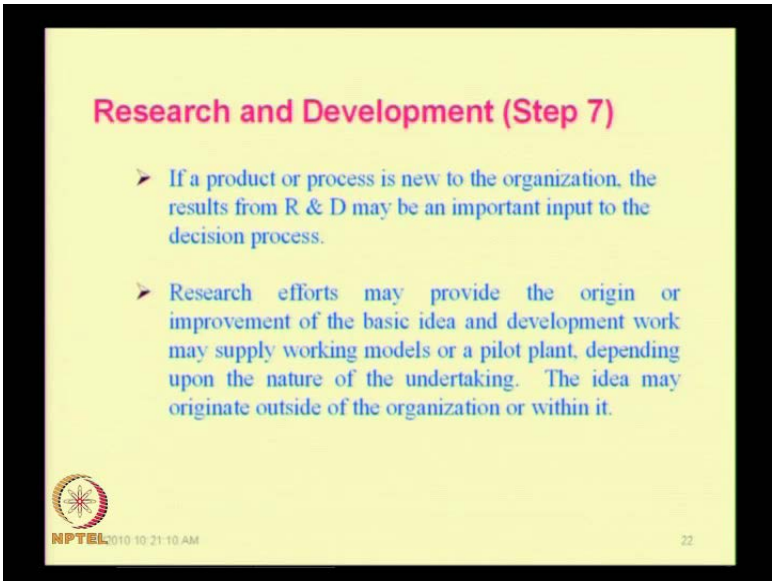

R and D, so the researchers in research and development may be an important input to the decision process for an organization. Research efforts, research may provide the origin or improvement of the basic idea, and development means, you make pilot, you make a pilot study.

There is a difference between research and development right. It is first research and then development, and then you make it into, transform it into product. So, depending on the, so you just look at working models or pilot plant. That is development work, and the idea need not necessarily within the organization. You can also use your rivals or idea of the rivals or competition.

When you go to big companies, I went to Schneider Electric in Bangalore. They had some problem; we want to do some consultancy and so on. So, they took us to the lab. They make the big circuit breakers for power plants, right. They have big circuit breakers, all big, big switches in their labs. They have a full circuit breaker of Siemens and they are studying the performance of Siemens. So, RGs are there everywhere. I am very happy. I do not know Siemens. No sir, we want to study how it. No, you are in the market for so many years now, but we want to, if there are some good features in that product we will adapt. I think if you go to, if you go to the Maruti factory R and D, you can see I10, I20, Ford Figo, everything there. So, that is the way. So, the idea may come from outside the organization also.

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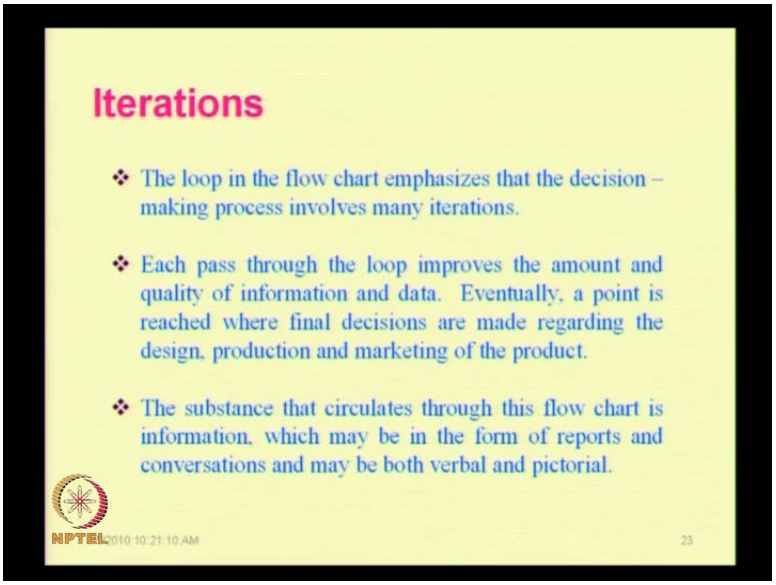

Iterations, the loop in the flow chart emphasizes, that the decision making process involves many iterations. Each pass through the flow chart improves the amount and quality of information. What is flowing through in flow chart is basically information, and information gets refined. After it goes through sufficient iteration and you are confident, you stop the process and take a decision, whether to go ahead with the project or not.

This basically is the anatomy and the morphology and physiology of design. Eventually, a point is reached where final decisions are made regarding the design production and marketing. The substance that circulates through this flow chart is information. This information could be in the form of reports, conversations, e-mails; whatever.

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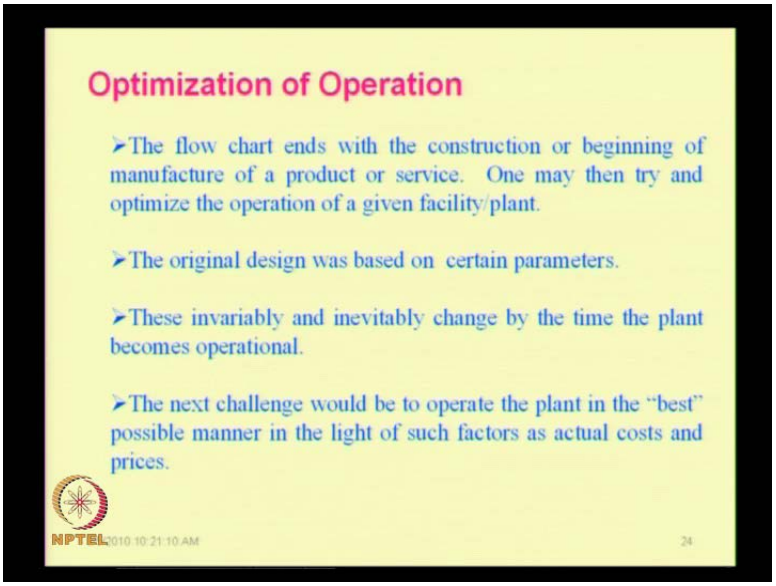

Optimization, there is no optimization in this flow chart. The flow chart ends with the construction and beginning or the beginning of the manufacture of a product. Then, you manufacture it, allow it to run. This is the conventional design. The original design was based on some parameters, but during the operation of the plant many parameters will change. Therefore, the next challenge would be to operate the plant in the best possible manner, but I think, that is not the best way to do an optimum design because I took this material, I have acknowledge that.

This first lecture is based on the books by (( )), which is one of the references given to you. I think optimization should be integral with design itself. Here is left to design, have

just taken it, and you say, that after it is start, you can look at optimization. But now, with all finite elements models and all that, it is possible for you to look at various options without having to build models, right, without having to build prototypes. You can do your pro-e or what is that, pro-e, you can do solid model and then you can analyze and then find out whether the stresses are ok and all that, and then you can, you can do what is called virtual design, right. You can do a virtual design and then pick and choose the best one; engineering design versus analysis. We will stop with this.