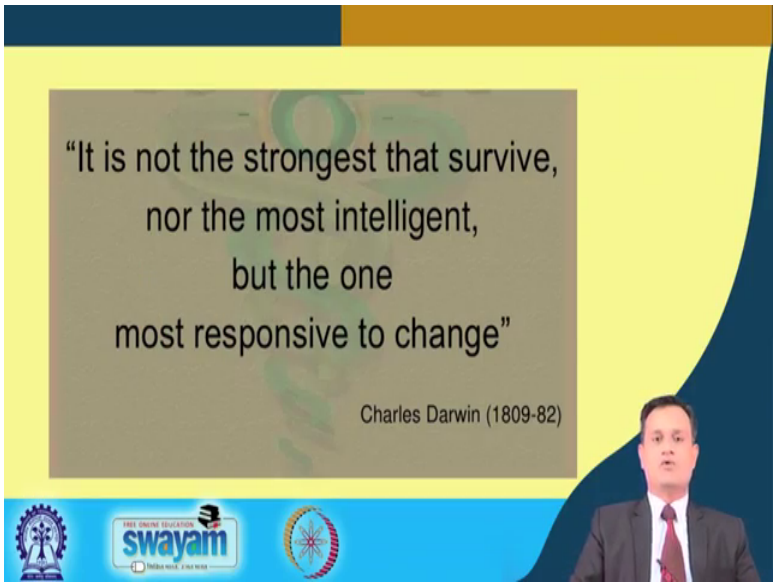
Six Sigma
Prof. Jitesh J Thakkar
Department of Industrial and Systems Engineering
Indian Institute of Technology, Kharagpur

Lecture - 60
Design for Six Sigma (DFSS): DFX

Hello friends, you are welcome to lecture 60 on Design for Six Sigma DFX, we have already coined this term that you need to have an X factor. So, many a times on television we see we watch couple of serials and there they talk about X factor. What is your x factor? Similar way think about your product and process and what is that X factor that can really make your product process, more customer, centric, robust reliable and useful to the customer and the society. So, we will try to deliberate upon couple of issues as a part of lecture 60.

(Refer Slide Time: 01:03)



Once again I would like to remind you, that it is not the strongest it is not the intelligent, but the one who is responsive to change will always survive.

(Refer Slide Time: 01:15)

(Refer Slide Time: 01:21)

So, we had discussed on DMADV, DMADOV and little bit introduction to de effects. Now, I will just open the box of X and this includes say design for manufacture and assembly, design for reliability, design for maintainability, design for serviceability, design for the environment, design for life cycle cost, design for cost testability and robustness.

Now, you just think that if you even miss at least one or two out of these, then you will have to experience many; many difficulty at the downstream stage once your design is

released it will go to manufacturing, planning, packaging to customer end or the service they will face lot of difficulty if this X are not catered right at the design stage.

(Refer Slide Time: 02:11)

So, DFX technically I will say that the scenario in which the products are frequently changing, the customers are becoming more and more demanding, then the scenario led to the development of the design by team. A cross functional approach, you cannot just sit in a room as a design person and keep the manufacturing, packaging, procurement your marketing, servicing, maintenance people out that approach will never help you. So you need to have a cross functional approach.

So, now, with concurrent and simultaneous engineering approach you try to address the various X in the design stage and for the first time stakeholders in the design function had a voice. So, stakeholders is not only the customer your internal customers, all the departments they are your stakeholders because ultimately whatever you will design finally, that will say affect their own performance just give a thought. Suppose McDonald ensures the home delivery, door to door delivery in 30 minutes.

This is only possible if the moment you place the order manufacturing of the pizza will trigger. Now a service boy delivery boy is just waiting at the restaurant and he is not getting the packet, he is not getting the pizza and the distance he has to covered is really large, which is not synchronized while taking the order, then definitely he will not meet

the stipulated targets or declared target by the company, so you are failing right at the design stage.

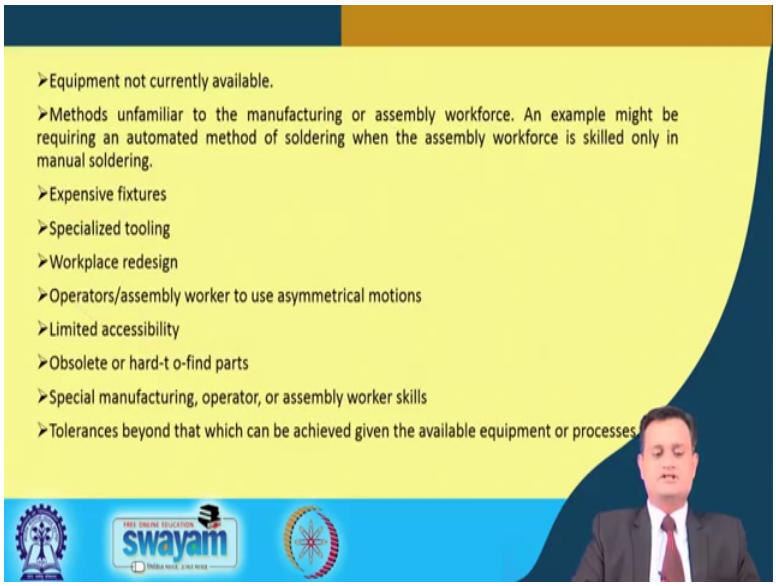
Always remember that if you look at the bottom, then what is bottleneck? It is the neck of the bottle. So, bottleneck is always at the top, so the way you design your product or process all other stakeholders in the company they will have to face the consequences. So, many a times we say that, the success or failure of the project is decided right in the first meeting directors meeting and it is decided in the room or board of directors.

So, can we really address this challenge and see that we do not end up with the unsold product, rework product, refurbishing product or just we have to throw away the product at a very low price because you have not addressed the DFX issues right at the design stage. So, these are couple of issues that we need to do through a cross functional approach in a company by involving the various stakeholders.

(Refer Slide Time: 05:23)

So, these are the 9 X which are quite popular and company they usually look for this majority of the X right at the design stage, so let us try to appreciate.

(Refer Slide Time: 05:37)



So, as I mentioned that there are couple of situations which really immediately demands the attention for DFX. For example, equipment not currently available you want to initiate the process, but the equipment is not available it means the order is not placed at the right stage. Methods unfamiliar to the manufacturing or assembly workforce, the way you have decided the specification and design requirements.

The kind of process is or the methods it demands are very much unfamiliar and you will end up with either lot of too much of training or a very poor performance of the people. Expensive fixtures you already have fixtures, but now your design is demanding altogether different kind of expensive fixtures again this has some say impact on the performance of your downstream stakeholder and calls for DFX.

Similar way you can see the need of specialized tooling, workplace redesign in order to streamline the flow of your manufacturing, limited except accessibility, absolute or hand to find parts there is lot of say obsolescence or the parts are difficult to get. So, maybe you are purchasing from the vendor, so when; when I interacted with couple of companies in India they say that we purchase the equipments, machinery, aircraft from other country.

And then we find lot of difficulty in getting the spare parts and components because either this design is absolute or these vendors, now they are focusing on some new parts. Similar way special manufacturing operator skill, assembly workers skill, tolerances

beyond that which can be achieved given the available equipment you know specified the tolerances are which are not achievable with the existing equipment.

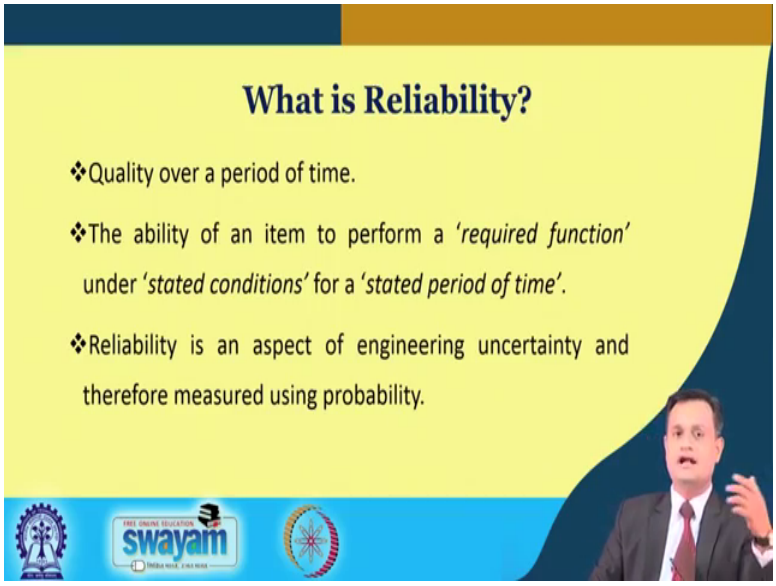
(Refer Slide Time: 07:43)

So, these are the issues that really calls for DFX. Now let us try to see the various DFX one is designed for manufacturing assembly. So, you can consider right at the design stage concept stage that what kind of manufacturing process is you would be needing and do you really have this kind of manufacturing setup or the equipments or the operator skill available or not. You can also think about error proofing poke yoke kind of strategy, so that you do not make the mistake while executing your production.

(Refer Slide Time: 08:19)

You have designed for reliability, so we all know reliability is the ability of the equipment or the product to deliver, the particular function or performance for intended function or performance for which it is manufactured. So, it is the analysis of load strength relationship for example, and design out inherent weaknesses you use the past data supplier history, potential failure modes, FMEA you can conduct and you can plan for reliability improvement right at the design stage.

(Refer Slide Time: 08:57)



So, quality over a period of time is my reliability, ability of an item to perform a required or intended function under stated condition. So, if let us say again I will say Maruti car four wheeler if it is used in the hilly area, harbor area, rural area all more or less the functions the performance of the car should fall well within a particular prescribed range I will not say it would be same, but it should fall within a prescribed range it should not just say go excellent or worst.

(Refer Slide Time: 09:37)

So, reliability is important you can just think the examples and you will get sensitized airline cost, automotive reputation, military equipment, availability, safety issues and so on.

(Refer Slide Time: 09:49)

So, products they fail because of many reasons that design inherently incapable, your items are overstressed, variation, wear out, specification design coding error there could be the noise factor which is responsible or the interaction among the subsystem may lead to the product failure.

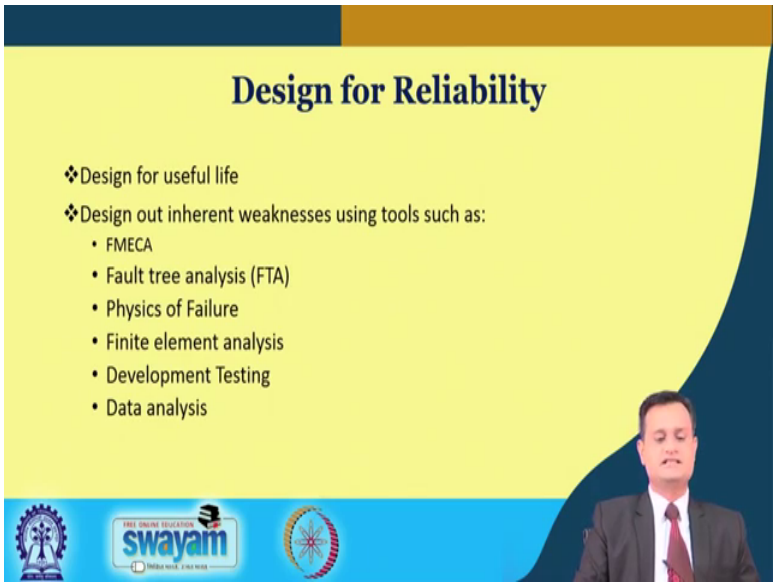
(Refer Slide Time: 10:17)

So, these are couple of reasons and when we talk about the design for reliability the aim is to maximize the reliability during the service life by measurement and control of manufacturing quality screening, optimize design and build process to improve intrinsic

reliability, assure no systematic faults present in the product you can do failure mode effect analysis and provide sufficient margin to meet the life requirements.

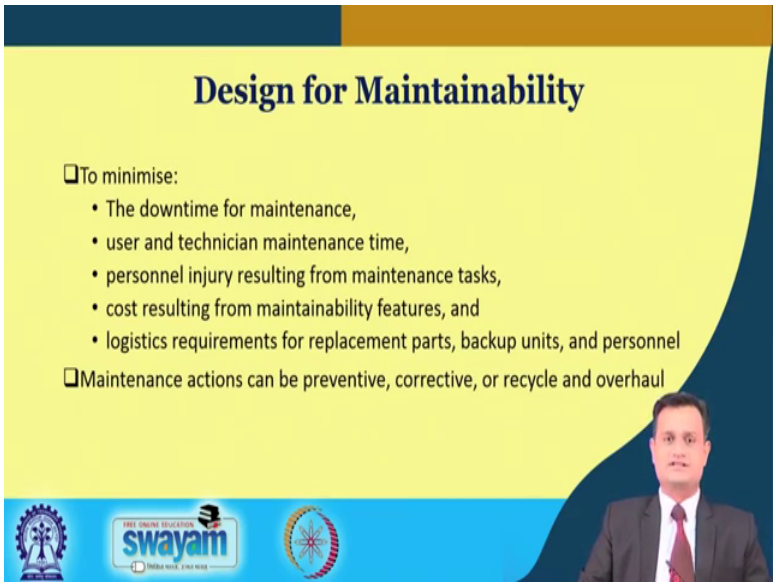
So, maybe you have designed a product for 10 years, but usage condition may be different. So, you can at least keep a margin, so that even if it is used under say little bit adverse condition, you will get more or less the same functioning of the product for the intended period of life.

(Refer Slide Time: 11:09)



So, you have designed for reliability and various tools FM EA or FMECA there are different variance available, fault tree analysis, physical say physics of failure study stress strain and other phenomena you can study finite element analysis development testing and data analysis.

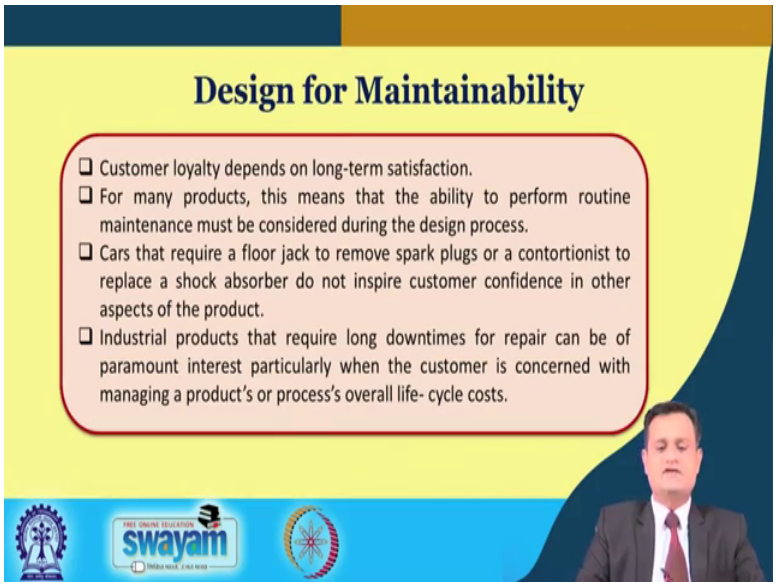
(Refer Slide Time: 11:33)



The another important X in D FX is maintainability, you have given the vehicle to the customer, but over a period of time there are some maintenance requirements and can you really reduce the downtime by focusing on say maintainability aspect right at the design stage. So, for example, in a very simple manner I need to change the spare wheel. So, is the location of a is the location of wheel is very remote and can I fit this par wheel or will it be too much cumbersome.

Similar way you want to replace some of the component of the machine what is it's location and will it really take too much time or the downtime will be very high. So, these issues you need to cater at the design stage. So, maintenance time, downtime, complexity in executing maintenance are a couple of issues, that can very well be addressed at the design stage.

(Refer Slide Time: 12:41)



So, designed for maintainability, customer loyalty depends on long term satisfaction and it is not only delivering the product, but once the product is delivered customer should be able to maintain it with a very very little difficulty and this is where long term relationship comes in picture. So, car that require a floor jack, I gave the example to remove the spark plugs or a say controller ness to replace a shock absorber do not inspire customer confidence in other aspects of the product you just see that such a small component and for that if you have to really use the floor jack or some other kind of say assisting equipment, then customer will lose the faith and loyalty in the product.

(Refer Slide Time: 13:33)

Designed for serviceability, ideally speaking I want a robust product and suppose I have purchased a washing machine, then this machine should give me the service for maybe 10 years and 15 years I would like to replace the product. Suppose I have purchased a refrigerator and nowadays we are getting such kind of excellent products. So, refrigerator hardly I feel I have gone for any maintenance in last 15 years.

So, a fantastic quality and after fifteen years you may feel like say replacing it with the new technology or space requirement exchange or some three star, four star, five star electricity saving technology has come or your refrigerants they are now eco friendly. So, you can opt for a new technology, but so far the duration of 10 to 15 year is concerned there is absolutely no need of service.

Fine this may not be possible in all the cases, but I must try to address that even if there is a need of service, then ability to diagnose, remove, replace, replenish or repair any component or subsystem to original specification with relative ease. So, poor serviceability produces warranty cost, customer dissatisfaction, loss sales, market rates mainly because of loss of loyalty and serviceability as say personal involved in the early stage they can give you lot of input. So, many a times we ignore this say down the line say people, who are actually struggling dealing with day to day service problem and if we really say approach them they can give a very good advice and this can really help in designing the better product.

So, many; many companies say let us say furniture manufacturing company for example, I have seen they will call a summit and in their summit they will call many small and big carpenters and these carpenters give them lot of inputs which can help them even to manufacture modular furniture which is now available on amazons and many other sites, that you can order and you can just fix it and you are done.

So, it is only possible if you have the inputs from such a skilled people who are acting or who are working at the downstream and really dealing with the product and serviceability issues you have designed for environment.

(Refer Slide Time: 16:17)

So, today we talk about sustainability, we talk about environment and definitely I cannot ignore this component. So, environmental concerns as well as post production, transportation, consumption, maintenance and repair and typically say economic evaluation is required both for maximum economic benefit and to estimate what the expected financial savings will be there. So, environment in terms of pollution environment in terms of say policy decision or the implications of the product in terms of safety or for the society all these issues I need to cater.

So, typically when we talk about the sustainability we talk about TPL sustainability triple bottom line, so one is environment other is economics and third is your social. So, we need to address these issues maybe as a broader umbrella of environment right at the design stage.

(Refer Slide Time: 17:47)

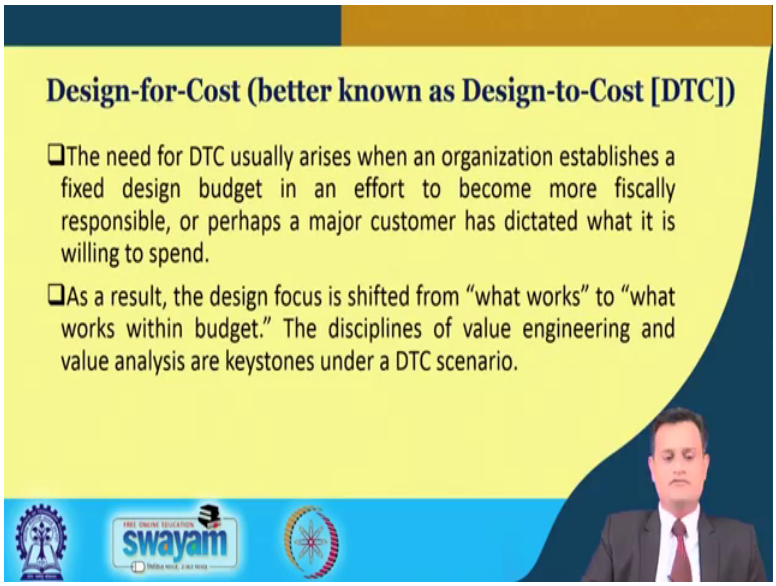
Many a times, say you want to opt for process modification, you want to use different chemical, you want to say launch a new product and you have to take the permission of many; many government agencies in order to satisfy the environmental regulations and requirements, so these issues also need to be catered at the design stage.

The another X is designed for lifecycle cost, so please remember that my product is not used only for a small period of time I must see that what is the total lifecycle cost, so this is the real cost of the design. So, this will definitely include say cost of defects, litigations; buy packs, then distribution support, warranty, implementation cost of the employed DFX methods and all this will add to the lifecycle cost.

So, my product right from the design stage to the end when it will end in terms of its life let us say whatever cost I will incur on maintenance or maybe my services or warranty cost all these needs to be our environmental cost considered right at the design stage and this is my life cycle costing.

The best approach is to go for activity based costing is a method of estimating life cycle costing and it is a process oriented approach activity based costing. So, ABC the objective is to identify activities in the design life and then assign reliable cost drivers how much cost it will say attract or extract and the consumption intensities to deactivates.

(Refer Slide Time: 19:21)



So, this is what we can do; now there is another design for cost and this is better known as design to cost. The previous one if you see it was lifecycle cost during the entire lifecycle of my product whatever cost I will incur in terms of activity based costing process oriented approach I try to estimate it by assigning some cost drivers, but this is designed for cost or design to cost, this is different than the previous one.

So, there is the need for DTC or design to cost typically when organization establish a fixed design budget in an effort to become more say physically responsible or perhaps a major customer has decided what it is willing to spend.

Now, in this situation you are forced, I have visited one small and medium scale enterprise and they were manufacturing say typically say furnaces electric furnaces. So, when I talked to the operations manager and design in a very lighter way they said that before we even know our cost our customers and suppliers they are well aware of. So, you just see it's a transparent world and you cannot just set the price or budget or cost which is not acceptable to the market.

So, design to cost comes in two way one is your fixed budget you have a salary of 1 lakh rupees and you have to manage all your affairs you cannot just say that let me spend 10 lakh rupees in one month and then I will remain hungry for next 11 months you have to manage all your affairs in the given salary.

Similar way you have a fixed budget and you want to manage your physical cycle. So, you have to be constrained by say this X that is design to cost or on the other side your customer is well aware of the cost and he is ready to pay only some amount willing to pay only some amount, then again you have to be extremely conscious about inclusion of the features requirements right at the design stage.

Suppose you are using the very traditional say this mobiles which button type mobile, then maximum say 1200 or 1300 rupees and even you get it in 450 or 500 rupees I have checked on the Amazon. So, nobody would like to pay anything more than 500 to 30,000 and you have to manage your design within this.

(Refer Slide Time: 22:15)

Design for test this is another very important dimension that what is my adaptability to test requirement or testability? So, testing may be an integral part of ensuring quality and it may be demanded by the customer. So, many a times in such cases design must accommodate an assembly test assemble type of production assembly process rather than rely entirely on functional tests of the finished product.

So, many a times say you have a product there are sub assemblies which needs to be tested and if this kind of testing is required rather than the fully functional product, then you really need to see that how the product can be assembled reassemble or it can without their say dismantling is there a location or space available for conducting some

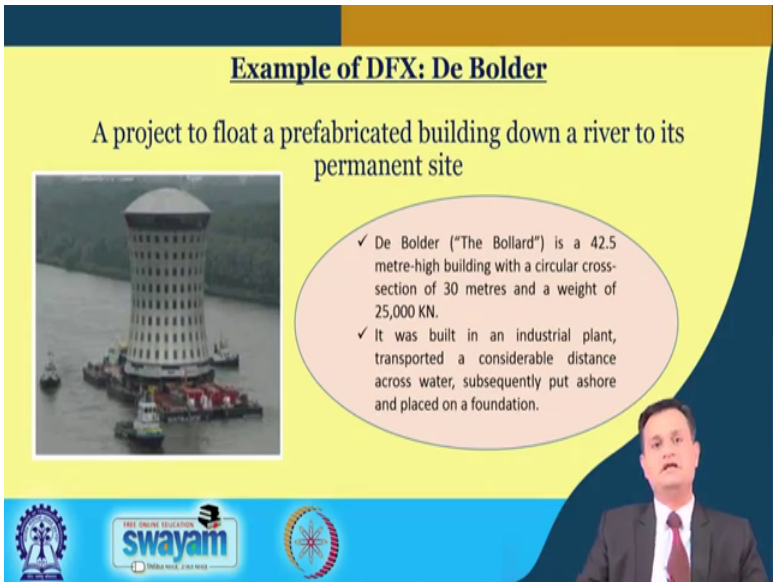
of the tests. So, such considerations are common with complex electromechanical equipment, including avionics and mass market consumer electronic products.

(Refer Slide Time: 23:33)

Designed for robustness this is the very; very important X required because nowadays products they have to perform in different; different environment and they must be sensitive to the noise. I am using this a particular word noise to remind you about our discussion on Taguchi and Taguchi has given the s band ratio which typically says that why to maximize the signal and minimize the noise.

So, you have to cater for the robustness and the variability of performance by deciding the tolerances, specifications and the complexity of the features right at the design stage. So, I have this particular X that is the robustness needs to be catered and I must see that design should be capable of accepting parts with some amount of variability and still it can produce the desired performance or the output distribution.

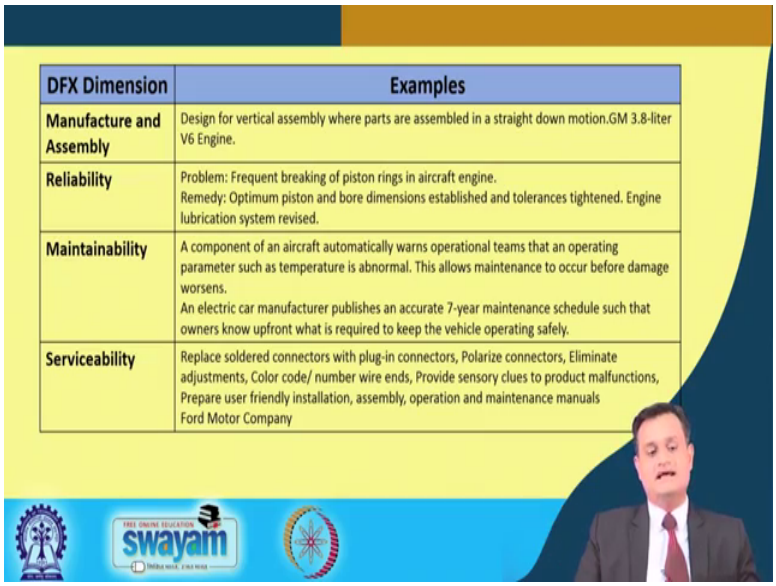
(Refer Slide Time: 24:41)



Just see the example of De Bolder you might be aware and this is a project to float a prefabricated building you see such a gigantic building down a river to its permanent site and this is a 42.5 meter high building with a circular cross section of 30 meters and a weight of 25000 kilo Newton.

So, it was built in an industrial plant, transported a considerable distance across water and subsequently put assured and placed on the foundation. So, you may just little bit do a search and thing that what are the factors that might have contributed towards the robustness of this de bolder prefabricated say construction.

(Refer Slide Time: 25:35)



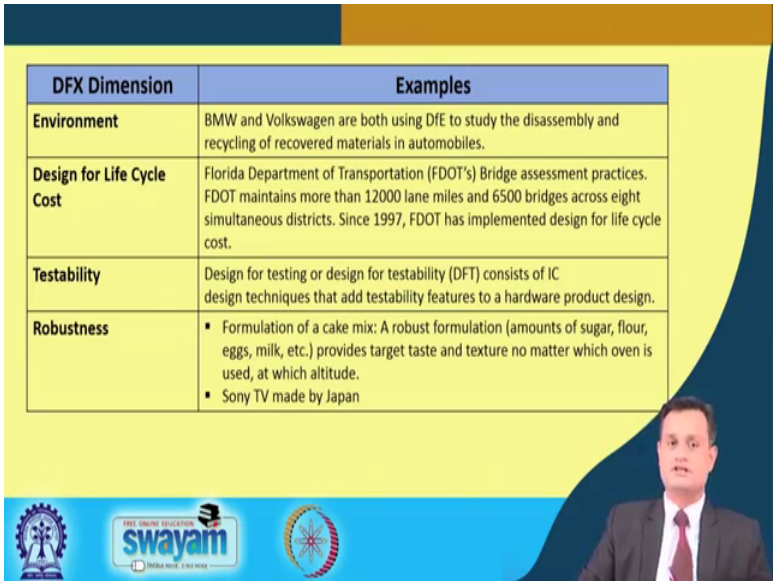
So, there are a couple of examples I have summarized just to make you better clear, let us say manufacturing and assembly design for vertical assembly where parts are assembled in a straight down motion GM 3.8 liter V6 Engine is the example of your manufacturing and assembly. Reliability the problem was frequent breaking of piston rings in aircraft engine, so, the reliability is questionable. Remedy was optimum piston and bore dimensions established and tolerance is tightened. So, engine lubrication system say revised.

So, this is just one example that they have revised the tolerances and they have worked on the dimensions bore dimensions and your reliability got improved. Maintainability a component of an aircraft automatically once operational team that an operating parameter such as temperature is abnormal, you see the signal is coming and this allows maintenance to occur before damage worsens this is maintainability. You are able to detect the problem; you can proactively act and lessen the say damage to your system.

Another example may be an electric car manufacturer say publishes an accurate 7 year maintenance schedule, such that owner knows upfront what is required to keep the vehicle operating safely the simple manual can even be the example of maintainability. Serviceability replace say soldered connected with plug in connectors, polarize say connectors, eliminate adjustments, color cod number wire ends. So, nowadays you are

using different colored wires also electric wires in order to say identify the fault and replace a particular cable when any problem is encountered.

(Refer Slide Time: 27:43)

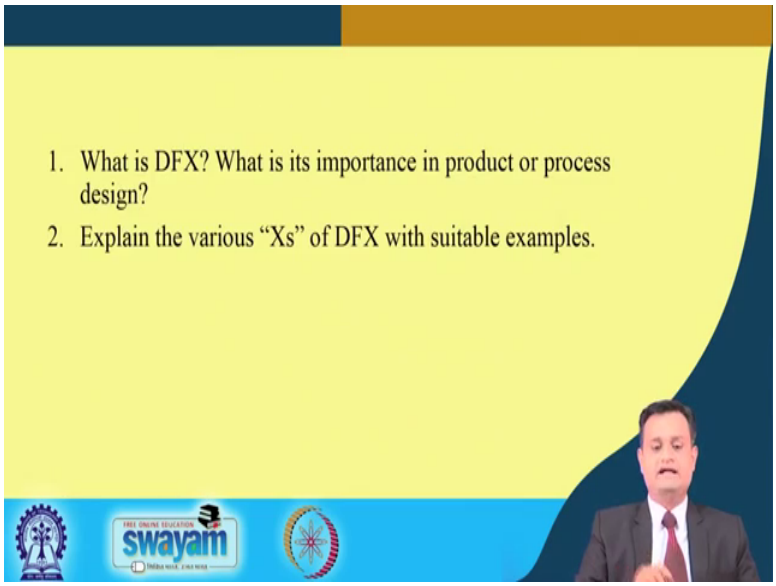


So, there are a couple of examples that we can refer about the serviceability. Environment BMW Volkswagen are both using DfE to study the disassembly and recycling of record material in automobiles. So, their concern for the environment is reflected in their say design; design for life cycle cost Florida department of transportation FDOTs bridge assessment say practices is one of the example and they maintain more than 12000 lane miles and 6500 bridges across 8 simultaneous districts.

Since 1997 FDOT this is your Florida department of transportation has implemented design for life cycle cost. Testability the example you can refer design for testing or design for testability consists of IC design techniques that a testability features to hardware product design, so integrated circuits you can have this kind of feature.

Robustness you can see Sony TV made by Japan I already explained that they are trying to produce more agree products a great products by having the process is more centric towards the say targeted value. Formulation of cake mix a little example interesting example you all like cake enjoy the cake. A robust formulation amount of sugar, floor egg, milk provides the target test and texture no matter which oh one is used or at which say altitude. So, if you have the right ingredient mixed, then even such a recite can give you the excellent robustness even if it is cooked in a different kind of oven or altitude.

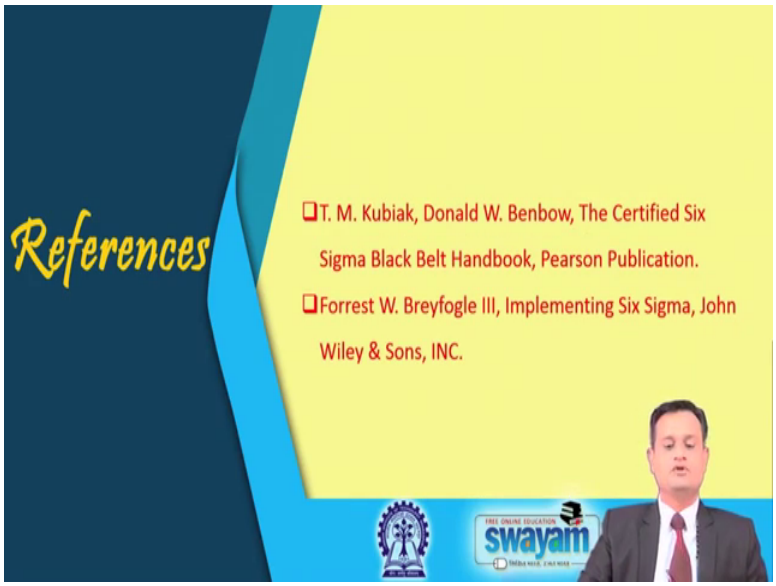
(Refer Slide Time: 29:41)



Before we end think it what is DFX? What are the different x we have discussed? What is its relevance and criticality in designing the product or process? And explain the various x with suitable examples. Just look around you and think about various products various features of the products and just see that how the particular x is addressed right at the design strange. Suppose right now you are sitting on the chair can you analyze the chair? You have put your laptop on the table can you analyze the table in terms of DFX? You are watching my video on the laptop can you analyze the laptop?

So, please try to analyze couple of say products in terms of DFX and just try to tick mark in a tabular format select three products that what are the X you feel that are really addressed in what way buy a particular product at the design stage.

(Refer Slide Time: 30:45)



(Refer Slide Time: 30:51)

So, with this you can go through this particular reference to have little bit more idea. And DFX helps to improve the quality and robustness of the product or process right at the design or concept stage. So, thank you very much for your interest in learning the concept of DFX, we have talked about various kinds of X that must be addressed in a cross functional manner by including the various stakeholders internal and external whether it is your manufacturing department, purchasing department, your packaging department marketing or maybe your supplier or customer or distributor.

And if you do this you can really develop a product which is sustainable for a long period of time because it is a highly competitive market and we will really catch the loyalty of the customers. So, we will continue with couple of more topics till that time keep revising keep introspecting keep applying be with me enjoy.