Product Engineering and Design Thinking
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Module - 02
High-Level Design and Fuzzy Front End of Innovation
Lecture - 08
Functional and Physical Decomposition and QFD

Welcome back to the 2nd module as we are discussing. The 2nd module is High-Level Design and Fuzzy Front End of Innovation and the 8th lecture here is on Functional and Physical Decomposition and Quality Function Deployment or QFD in short.

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So, as usual first I would touch on the concepts covered. And the functional and physical decomposition will be elaborated further as we started discussing in our last session. Product

architecture which would be actually discussed with the two of its components mainly like say functional decomposition and the physical decomposition physical elements and when we were discussing the product; that means, we are also discussing in the same way its different variants and the variants together forms their family.

So, we are also a presenting generic format on product family architecture which simply can be considered as a product architecture if we consider a singular variant. The importance of this decomposition in respect of high level design is discussed here again because that is very very important in terms of creating the frontal phase that is high level which is the basis for taking on the LLD or the low level design.

Then we will talk about the functional design which is actually the a conceptual entry and in this context we would use we would discuss one methodologies that is called quality function deployment which is very commonly used and is very useful and it is very I would say easy also to use. And definitely we would be discussing on this QFD model further in subsequent lectures, but this being the session on the functional design we will touch upon this topic as it is logical analysis is required.

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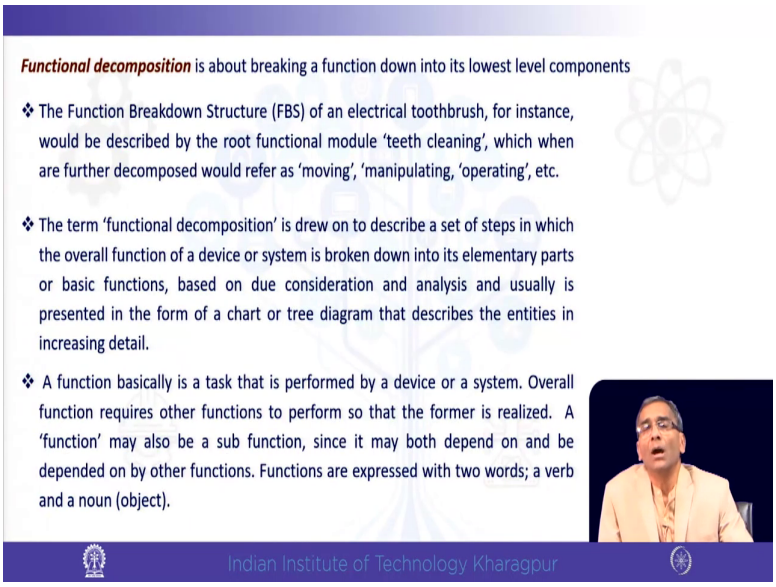

Now, functional decomposition basically it is about breaking the function down into its lowest level components the basic level of components. So, the functional breakdown of electrical toothbrush for instance would be described by the root functional module that is teeth cleaning that is the main purpose of the toothbrush though it is an you know electric operated toothbrush which can manipulate operate etcetera.

Then therefore, that teeth cleaning the function which when further decomposed that because we are decomposing the function what are the different function the elemental function because the idea is if we can go and break down the functions and then we solve those functions; that means, how to address and achieve those or realize those functions if we can do then the whole or the complex functionalities are achieved.

So, that breakdown is for that purpose that complexity is broken down into simplicity. Hence, if we take this teeth cleaning further and decompose it we would see that it is moving the brush, manipulating, operating etcetera. The functional decomposition the term is drew onto describe the set of steps which the overall function of a device or system is broken down into elementary parts or basic functions.

I have already mentioned this. Based on due considerations and analysis and usually is presented in the form of a tree diagram or a chart how it is coming as a top down model. A function what is a function? The function basically as a task that is performed by a device or a system overall function requires other functions to perform.

So, basically when a function is happening it is supported by other functions which again is supported by other functions. So, it is a hierarchy of functions. So, in the tree structure we would see that how the bottom level functions are contributing to higher level and ultimately going to the top level or the overall function or the function of the product that is to realize like in the case of tooth brush that I am just given example as.

A function may also be a sub function as a function is a term may be a sub function or sub function since it may both depend on and be dependent on by other functions as I have just explained. Now, it is interesting that any function can be expressed with 2 words a verb and a noun or that object. For example, if I say what is the function of a ceiling fan? The answer is; obviously, circulate air or circulation circulate air that is a verb and a noun or the object.

What is the function of a refrigerator? Cools product. What are the function of a automobile? Transport people. So, it is always is with a verb and noun and that is the best definition because that definition very precisely very precisely hit upon the exact activity of performance needed from for that.

So, now there are. So, when I am saying functions I just would like to make a mention here that I have talked about say for example, the primary function, but there are other functions also. For example, when we say that what is the secondary function of fan of that ceiling fan

that we talked about? The answer may be the primary function of course, is a circulate air, the secondary function is of course, is may be the to decorate room or decorate space.

Now, there is still another function which is called tertiary function which often is called esteem value or esteem function which adds the brand value or the image of the product in the market. Like say when it is a high branded fan or refrigerator or shirt or any camera or mobile then that tertiary value is there. But now for our discussion we would be talking about the functions in a general.

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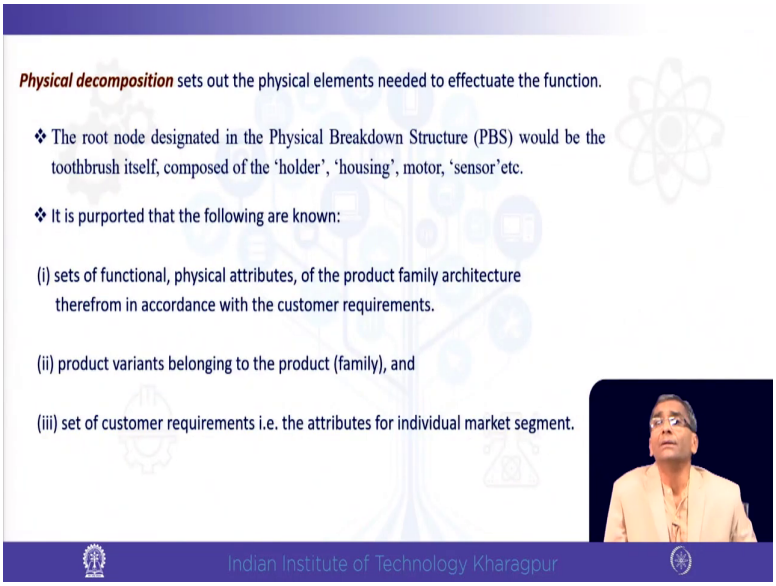

And would now proceed on to the physical decomposition after we have discussed the functional decomposition. It sets out the physical elements needed to effectuate the function. So, the function is one and how the function will be catered, how the function will be

effectuated that is the you know the physical element and therefore, the physical element will be will have to be broken down to take an image means the means would be a camera.

So, for example, the root node designated in the Physical Breakdown Structure or PBS would be the toothbrush itself in this case in this example of toothbrush composed of holder, housing, motor, sensor etcetera. So, the functions as we had discussed that it is moving, operating, maneuvering etcetera and these will be accomplished through these physical elements which I have just now named.

It is purported that the following are known what one sets of functional physical attributes of the product family architecture they are from in accordance with the customer requirements. That is the first one in accordance with customer requirements what the customer wants, what the customer needs.

Product variants belongs to the product family and set of customer requirements there is the attributes for individual market segment. So, when we are talking about a product essentially we are relating to a particular market segment or the target market. So, to say there are different varieties of cars, some cars are luxury cars, some cars are low end cars. Similarly, if you look at bicycle the bicycle may be available at 3000 rupees a bicycle may be available at 20000 rupees also.

So, so, is for the mobile phone so is for very very many other products. So, when we are talking about a product we must and its functions required and its features required and the customer need in particular we should always be at this blind that the product is always intended for a market target market.

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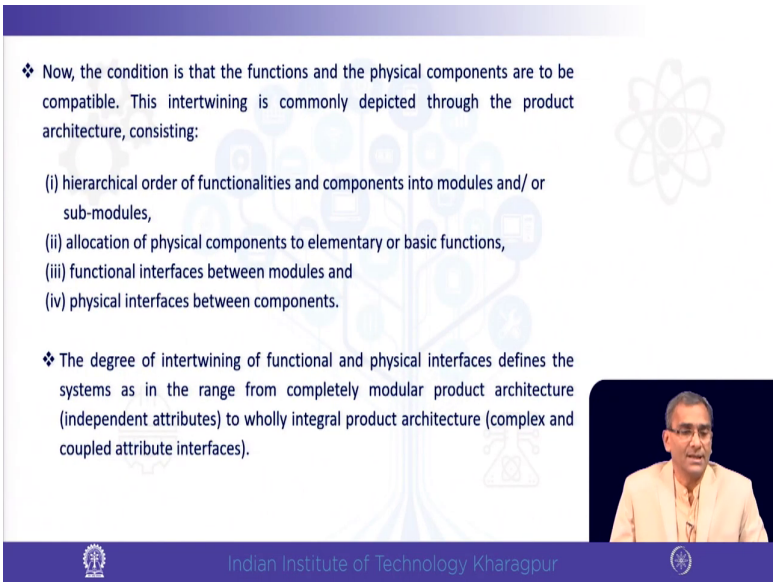

So, that is the thing. Now, the condition is that the functions and the physical components are to be compatible. Obviously, the when incompatibility cannot deliver the function through that physical element or physical path or component. This intertwining is commonly depicted through the product architecture consisting that architecture we have been talking about a little while ago.

Hierarchical order of functionalities and components into modules and or sub modules. So, a basic a basic architecture say car is having say its engine, its transmission system, its electrical system, its steering system and so on and so forth. Allocation of physical components to elementary or basic functions. So, which physical component will perform what?

Which would roll the film in a camera is that you know the lever through which that function is to be accomplished. What is that button which will change the screen? So, these are the physical part and that is the function to be realized. Functional interfaces between modules because after all the it has to act as a whole. So, the function should have interface between them. Physical interface also naturally would be necessary. So, that goes without saying.

The degree of intertwining of functional and physical interfaces defines the systems as in the range from either completely modular like you see in your laptop or any say on your mobile phone it is modular. Say if hard disk is defective one can change the hard disk if the motherboard is defective or is to be replaced or the construction is like this. The design is like this ultimately. So, it is modular.

Maybe you also have heard in recent time things called modular kitchens where depending on the need you can keep on adding the you know units. So, modularity is a important consideration in design and already another aspect is that if suppose it was not modular, but it was all interconnected and consider it is a whole and it is integrated product that also is possible.

But, but these are the two features that we are talking about that which will have complex and coupled attribute interfaces. This these are the two extremes.

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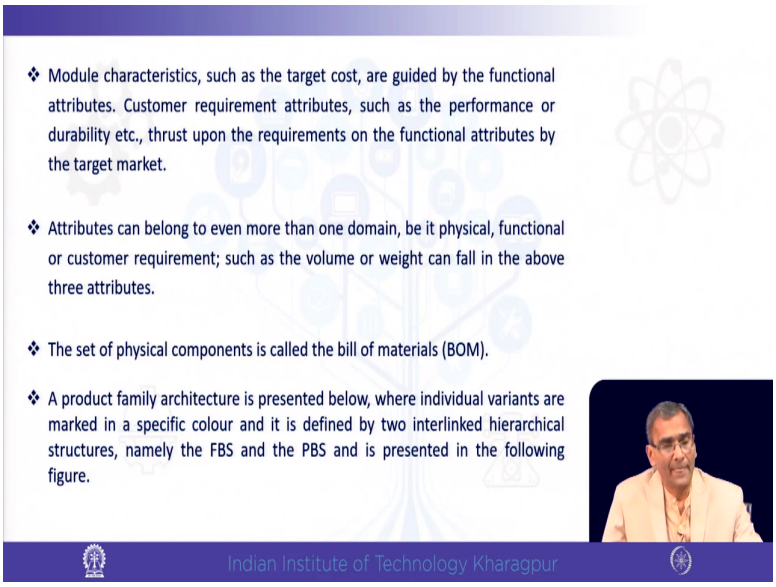

Module characteristics are such as target cost that is the target cost is that it is the; it is the cost at which the product needs to be built. It is not the price. Price is at which the product needs to be sold. When we sell a packet of biscuit in the market at a price say 50 rupees its target cost may be 25. Question is why? Question is because there will have to be a margin for the organization that is manufacturing it.

So, cost and on top of that part of profit. Then there would be distributors who will also keep some margin and then the retailers from whom you buy a packet of biscuits every day. So, that is the retailer's margin. So, if you remove those margins then the cost becomes nearly half or say 60 percent of that or something like that. So, that is to be borne in mind. It is not only for biscuits, but it is true for practically all products.

So, target cost is very important. These are guided by the functional attributes, customer requirements attributes such as the performance of a product. Its durability how long it will endure how reliable it will be reliability in functioning how robust it is. So, these are the customer requirement attributes. These are thrust upon the requirements on the functional attributes by the target market.

So, target market asks for this that it needs to satisfy this, it needs to have this kind of clarity in the TV screen of the TV screen. This will be the quality of audio, this will be the voltage stability of the battery so and so forth. So, these are the things that the market thrusts upon on the functional attributes requirement.

Attributes can belong to even more than one domain be it physical, functional or customer requirement such as the volume or weight that can fall in the above three attributes. That is the see for example, a laptop. It has the that laptop will be a customer requirement, the lightweight, the lightweight of the customer requirement, its size and lightweight at all.

Similarly, its functionality and its components or physicality also will have to accommodate the same. So, those are the issues to be considered together. Now, when we are talking about the physical elements after breaking down, they form the list of items. The list in the list is an English word which normally in American word is called bill and from that a common a very popular term bill of materials have come. So, it is called in short bom or bill of materials.

A product family architecture is presented below, will show where individual variants are marked in a specific color and it is defined by two interlinked hierarchical structures namely FBS and the PBS the Function Breakdown Structure and the Physical Breakdown Structure and is presented in the following figure.

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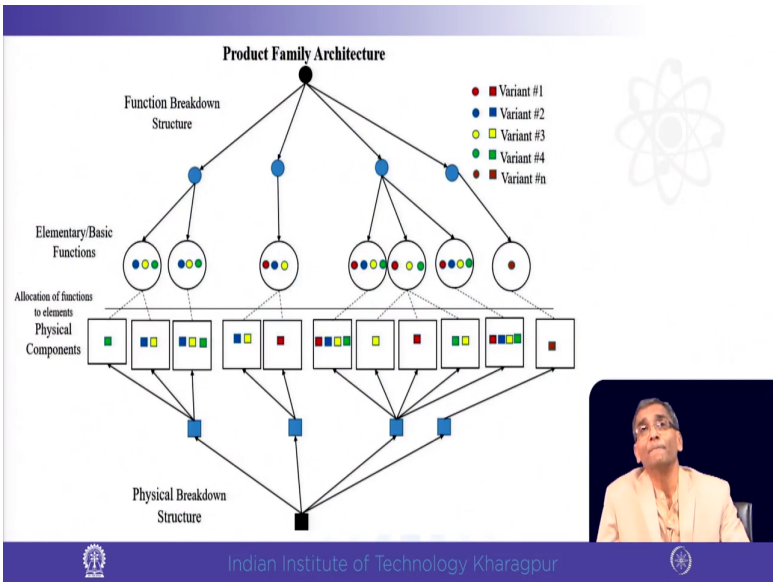

The figure is something like this which tells us that product family architecture on top. So, if you remove the word family, it becomes one product, just one variant one variant, but. So, you can look at any of the nodes. So, the product architecture if we break down the function through the function breakdown structure, you would see the elementary or basic functions.

And from the bottom if you see the physical breakdown structure, then we would see those elements that in terms of further decomposition, these are decomposition, let us say blue node to the subsequent decomposition is happening. So, at the lowest level we are showing the decomposed variants and similarly the physical components are there in the physical breakdown structure.

Now, these are the physical, the allocations of functions are to the elements, the physical elements which function are to be catered by future element. So, that is the interconnectivity

which is shown through a dotted lines which is you know indicative lines from that it is a; it is a indicative diagram. So, that from here you understand what is this.

Now, what these colors are? If we choose any single color say red, then it becomes one variant and wherever the red dots or red squares are appearing, only that will be the product structure, simple. So, this diagram shows say four variants or n number of variants if that say brown color spots are also to be considered, but that is a generic this thing, but I would explain basically with those four variants. Now, red, blue, red, blue, yellow and green, these are the variants 1, 2, 3, 4.

So, if you find only red, so, grades will be that product structure. Similarly, if it is blue that will be that product structure. So, somewhere some functionality is there and in some variant that functionality is absent or rather another functionality is may be added and those are catered by the physical elements.

This is the one I mean it is quite self-explanatory, it is easy to understand that is why in fact, I have developed with this color code. This color coded diagram is not available though these variants are available in a different other formats, but this will help you to understand it very easily.

So, that is a diagram that I have prepared may be it will be of help. So, you can study that later in quietly and with taking time and you would understand it very well.

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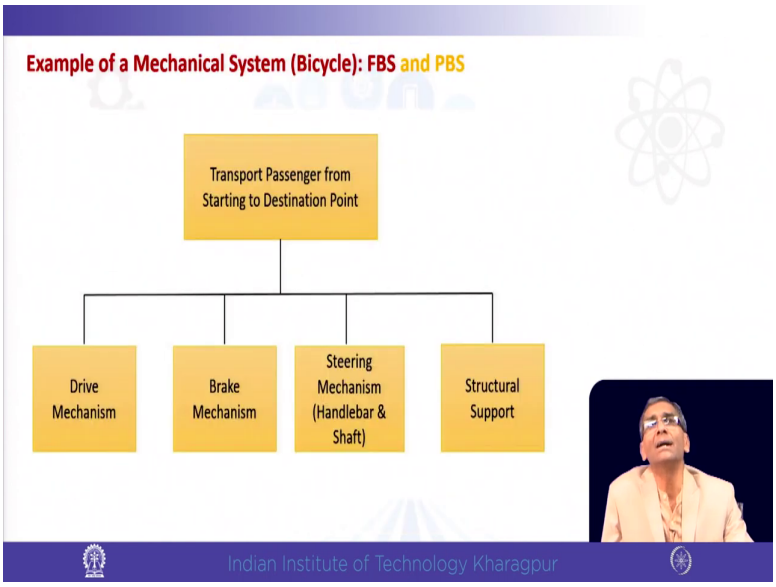

Just an example of mechanical system which is a bicycle. Here if we do functional breakdown structure by and physical breakdown structure in this slide we are showing only FBS, Function Breakdown Structure and the next slide we will be showing that physical breakdown structure. It is a simple just to present an example, transport passenger from starting to a destination point.

So, that is the purpose of a bicycle. Now, if we look at the function then we would see that the drive mechanism, brake mechanism, steering mechanism, comparison with the handlebar and the shaft, structural support, that frame etcetera are there.

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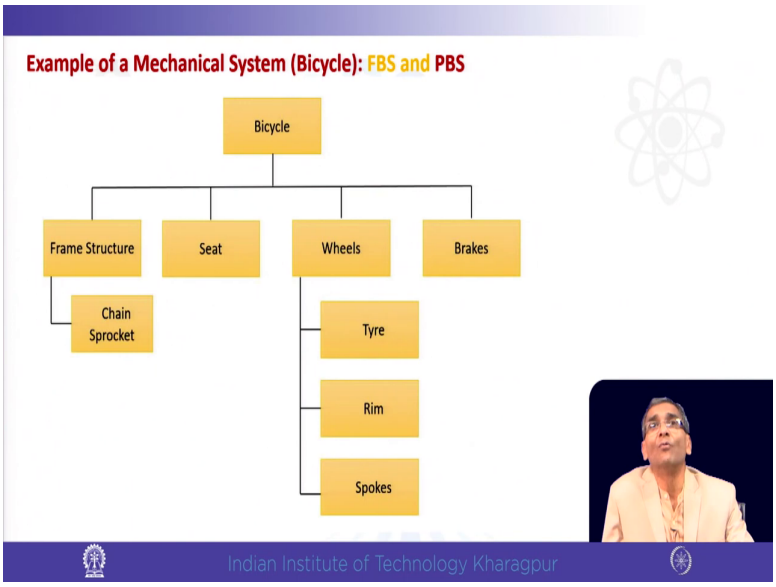

Now, to cater to this what we need is the physical breakdown structure. The physical breakdown structure is a the main whole entities of bicycle itself. Like the example I said the whole entities tooth brush itself. So, now if we break down very well you can see that if we break this bicycle down into its elements we will have frame structure, seat, wheels, brakes.

Again if we break down the wheels we would further decompose it as a tyre, rim, spokes and those elements. So, why are we discussing this? We are discussing that because these breakdown is absolutely necessary because the we are the it is a hugely difficult to solve the whole problem, the large problem which is a complex one as a whole. So, basically we break the whole thing down and then we create the separate solution for each and by solving each we solve the whole you understand.

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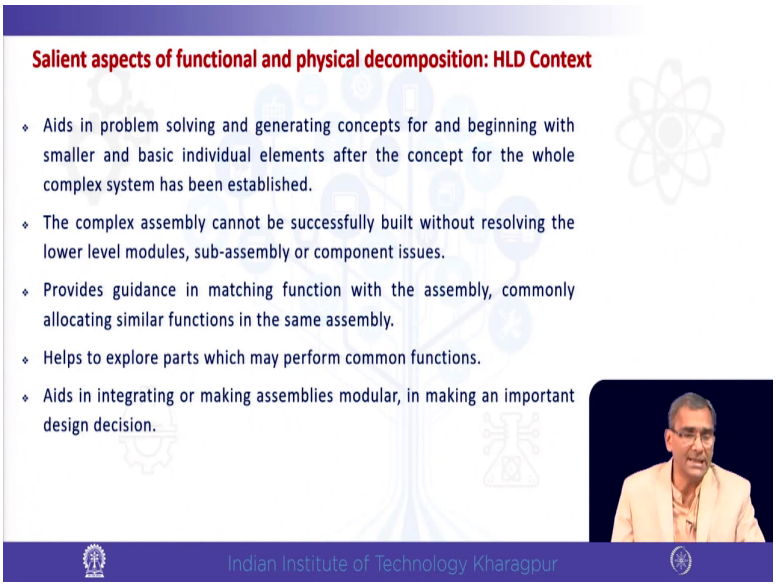

Now, this is an important why are you discussing this functional physical decomposition as I just mentioned, but more explicitly here it would be it aids in problem solving as I said that it problem solving for each element solving and generating concepts for and beginning with smaller and basic individual elements after the concept for the whole complex system has been established.

So, after the whole complex system is established we are breaking it down and we are solving individual problems thereby we are solving the problem of the whole. The complex assembly cannot be successfully built without resolving the lower level modules or subassemblies or components and those issues involved.

This provides guidance in matching function with the assembly, commonly allocating similar functions in the similar assembly helps to explore parts which may perform common

functions. This is a very important a part dual activity. So, that is also needs to be taken into consideration.

Um Aids in integrating or making assemblies modular as I just spoke a little while ago because modular design is an important feature and modular design is helpful many ways from the replacement point of view, maintenance point of view and therefore, in the context of total cost of ownership of the product. If the maintenance becomes easier and cheaper, then that is the option the product designer would like to take.

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Now, in the last leg of our discussion we will talk about the functional design. Functional design refers to mapping a set of customer requirements which we already have discussed to a set of functional requirements that is the design aspect. From that we will come down to the

lower aspect of designing say is a conceptual design and all, but first we have to start at this stage which is the functional design.

Designers have to extract pertinent information from huge divers as we said in the front end that there are various sources in diver sources. Sometimes the customer responses are also not very consistent and the responses are also quite unstructured. So, in that given situation that this gives a primarily intangible solution neutral and rather subjective and consequently its outcome that is functional design that is necessary.

It influences heavily in the formation of innovative design thinking especially in the front end because things are rather fluid and information data is rather subjective. So, by and by we have to bring it to the core and forth. So, this is about managing coupling of Customer Needs or CNs and Functional Requirements or FRs focused on dependency relationship because they have interrelationship.

How the customer requirements are to be met through the functions or rather as we discussed in our earlier discussion how, what's and how's, how, what's will be met by how's, how's means how's, how's. So, many what's the customer requirements are what's and the means or sometimes called technical descriptors are the how's and for this a very handy tool is QFD or Quality Function Deployment that combines or that brings in the these two the CNs and FRs in a metrics form which is very easy to comprehend.

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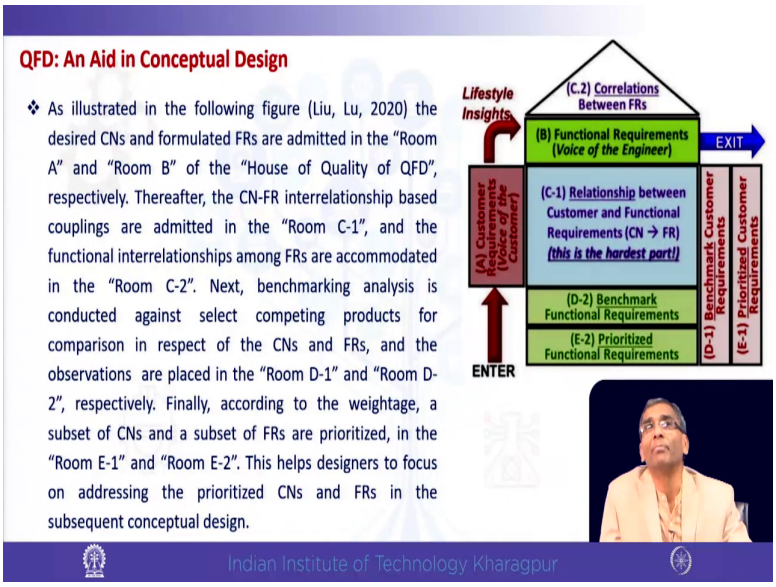

And so, here and it is also often called a how's of quality or it is also called voice of customer because the voice of customer is being captured through this model. But I will briefly tell you we will discuss that in detail, but since we have to set the context I am just presenting it as a case that if you just look at this on the left hand side in the that red box you will find the customer requirements and that the on the top you would find the functional requirements.

Now, on this left; that means, the if you see on the 90 degree angle on the horizontal plane you have the customer requirements and on the vertical plane you have the functional requirement. So, when the horizontal and vertical intersection happens it gives that relationship metrics which is that this customer requirement to the functional requirement. It looks like a house as we used to draw in our elementary schools.

So, that is how the name came and it is called house of quality and so, apparently in a house there would be several rooms. So, this is what the explanations are and of course, we will discuss in detail, but since it is helpful in conceptual design it is necessary that we make a preamble here that the relationship appears in the middle which is in the blue room or the room number C 1.

And the A is the room for the customer requirement B is the room for the functional requirements and it gets the allocated in the rooms C 1 and then the interrelationship between the functional requirements are in C 2. Say for example, there may be material and process which are compatible to each other.

Say for example, die casting for die casting if it is a process it is more suitable for aluminum than steel. Similarly, if it is welding it is more suitable to steel than aluminum or some other metal. So, that is the interrelationship between the functional requirements and therefore, you can see from here that the observations are placed in room D 1 and room D 2 that is the benchmarking analysis conducted against the select competing products.

Where competing products means where the best in class say this company or a enterprise that organization that is talking about or the product that we are talking about vis-a-vis the competitor's product that is being compared. So, that comparison the one the functional and from the customer both are compared in this and from that the prioritization happens which is the priority? Priority means on which we have to act.

So, after analyzing all may not be priority the priority is where customer is paying maximum attention or emphasis. So, that prioritization is necessary for conceptual development, conceptual design development and this prioritization both in terms of the customer requirements and the function requirements are necessary that we finally, get from this diagram of QFD in this context.

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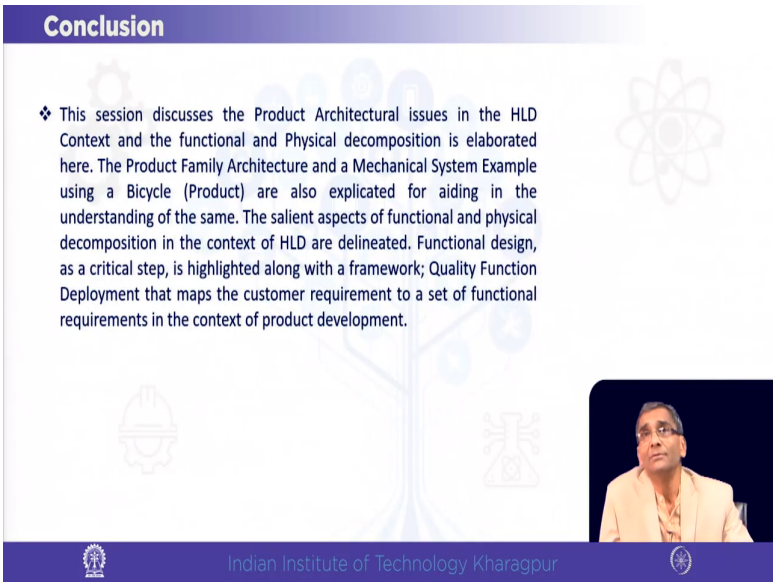

Now, after saying this which you have understood why the importance is I would conclude by saying that we have discussed the product architecture issues in HLD context and the functional physical decomposition is elaborated which was absolutely necessary to understand. We have discussed the product family architecture or product architecture family because we have considered various variants.

We have taken up the example of that bicycle product and the salient aspect of the functional physical breakdown structure is also discussed. In the context of HLD functional design as a critical step is highlighted along with a framework, the framework here is in the form of QFD that we have discussed which is to understand the requirement versus the customer requirement versus the functional requirement and that would help to proceed in the conceptual design domain.

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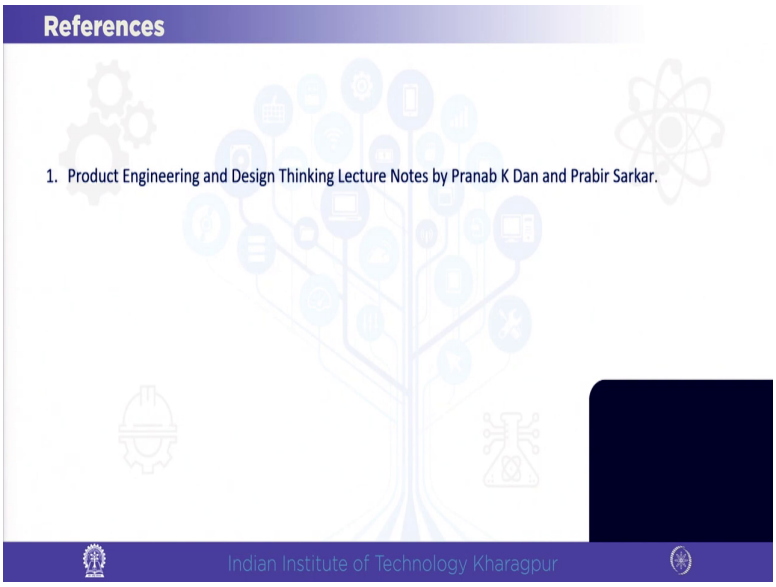

And the reference is this the Product Engineering Design Thinking lecture as we are presenting. So, this will be a good source of or study that you can use later. So, that is why the material that I have prepared it is in textual form. So, that later on when you see this you can look at the contents and learn it nicely. Thank you very much for attending this session, this lecture and hope it has helped you and.

Thank you once again.