**Advanced Green Manufacturing Systems**

**Prof. Deepu Philip**
**Dr. Amandeep Singh Oberoi**
**Department of Industrial & Management Engineering**
**Department of Mechanical Engineering**
**Indian Institute of Technology, Kanpur**

**Lecture - 18**
**Green Quality Function Deployment - Part 2**

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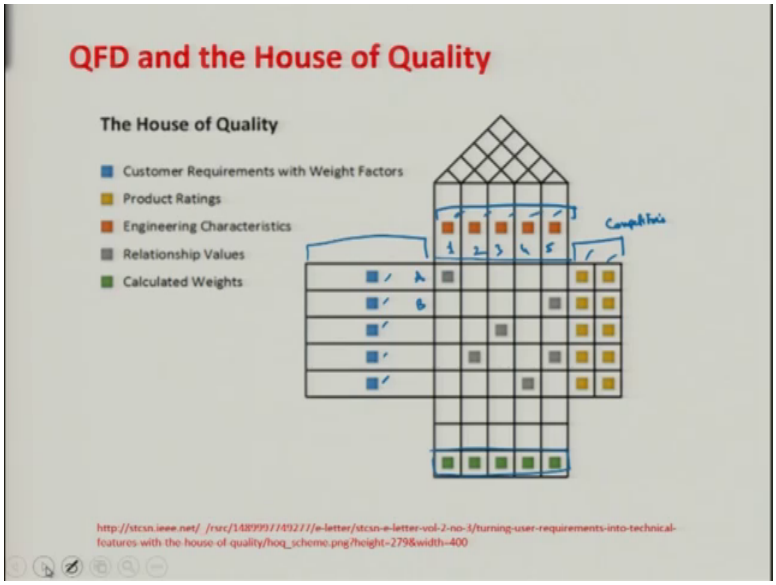


Good morning, welcome back to the course. In this lecture, we will discuss Green Quality Function Deployment. So, these are the rooms that we have discussed.

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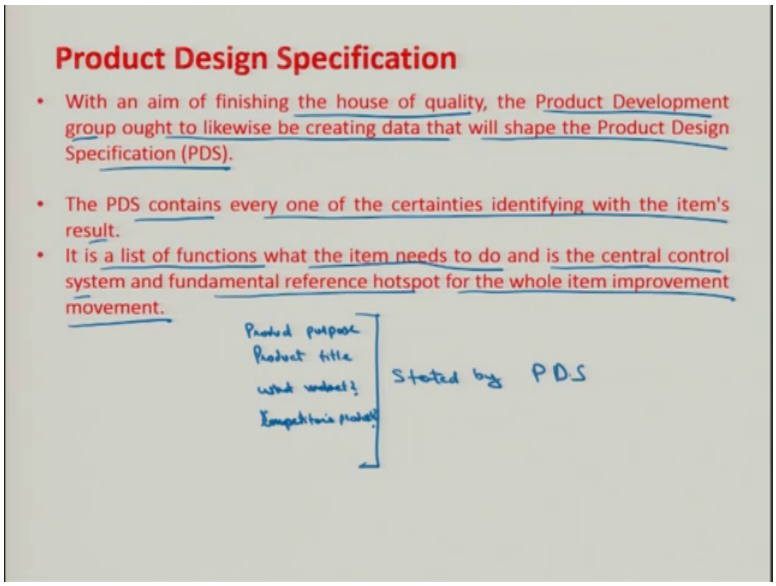


Next is product design specification. When we think of when we are going to design a product using quality function deployment product, design specifications need to be known. The certain specifications that can be considered. With an aim of finishing the house of quality, the product development group ought to likewise be creating data that will shape the product design specifications. The product design specification contain every one of the certainties identifying with the item's result. It is a list of functions what the item needs to do, and is the central control system and fundamental reference hotspot for the whole item improvement movement. So, these are product design characteristics.

So, this can be may be product title or I can just put product purpose, these are things that are stated by a product design specification the product title, what is the product. Then what market is there what market would be there ok, then why is the need, so what are the competitors products to against which kind of product segment is it going to come ok. These are the things which should be stated by product design specification.

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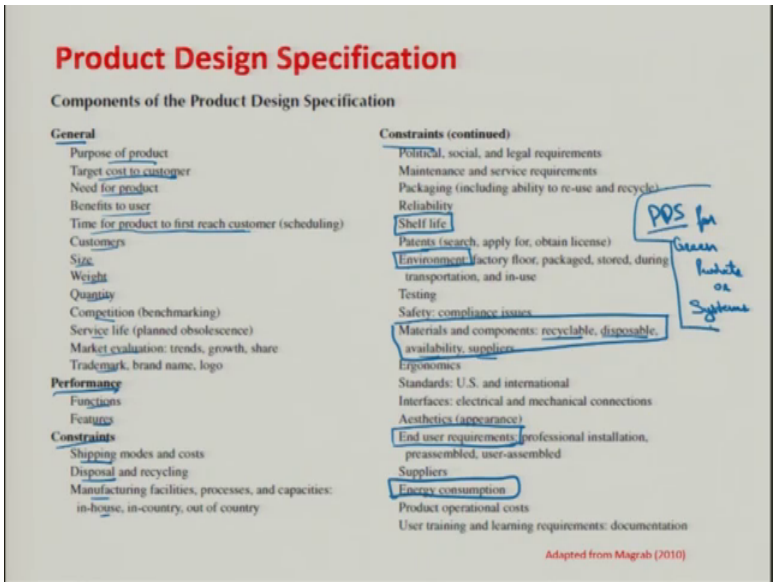


Such a product design specifications can be classified in these ways general, performance, constraints. General all purpose of the product, target cost to customer, need for the product, benefits to user, time for the product put to reach the customer, customers, size, weight, quantity, competition, service life, market evaluation trademark.

Performance is functions, features. Constraints can be shipped, disposed, manufacturing, what I need to make the point here is that. In the constraints, we can think of energy consumption as one of the constraints. Also we can think of the environment though they are talking about the factory environment, we can think of the environment. Also we can think of the end user requirement, then recyclability, materials and components is it recycle able is it disposable, is it available or the suppliers recyclability, then shelf life. So, these are the things that we can consider. So, product design specifications that we can consider for green products, and QFD can also be applied to services and systems. So, I will put products or systems ok.

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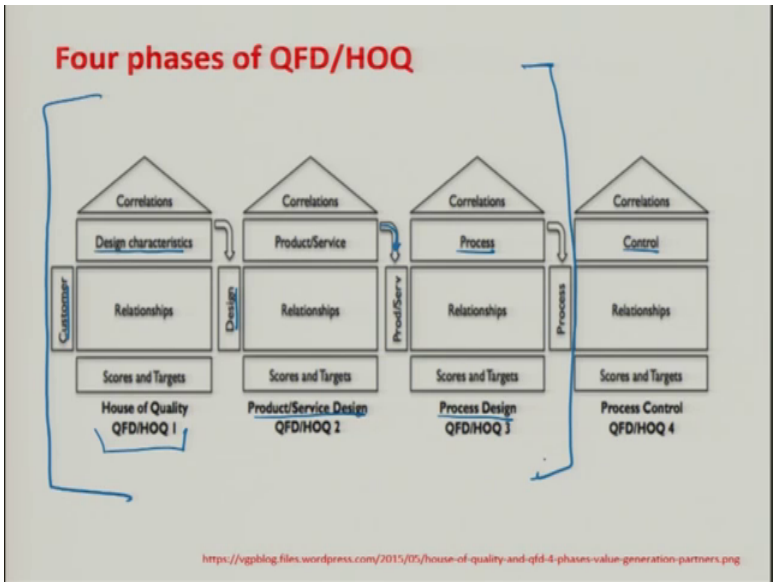


QFD is generally run in phases. The first we what we have seen, we had the words from the customer taste, cost, appearance, we had the technical requirements or not exactly technical we had the quality requirements weight, size, but can manufacture use these requirements to actually build can he decide what kind of heating process, he would be used to bake the biscuits, what kind of material would he use.

In a example what we had, we had the customer voice, so the voice of the customer. The customer voice was translated into design characteristics. Now, these design characteristics using the house of quality phase-1 are got and they become the input for this 2nd-phase. This is 2nd-phase the 2nd-phase is the first phase was house of quality, the 2nd-phase is product design phase in which design specifications become the input, and the product of service characteristics are developed.

Now, these go to the phase-3 these go to phase-3 to get the process is which are need to be used to actually manufacture, this is process design. Next we have the process is and the control how can we control the process. At least these three phases are there. So, process control if not developed or established, at least the process which are there are to be mentioned, so that is there with the same example.

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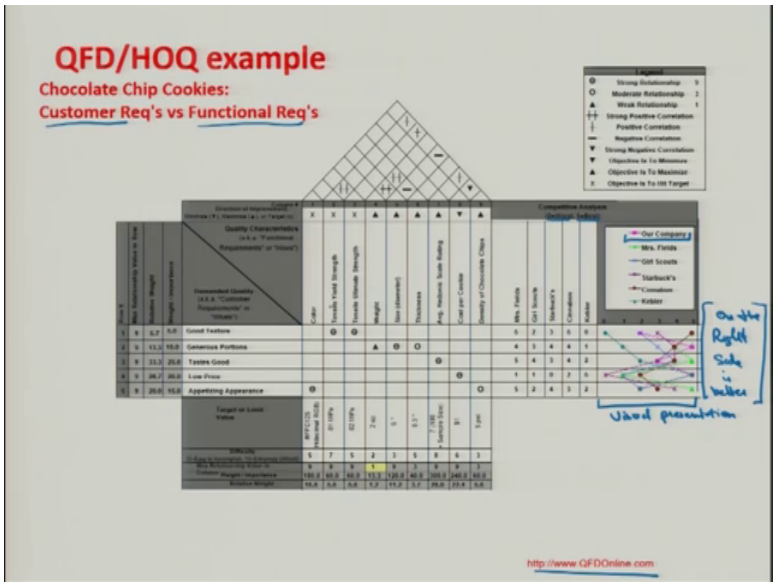


You can go to this website also to see the details in this example. This were the customer requirement and functional requirement, those are related this functional requirement.

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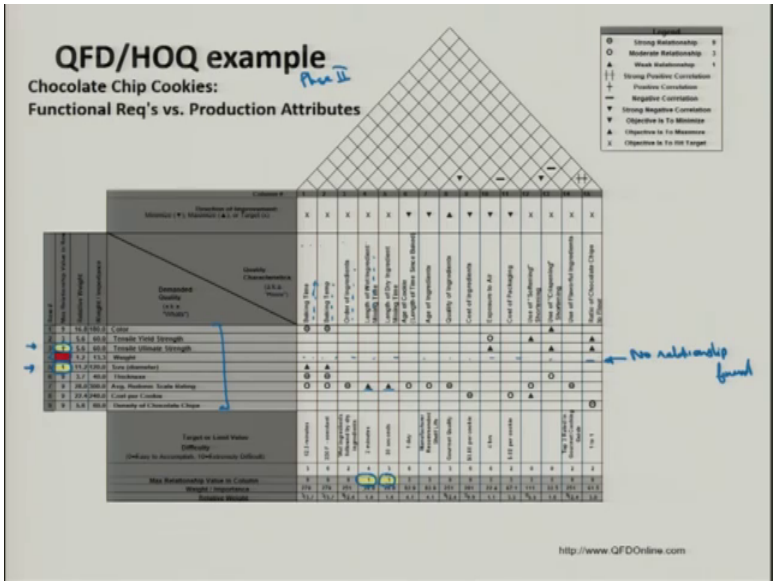


Now, these are the kind of design specifications, which makes our input for the 2nd-phase, this is phase-2 ok. This was phase-1, this phase-2 is something where we get all these design details baking time ok. And (Refer Time: 06:03) specification you can say baking temperature, order of ingredients, length of wet ingredients mixing time.

Now, we get these values, you might be noticing a few highlighted values here. These are the values 1, and red color, and 1. These are the values 1 and 1, what are these values. The weight in row-4 is not being addressed, it is red, it is not even present here, no relationship found right. So, weight is not even being addressed, these values 1 and 1. The row 3 and row 5, these values 1 means, they are not being substantially addressed, because they are not having a great contribution towards our analysis here. Similarly, in the previous matrix this weight was 1, this is also not significantly addressed. Because, we can see their maximum relationship value is too low it is 1 and 1 that and the maximum value is one only. So, these are not been addressed.

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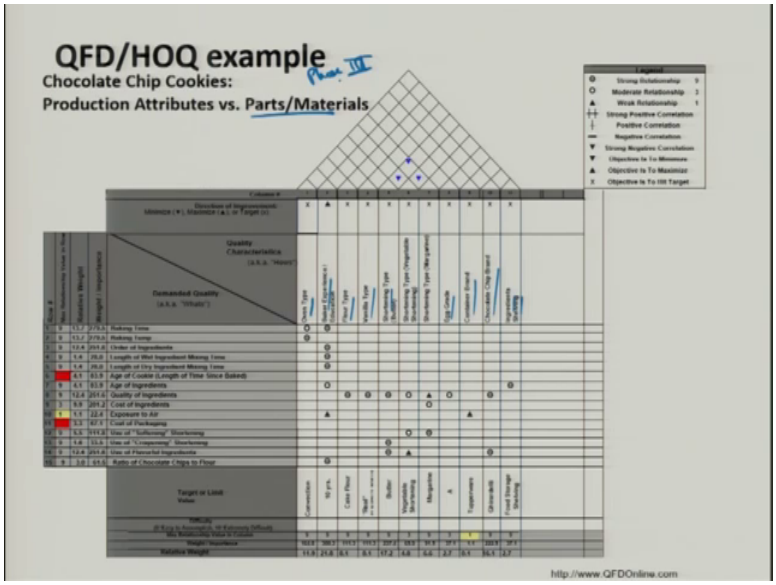


Next phase we have the phase-3, where we get the parts, and the materials the oven type, the baker experience, flavor type, vanilla type, shortening or the butter that we need to put egg grade, container, chocolate, ingredient or shell wing. So, this is the third phase, third phase in quality function deployment or house of quality. This is the way we get to translate the voice of customers to the manufacturing specifications in three or four steps. So, this is quality function deployment.

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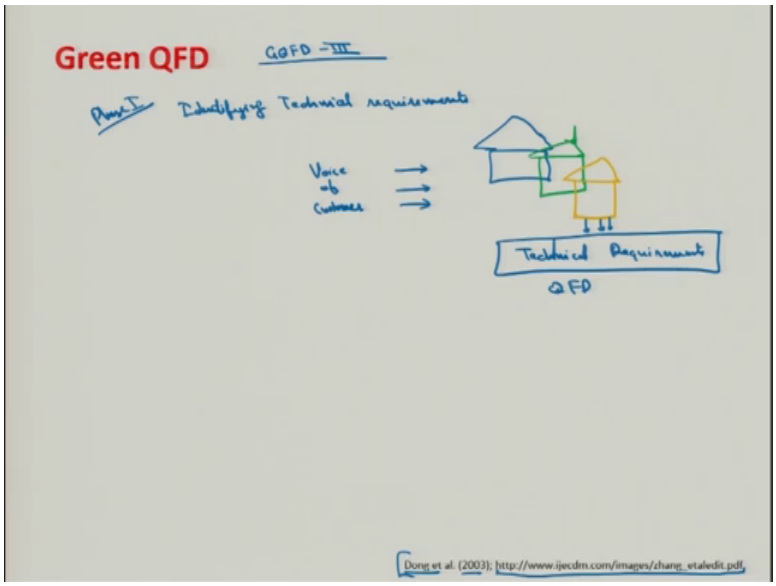


Now, how can we divide this green quality function deployment or green house of quality? Green quality function deployment, this is the study done by dong et al and you can go to this link to read the whole paper, this is the research paper which was done in 2003.

This had there a certain phases to establish the green QFD, they call it GQFD-3. First phase is the general phase in which we get the voice of customer to the technical requirements. These are done through these HOQ's house of qualities. First HOQ, then the second HOQ would come ok, then the third what would come right.

So, these will give us the technical requirements, those are gotten from these. All these illustrations are adopted from this research only dong et al. So, this is the QFD that we conduct. So, voice of the customer is the input, and we get a technical requirement. So, this is the technical requirement or identification or identifying technical requirements. This is phase-1 in GQFD green quality function deployment.

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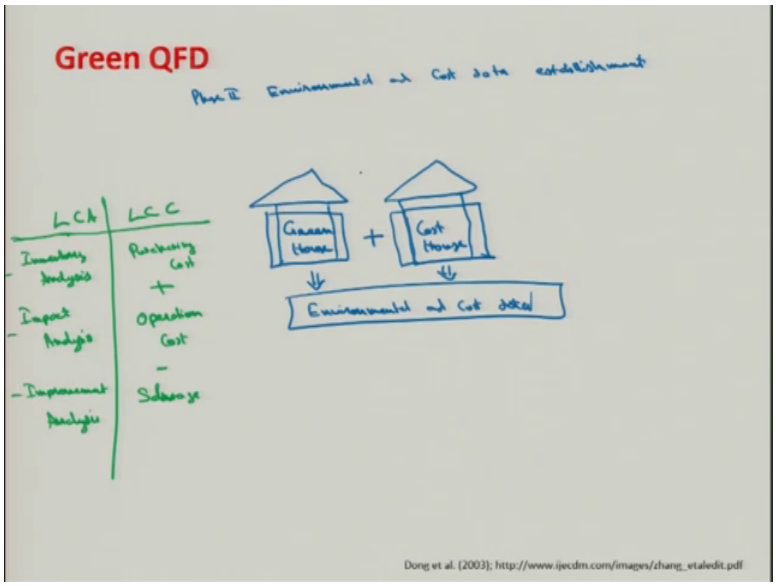


Next is phase-2, in phase-2 what we do, we have two houses. We get to make green house, and cost house ok. This is the green house that we make, and a cost house is made. These two houses when they are taken together, I am putting a plus sign here. They give us the environmental and cost data ok. Input is from this side, and from this side, this is phase-2, and cost data establishment right.

Now, what is this environmental data? Environmental data, we have here lifecycle assessment, and lifecycle costing lifecycle costing as I said, it is the purchasing cost plus operation cost minus salvage cost. The total lifecycle, the total cost that is spent on the product for the whole lifecycle, you purchase a bike the bike the cost of the bike rupees 50,000, you use the bike for 10 years in 10,000 you have spent. The price on fuel and the maintenance that means, that price is around 100,000. And you have sold the bike at rupees ten 10,000 so that means, 50,000 the purchasing cost plus 100,000 that is 1.5 lakhs minus 10,000, 1.4 lakhs is the lifecycle cost. So, we can compare such an products in the similar range using lifecycle costing.

Lifecycle assessment is when we have inventory analysis, impact analysis, improvement analysis, I will tell you this is inventory analysis, then impact of the product to the environment. And can we improve it, improvement analysis ok. These are certain stages, I will discuss lifecycle analysis in very detail in the coming sessions, which I will take next.

Lifecycle cost is the purchasing cost plus operation cost minus salvage. So, these are the inputs in green house. Cost house is a general cost house that we have seen in the cost of the product that we can just estimate or we from the past data. The certain ways to estimate the cost, the certain ways to do the cost analysis those are does it different indent. Cost analysis is simple we are now more concerned about the green house here both, green house and cost house make the input in phase-2.

Next phase here is now in lifecycle assessment, this suppose considers all the material and energy transfers, which are involved in raw material extraction, processing, and manufacture including cradle to grave of a product while lifecycle costing is a methodology used by designers in conjunction with lifecycle assessment, it takes into account the cost involved in handling, processing using and so froth and salvage in all the lifecycle stages of the product. So, these two are the inputs to the houses and we get the environment and cost data.

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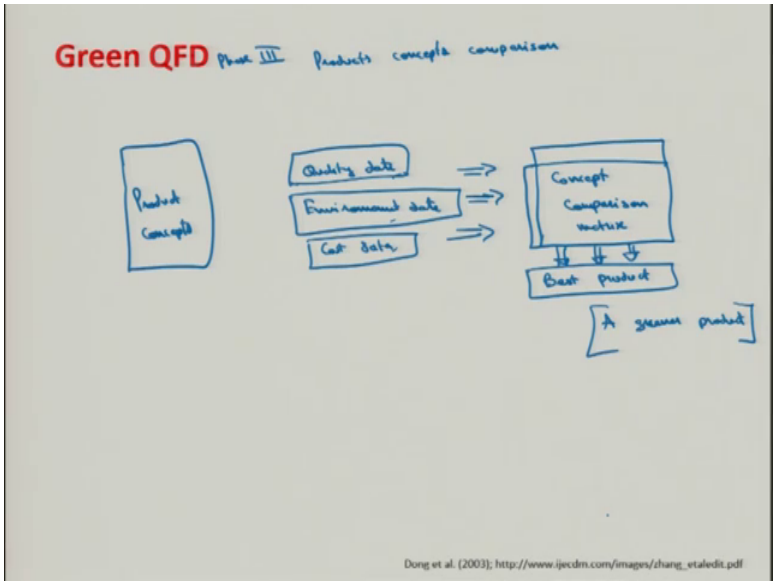


Next come the third phase. Phase-3 is product concepts and comparison phase. What happens we get the performance data or the quality data, the environment data, and the cost data. These are now given as input to the concept comparison matrix, which again to another house again right. So, there are certain product concepts, I can put here product concepts, different concepts for the products are there. And using these data these

different kinds of data these goes as input to our concept comparison. So, we get the phase-3 in this way that is product concepts comparison.

So, what essentially in these phase, in phase-3 the concept comparison matrix is established this matrix is established, in this matrix all the product options under consideration are documented with their quality, cost, and environmental attributes. These data derived from the house of quality, the green house, the cost house that we had in the previous phase, these data's developed from here. Those data are given as input here the choice for the best products option is made in this phase, we get the best product here. So, this is the final output in this phase right.

Next is the product process design phase, we just need to select the best product based upon the green criteria, because we had we have green house here, we have cost house here. This green house is now bringing in the ecological factors or the sustainable factors here, so the product that we have got here is now a greener product or choice. If we if we are comparing one or two products, this is a greener choice that we have taken, and also cost and performance is taken into consideration.

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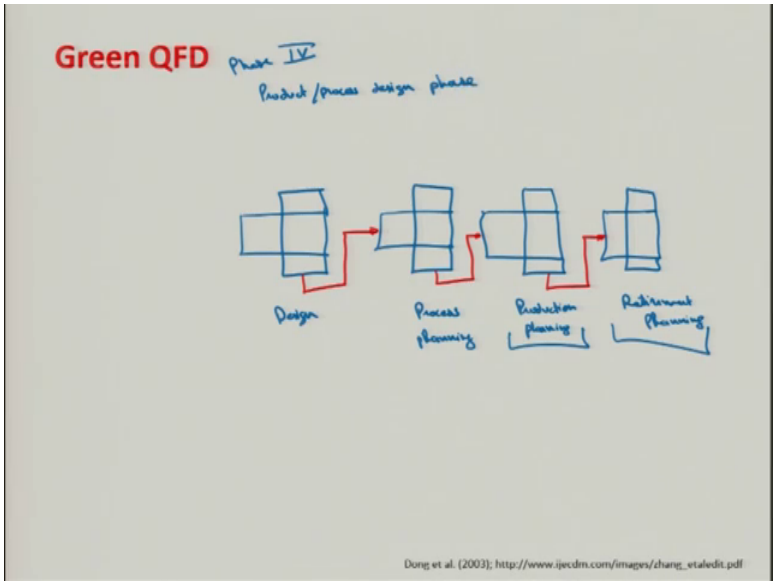


Next phase for is the general QFD phase, we again have the four phases of QFD with us 1, 2, 3, and 4. So, this is design process planning, then we have production planning, then we have retirement planning, because we also considering the green factors retirement planning is the part of the green QFD. Green QFD is end of use or after use if we

remember, you have three phases before use, during use, after use. All these phases we also see how we can put there, so that the government planning part of the QFD green QFD here is a process planning. So, this is design deployment. .

So, these goes as input in here second one, these goes as an input here, and these goes as an input here. So, phase-4 that is the product and process design phase. In this QFD techniques are utilized to develop an optimized manufacturing process for the product concept that is chosen in phase-3, the product is chosen here this product is taken to phase-4. And finally, we have this production planning, and retirement planning. These two are the development in the phase-4, so phase-4.

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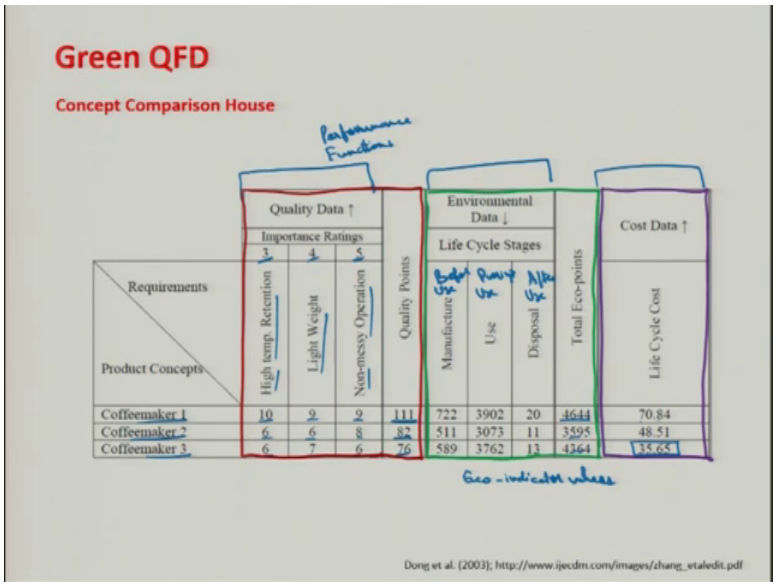


Let me put it in a clear way phase-4 is our product or process design phase. This Dong et al has conducted a study in comparing the coffee makers, they have developed this data, quality data, environmental data and cost data. If this is a house we can say this as a complete house quality as a complete house environment has a complete house or you can say these are rooms in one house. So, this specific first house is comparing the quality data, quality means performance as we say performance or functions that we said right.

So, this is high temperature retention by the coffee maker is one of the functions, light weight is another function, non-messy operation is the third function, ease of operation or light weight and high temperature retention. So, they developed this and they

established this rating, these ratings give us the total quality input. Let me differentiate these, this is our environmental data . This is the quality data. The third one is cost data .

Now, these are developed using the similar way that we have seen in our previous slides. So, they conducted the study and developed these ratings for the quality of the performance of the product. And the final quality points are obtained 1, 1, 1, this 1, 1, 1 is 10, this 10 into 3 plus 9 into 4 plus 9 into 5. These are the points quality points from the quality view point observed that the coffee maker one is the leader maximum points.

And in the lifecycle stage is just manufacture use and dispose if you remember manufacture is before use, before use. This is during use. This is disposal is after use .Tthis is the same pat rent that we have seen in the previous study that we conducted on value engineering, before use, during use and after use. So, they identified the carbon foot print or the ecological or the points that the gain here more points means more environment friendly product means lesser pollution, lesser wastage. So, the maximum here is again for the coffee maker one but the cost for coffee maker one is quite high ok, in the terms of cost the minimum cost is for coffee maker 3 and coffee maker 2 is in between.

So, these three rooms are developed in this concept comparison house. And after detailed technical analysis of each product option, a design team is required to indicate the extent to which each product to satisfy each of the customer requirements, this is done using numbers in range from may be 1 to 10 a high number indicates a better degree of achievement. So, those quality data developed here in the quality room. Then the total quality points for each coffee maker is calculated as I said buy multiplying the importance ratings for each customer requirements by the corresponding quality points here.

Now, environmental data room documents the eco indicator; this is the eco indicator. These are the eco indicator values which are associated with each lifecycles stage of the product option, then these values are obtained from green house which is established for each coffee maker, and those are put here . The cost data room documents the lifecycle cost of the product.

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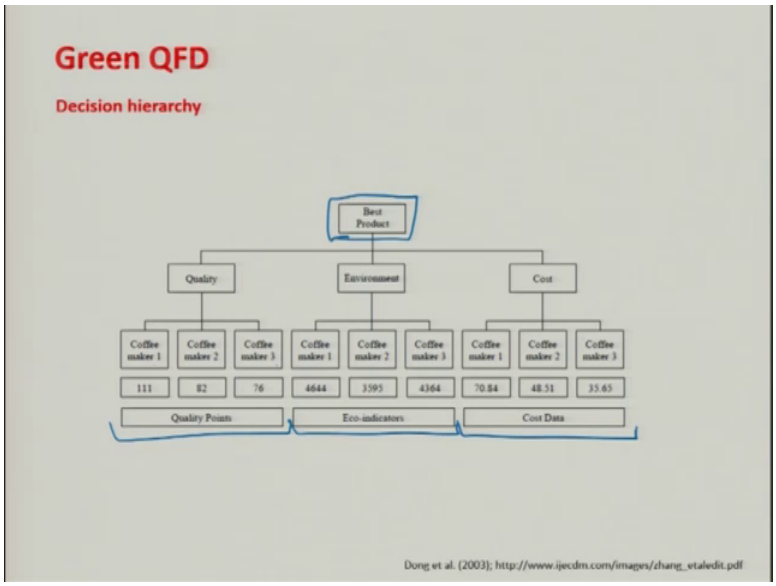


Next we have a decision tree, decision hierarchy, best product has to be gotten from coffee maker 1, 2 and 3. We have the quality points, eco indicators and cost data right . In order to compare the products in terms of the environmental quality and cost attributes, peer wise comparison was carried out for each of the products, the contents of the content comparison matrix, this content comparison matrix was used for this purpose.

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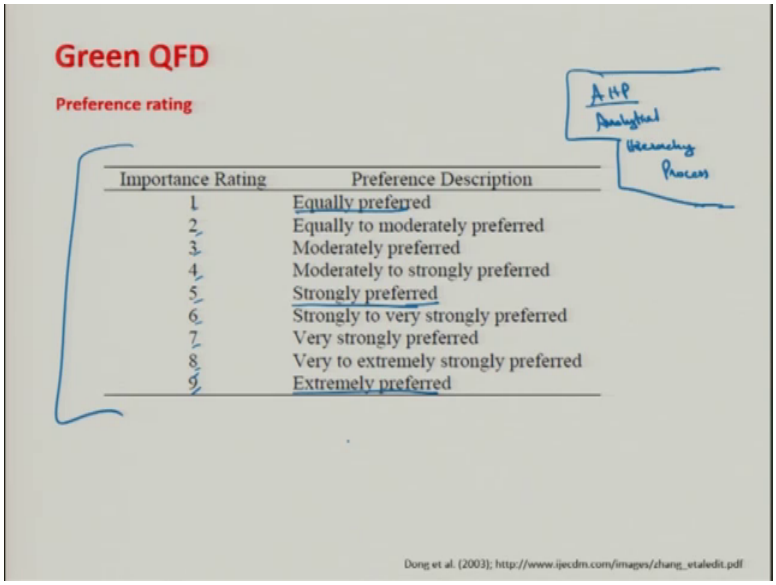


And the peer wise comparison were carried out using these ratings . So, they actually conducted AHP that is analytical hierarchy process, need not to go into detail, but you

can read about AHP will definitely provide you the notes or the links to read this. So, these are the performance ratings in 9 levels; we had only 3 levels in our numerical comparison study, but they had 9 levels in which the first level is equally preferred . And the ninth level is extremely preferred in between the five one is strongly preferred, fifth one is strongly preferred here.

So, these ratings where used to get the numerical comparison. So, the comparison with our product design is done using a scale from 1 to 9 here for comparing coffee makers in terms of quality attributes, the quality points documented in quality room, these points where used. And for environmental and cost comparison green room and cost data for environmental and cost comparison this environmental and cost room data where used .

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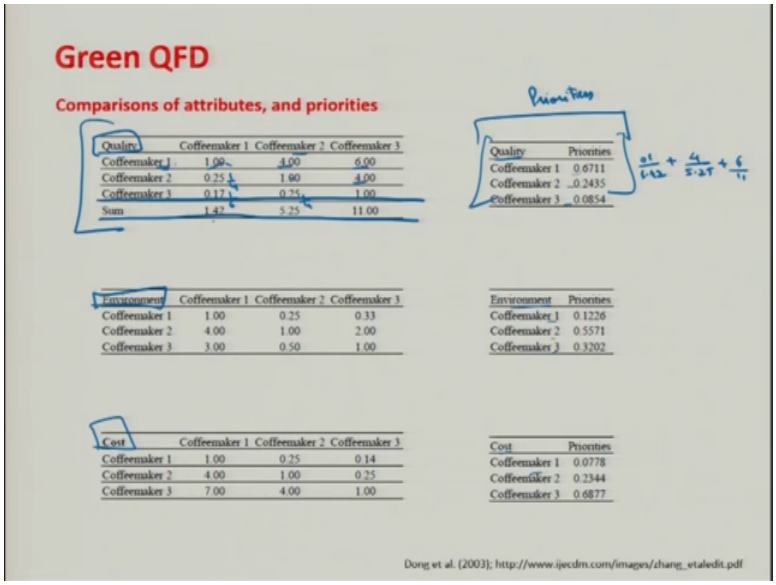


Then they developed these comparisons, this is for quality; this is for environment and this is for cost . Please do not get confused with this chart here. So, this is another way to see the numerical comparison that we did this is 1, 1, 1 means no difference coffee maker 1 can it be compared with coffee maker 1, this is the importance rating. This 2.25 means if one coffee maker 1 and coffee maker 2 are compared, and coffee maker 1 is 4 is moderately to strongly preferred over coffee maker 2; coffee maker 1 is preferred over coffee maker 2. That means, coffee maker 2 is 1 by 4. This is actually 1 by 4. This is 4. This is 1 by 4. This is 6 in the opposite, we have 1 by 6.

If this is again 4, this is 1 by 4 ok. So, these gives us these quality priorities. These are in quality priorities we can see the coffee maker 2 is moderately to strongly preferred to coffee maker three again 4. So, the diagonal elements are always 1 and the remaining values are reciprocal values this is 1 by 4 1 by 6, 1 by 4 reciprocal values depending on the previous assignments that we have made. The priorities are found after normalization to the table values. This is normalization of the data. Normalization is the we take sum of the values, these are sum for the very first chart the sum is given for these are . This is sum ok. This priority is these values are obtained 0.6711 is obtained such as 1 by 1.42 this is actually 1 by 1.42 plus 4 by 5.25 plus 6 by 11, or this is the priority for coffee maker 1.

Similarly, we can get priorities for coffee maker 2 and 3 in the terms of quality, we can get the priorities of coffee maker 1, 2 and 3 in the terms of environment, then for cost. Now, these three priorities are gotten. Now, these three become the criteria as in value engineering, these become the criteria quality, environment, and cost.

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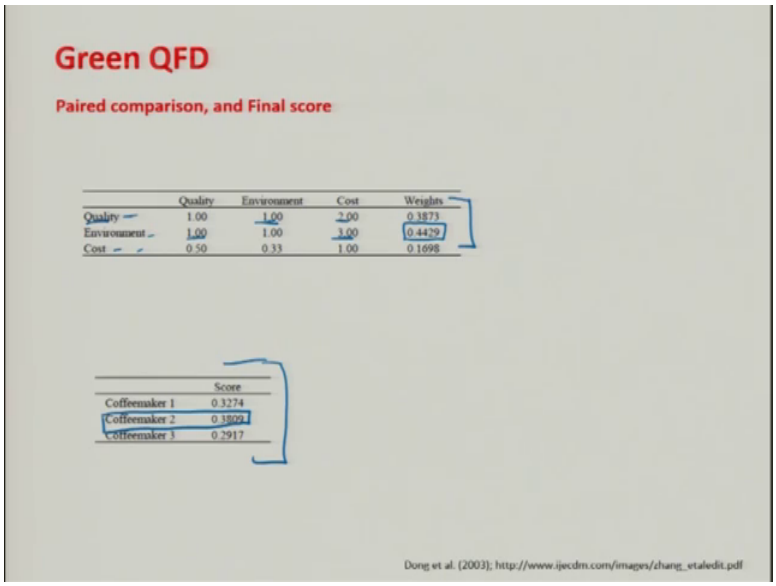


Now, these three are compared here . The quality environment and cost are compared. When these are compared it was seen that the environment and quality requirements are given an equal preference, quality environment are given an equal preference is one here and similarly one here. The environmental requirements are given moderately higher preference over cost requirements, and the quality requirements are given higher

preference over cost requirements, quality over cost is higher and this is moderately higher.

So, we got the weights for these values for quality environment and cost. In this case, the environment is given the maximum weight you can see here. Based upon these weights, we get score for the coffee maker and finally, coffee maker 2 wins the battle in the terms of quality, environment and cost. This is the study you can read at details in this research paper . You have given the link here. And it is conducted by Dong et al., in 2003, you can see this is an open excess which is available. This is green quality function deployment.

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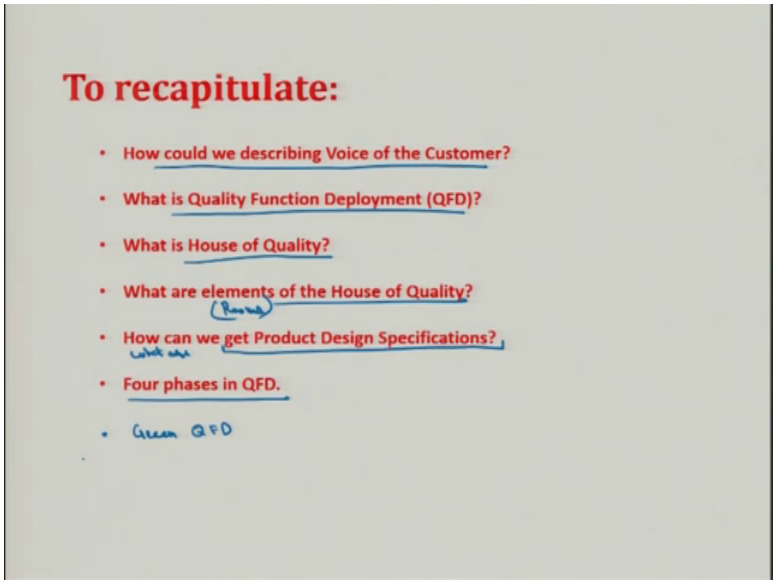


I would request you to do a task let us recapitulate before. We saw how could we describe the voice of the customer, we saw what is quality function deployment, what is house of quality, how is it uses a technique in quality function deployment, what are different rooms or elements in house of quality, how can we get product design specifications ok, or what are what are product design specifications, then 4 phases in QFD . Then we discussed green QFD . So, this is what you have seen in this lecture.

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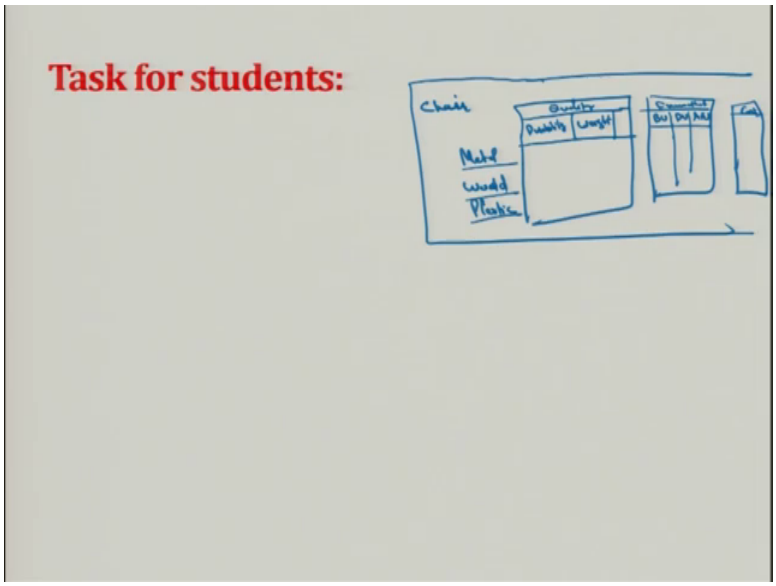


The task for you people is like we have seen QFD for biscuit. So, I would like to request you to pick a product or you have already identified the product in value engineering study. You can speak the same product that is let me say the product is chair ok. I would request you to do the similar kind of analysis as we have seen is seen in this green concept comparison house. This was coffee maker 1, coffee maker 2 and coffee maker 3. In place of these, you can put different materials for chair. Chair made of metal, made of wood, made of plastic, then you can get the quality room, environment room and cost room . It is up to you the product that you select here, you select quality, environment and cost .

In quality you can put here the function such as durability ok, then weight with the attributes. You can see some attributes, what are the different specifications of a chair. In environment before use, during use and after use, these attributes can be put. In cost, you can determine or estimate the cost of these elements. Or even you can conduct the QFD, if you want to do detail task you can conduct different phases of QFD, and you have to find some information available on the internet or in various journals or various periodicals on the specific product that you have chosen. So, this is the task for today.

With this green quality function deployment chapter is over. And we will meet in the next lecture, we will discuss design for experiments and lifecycle assessment, also we

will work on certain online and offline software tools while assessing the lifecycle while having while conducting the lifecycle assessment. Let us meet in the next lecture.

Thank you.