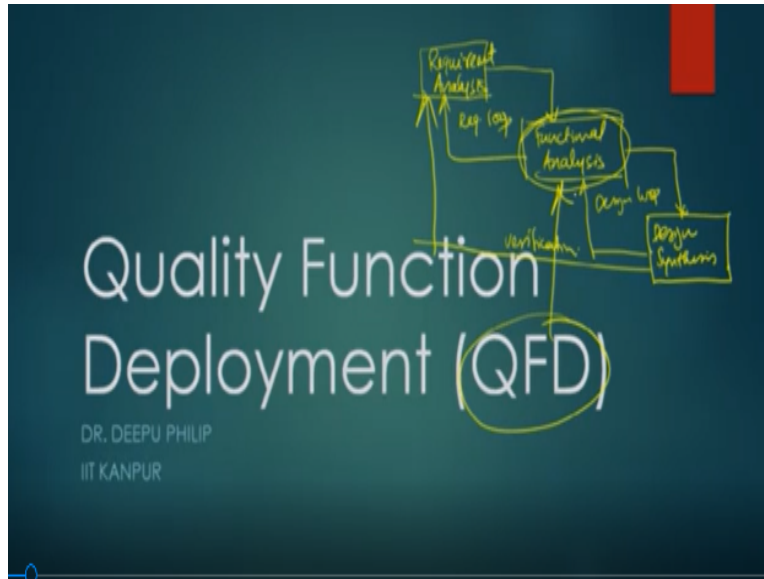


Systems Engineering
Prof. Deepu Philip
Department of Industrial & Management Engineering
Indian Institute of Technology- Kanpur

Lecture- 21
Quality Function Deployment

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Again, good afternoon. Welcome to one more lecture 21 of the Systems Engineering Course. Today we are going to discuss about one important tool that is used in the functional analysis step of the Systems Engineering which we call it as Quality Function Deployment. At this point of time again, a quick recap. We were going through the three cycles which is the one is the requirement analysis. The next one was the functional analysis and then design synthesis.

We add requirement analysis to the functional analysis as the requirement loop. And then, functional analysis to the design synthesis and back as the design loop. And we add the verification loop like this. And we are currently at this place. And we have already seen few tools and some like functional flow block diagrams FFBD and stuff like that. So, we are seeing another tool today called QFD, which is applicable in the functional analysis called as Quality Function Deployment. And it is a important tool in the Systems Engineering process.

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History of QFD

- ▶ Developed by Dr. Mizuno of Tokyo Institute of Technology
- ▶ First applied in Mitsubishi Heavy Industries in Japan
- ▶ First major product through QFD was the mini-van of Toyota
- ▶ QFD thus is considered to be applicable to all manufacturing or service industry
- ▶ QFD is a planning tool used to fulfill customer expectations.

Handwritten notes:
 QFD was envisioned as a tool that can be used to develop a product (or a system) that can satisfy customer requirements needs specs.
 QFD migrated from manufacturing industry - later adopted by Systems Engg group!
 ↳ planning of functions (functional design of the system)

So, what is the QFD? So, we need to understand the little bit of history of QFD. It is a tool that the systems engineering adapted very well from the manufacturing side. Lot of this credit actually goes to Japanese manufacturing industry. Developed by Mizuno of Tokyo Institute of Technology. And first applied in the Mitsubishi Heavy Industries in Japan. So, this was actually developed as a tool to quantify the customer expectations or customer requirements. And then developed products according to it.

So, the QFD was envisioned as a tool that can be used to develop a product in our case, or a system that can satisfy customer requirements or we can call it as needs or specific specs, etc. So, it was envisioned as a tool that can be used to develop a product. The initial version of this was developed for product manufacturing side. Automotive and ship-building, those kinds of things. And later it got approved migrated to Systems Engineering.

But the main aim, it is a tool that can satisfy, that can be used to satisfy customer requirements so that the final design of the product or the system can satisfy the customer requirements. The first major product, the first major product can be the system also. Because an automobile can be considered as a system through QFD Quality Function Deployment was the Toyota mini-van. And it went to become a big very popular product in the world.

And it had like lot of the customer requirements who actually are avid users of mini-vans. Lot of their requirements were satisfied as part of this. So, hence QFD is thus considered to be applicable to all manufacturing or service industry. So, the origins QFD originated from manufacturing industry. Okay. Later adopted by systems engineering group or systems engineering people. So, it is a planning tool. Again, it is a planning tool that is very planning of functions or functional design of the product functional design of the system.

When you are planning the functional design of the system. When you are planning the system functions, this is a really good tool that you can use to fulfill the expectations of the customer. We will see what the tools are and other details in the following slides.

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What is QFD?

- ▶ It is a disciplined approach to product design, engineering and production allowing for in depth evaluation of a product.
 - Systems Engineering is a disciplined approach to develop complex systems or system of systems (SOS)
 - System
 - of the system
- ▶ Customer specifications is referred to as voice of the customer in QFD
 - Customer requirements = Customer expectations
 - in the system that
- ▶ What are the qualities the customer desires?
- ▶ What functions must the product serve, and what functions must we use to provide the product or service?
 - best fit
 - Functional Analysis!
- ▶ Based on our available resources, how can we best provide what our customer wants?
 - Trade-offs and capabilities (Alternatives)
 - How best can the customer needs be satisfied with whatever is available?

be used

So, what is QFD? The simple definition or in a way, the best way to describe it is first a disciplined approach. Remember systems engineering. Systems engineering is a disciplined approach to develop complex systems or system of systems (SOS). Okay. So similar way, QFD is a disciplined approach to product design designing a product, engineering it and then producing it allowing for in depth evaluation of a product.

So, it actually helps you in evaluation in depth evaluation of the design of the product, the engineering of the product and the manufacturing of the product. Same way, in our case it is a, instead of the product, if we replace this with system. It is a disciplined approach in systems

design. Engineering of the system and instead of production you can say development. Instead of development we can call it manufacturing. Or manufacturing of the system.

Okay. This also QFD becomes extremely applicable to the field of systems engineering. So, in the expectations, what we call as customer specifications or what we call in systems engineering as customer requirements or customer specifications or customer expectations. There are many ways people describe this aspect of customer specifications. About the view on the system how the system should be. All those aspects.

Okay. It is referred to as voice of the customer in QFD. So, in the QFD, the tool, the Quality Function Deployment tool, the voice of the customer whenever you mention here that the phrase the voice of the customer it is exactly same as the customer specification or customer requirements or customer expectations. These are all one and the same. Okay. So. Here the main important things that we think about it this is where the parallelism with the function analysis comes into picture.

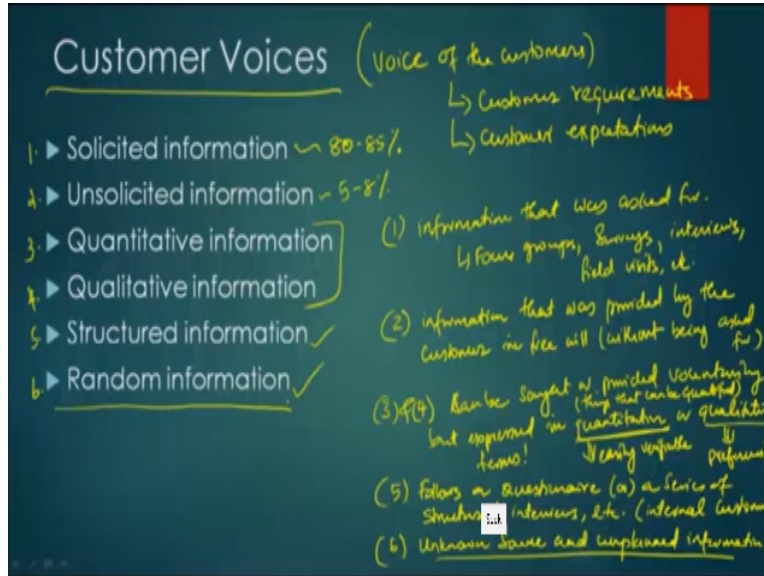
What are the qualities that the customer desires? So, what are the qualities you can think about in the system that the customer desires? Okay. What are the qualities that the customer is looking for? What functions must the product, instead of the product, you can think about it as the system, what functions must the system serve? And what functions must be used to provide the product service or in this case you can say system is the right way to look at it.

Okay. So, this is why it gets applicable in the functional analysis. So what functions must the system serve? And what functions must be used. Okay. You can think about it as 'be used'. To provide the system or to develop the system. Okay. So, these things become a very important question of a functional analysis. And the third part based on the available recourses how can we best provide what the customer wants?

This is where the trade-offs comes into picture. Trade-offs and capabilities. This translates directly to what we call as the alternative analysis the alternatives. How best can we provide how best can we satisfy? The question is how best can the customer needs be satisfied with whatever is

available. So, this is also the aspect of it. Hence this is why QFD is a you can think about QFD as a best fit in the functional analysis aspect of a systems engineering or system development.

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Now if you look at it the customer voice okay, whenever you hear the voice of the customer, or whenever anybody mentions voice of the customer, or in system engineering parlance it is the customer requirements or other word is customer expectations whatever the phrase we use whether the customer expectation or requirements or voice of the customer or expectations, they can be in the following six forms.

Number 1 Solicited information, Number 2 Unsolicited information, Number 3 Quantitative Information, Number 4 Qualitative Information, Number 5 Structured Information and Number 6 Random Information, solicited information is if you think about it, Number 1. Is information that was asked for. So, you conduct different mechanisms like focus groups, surveys, interviews, field visits, etc. And then ask the customer especially information what do they want?

Okay even one of the example videos we have seen in the form of class, a solicited customer information, this is typically on an average about you can say 80 to 85 percent of the information that is required in the designed of the system comes through what we call as solicited information and number two what we call as unsolicited information. This is information that was provided by the customer in free will okay without being asked for.

So, the customer gives the information without being asked for it. The customer was ok with sharing this information and go away from them. So, like many certain times the people who are actually like you know you can say that this usually happens in the case of like many other consumer products. Where the marketing executives they will actually find people, who are using the product.

And sometimes somebody would share this information saying ok this is actually a problem and the people will actually get to know about it and then you said accordingly. Okay. So, one of the classic example of this is in India the popcorn chicken rice that was made by KFC where one of the customer actually went and provided this unsolicited information to KFC saying that why can't you have the rice the vegetables rice you make and you mix popcorn along with it.

And add a little bit of sauce and sell it as a popcorn chicken rice and nobody asked for it and KFC felt that this is a good idea and they came up with the new product and became quite successful. So sometimes unsolicited information or so you say it is a good way of getting aspects for product or a system design, you can think about some of the varies between five to eight percent typically of a system.

Okay. Then there are things like qualitative information and quantitative information. So, three and four, ok, are again can be sort or provided voluntarily but expressed in quantitative or qualitative terms. So, one percent saying that okay I want to have a soft touch leather as the seat cover in the car that is the qualitative information, qualitative information, sorry and the quantitative information would be somebody saying 0 to 100 in three seconds.

Zero to 100 kilometers per hour in three seconds is what the acceleration I required that would be a quantitative information. So quantitative would be things that can be quantified numerically quantified. It is also easily variable, easily verifiable. Whereas qualitative sometimes is like you know preferences ok sometimes this is not really, you cannot really put a numerical value to it. That is the trick part of it. Then comes the five which is structured information.

Structured information is an interesting type of information because it can actually result in most of the length this follows a questionnaire or a series of structured interviews etc. so like sometimes when new product is built what happens is it is actually given to a limited set of users and people who are experts using the systems are basically asked to try the system. And then the feedback is collected.

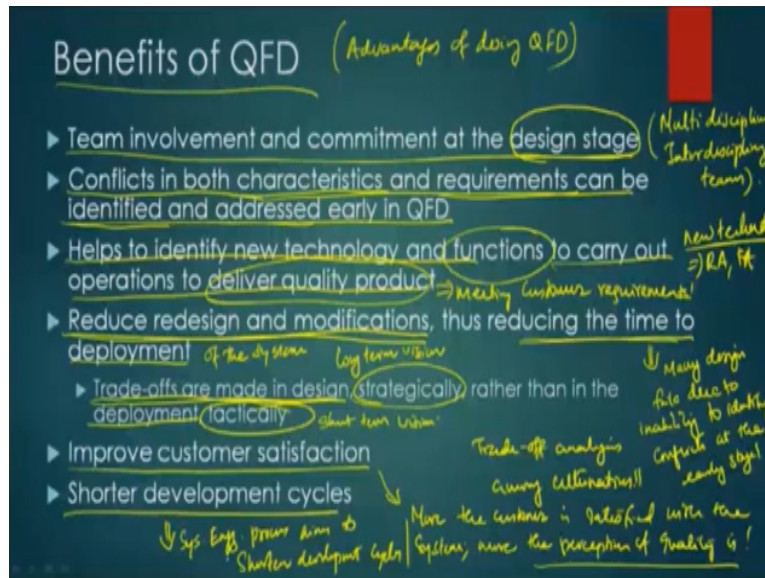
And based on the feedback of structured analysis of the system is conducted. This is also an important aspect because sometimes you know this is the internal customers, lot of internal customers of a system provides this input in the structured information. Then comes the random information which is like you know, what you call as the unknown source and unplanned information.

One of the big classical example of this is the usage of crash guards, the metallic crash guards in on four wheelers on India on different Metro roads, metro cities, that big steel chrome plated steel bar that is where people is attached so that it prevents motorcycles and cycles bicycles and cycle rickshaw hitting and bending the expensive bumpers of the car. That is what the idea was and that was what basically created, developed as an aftermarket art accessory.

Which almost every person was doing it and buying it and using it. Then the car manufacturers themselves felt like okay why do not we provide like a standardized accessory because this looks like almost everybody is using it. So, then this was you know a random information that was available to them and from which that was many of the car manufacturers. Currently in India provide that type of a crash guard as a standard accessory to the vehicle.

But that the motivation or the information that was available to them was purely a random information from which it was developed and arrived.

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So, what are the benefits of QFD why do we need QFD, the important question that need to answer, we need to answer as part of this whole exercise. Why do we do QFD? What are the benefits, okay, what are the advantages of doing QFD? Obviously, there are quite lot of advantages, the first and foremost is the team involvement and commitment at the design stage. we talked about multi-disciplinary and inter disciplinary teams.

Okay, the team involvement and commitment is because, these multi-disciplinary and inter disciplinary teams need to be involved at the beginning of the, even before the design of the product. Ok. The worst-case scenario is they should at least be involved at the design stage. When the design of the product begins they should be involved. In our case when the UAV was designed during the time we were doing functional analysis itself.

Many of these multi-disciplinary and inter disciplinary teams were actually involved and they were committed to the development of UAV. So, this QFD is a good tool that actually allows you to ensure the involvement of such teams. Then second part is Conflicts in both characteristics and requirements can be identified and addressed early in QFD. So sometimes you find out that there are some characteristics some customer wants.

And some of the requirements can be conflicting and when you have conflicts you have to identify the conflicts and you have to address the conflicts. So, like for example, a customer would say the

UAV would climb to an altitude at a very fast rate that means the UAV should have a climb rate so it should be able to fly fast. Then the person will also say that he should have a very high glide ratio.

Normally both of them does not go together, they are both contradicting requirements. That is the point you have to say which one is more important to you. Is the glide being more important or the rapid climb is more important. Then the customer says rapid climb is not that important of a thing well we asked this question to customers they said the most important thing is they has to maintain the high glide ratio.

So that even if there is something happens we do not know the too much of redundancy. So, if it does have high glide ratio we can bring the UAV back to our home. So, the high glide ratio is important. So then ok fine, based on which the wing was designed. then we said ok this is the maximum rate at which it can climb and the customer was ok with it and that is even before the product was designed this conflict was identified and addressed.

So that, it even did not even once the product was designed then this we would have wasted money and time, if we did not catch it at the early phase. Third one is it helps to identify new technology and functions to carry out operations and deliver quality product. So, the idea is that, we can the new technology options. We already said from the requirement analysis as well as functional analysis, new technology identification is a critical aspect of any system development.

And QFD allows you to identify new technology and as well as new functions that the system should carry out to deliver the or meet the customer expectation. When you say deliver the quality product that means it is like meeting customer requirements. When we talk about quality we can say that in a way it is actually meeting the customer expectations in a way to say to address the quality of the product.

Then The third, fourth aspect of it is it reduce redesign and modifications thus reducing the time to deployment of the system. So, if you identify and reduce and address many of the conflicts and as well as the characteristics requirements and as well as the performance parameters and stuff like

that. When you identify them in the early itself you are reducing the redesign and modifications to the system development.

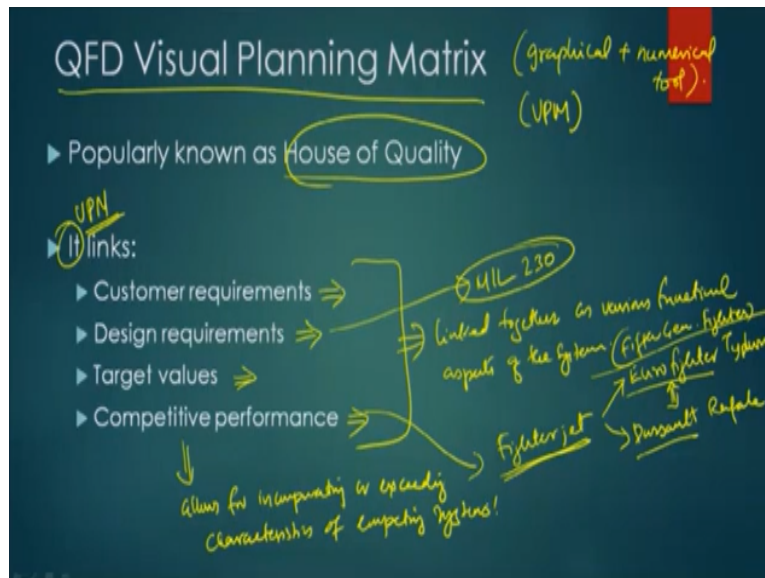
So hence the time to the deployment of the system can be significantly reduced, to a large extent many of the system designs fails so you can say that many designs fail due to inability to identify, inability to identify what, conflicts, at the early stage. Because once the product is built the processes are there, it is quite hard to address these. So, this is very important. So, this is where the most important word called trade off.

Okay so Trade-off Analysis among alternatives is a key criteria in this case. So, the trade-off s are made in design, ok, the design phase itself. So, this kind of a trade-offs are called strategic trade-off. So, these are the long-term ok vision. Strategy is the long-term vision rather than the time of deployment. So, you deploy the system and say oh there is a problem now we need to deal with this and we need to make the trade-offs.

Such ones are called tactics because these are short-term vision. So, the QFD allows you to make strategic trade-off rather than tactic trade-offs. So, traders are made at the design itself rather than at the time made of deployment. Then we talk about improving the customer satisfaction. Obviously, yes, the quality of, more the customer satisfaction, more the customer is satisfied, with the system more the perception of quality is.

If the customer is satisfied with the system sufficiently well then if the perception of quality is also pretty high. Then last part is shorter development cycles. We saw that the system engineering process aims to shorten development cycles. So, in this regard QFD is a good tool that allows, the systems engineering or system engineer to control the development cycle and actually reduce the time required to develop the product.

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Okay So QFD has actually a visual planning matrix. It is again to an extent, people call it as a graphical and numerical tool. So, I usually call it as a graphical plus numerical tool. So, we would be sharing a case, of QFD the usage of QFD designing an automotive system which will be a part of the reading assignment in this course. So, you will understand how QFD can be used and used for product planning.

And which to an extent to extend it to the system planning so this visual planning matrix is typically known as house of quality. So, somebody saying house of quality, I am doing a house using a house of quality tool or diagram to do the product design that means they are using a quality function deployment and what does this links, this QFD this visual planning matrix, the VPM the visual planning matrix it basically links the, it is the visual planning matrix.

The visual planning matrix links the customer requirements and design requirements, target values and competitive performance. So, all these four are linked together as various functional aspects of the system, so whatever the customer wants it is linked with design requirements. So, this would be whatever the customer required this would be some of design requirement let us say for example.

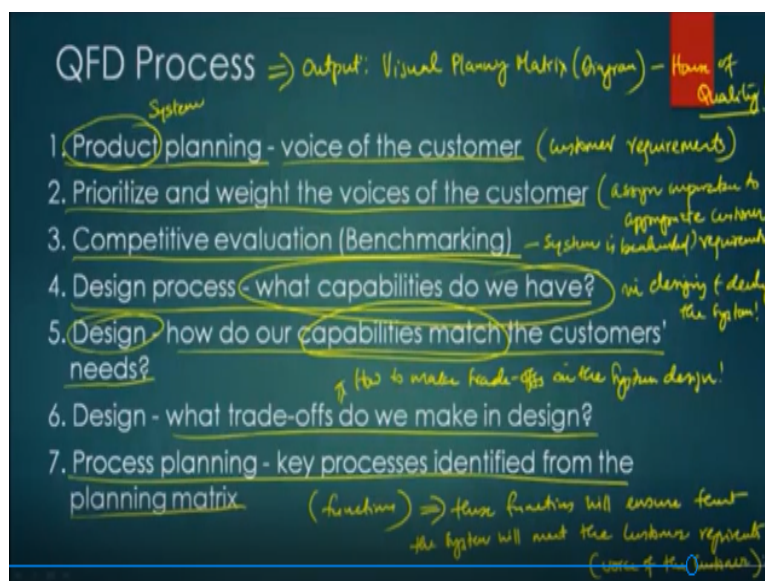
If you say I am following a mill 230 standard or something like that then that particular standard that is a design requirement of that certain target values are required. So how to achieve the target

values and what is the competition doing? So, if you are building a fighter aircraft fighter jet like lot of the, like classic example of this is the Euro fighter typhoon and the Dassault Rafale.

You can see how these systems which are these two fifth generation called as the fifth, they wanted to make as the fifth-generation fighters. Some people called us 4.5 generation. we can argue on that we are not going to worry about it. But these two cases if you compare then you can fight that how the competitive performance. How when they dissolved by developing Rafale on the euro fighter.

The other consortiums of European Union Countries were trying to develop the typhoon how they actually compared with each other and try to outsmart each other. That is the competitive. The performance of the competitor was taken into account. So, this allows for incorporating or exceeding characteristics of competing systems. This is another important aspect of the visual planning matrix or what we call us the QFD aspect.

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So how is the QFD process happens, so this is a seven-step process and the seven-step process allows you to actually build QFD or what we call as a house of quality. So, the output of this QFD process, the output will be the visual planning matrix or some people call it as a diagram or the simple way to do is, it is the house off quality. See you will have a diagrammatic tool that allows you to compare allows you to link customer requirements and as well as it allows you to link.

The design requirements it allows you to incorporate target values and it allows you to merge in competitor information into this, so that the final design of the system will actually meet or exceed the customer requirements. So, the QFD process, the first thing is you have to do product planning. Instead of the product planning, let us think about it as system planning. You start with the voice of the customer. You start with what do we call as the customer requirements.

You take the requirements of the customer and from there you actually start planning for the development of the system. And within this customer requirements, you have to prioritize and weigh the voice of the customer. So, assign importance to appropriate customer requirements. Okay so their customer will have hundred different requirements. But you have to prioritize and weigh them according to what you think as the best option available at this point.

Then once it is done, you have to do competitive evaluation or you have to bench mark. You have to bench mark the system with accessing system. If there is no accessing system is available, you have to bench mark against something. Or something against target values or benchmark against the customers what it is expecting and how far you are able to achieve, what was the customer was expecting something like that.

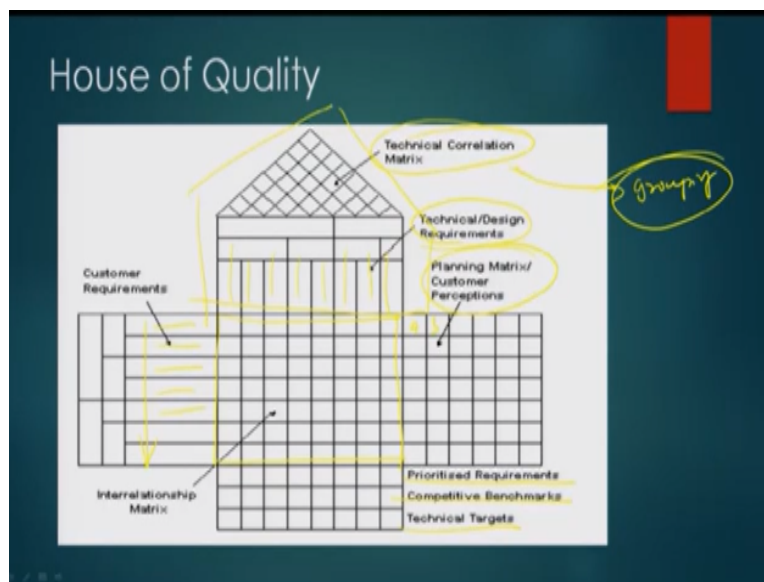
Then, once the competitive evaluation is done is the system is bench marked. This is where the system is benchmarked. Then we let into the development of the design or look into the design of the system. Where the primary question we say is, what capabilities do we have? In what capabilities do we have in designing and developing the system? Is the most important question that we have to do?

Okay, then the second part, that part. Once you have establishing the capabilities like these are we have or we do not have capabilities. Then the obvious question is do we have to build these capabilities or do we have to go with something else? Then once we understand these are the capabilities, how do our capabilities match the customer needs. Ok, so the actual design is, how to matching up the capabilities of.

The organization that is doing the system design, with the customer needs. That is where the design comes into the picture. And sometimes we find we don't have that capabilities. What trade off do we make in design capabilities? Ok. this is where how to make trade-offs, in the system design. This is also another important aspect of this. Once this is done, once this all 6 steps are done, and if you are satisfactorily answered all these questions and everything.

Then you would think about planning of the process. Ok, so fine you may think these are the most identical thing inside you have to plan for. And these processes are or none other way you think about it as function. These are the key functions that we need to ensure that the system should be capable of performing. So, these functions will ensure that the system will meet the customer requirements. Or in this case what we call us that voice of the customer.

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Okay, finally we just look into how this house of quality, or the planning matrix how does it look like? So, it is a tool this is why it is told as a kind of a house, this portion. This specific portion, it looks like idea of a house. Otherwise, people called as house of quality. But the first and foremost the customer requirements goes here. This is where the customer requirements. Each one of the customer requirements are listed here one after another.

Okay, and technical requirements the designed requirements are listed here, One after another. In this area. Then both of these kind of things, between this will be able to create, what we call as the

inter relationship matrix. The customer requirements and its relationship with technical and design requirements and also what we call as another one is planning matrix or customer perception. Because, this were we put appropriate perception about.

What each customer would think about each and every customer requirements. So, when you put a perception value here like 4,3 something like that on a different scale, once it is established whatever it is. Then we know what is the customer perception against that particular requirement. Ok, and what is the technical requirement, technical design requirements. Since the customer perception is very much low than the technical requirements.

Then you will know that there is task that you educating the customer. Like ok, the customer might say in some point time the customer might say that, in India might say that, why do I need an seat belt. And many of the automotive vehicles in India does not have small car does not have an air bag. People are like; we are not going to drive very fast. But if we look at the people, who actually who lose their lives in accidents. Lot of them are these small car drivers.

So, the customer perception of safety for a small car or a compact car, might be completely different, and hence when you say that, Ok, I am adding all these air bags and safety belts, and pre-tensioners, electronic brake distribution systems, ABS all those kinds of things. Then the customer will say, I am not willing to pay for this. Because, I don't want this. Because the perception of safety is much different from your perception of safety.

So, that actually helps here. Then also these three things. Prioritization of the requirements, the competitive benchmark, what are competitors are doing. In this particular case, against each of the technical requirements and the technical targets, what you finally target out of it. Is also a part of this and there process? Similarly, the technical co-relation matrix, it allows you to co relate between the each individual, technical or design requirements

With that of the other requirements. This is where you actually co-relate one of the requirements with another. This also allows for one of the famous things that told was grouping. Identifying the specific functional grouping. That is also is an important aspect of the system design. So, with

this we will conclude, and you will all get a case that you need to read, and the case is very well explaining process goes through in a simple of case of design and development of an automotive system.

Especially just a door, passenger side door of a car and how is it built. And how is the QFD function was useful identifying the what are the technical requirements. And how the voice of the customer was built into this, and then you will understand how it is and lot of the time, for each individual component, or the major at least for the system components QFD is used. So, I would request you guys to go through that, and then using the information that is provided.

I think all of you will be able to understand the tool, it is a simple graphical tool and we will continue to, I will continue to expose you guys, to more tools in the following lecture to come. Until that time, happy reading. Thank you.