

Design Practice
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Lecture - 38
Failure Mode Effect Analysis

Hello and welcome to this design practice module number 38. In the last few modules you have seen how you know different aspects of design; like for example, principles of material selection in design, development of any process or system or for example, design issues related to formulation of a work system and also axiomatic design, as a concept in the theory has been taught to you. It has also been, you have also been taken across the various theories of group technology which is a very important essential tool for concrete engineering, which we did in a very elaborate manner at towards the beginning of this course.

So, I would now like to introduce two more very important concepts, as regards the steps related to concrete engineering. One of them is better known as the failure mode effect analysis and the other is also known as the quality function deployment. So, all these different steps like group technology QFD quality function deployment or failure mode effect analysis. These are nothing, but techniques which will improve the design and there are direct benefits which happen, if you invest in these processes even before the production starts setting in.

For example, in case of QFD if we invest more towards design planning design development by making customer as your center of attraction or your focus. You will see that towards the start of the production and beyond the start of the production, the processes would be very simple in the cost that would be involved, would be tremendously low in comparison to, if you would do this development after production starts. So, we will also give an example of shipbuilding, when we talk about introducing these QFD concepts.

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Failure Mode Effect Analysis ↖

- This is an important technique that is widely used in industry, including the big three auto manufacturers, for continuous product quality improvement to satisfy the needs of the customer.
- FMEA can be described as a systematized group of activities intended to:
 1. Recognize and evaluate the potential failure of a product/ process and its effects.
 2. Identify actions that could eliminate or reduce the chance of potential failure occurring.
 3. Document the process.

It is complementary to the design process of defining positively what a design process must do to satisfy the customer.

FMEA is a generic approach that can be used to identify failure modes and analyze their effects on the system performance with the objective of developing a preventive strategy.

So, let us look first at FMEA or failure mode effect analysis. So, it is a very important technique; that is quite widely used in the industry now and mostly related to automobile manufacturers, particularly the three major automobile manufacturers and FMEA is used as not only planning for a product or product design, but also for process design. In fact, an example will be shared with you more towards the process side here, when we talk about a very simple problem of rusting in doors associated with paint shop and associated with vehicles during its manufacture.

So, the FMEA technique is typically used for a continuous product quality improvement so that you can have. Generally, a customer satisfaction and indices can be drawn to find out whether FMEA is working in a proper manner. So, generally FMEA can be described again as a system, I systematize group of activities intended to do three-fold development. One is to recognize and evaluate the potential failure. Modes of a product meaning thereby that we need to identify what is the cause of a certain defect or a failure to happen which will create customer dissatisfaction.

And then associate what are the important processes, which are involved in such a product development failure or product failure and also what are the effects of these processes which will set in the failure, then we can identify as a process of the FMEA. Some actions or countermeasures that could eliminate or reduce the chances of such potential failure modes to happen. So, that you can have quality improvement within the product design and also

product manufacture and then finally, you document the process in a proper manner. So, that references can be made in the future, supposing this failure mode occurs again during the product life cycle there.

There can be an easy way of eliminating by just looking back into the process and seeing whether whatever stipulated action was frame or stipulated countermeasures were identified, are they being followed or not. So, it is a very organized manner of the identifying the modes, because of which a failure would happen in a product and trying to eliminate those and also there is a qualitative judgment which is involved here. So, there is some kind of a rating which is given at different steps and we can, as monitoring the failures are continuously going down by looking at numbers associated with these ratings.

So, you can not only validate everything qualitatively, but also looking at some of the numbers, in order to certain, whether a failure mode is really coming down, because of the countermeasure, which has been implemented or action which has been identified as causing to reduce the modes of the failure behind the product. So, FMEA is a generic approach. This can be used to identify, as I told failure modes and analyze their effects on system performance. And the objective is to develop a preventive strategy, so that failure mode should not happen and how we do FMEA is that, there is a threefold methodology which is used.

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Failure mode effect analysis

- Process FMEA is a methodology for evaluating the process for possible ways in which the failures can occur. The primary objective in process FMEA is to eliminate potential production failure effects by identifying important characteristics that have to be measured, controlled and monitored.
- The FMEA philosophy is based on the characterization of potential failures. Failures are characterized by the following tuple: (Occurrence, severity and detection).

Occurrence: How often the failure occurs? ↗
Severity: How serious the failure is? ✓
Detection: How easy or difficult it is to detect the failure? ↗

Examples of typical failure modes include cracked, dirty, deformed, bent and burred components; worn tools and improper setup.

So, in the in the processor FMEA, typically we formulate a methodology for evaluating the process for possible ways in which failures may occur, failures may occur in the production or the product; that is being produced. The primary objective is to eliminate the potential production failure effects by identifying important characteristics that have been measured, controlled and monitored.

So, typically how FMEA is carried out is that the philosophy is based on characterization of these failure modes in terms of their occurrences. Occurrences mean how often a failure would occur. For example, if there is a certain defect like a dust pot and a paint, how often it is going to repeat. You know in a in production is something of importance when we talk about FMEA; obviously, you have to do some kind of prioritization in terms of what are the most abundantly available defects and what are the less abundantly, and how important it is to as a as a consequence to the product if the particular failure mode happens on the product.

For example, in an automobile, if you look at failure; like a wheel nut not torqued properly can cause a life or life loss or a limb loss or an injury. So, there may be very important from a priority point of view in comparison to something, like an appearance defect, like a dent. So, therefore, it is very important to sort of prioritize what is the failure mode, which is of consequence and what is, which has lesser consequence, which may not be tackled at the outset or at you know and may not be even sometimes tackled, and that way you get a perspective of where your efforts need to be done towards the beginning, in order to improve the failures related to the product.

So, the occurrence is followed by another parameter, the severity. So, how serious the failure is, in terms of it is contribution to the failure; that is in question and then of course, once the occurrence in the severity is mapped. The third issue is, how easy or difficult it is to detect whether the failure is happening or not. So, one part is; obviously, what is the failure and other part is how often the failure happens. Then it is about how severe the failure is, and then how easy it is to detect. So, you are giving all aspects of a failure mode and if these aspects are covered in a very organized manner and everywhere, there is some improvement which is given.

Maybe in the modes in which detection of failure is possible or even you know doing something with the design improvement, where there is a lessening of the severity, this failure happens or even something related to countermeasure which may just reduce the occurrence

of the failure you ensuring that the product is good quality and that is exactly what the whole essences of FMEA activities. Failures can include many different aspects.

Like for example, there may be components which are cracked or dirty or deformed or bent or burred, you know and sometimes tooling's which are worn and improper setups may create a variety of such failure modes and identification of these, an elimination of this is very important. So, to implement the FMEA a certain algorithm is followed and this algorithm is something that is important for me to tell.

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Failure mode effect analysis

To implement process FMEA, the following steps may be taken:

- Identify the problems for each operation using brainstorming and committee discussions. Cause and effect diagrams can be used. For example, the potential causes of machine failures could involve mechanical or electrical subsystem failure, tools, inspection equipments, operators and so forth.
- Use flow process charts as a basis for understanding the problem. This provides a common basis for communication among the committee members.
- Collect data. Data collection may be necessary if data are not already available.
- Prioritize the problems to be studied. The ranking of priorities is based on the following:
 $RPN \text{ (risk priority number)} = \text{occurrence} \times \text{severity} \times \text{detection}$
- Use appropriate tools to analyze the problems by making use of the data.
- Implement the suggestions.
- Confirm and evaluate the results by doing some experiments and ask whether you are better or worse off or the same as before. Repeat the FMEA as often as necessary.

You will do it in terms of a process, which is carried out in a paint shop, related to waxing of the doors. You know the, there is a door inner. Typically, a door of a car is comprised of a door inner and outer, which is hemmed together at certain points and the defect that we will consider here is that, because of splashes coming out in the road from. Let us say splashed water or splashed mud. There is always a possibility of a water level to go inside the door which may create, which will jeopardize the different components associated with either the door closing, opening or the windows, which are an essential part of the doors in an automotive.

So, what we are going to do is, through FMEA process try to see, if there we can make a system level and a process level improvement. So, that this defect or the failure mode comes down. The failure in this particular case would be related to rusting of the door. So, the following steps are usually followed in the algorithm for doing FMEA. One is identifying the

problems for each operation and this can be using brainstorming or committee discussions and then try to plot, maybe cause and effect diagrams which will give you an idea of what are the reasons in terms of man, material, machine and methods, which all together give you the onset of a problem or a failure mode.

And once this organized fishbone diagram is put on the table. It is very important to one by one eliminate the different causes related to the people who are involved in the production or the machines, which are involved in the production material, which comes in for the production and the methods, which are being utilized for the production. And in all these four aspects, you would have some countermeasures planned, so that overall, there is a systemic improvement which happens for this failure mode to completely eliminate.

So, for example, the potential causes of a machine failure could be involving mechanical, electrical subsystem failure. It can involve failure of tools; can involve some inspection equipments which are not able to do a preventive maintenance in a proper manner or even operators. So, all these identified have to be removed, identified contributions to the failure modes have to be removed somehow. So, you can use process flowcharts as a basis for understanding the problem, the problems this, it may provide a common basis for communication among the committee members. So, that in an organized manner you list down what are the basic reasons for a failure to happen

And in order to again numerals the various aspects related to occurrence severity and detection related to a process, we can look into a list of for example, failures, we can countermeasures and a list of detection methods for the failure to be detected before it it goes out as a part of the product and then try to find out what is the occurrence level in terms of a rating, rating could be between 1 and 10 in a group of failures. Or what is the severity of a failure related to other failures which may be existing, again rated in a group of 1 to 10 and then the detectability of a certain failure mode, how much probable it is that the failure would escape the notice, the people who are involved in make contributing to some kind of a process deviation which leads to the to the failure.

So, that also can be rated in terms of some 1 to 10 numbers, and then we generate something which is known as a multiple of this tuple; that is occurrence severity detection multiplied to each other and we call it a risk priority number. So, this is a index number, which is given

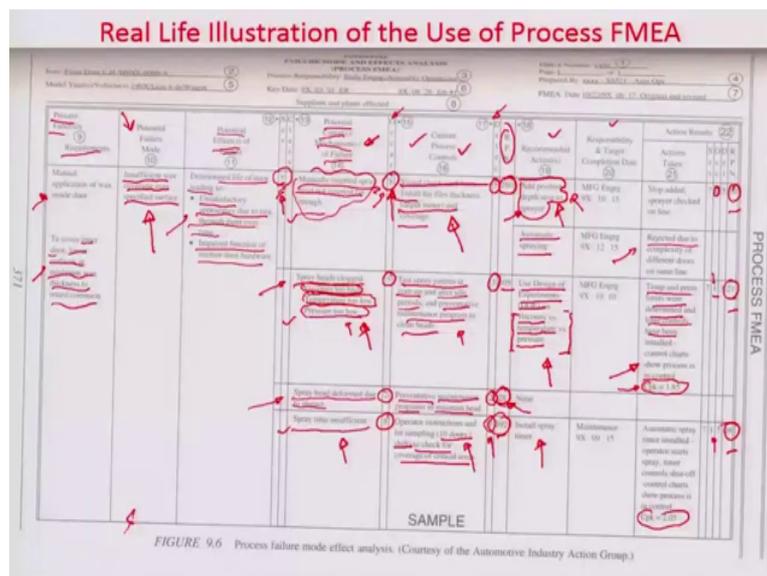
your judgment of a certain process and your ability to judge things in terms of priorities or failures, occurrences of failures, severity of failures, detection of failures.

You are trying to get your judgment to a set of different failures, so that you can identify what are the most probable contributors to the overall failure of a product, and then do a praetor analysis, so that the first 20 percent which contribute to 80 percent of the failures can be sort of removed and countermeasures can be planned in those areas. Again rpms can be revisited with different iterations.

Iterations could be in terms of different countermeasures, countermeasures could be again in terms of improving the detectability or why, you know from a root cause analysis of why a failure is coming and try to remove that or even doing some design improvements, so that a failure may not be as severe to the product as possible. So, all these different things are necessary for having an RPM number and how the RPM number would change is also very necessary, to give you an indicator of what you are doing is effective or ineffective in terms of elimination of a failure mode.

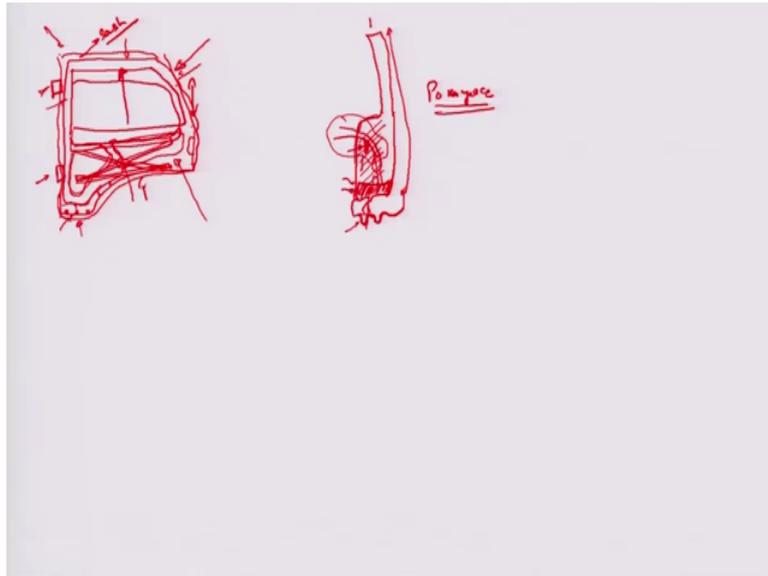
So, we will try to do this again in a problem example, where you will understand it better what I am saying in terms of, you know how ratings could affect by generating a number and revising the number after various countermeasures have been carried out.

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So, let us look at a problem example from one of the automotive companies, which talks about a failure mode, related to insufficient wax coverage over a specified surface of the door inner. Generally, if I look at how a door of an automotive would be looking like. So, if I remove.

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Let us say the door stand alone and if I wanted to investigate the door by looking at a cross section of this door, you may find out that after removing of all the trim boards etcetera which are there within the passenger cabin, the door looks like a structural hollow with some ribbed members on the inner side and an outer member which is a metal sheet on the outside and it has the curves and curves or the overall automotive.

There is of course, a provision of a window, which is somewhere in this region and this window is supposed to go all the way to the upper corner of the sash right here and fit, so that is it basically becomes a leak free system. And; obviously, for moving this window, there are various, different equipments which are mounted within the door inner. One of them being some kind of a Caesar lift, which if you rotate the window regulator, would allow the window to sort of move up and down along this sash and fit on the upper sash right here, so that there is a leak proof joint.

So, there are a lot of components, then there are door hinges of course, the hinges are on let us say one side of this particular door. There are door locks which would allow the door to sort of fit to the remaining portion of the body and then there can be a latch analog both,

where in one case the door can simply get press fitted another locked. So, that one cannot open it without removing some kind of a lever for actuation.

So, this is a very complex geometry or complex engineering product, where there is a problem, because if we look at the door and if we look at the pressure that it creates with respect to the body, in order to prevent the shower or other leakages, coming out from the door, there is a weather strip door, weather strip which is around this whole door and it is basically a rubber cushion which actually press fits from with door on one side and the side body on another side, and this rubber cushion is actually fitted with some small holes which are there at different portions of the door inner and outer.

So, the inner and outer, the inner member being the, the ribbed member and the outer member being a continuous member are hemmed together. So, the cross section of the door might look something like this, where there is an outer member, which is actually connected to this inner member and there is a hemming which happens. The outer number of course, has the same curves and curves as the automotive outer and the inner member as the rip kind of structure, where there are many components which are in this space you know inside, the hollow which is being created because of the hemming here and maybe somewhere here of the inner and the outer structure of the door.

The weather strip is connected in the manner. So, that the weather strip place you know it is role in terms of generation of pressure, there are certain lips which are probably there which sits to the car body and if I looked at the weather strip, the weather strip actually goes all way round this periphery, as you can see here and it might have more than two lips which would create, you know and these are made up of completely made up of rubber with a certain you know lips which would create a sort of pressure a closing pressure or the door on the on the side body of the automotive. So, that there is prevention of leakage which may happen.

So, because there are certain holes in the whole periphery of the door which will create the fitment of this rubber strip to be possible there is always a problem that if supposing some of these holes are, because of the natural degradation of the rubber and the rubber coming off, may be exposed to do splashes and particularly when the door is, when the automotive is moving on a road there is a chance of leakage of water from this gap which is created between the rubber strip.

So, there is a point typically where there is not, so much of pressure, because of some deterioration of the rubber part and the water may actually go inside the door and create a logging water logging and this water logging, if it continues after, let us say a few thousand miles of driving, may create rust problems associated with lot of bad appearance defects particularly when the automotives are older.

And also it creates jeopardizing, or it creates or it sort of tries to jeopardize the moving components within the door which may be related to the hangers or let say related to the scissor lift which is used for the regulation of the window or movement of the window along the door sash etcetera of an automotive. So, such is a problem which has to be investigated in this particular case and we had to draw out a way or a method for doing this prevention of water logging to happen and so, normally auto manufacturers use some kind of a wax dispensing unit, particularly when the body comes from the welded body and goes through the decode process and goes into finally, the primary secondary and tertiary coats of a paint.

So, just before the final paint coating and the end of the E D process, the on the line there is a wax applicator which would create a sort of a wax layer on the door inside, meaning thereby we are targeting this particular region with the wax layer, which we are trying to whose out through a wax gun on the line.

And, so typically if the automotives in a paint shop, if you look at this process, it may be something like trolleys carrying the automotives with door in open position and the wax applicator with the manual application station, where there are operators which would actually dispense the wax while moving the gun from inside periphery through these skeletons or through these hollows which are there on the door inside. So, this wax application process may result in some kind of water longing action, if it is not carried out properly. If the wax layer thickness or the viscosity or let us say the application points are not as per the specified limits, there may always a problem of, there may be always a problem of holes getting uncovered and, because of which water longing must are taking place

So, the FMEA process that we want to develop is to sort of study the wax application in a more appropriate manner within the inside of a door, so that this problem of corrosion can be retarded and the potential failure mode happens, because of insufficient wax coverage over the specified surface, which relates to a process function requirement, which is about, you know the main functional requirement of the wax is to sort of manually apply inside the door,

so that you can cover the inner door lower surfaces at minimum wax thickness and corrosion can thus be retarded within such assemblies, door assemblies.

So, the potential effects of these failures may be many, including it may be and it may lead to deteriorated life of the door of the door parts. There may be impaired functionality of the interior hardware of the door. For example, after a substantial amount of water longing for some amount of time, the way that the window regulator is going to move you know in placing the window back into place in the window up position on the window down position that may get impaired, because of rust and improper lubrication.

Rust actually spreads, whenever there is a metal to metal contact. It may also lead to some kind of movement problems related to the door hinges, you always find spooky noises when doors open in old automobiles, let us say after 5 years 6 years of drive you always find that the improperly lubricated door hinges may result in some very strange hearing kind of squeaky noises, while opening which may not be very well appreciated by the user or the customer.

So, these water logging problems would result to such kind of failure modes. The other most important potential effect for the failure could be related to the appearance problem due to rust coming up from the door outer, sometimes there is a paint scratch or a paint peel off on the outside, and then if there is a rusted door in the rust may always come up on the surface of the automotive and it may be a very bad look and it may jeopardize the whole painting process. So, a layer of paint may get actually peeled off, because of such rust coming out and it may be again another consequence or consequential effect of the failure mode related to insufficient wax coverage.

So, here after looking at several different defects or a group of different failure modes, a quality engineer analyzes the severity of this particular defect and he rates the severity of this defect to be 7 on a scale of 1 to 10, as compared to the other defects which are probably around. And then he tries to understand what are the potential causes why this failure is happening on a line by doing a line study, and what he finds out is that there are more than one causes, multiple causes which lead to such failures.

One is that the manually inserted spray head, which is supposed to spray the wax on the door interior, is not inserted far enough, so that it can go to the right depth where the wax needs to be spread. For example, if I looked at the door in our hardware and there is a wax gun which

comes all the way here, the wax gun should actually come to the bottommost point where the thickness of the wax should start and if we just allow the gun to not come or come in sufficiently.

Let us say for example, in another case if the gun comes somewhere on the top here and is not able to come all the way to the level where the wax dispensing has to happen, there may be a possibility of wax falling down as lumps and it may not be a continuity. So, it may have beads of wax without having any connections between those beads and there may be holes in between, because of such application, unless the wax melts and reflows back. In such kind of cases, because we are talking about automotives running in all sort of conditions, wax also and the viscosity and the melting point of the wax also is sufficiently revised. So, that the melting does not happen ah; otherwise remember there are always holes through which the wax may flow out.

So, these melting temperature of the wax probably that is being used is a little higher than the normal operational temperature which may be close to about 48 or 50 degree Celsius in a peak summer period. So, we are talking about wax of a slightly higher melting point also. So, there is a possibility that reflow and leveling of the wax. Because of the incorrect disposal of the wax at a certain height may not be possible leading to beading and discontinuity of the wax layer which is being applied. So, that is one issue because the manually inserted spray head may not have been inserted far enough because of an operator.

There can be another failure mode related to the clogged spray head. Sometimes because of continuous spraying and insufficient maintenance the wax may jeopardize the orifice of the dispenser the dispenser and it may create to lesser flow. Lesser flow may always you know, because there is a certain time cycle which can be utilized for coating the wax on the door inner, you cannot go beyond the time cycle because always you know in a line production, this cycle time has to be obeyed. There can be that there is a possibility that you may leave one vehicle, because you have made sufficiently longer time on another vehicle in front of it.

So, in order to line balance, the situation, if the spray head has been clogged, the only alternative can be that within the time cycle that the operator needs to do for one vehicle. he may dispense of a thin layer which may get jeopardize later in terms of cracks or holes you know. So, the clogged spray heads may occur due to various reasons. For example, if the viscosity sometimes is too high that may create such clogging, even when we are applying

the wax from the line, there may be an overall temperature, low temperature at which this applicator is working.

So, that could be one of the reasons again for clogging, or even if sometimes the pressure is too low, the pressure of pumping the wax from a wax cylinder onto the dispenser even that also may lead to clogging and. So, therefore, there has to be a checkpoint related to, whether the wax spray is reasonably on the door inside, so that you have a thin layer of wax, sitting on, covering those holes which will prevent water logging from happening.

Sometimes the quality engineer also observes that there is a case of spray head being deformed due to wrong handling of the gun. Guns are sometimes used to impact the doors to open it you know; you have to remember it is post electro deposition process that we are trying to apply the wax. So, always there is a E D oven and E D tank which is involved and there may be a possibility that the doors might not open up so well. There may be some restriction between the door and the outer body and that may be that may be open by sometimes using a false pretext particularly by operators working on the line, where they may use the gun as a potential hammering unit for opening the door. So, that may lead to some spray head deformation and because of which there may again be a problem of insufficient wax application.

Also there is another problem that the quality engineer finds, which is in terms of spray time insufficient. So, sometimes you know, because of the untrained operator, because of his inability to go on in flow with the production process, you might find time between many vehicles which are come in sequentially, to be insufficient to coat the whole vehicle with a certain wax layer. On one hand the line is balanced for a skilled operator and if you put an unskilled operator these problems are going to happen.

So, the quality engineer again tries to decide on the occurrence levels, which leads to this failure mode of the various mechanisms. So, he rates the manually inserted spray, not inserted far enough failure mode or failure mechanism, to have a rating of 8. Similarly, because the spray heads clogged he rates this occurrence to be 5; that means, almost 50 percent of the times this might be the reason or 80 percent of the times manually inserted spray, not inserted far enough maybe the reason, about 25 percent of the times he feels that spray heads are deformed and he does it on a large set of observation, maybe he observes few shifts shifts in an in a month you know and then based on that he concludes by giving his rating.

And then he also records the spray time insufficient, reason to be about 80 percent of the times the main reason why a failure mode should happen. So, therefore, what he has done is a sort of a defector analysis, where because of this failure mode, whatever are the reasons associated with the failure mode are rated in terms of how much contribution they made to contribute to the failure mode in terms of their occurrences etcetera.

So, once this is classified then he looks at that; obviously, if these are the various mechanisms of failure, are there any check points to see, whether these failures through these different reasons are being monitored and are being controlled and. So, he finds out that there are certain current process controls which talk about, what are the you know, what are the monitoring points through which such mechanisms for the overall failure can be influenced.

For example, in the manually inserted spray head not inserted far enough may a mechanism for failure, he finds out a process control is to visually check each hour, maybe one vehicle per shift for a film thickness. This can be done using a depth meter where you know the insertion into the wax layer might give a marking on the scale through which you could measure, what is the thickness of the wax which is being measured.

And also the coverage can be measured by, maybe just jeopardizing one wax layer from, by moving the pointer from one side of the door to the other side of the door to see, if the whole layer is executed or if there is some kind of a you know hole or a crevice in between which has been left or if it is insufficient at certain times, because of beading and other effects.

So, only a visual check is initiated at this particular you know failure mode for doing a process control. Similarly, for the spray head clock, there is a test spray pattern which is being utilized at the startup and after ideal periods. There is always a possibility that the wax which is coming or being dispensed out of a cylinder, wax cylinder which comes from a vendor, may have these different parameters like viscosity or temperature or pressure dependence, and it may result in lower flows through the spray heads and also some remnant wax inside the spray heads may get clogged and make the orifice smaller.

So, the best idea is to sort of at every shift end or at every shift beginning, check whether the dispenser is properly dispensing by spraying a pattern and seeing how much of that is being covered. So, that is one preventive maintenance step that is there for the current process control. For the spray head deform there is of course, a program of maintenance, where it is

necessitating to check every Sunday or every Saturday at certain point after the shift is over, you know whether the spray head is really in good shape or it has been deformed.

And so if it is deformed it is replaced, but then again it is after certain time intervals and what happens if something happens in between is also not there. And based on that, also for the spray time insufficient probably there is a 10 doors per shift check point done by a certain supervisor, to ensure that if some operator is untrained and is not doing the job properly and the spray time is insufficient. So, the 10 doors per shift checking protocol is just to see whether these spray time is insufficient, and because of which there is a coverage issue of the wax on the door inner.

And again the quality in charge who looks at this defectory, sees the various you know levels of detectability with the current process controls and rates about you know 50 percent to the step 1; that is visual check for film thickness. So, about 50 percent of the times you can detect the manually inserted spray head, not inserted far enough through just a visual check on the film thickness. About 30 percent of the times again you can detect whether the spray heads are clogged through the test spray pattern control point which is there on the in the system already, and then with preventive maintenance again about 20 percent of the times you are able to see the spread spray head gets deformed, because of in some in inappropriate operator use.

And similarly this 10 doors per shift checking gives you a very good instance about 70 percent of the time you can detect this spray time to be insufficient or not. So, these are the various detectabilities. So, the RPM number which is again the multiple of this tuple; that is severity occurrence and detectability, is calculated here to be 7 cross 8 cross 5 that is 280, and similarly for the other different root cause tree which is causing the of, which are the responsible causes for the or mechanisms for the failure to happen, the RPMs are calculated to be 100 and 528 and 392.

So, now, one has to do something, so that the RPMs could change, and the RPM have to be brought down in terms of maybe either decreasing the occurrence percentage of a certain defect cause or again you know, do some design improvements, so that it may not be as severe. The failure mode may not be as severe. So, in this case it is out rule, because the process is fairly well established the design is well established.

So, we cannot do anything about the severity, but; obviously, we can make some countermeasures, so that overall occurrence of a certain defect can reduce and then also the detectability can, either be at the same level or go slightly up. So, that overall the RPM, because of the dominance of the reduction of occurrence may come down. So, the idea is to tackle actually you know the occurrence part and make it lesser and detectability part to go higher.

So, that you can ensure that any failure mechanism which is causing this particular failure mode to happen, eliminate completely and whatever you know generation of that failure mode or that reason is still existent, is very well detectable. So, that it does not lead to much occurrences or it does not lead to much undetected failures going out of the process.

So, in a way by controlling mostly the occurrences by control measure planning, proper countermeasure planning the RPM should be reduced. So, in this particular case the following actions are recommended by the quality engineer. So, for the manually inserted spray head, not inserted far enough, the engineer suggests a sort of a full proofing. The full proofing is related to adding of a positive depth stop to the sprayer. It may be some kind of a limit switch which will lead to; you know a signal to the overall PLC which controls the assembly line. If supposing the spray gun is actuated with some kind of a liber.

Let us say there is a liber here, which gets pressed, because some component in the door at a certain depth fouls with this liber which allows this liber to go all the way down here, only then such a pressing of this particular liber may happen. So, this adds a signal which will allow the line to continue otherwise the line will stop. So, these are known as poka yoke or full proofing, from a lean manufacturing system standpoint and such a full proofing is abundantly present in the line particularly for automakers, to ensure that some of the criticalities get obeyed in terms of compliance to quality standards.

So, in this particular case the adding of a positive depth stop may necessitate, that if the manually inserted spray head is not inserted to a certain level, the line will not even work and the line will stop. So, therefore, it has to ensure that that particular lever gets hit and it gets deflected for a count, so that the PLC can signal the line to start again. So, this is sort of a full proofing which has now, as you can see led to a situation where the multiple occurrences of this particular event has been reduced to almost 20 percent of the times, earlier it was 80 percent. The other step that is recommended is sort of a automatic spraying you know.

So, basically you have a robot oriented spraying process where the gun actually goes into the door inner at a certain level and start spraying for the whole span of you know length over which the spray has to be made, but such a solution is rejected, because there are different contours of doors, there are there is only not a single model production, but mixed model production in such lines, and handling such an automatic, fully automatic system may be a problem and. So, therefore, this idea is rejected completely and the idea for the positive depth stop has been implemented.

So, for the process control test spray pattern and also the spray head clock problem and the quality engineer suggest the use of DOE or design of experiments to get a proper, you know value related to the viscosity temperature pressure based on the operating conditions or the operating temperatures, in which this process is carried out on the line and. So, this DOE gives you an idea what is going to be the optimum, you know biometrics in terms of operational viscosity temperature and pressure values.

Also a additional checkpoint is recommended, where you know it is recommended by the Q A that a fraction defective charge be plotted here, in order to show that due to this particular reason, how many such problems of insufficient wax coverages result, and, so the temperature and pressure limits are kind of obeyed or not, gives you a sort of you know an idea of what is going to be the fraction defective coming out of the particular line. So, it is recommended that a P chart are to be plotted in this particular case, in order to maintain the deviation if any from the optimized parameters, which have been fine found out using the DOE

So, here again the occurrence goes down severely from 30 percent earlier. So, from 50 percent earlier to almost about 10 percent and that results in an overall reduction in the RPM again. So, the RPM changes in the first case to about 70 from 280 and about 21 from 105. There is no need for change of RPM in the third case; that is pre head deform, because already the ipn is quite low and then in the fourth root cause; that is basically spirit I means insufficient again, it strongly suggested by the Q A to install a spray timer which will lead to automatic spraying for a certain time and until and unless that time cycle is obeyed the next vehicle will not come up and the line will stop.

So, again a full proofing and also a maintenance of a C P K value showing, how much of fraction defectives go after the installing of the spray timer and how much was there before,

in order to find out whether there is any change. And so in this case 1 records that from 70 percent occurrence, the occurrence has come down to almost 10 percent and the RPM is reduced to about close to 49 from 392. So, this is definitely a process improvement where the occurrence is reduced with the probably same degree of severity, and maybe a slightly higher detectability limit. As you see here in this particular case, the detectability does not change much you know in almost all the root causes, but generally if an additional step can be done to see the minuscule amount of occurrences to be detected very accurately, it may be a better strategy.

So, reduction in RPM as recorded through these countermeasures are documented finally, So, that 10 years down the line is the same defect gets repeated, you can come back to this particular documentation of a one sheet representation of the whole defectory and the countermeasure, and then see what went wrong, so that the defect again came up. So, this is the sort of a control which needs to be there for every process, every design aspect related to a product, which goes through a manufacturing process and it is a very useful tool as such to carry out good quality product synthesis.

So, we will also like to now visit another very important tool after this FMEA tool, which is heavily used for the conquer engineering environments and that tool is known as, better known as quality function deployment or Q F D, which is about again the planning of a design at the very beginning and investment of resources and manpower towards the beginning, even way where before the production starts to take place, so that you do not have any hiccups after the production has happened and you know the product lifecycle he can get executed without much of breaks, because of this initial investment.

So, let us look at quality function deployment. So, QFD or quality function deployment is merely a tool, it is a quality tool, which is typically utilized for betterment of the product design. So, that there are not many hitches towards the end of the road, you know in the product development process or even post manufacturing product life is part of product life cycles, parts of product life cycle.

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What is QFD?

- Quality Function Deployment, QFD, is a quality technique which evaluates the ideas of key stakeholders to produce a product which better addresses the customer's needs. ← (VOC)
- Customer requirements are gathered into a visual document (House of Quality Worksheet) which is evaluated and remodeled during construction so the important requirements stand out as the end result.

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So, a definition if we look at, what really is QFD. The term QFD actually calls for quality function deployment, it is a quality technique which evaluates the ideas of key stakeholders to produce a product which better addresses the customer's needs. So, typically we call QFD to be the voice of the customer or VOC. So, this voice gets trapped somehow in the design phase itself of the product. So, that it caters better to the needs and necessities imposed by the customers, because of which the product.

So, the voice, the customer's voice is trapped at the very initial phase towards the development of the product and it is basically a way of also evaluating where you are placed in terms of your service or your product in comparison to your competitors. So, in a way, it gives you a variety of information related to what is the current status, how you can record the voice of the customer and how you can imbibe that, so that your status with respect to your competitors are different you know, and there are more preferential inclinations towards your products in comparison to the competitors were there in the market.

So, the customer requirements are gathered together into a visual document, it is also known as the house of quality worksheet and I am going to typically focus on this house of quality worksheet and tell you about the various instances. And we will do some design related to the dry cleaning business, where we will talk about setting up a dry cleaning facility and compare it to the existing facilities which are available. So, that we can get an idea of what needs to be

the focus in the process of setting up a dry cleaning business for the business to run well in comparison to the other competitors.

So, the customer requirements gather into a visual document or a check sheet are, you know evaluated again remodeled and these are carried out many times iteratively, so that we can have a proper construction of the whole product of the service that we are aiming at and. So, through this whole process of recording in a worksheet, what you essentially get, are those important requirements which sort of stand out, which need to be addressed in order to improvise the product of the system which is in question. So, let us now look into some of the requirements of what really is required by this area of QFD once you plan to do it with your products and processes.

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What Does QFD Require?

- QFD requires time, effort, and patience.
- QFD requires access to stakeholder groups.
- The benefits of QFD are not realized immediately. Usually not until later in the project or the next project.
- QFD requires full management support.
"Priority" for the QFD process must not be changed if benefits are to be realized.

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So; obviously, one of the major investments that you have to make, if you really want to do this quality function deployment are a lot of time and effort and also patience towards studying properly a process or a product and mapping it to the aspirations of what a customer would really like to have. He would also necessitate the a proper, you know and impeded access to the stakeholder groups, the people who are customers which would finally, use the product of the service.

So, you need a proper access to all their minds and; obviously, how you will do that access is dependent on you, but if the customers are open to such discussions, then the QFD process definitely becomes a lot better, in terms of the output that it yields. The benefits of QFD are

not realized immediately. So, you have to patiently wait for this, not until later in the project. So, once the manufacturing just starts to happen, you have to wait quite a bit for the whole product lifecycle to be executed from post manufacturing services to 1 D troubles to you know the service requirements and followed by finally, the product end of lifecycle disposal so on so forth.

So, it is a huge amount of weight, up till the full results can be realized, but the results are definitely better, as I will illustrate in some cases later on. If you do QFD base planning towards the very beginning of the product cycle; that is at the product design stage; obviously, the amount of cost invested are the number of impediments which would come, they would be very favorable, when you talk about implementation of QFD at the design phase. So, QFD also requires full management support.

One needs to understand that the additional time effort which is being invested in two is going to make something better over a long period of time. It may not necessarily result in immediate returns, which may be a point where management starts thinking about whether it is worth, but the essence here is or the impression that has been generated out of a repeated application of these processes is that in the long run definitely organizations with the proper quality function deployment scheme, function much better and much healthy in comparison to those who do not.

So, priority for the QFD process must not be changed, if even if the benefits are quite long standing. And if really you want to get the benefit out of QFD, you need to wait patiently and keep or keep investing resources in terms of times and efforts for substantial amount of time. We also talk next about why we use QFD, is there reason why QFD leads to making a difference in the businesses.

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Why use QFD?

- The QFD process leads participants to a common understanding of project direction and goals.
- QFD forces organizations to interact across their functional boundaries (Hales, 1995).
- QFD reduces design changes (Mazur, 2000).

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So, QFD process leads participants to a sort of a common understanding of the project direction and goals. This helps quite a bit, because now team efforts can be well directed towards a certain goal, a certain objective. It forces organizations to interact across their functional boundaries. Again it goes very much in line with what concurrent approaches have said earlier that all wings of organizations work together.

Ah it reduces design changes, because; obviously, whatever you are designing at the first instance, if it maps the customers mind well and the voice well, then not much changing is needed, because whatever you are developing is what is the aspiration of the customer. So, later on down the line post production, if you want to incorporate a change it is always costlier. So, do it at the first before even production starts beginning, so that there is no, you know additional cost impositions because of changes later. So, that is how, that is why one must use the QFD.

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The House of Quality (HoQ)

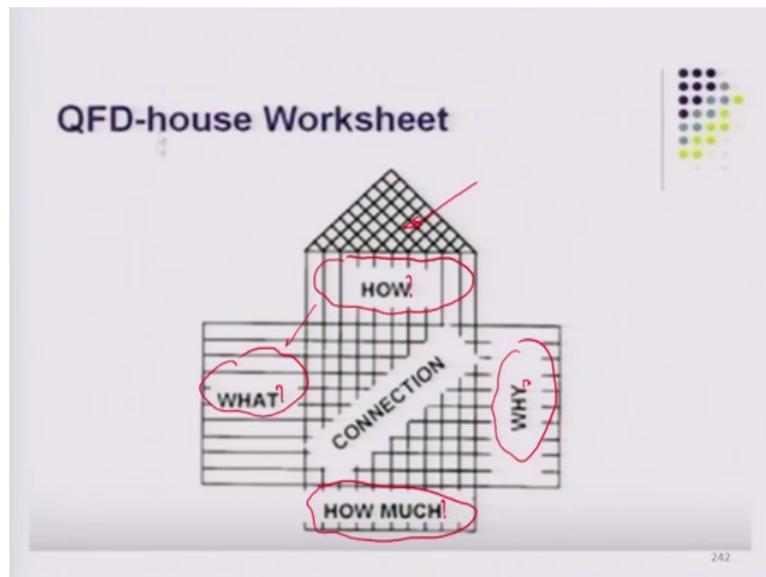
- Is a set of matrices which contains the requirements (What's) and the detailed information to achieve those requirements (How's, How Much's).
- Stakeholder groups fill in the matrices based on their priorities and goals.
- A key to the HoQ is making sure each group answers the same question about the same relationship, What vs How, cell.

Now let us talk about the organized approach the algorithm which is needed for doing QFD, just as we did in FMEA. So, it is a set of matrices which contains the requirements, requirements could be in terms of what's, and what's typically would mean things related to what are the exact customer requirements behind a certain process or a certain product. We look at a dry cleaning example as I had mentioned.

Ah it also in one particular sheet mentions about the, not only the, what is, but also information to achieve those requirements ah; that is the how's and the how much's. For example, if supposing we wanted to achieve, whatever is to be achieved, how much should we achieve them and how should we achieve them. These are two different aspects of one is related to the logistics of what changes, so that what changes can be incorporated. So, that the, what is can be achieved and to an extent of how much that should be changed we incorporated. These also are indicated in that one sheet which we call the house of quality check sheet or a work sheet.

So, the stakeholder groups fill in the matrices based on their priorities and goals, and a key to this house of quality is making sure that each group answers the same questions about the same relationships, what versus how cells are typically placed. So, the what versus how cells are typically represented as shown here.

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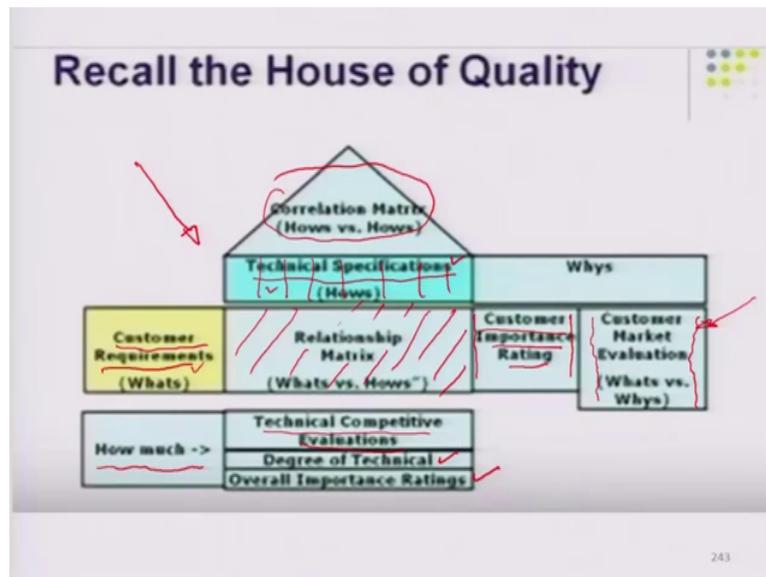


So you have a how segment here, how do you achieve, what do you want to achieve, how much do you want to achieve, what do you want to achieve and why do you in to achieve. So, So, there is a sort of a common connection between all the different questions here, what, how, why and how much and that is what is the organized way of looking at the product development process or a process development scheme. So, there is of course, a roof part also which talks about correlations between the different houses.

There may be a possibility that many strategies are involved in achieving, what do you want to achieve, but there may be some kind of a tradeoff between these possibilities. There may be some kind of a strong correlation or poor correlation between these possibilities. So, therefore, if one gets you know imprinted access and the other one is poorly correlated to that, only then you need not consider the second one if one is excess.

So, these things like that are more on a quantitative level can be a certain through these house of quality worksheet. And basically the it is again a correlation matrix which will give you connections between all these different questions that have been asked about any process or any product which is being developed.

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So, let us just expand the house of quality matrix a little more. So, the what is typically are the customer requirements, about a process or a product. The house are the technical specifications which will take you to satisfying some of the requirements. The whys are the importance ratings of, you know let us say all the requirements, may not be as important to the customers and there may be some variation in the level of importance. There must be some requirements which are the most important requirements.

So, it is a sort of a organized scale to look at you know prioritization of even the requirements, if there are huge amount of requirements. And the whys are also trying to support market evaluations for example, if there are many competitors, where we talk about the what is versus whys we can we can talk about that whatever are the customer requirements are being executed across through a variety of players in the market, and where we are positioned with respect to those players. So, that can be given through this y end here.

There is also a section for how much, which means once the requirements in terms of technical specifications are defined, each technical specification should have a certain base level and we must evaluate our competitors with respect to that base level in comparison to what we have. So, that this gives you an illustration of technically where you are placed with respect to all are your competitors, as regards these technical specifications which are important to carry out the requirement levels. And of course, these specifications are related

to the requirements through this matrix right here, which is also the relationship matrix which talks about what is strongly related one is weekly related.

Not all technical specs are important for all requirements. Now, there has to be some correlation rating, based on which one can think of the relationship between requirements and specifications. Then we also give some overall importance ratings in the how much about you know different technical specifications and how much they can be thought of to contribute to the what is are the requirements.

And then we can evaluate the degree of technical you know maturity of, again our organization or our process with respect to the competitor's process. So, all this with a correlation matrix about you know the different technical specifications and their associated correlations, which is available in this roof part, formulates what we call the house of quality. Now let us look at a clear cut example problem, which will talk about establishing of, let us say a drycleaner shop. And here in this particular problem I would like to draw the house of quality matrix for such a requirement. So, supposing we have a problem statement given to us that we would like to set up a dry cleaning business and there is already existing competition in this business.

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So, we want to see a process, understand the process in terms of the house, the what is, the whys and the how much is and formulate a correlation matrix, for us to be very clear about what needs to be done as a next step, if you want to set up such a business. So, let us talk

about first the how is, first the what is or the customer requirements in a dry cleaning business. So, I will just draw a correlation matrix here.

So, on one hand we have the customer requirements, but recorded in this vertical column here, and let us say some of the requirements that are rated here are 5 in number for a dry cleaning business. One of them could be that one of the requirements major requirements of all customers is that the clothes that they get should be completely clean. There should not be any spot or any speck of dust in those clothes that come out of the dry cleaning shop. There could be another requirement here of that the press of these clothes should be perfect.

So, let us say we have a pressed perfect cloth here in the customer requirements. So, a completely clean cloth, pressed perfectly is what is the majority of the customer's aspiration about a dry cleaning business. There can be some additional requirements which the customers would like to be very happy on; one is that there should not be any delays at the counters. So, no delays at the counters supposing the concerned person who is running the business, you know has given a certain target date or time when the customer needs to collect the clothes, you know which have been pressed and dry cleaned and then the customer comes on that particular stipulated time and date and finds out that the clothes are not he had done and he has to wait quite a bit at the counter in order to take the clothes.

So; obviously, that is something that the customer will not want to do every time and there may be lost business and non-sales because of that. So, therefore, delays that the counter should be by and large avoided. So, that is one requirement, customer requirement. Then there is a requirement about a quick turnaround time, how much time the dry cleaning shop takes to return back the completed operation on the clothes that have been submitted.

So, supposing there is a dry cleaning shop which has a longer turnaround time that said gives 2 weeks before the customer can come and pay, so; obviously, the customer will not be happy as opposed to somebody who is going to give only 2 days or 3 days, before the customer can turn back and take the clothes. So; obviously, the second case would be more preferable to the customer in comparison to the first case. So, that is another customer requirement. There could be additional requirements which we probably do not realize, but you know it is probably important in the game when we talk about customer's minds; one of them could be how friendly these services.

So, if at one instance for example, some, one of the dry cleaner shops decide to just put a curtsy SMS to a person or maybe let us say a phone call which is made to the person on the day of, schedule day of collecting of the clothes or the collecting of the finished clothes, that the clothes are due and you this may be collected at so and so time. So, it always makes an additional plus delta to the customer which might make the customer very happy.

So, or maybe delighted. So, something like this where you can, from your side offer some kind of a friendly proposition or a service, which might be a reminder email or a reminder phone call or reminder a SMS would always be preferred by a customer and that could be one other important customer requirements. And thus with all these different requirements we can probably, look at now some of the specifications related to the dry cleaning process which might help in realizing some of these customer requirements.

And before going there, we would like to just rate these different requirements of the customer in terms of some importance ratings. So, not all of them are equally preferred by the customer. So, there may be some which would prefer definitely, and some which may not be that much needed. Although it might just give you a plus delta pleasure or cause a customer delight. For example, but the definitive requirement that any customer would want from a dry cleaning shop is a completely clean set of clothes and of course, perfect pressed on them.

So, this can be number 1 and number 2 in terms of importance ratings. Let us call these importance ratings to requirements from the customer. Quick turnaround time would be again something which would have, which would be number three. Similarly, friendly service could be number 4 and no delays at the counter could be number five. So, these are the order of importance ratings after talking to variety of customers, which probably our line of business, which we want to establish, the dry cleaning has done.

So, again for this particular study you have to have access to variety of customers who come to the existing shops. Remember you are setting up your own drying cleaning unit in comparison to what is going on in the market and there are two such competitors that you have in the same place, where you have to have the access to all the customers which code these places in order to get an idea of what they would like and what they would not, in terms of their importance ratings to the various requirements.

Even these requirements also as a matter of fact come from, talking to the customers, preparing questionnaires and trying to then summarize on the basis of a huge amount of

response over a few months' period, which gives you what exactly would be the top requirements and what is going to be the ranking of these requirements.

So, when we talk about the technical specifications which are needed by the DC business or dry cleaning business to serve some of these customer requirements. We get into the operations of stage and there are certain operating requirements, which would provide the house, how to get you know the customer happy or how to get the customer requirements to be fulfilled. So, let us look at some of these operating requirements for the dry cleaning business, and if I were to look at some of these requirements related to, particularly dry cleaning.

One of the basic requirements for the whole process to be proper, whether it is completely clean, you know a set of clothes or perfect pressed set of clothes is good training so, if the people who are handling the job, they are at that the dry cleaner is are quite well trained to do a proper pressing or a proper clean clothes, then that is going to be one of the most important components for probably meeting a lot of these customer requirements.

So, one operating requirement is good training. So, let us look at some of the other requirements. One of the requirements could be related to the relatively clean, dry cleaning solvent. So, whatever soap solution or whatever other solvents we are using for doing the dry cleaning, should be relatively cleaner. They should have a high degree of cleanliness, because otherwise they will stain up the clothes and then this requirement of completely clean may not may meet, because of such unclean kind of solvents which may be occasionally used, if not careful.

We can also check you know the filters related to the dry cleaning machine. So, we should have clean dry cleaning filters. If the filters are not cleaned from time to time, then also there is a reason why thus could be carried back into the clothes while the cleaning process is on, and it might result in some kind of a you know unclean surface or dusty clothes being given. So, that is another aspect related to the operating requirements.

There could also be a requirement of we should not allow any rust on the fluid lines. So, let us say, because you know in this whole dry cleaning business, because it is a high throughput process there are lines of solvents which have in pumped into the machine, which does the cleaning and also the drying. So, these solvent lines are very important to be maintained from

time to time. One must ensure that there are no rusts on these lines, because they are typically hidden behind the machine and.

So, there has to be some kind of a preventive maintenance or a strategy to look into it. So, let us write this is one of the operating requirements, no rust in fluid lines. Let us call it solvent lines. So, that is another operating requirement. There could also be an issue related to the press pads and by and large one wants a stabilization or a steady set of pads over which the ironing or the pressing is done. So, we can call this as the firm press pads, which are also another very pressing requirement for a proper ironing of the clothes.

So, firm press pads and then of course, overall we must have good equipments, well maintained equipments, we do not get which do not run into trouble or you know do not jeopardize the delays at the counter probably. So, we can give one of the major requirements of operations as good equipments. So, when we talk about the house, of how to achieve whatever we want to achieve here between one to five as indicated in this side of the, you know customer requirements side of the table.

We can achieve them through these technical specifications good training, clean DC solvent, clean DC filters, no rust in solvent lines, firm press pads and good equipments. Again these are some things which are found by talking and having proper access to the people who are already owning the dry cleaning shops, which are in question and just trying to find out from them what all are very important for the dry cleaning business. So, you get a learning experience for that.

Also there is a correlation between some of these points, you know on the house side to the, what side and this correlation we can probably express in terms of some numbers. So, let us say we have three different relationships. Which are like rating numbers between the house and the what is. So, in one case we represent this through a black dot, which means a strong relationship. So, on a scale of one to nine maybe, the level of relationship is about 9. Similarly, there could be one which shows a medium relationship. So, that could be shown by let us say an open circle, something like this.

So, here we could have a medium, for example, rating three kind of relationship between a one to ten scale. And then we could also have another smaller rating with an open triangle, which could show a rating of about one. So, when we talk about these different what is or

customer requirements, we can probably find out these, how these specifications do with respect to the what is or the what requirements.

For example, let us say if we wanted to consider the specification good training. The good training probably is related in a medium way to almost all of it; like complete cleaning, a perfect pressing, or no delays and that the counters or quick turnaround time or friendly service. These are all a part of training and, so a good training would probably ensure most of the customer requirements as illustrated here. Then when we talk about let us say the clean DC solvent.

We might have a strong correlation of complete cleaning with the clean dc solvent; one thing which is very important to be there in the dry cleaning business, is to have a solvent which is really good in terms of it is cleanliness. So, that you know there are no oil or dust which is brought into the region of the cleaning of the clothes or they may not leave any stains in case that the thing happens and. So, there is a strong correlation between these two.

Similarly, there would be a strong correlation of clean DC filters or clean dry cleaning filters, with respect to the complete clean requirement of the customer. There may be also the same degree of strong correlation between no rust on the solvent lines reserve is the complete clean, the requirement of the customer. So, when we talk about firm press pads, they are of course, very strongly related to the perfect press, if the press pads are somehow unstable or they do not have, you know they, they are not they are amenable to movement or vibration, while the ending is happening, there is going to be imperfect pressing and they are going to be creases in the clothes which come out. So, therefore, there is a strong correlation we can indicate that by a black dot again.

Again good equipments are completely responsible for or strongly correlated to complete cleaning and perfect pressing. However, good equipments can also have a very small correlation with the turnaround time, because if the equipments are down then this turnaround time may be affected quite a bit and that should be correlated in a small manner, the good equipment should be correlated in a small manner to the quick turnaround time. So, these are again a matter of perception of the person who is doing a study by talking to the various stakeholders like the people who are doing the dry cleaning as well as the customers and this importance rating is based on such studies.

We can also give some kind of a weighing to all these different technical specifications; like training, you know clean solvent fluid or clean, let us say filters or even like no rust on the pipelines or firm press or good equipments, by putting some numbers. So, we can give importance road ratings to these how matrices.

So, while doing that the concerned person who does this rating, finds out that the good training might have a rating of 15 on a scale of, let us say one to 20 again. Whereas, the clean dry cleaning solvent might have a rating of 9. Similarly, the clean filters might have another rating of 9, the no rust on the clean lines or solvent lines could have a rating of 9. Similarly, from pressed pads whatever rating of 9 and then good equipment would be very important, so it has a rating of about 19 on a scale of one to 20.

So, that is how you can do importance ratings to this different house, which would help in achieving the customer requirements; that is what is and then we can also have a sort of a correlation matrix between all these different specifications which have been laid out which are important for the dry cleaning, a proper dry cleaning action to happen. So, let us draw a correlation matrix between the house and the house now. So, let me first make this matrix here.

So, we can actually have a matrix drawn like this on the roof of the house which will give you an idea about, how these are correlated with respect to each other. So, we would like to have a correlation factor again of three different levels, when we relate the different house with respect to each other, actually four different levels. So, in one case we might need, we might make a very strong positive correlation between the two houses, which are on records. I will call this positive strong. We might also have just a positive. So, represented by a just a open circle. So, we can say positive.

We might have a negative correlation and a strong negative correlation again. So, let us say in one case we might use a notation of triangle as a negative correlation and a closed triangle is a strong negative or negative strong. And let us look at now the various house and how they are correlated to each other. For example, if I look at good training and how it is correlated to the let us say the clean dc solvent. So; obviously, if a person is well trained, he would be able to look at a solvent and see how clean it is and it might be having a positive minor positive correlation. Similarly, the good training might have minor positive correlations with almost

all these different tools which would indicate clean dry cleaning filters, again no rust in lines solvent lines so on so forth.

When we talk about no rust in the solvent lines, we can also have a sort of a you know negative correlation or a strong negative correlation with good equipment. So, if the equipment is good, then the possibility of having a strong rust on the solvent lines is almost eliminated. So, I would mark this as a close triangle, and in this manner I would like to correlate the various things or various house with respect to each other. So, this gives you an overall idea, about if two or more of such factors which will cause the, what is to come in are related or not related or unrelated. It will give you a basis of how much independence you can associate with respect to the different house you know in order to correlate the different whys or what is.

So, then we talk about how we detect what are the levels of these different technical specifications and we set up some kind of target values of doing inspection or checking, of these different associated house about how to achieve the customer requirement. So, let us say we set up some target values here. This kind of gives you a modality of how do you want to achieve what you want to achieve.

So, let us say a good training module is considered to be a 4-hour formal training plus a 2 week on the job training. Similarly, for the technical specification clean DC solvent; one can introduce a visual check daily. So, let us say we have a visual check daily as a target value. For clean DC filters again we can have a visual check daily and probably clean in a monthly basis.

So, we have VC daily and cleaning monthly as a target value. For no rust in the lines again we can have a visual check daily. So, we say this is VC daily. again for the firm press pads, we might be able to change on a monthly basis the press pads, so that there are no issues of movements or creases getting altered or spoiled, because of such movements or the pads. For good equipment there can be a maintain a schedule plan, we talked about let us say maintained on a monthly basis.

So, you have a monthly plan or maintenance and these can be some of the target values at which you set up the house of how to achieve, what do you want to achieve. So, these are the, what is and you have completed the how is. hows are correlated and between the what is and the hows also we have certain degree of correlation, as given by this matrix. We have an

importance rating so far to all the what is. We also have importance ratings to all the hows and target values associated with them.

Now, we come to how we are placed and for that we need to look into our competitive evaluation. Here we talk about let us say two different companies or two different shops which are into the same business as we are. Let us say we have a shop A and B. So, shop A is run by a competitor A and shop B again by competitor B. We read ourselves as x. So, let us say this is what we are, and we want to see in terms of all the what is and all the hows where we are placed with respect to our competitors.

So, we will evaluate our competitors in terms of five different ratings with 1 2 3 4 and 5, where 5 happens to be the best in business and 1 is the worst. And so we will see where we are positioned with respect to our competitors. So, when we look at, let us say competitors A and B for the first component here are the, what is that is completely clean. We find out that they are rated somewhere around 3 and we are much better or much above them in the completely clean business. We actually need to be above them if you want to setup the business, because the complete clean is number 1 requirement for all customers as you are seeing here in the importance rating.

So, you have to be somewhere, at a higher level than A and B both in terms of what they deliver has completely clean. Similarly, when we look at the perfect press we see that B is not very good at it and A is reasonably good. So, we can actually B somewhere around 3 rating, so that we can have the second requirement; that is perfect pressed requirement met completely. The no delays at the counter requirement which is slightly lower in importance level when we talk about DC business, can may be this done away with.

So, A is really good at it. So, a somewhere in 5 and B is somewhere around 3 and we cannot beat the competition here. So, we may as well keep it slightly below, let us say because we are just starting the business, sending an SMS or something like that, may not be really or, there may be some delays associated with the process, but because it does not have much of an importance rating we can do away with it.

Similarly, when we talk about turnaround time we see that both A and B are quite high on that, A being placed at three and B's place at you know four. So, we can do away with probably slightly lower value your turnaround time as well. I mean even if we have a high

turnaround and we do a, very good job in terms of the primary requirements which is complete cleaning, and the perfect press fit, a perfect pressing.

So, we should have more customers in comparison to A and B. And then finally, when we look at friendly service A and B are probably placed at number 1 and we can be slightly better off here so, that we can design our system in a manner given by this curve right here as A walkway for our competitive evaluation.

So, we can give different levels to the different what is as required by the customer in respect to the customer in, the other competitors. A similar evaluation be carried on the technical front. So, we will do a technical evaluation here, right below. We have similar ratings between one to 5, I place 5 on top here 5 4 3 2 and one, we call this technical evaluation and try to see where we are placed with respect to our competitors. B is quite high on the on the job training and A is somewhere low, so we can be somewhere in the middle.

Similarly, A and B are placed at number two and number one as regards the visual check daily for the DC solvent lines we can probably, because we are claiming to have complete cleanliness and better off in terms of A and B, we can place the visual check scheme of clean DC solvents. slightly higher above A and B. We can again be placing the clean dc filters, where A is rated 5 and B is rated one, somewhere in between. So, we can rate this at two. Mind you if we are not giving enough importance to A particular technical spec we are saving cost, we must have that idea as well in mind while designing the system.

Then we will talk about rust on solvent lines, you know A and B are rated somewhere around 2 and 3. So, we can probably position ourselves slightly better off than them, maybe at 4. And then when we talk about again the changing monthly schedule for the press pads, again we find out A and B are rated as 3 and 5. So, we can position ourselves probably somewhere in between we when we talk about again good equipments, A and B are rated again on level 3 and level 4. So, we can actually rate ourselves quite higher to A and B and develop a strategy for us, given by this lines connecting all these x marks, through which we can place ourselves in terms of the how is.

So, we now exactly know what has to be done in our business, that all the hows can be positioned with respect to our competitors by tweaking the various levels of the different technical specifications, and all the what is can be achieved by looking at our competitors and focusing more on certain aspects and the others. So, that we are always being, we can get a

better share of the market or a better customer share at a slightly lower cost than our competitors.

So, in one, in a nutshell this one page that we have drawn here, gives you a sort of a correct positioning of where you need to position your process or your system, so that you can do a better job from your competitors. So, this is how house of quality is done on processes. We can do similar activity for products as well and you are feed do things related to, let us say cell phone businesses, setting up a new cell phone model in the market when already there is an existing, variety of cell phones which are there or maybe new laptops in comparison to the laptops which all exist.

Ah only thing is in this case you need to have access to a proper database of customers as well as manufacturers, for you to be very appropriately placed in terms of what and hows and how much is of the particular business that you are going to design. So, let us look at.

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Correlation Matrix

- "Roof" part
- Identifies how "hows" items support (positive) or conflict (negative) with one another
- May combine strong positive items to reduce development effort
- Find trade-offs for negative items by adjusting "how much" values ↩
- Trade-offs must be resolved or customer requirements won't be fully satisfied. ↩

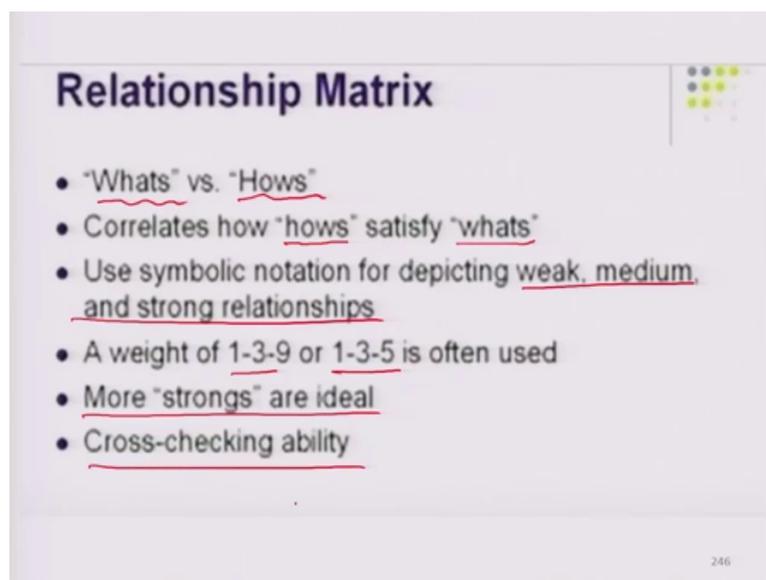
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Some of the key correlation matrices which are there is a part of the house of quality; one is the roof part of course. So, this identifies the items hows and you know the, it is basically how versus how and it kind of gives either a strongly supportive positive correlation or a conflicting negative correlation with respect to one another. So, these are going to give you an illustration of technical specifications, which you may combine, when you find two or more strongly positive items, to reduce the development effort.

So, you can probably combine them together and not treat it as an independent entity and you know if one is strongly correlated to the other, the essence of one being there would indicate automatically or be an indicator of the other being there automatically. So, your development effort is saved, because you are able to get rid of one of the important technical specifications, because it strongly correlated to another which you are actually developing or doing.

So, you can also find tradeoffs for negative items by adjusting how much values. You could trade off you know tradeoffs; obviously, must be resolved or customer requirements will not be fully satisfying. So, you can take care of all the negative items separately and all the positive items, strongly correlated items together for you to design a good correlation between all the hows.

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Relationship Matrix

- "Whats" vs. "Hows"
- Correlates how "hows" satisfy "whats"
- Use symbolic notation for depicting weak, medium, and strong relationships
- A weight of 1-3-9 or 1-3-5 is often used
- More "strongs" are ideal
- Cross-checking ability

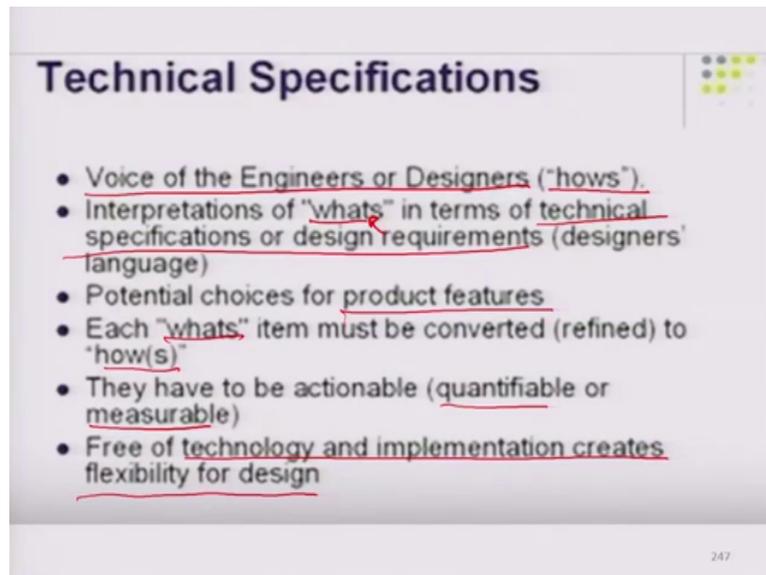
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Similarly, there is a relationship matrix between the what is and the hows, which indicates you know different levels of relationship; like strong, medium and small, correlate hows or how the hows satisfy the what is. So, there are use of symbolic notations for depicting the weak medium and strong relationships. If you may remember we did this in our analysis here when we talked about these three different relationships, which you plug in this correlation matrix right here.

And here you know A weightage of 139 or 135 is often used, in order to gauge what is going to be the level of relationship between A what, which is a customer requirement to a technical

specification which is the how ok. So, more strong are; obviously, an ideal choice. We prefer to have strong relationships between whatever we are saying as the operating requirements or the hows of achieving, what we want to achieve and the what is of what we are achieving. So, we should have a cross checking ability to this relationship matrix.

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Technical Specifications

- Voice of the Engineers or Designers ("hows").
- Interpretations of "whats" in terms of technical specifications or design requirements (designers' language)
- Potential choices for product features
- Each "whats" item must be converted (refined) to "how(s)"
- They have to be actionable (quantifiable or measurable)
- Free of technology and implementation creates flexibility for design

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We also talked about technical specifications. This kind of reflects the voice of engineers or designers and, the technical specifications of the hows are interpretations of what is in terms of technical specification or design requirements given to achieve the what is. So, potential choices for product features for example, could be a part of technical specifications, each what is must be converted to hows somehow through this relationship matrix.

They have to be actionable, quantifiable, measurable and also the technical specifications should be giving enough flexibility to the design, and it should be kind of free of technology and implementation to create a flexibility for design. So, that is how technical specifications would be recorded.

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Customer Prioritization

- Prioritizing the importance of each "whats" item to the customer.
- Rate each "whats" item in 1 to 5 rating
- Completed by the customer
- AHP can be used

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So; obviously, there is also an aspect of customer prioritization, prioritizing the importance of each what is of the customer. We have given importance ratings to each what is and the ratings are given in terms of 1 to 5 for example, and these have to be completed after due deliberation with the customers. So, therefore, the access is very important here, and this is how you get the ratings right here or the matrix in this particular portion of the matrix, when we talk about different what is or customer requirements rated as 1 to 5. So, that is about the prioritization.

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Evaluations

- Comparison of the developer's product with the competitor's products
- Question: "Why the product is needed?"
- The customer evaluates all products comparing each "whats" item
- Rating of 1 of 5 is given
- The results help position the product on the market.
- Identify the gaps

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Obviously there are evaluations, evaluations in the competitive basis or the technical basis of where you are positioned. So, therefore, there is a rating given of one to five for each. And again the question that is asked is why the product is needed. So, the customers evaluate all products, comparing the same domain, and try to find out what are the items which are needed on those products which are of importance to him or her.

The results help you to position the product on the market, and similarly you can also identify the gaps and create strong thirst in those gaps, where you could position yourself as.

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Target Goals

- "How much's" of the "Hows" (measurement) ✓
- Answers a common design question: "How much is good enough (to satisfy the customer)?"
- Not known at the time when the "hows" are determined.
- They are determined through analysis.
- Clearly stated in a measurable way as to how customer requirements are met
- Provides designers with specific technical guidance
- Can be used for (acceptance) testing.

By respecting all target requirements and their priorities as found by VOC, QFD maximizes customer satisfaction

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So, that is how quality function deployment is done; obviously, there is to be a certain target goal, which is going to be there for determining the specification that is in there, for the dry cleaning business the specification was about inspection and measurement of cleanliness or inspection and measurement of tools related to ironing or pressing of the clothes.

So, by respecting all target requirements and their priorities, you are basically training the voice of the customer in terms of the design requirements that you finally, give to a certain product or a process and; obviously, carrying out QFD at an early stage maximizes the customer satisfaction. So, it is quite needless to say at this level.

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So, the difference between the conventional product development approach and the QFD driven approach is that in, in the conventional approach, your specifications are based on internal demands, everything is important, you have to listen to the manufacturing about what is there in the process. You develop and manufacture again specified tolerances. Try to keep on the tolerances because change of them would really need to change a lot of internal dynamics and there are a lot of resistances to such changes within the organization almost always.

And the approach is kind of passive to reaction from customer problems. Customers keep on complaining about a problem, one can look into the process and try to do something incremental change, so that the process can change. So, that it might result in some level of satisfaction, although the entraining of the customer's mind into the product itself is never there, I never achieved.

As opposed to this in the QFD you listen to the customer, decide what is going to be important for you to do and develop and manufacture towards the measured goals which are from the customer's voice right here, and then you optimize the products and processes in a proactive manner, so that the customer is happy. So, that is how you have a major difference between the QFD and the conventional product development process.

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The use of QFD

- Become better to make demands ✓
- Systematic working method ✓
- An effective target direction tool ✓
- Knowledge collection ✓
- Transfer of knowledge ✓
- Systematic evaluation of existing products
- Less and earlier engineering changes ↗
- Reduced development time 30-50% ↗
- The need of the Customer is *really* focused

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Use of QFD definitely becomes better to make demands; it is a systematic working method an effective target direction tool. it is also a knowledge collection tool, the sheet that you are preparing is sort of a history and geography of how a product or the process can be envisioned or can be implemented. QFD also leads to transfer of knowledge; obviously, you are documenting when you are making a sheet and the sheet is sort of a pivot point for all future business developers in the area, where you could actually modify the sheet and try to again get back into business.

Ah you also have a systematic evaluation of existing products. You have lesson earlier engineering changes, required even before you set up your dry cleaning shop or your process. So, that you can have exactly the map made, in a manner that customer wants it. You reduce development times by almost thirty to fifty percent. The need of the customer is really focused when we talk about use of such QFD tools and basically whatever causes designs to fail are kind of eliminated, because of this.

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What causes designs to fail?

- Not enough basic knowledge at hand when a design project starts
- Corporate Management view is to simplistic
- Too little activity in the beginning of the project
- Unspecified demands and constraints ←
- Bad and/or non existing demand specifications
- Time is not enough to be thorough ←
- Unrealistic time frames ←
- Bad co-operation between marketing/customer design, engineering, and manufacturing ←

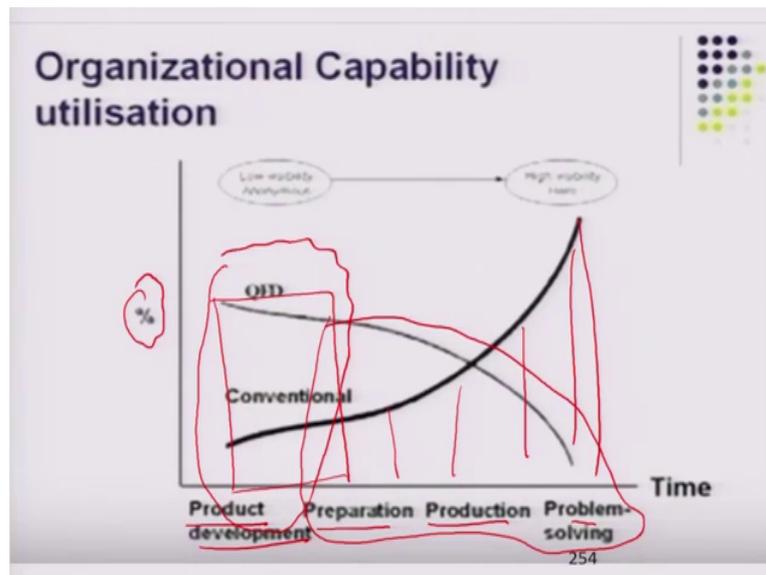
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The different causes that why the design should fail, could be related to not enough basic knowledge at hand when design project starts. It could be related to corporate managements, ever growing strategy of viewing everything simplistically, not really giving a lot of depth and importance to each and every angle, which may be very important for the user. There the is also you know a reason of too little activity at the beginning of the project which causes most of the projects to fail, designs to fail.

There might be unspecified demands and constraints which suddenly prop up and you are not enable to modify the design accordingly, because of which you might fail. You can also have bad or non-existing demand specifications. Time is really not enough to be thorough enough at various levels. There are unrealistic time frames, because you do not know how much effort needs to be pumped in order to realize something which is a good design, and then you have bad cooperation between marketing, customer, design, engineering and manufacturing, because there is hardly any crosstalk.

Whereas, if you use the QFD and the content engineering routes, almost always these issues get mitigated, because everything is teamwork, everything is done in a cross functional basis.

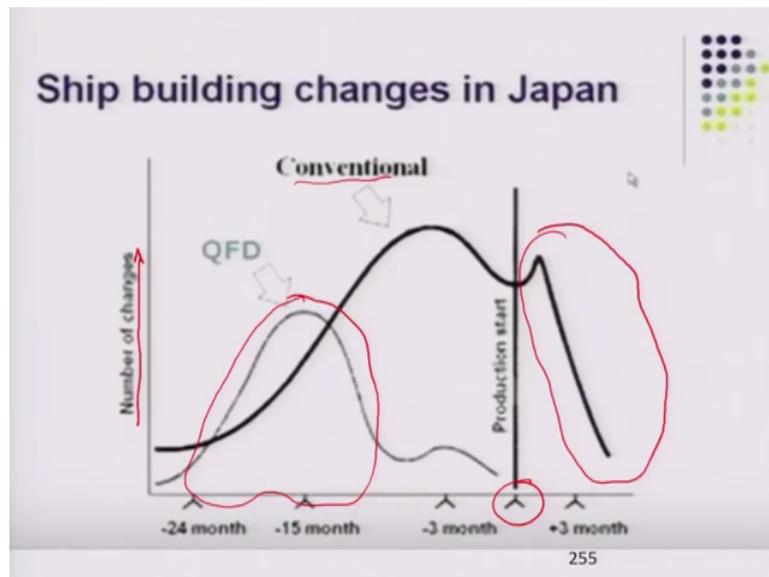
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So, here is what kind of you know gives you a sense of where you need to focus. So, the y axis here shows about capability percentage utilization. And you see that in QFD processes or organizations driven through QFD processes. There is a lot of emphasis a lot of utilization of all your resources and capabilities towards the beginning add the product development stage. So, that the subsequent amount of utilization reduces with time, in all the other ends for example, preparation for, processors or production to start a problem solving to happen. Whereas, in conventional as all the other things come into picture, there are relative learnings through which design improvements happen and every time you have to put a lot of capacity utilization.

So, I think it is always a better strategy to spend at the very beginning towards the product development stage more in terms of efforts or patience or capital capacity utilization, so that you have lesser hurdles at futuristic times for a process to go through the product lifecycle.

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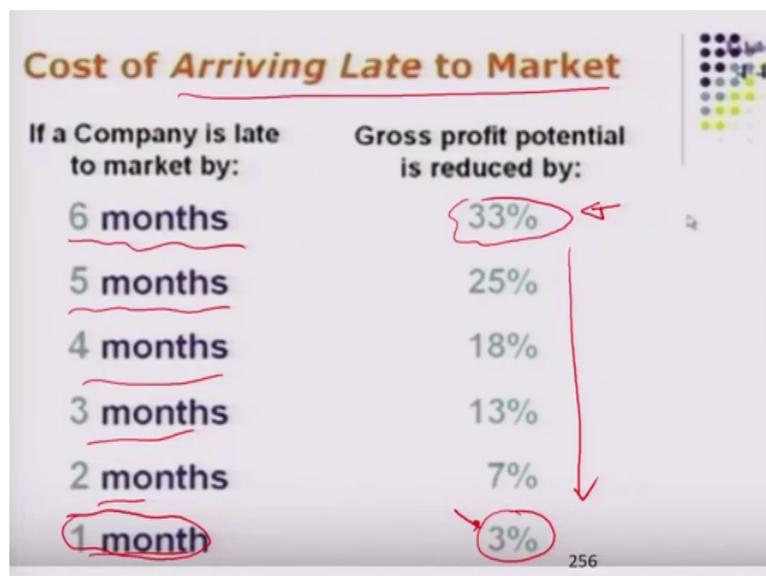
QFD actually started way back in Japan in Kobe. QFD was first realized to be a very important process from shipbuilding industry. There is a shipbuilding yard in Kobe where, earlier the strategy was to design something by planning engineering specifications or design specifications, according to a team of engineers and design designers on what they felt and then later on validating after production whatever they felt through the customer.

So, the customer almost always would have different opinions about how the mast would look like or how let us say the, the hull of the ship would look like and eventually they would result in post-production modification of the product, some time to be to the extent of about 30 to 40 percent and still the customer will not be happy. So, QFD actually started first from the shipbuilding industry, where they learned that if the customer aspiration could be taken at the very beginning of the product, then the production date does not get shifted too much and there are not many production delays and post production problems, which otherwise would start happening, if you design in a conventional manner.

So, here is sort of an illustration of how improvements got registered in the shipbuilding industry, because of QFD. So, when we talk about the y axis here, it shows the number of changes, and if the number of changes are high at the very beginning, let us say during the product development process prior to the production, you always end up into a timely schedule for the start date and subsequent production.

Whereas if you do not do QFD and go in a conventional manner, there are production delays and post production problems. a number of changes go almost way into post production stages which are always hard to do. shipbuilding may be again a process where the product does not move and all the operations move with respect to the products, and it may be a better idea to plan everything at the outset. So, that it gives you a well-defined role of such processes at a later stage, to construct what you have planned or design with a lot of feedback from your ultimate end customer who is going to buy.

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So; obviously, there is a huge cost or penalty of arriving late to the market, if the production schedules are delayed, then if the company is delayed by six months, the gross profit gets reduced by about thirty-three percent and that is how the shipbuilding statistics say actually. Similarly, if it is five months, four months, three months, two months, and one months. So, the gross profits as you see are reduced by a lower amount if you are early in the business, or, if your production dates are earlier.

So, this is the kind of history also of QFD. So, with this we would like to end this particular module where we talked about two different very important techniques of concrete engineering; that is about FMEA and QFD. And in the next module, we will learn more about forms and shapes and how to handle these using computer aided design.

Thank you very much.