Health, Safety and Environmental Management in Offshore and Petroleum Engineering

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Module - 02
Operational Safety
Lecture - 23
FMEA-example-II

Welcome friends to the 23rd lecture on Module 2 on Online course on Health, Safety and Environmental Practices in Offshore and Petroleum Engineering. We are discussing lectures on module 2.

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You know module 2 is focused on operational safety. Today is going to be the lecture 23. I will continue with FMEA and give you one more example. Let us quickly rewind back and see what FMEA is. FMEA we are going to discuss about the failure modes and effects analysis. It is one of the hazard or risk assessment methods which can be used for electro mechanical system. Successfully this got both the components, qualitative and quantitative. Qualitative part is what is identifying the basic deviations in the functional aspects of the components and identifying the causes for those deviations and then, relate these consequences to the overall efficiency or overall performance of the system.

So, in general FMEA is a component level analysis. To be very specific, let us say design FMEA is a component level analysis which examines the performance of the system. Let us say the performance of the complete system through performance or performance evaluation of the components of the system. So, the example yesterday what we discussed in the last lecture that is I skid breaking system of a passenger car. We already listed out the components which are responsible for any serious consequences in such failing of a breaking system, the sensors, the microcomputers, the valves. We have seen them in detail.

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We understood the inter relationship between the components as well as their sequence of operation leading to the performance of the system. So, we have understood this, and then we have perceived the failure modes of the components. These are actually assumed what we can say, imagined, perceived and for those failure modes we are able to locate the causes and consequences and so on. So, we have made a table where we have explained qualitatively how an FMEA address the problem in terms of efficiency of the overall system for electro mechanical component or a system.

So, we already said that one should be interested in connecting the qualitative observations of the risk analysis to quantify them because we are interested in prioritizing the risk. It means I am interested to identify the most vulnerable component or on the other hand to be very specific, most critical component there are many ways of

doing this. However, as engineers and technicians, we all agreed that criticality cannot be evaluated under qualitative brackets. We want to really say something as critical you have got to quantify them.

Thus qualitatively, it is very difficult to compare a and b because the conditions at which a and b are performing or the performance evaluated may not be similar, whereas we may quantify them when I try to bring them on a numerical values. Therefore, you are trying to normalize the performance of all the parameters or here all the components in such a manner and then, they can be compared easily.

So, relatively we want to know amongst all the components present in the given system which is the most critical one now as engineers, as HSE managers and practicing professionals. One will be interested to know sir why do I have to identify the most critical component. The answer is very simple if you know what the most critical component in a given electro mechanical system is, you can pay more attention to improve its quality either during the design stage or manufacturing stage or assembly stage etcetera, so that the probability of failure of the whole system is minimized.

Now the most critical component is the most expensive one. The answer is no the criticality of the component depends upon its functional contribution to the degradation of the whole system. If you award a component whose failure will cause serious consequence to the efficiency of the overall system, then that component is a most critical component. It may not be an expensive component in a given system at all. It is related to its size to some extent. Yes to some extent, yes any micro level components are sensitive and they may become critical. Because of the very interesting reason the detectability of failure of micro components are very difficult. Since the detectability is one of the factor in arriving at the risk priority number, therefore detectability which is inferior in case of micro level components plays a very important role in identifying the critical component of a given system analysis.

Now, it is very interesting for us to now deliver and converge quantitative aspects of FMEA which is continuation of the qualitative study of FMEA what we discussed in the last lecture. Now, for understanding this let us look at what are those variables which can quantify the priority of risk presence in a given system. So, we call them as FMEA variables.

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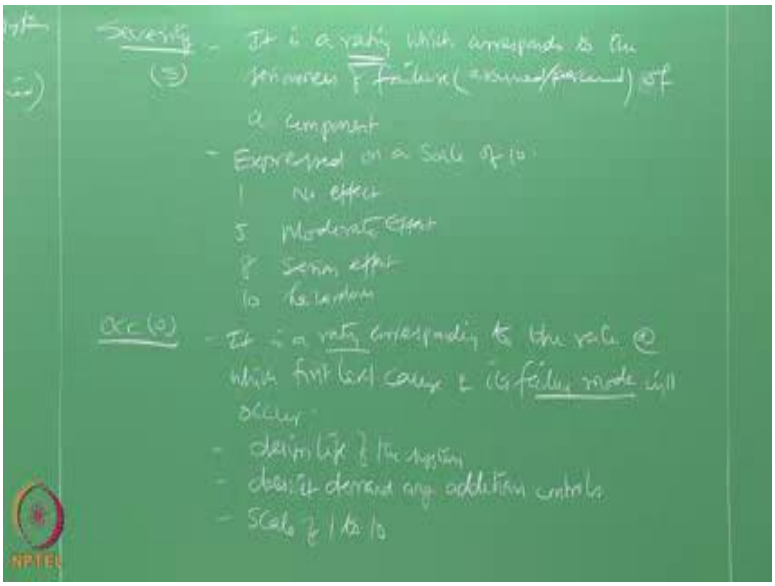

Friends, in fact failure modes are also variables in a given system; however I will now differentiate between the qualitative studies. What we discussed in the last lecture to that of the quantitative on which I am going to discuss now. So, we call this as FMEA variables. These variables are of three in nature. One could be severity; other could be the occurrence and third could be detectability. So, one can easily get a hand of idea about the moment I say occurrence which is something related to frequency of occurrence or probability of occurrence etcetera. You are involving slightly risk into the whole discussion if you know severity which is related to the consequence of the occurred event. Then again risk is playing a role in the whole picture. Therefore, one can easily guess an idea.

Now, the moment I introduced these two concepts in my discussion, I will quantify the risk automatically. Therefore, this is going to be also a method of QRA which is Quantitative Risk Analysis. So, FMEA plays both the role. Actually FMEA is one of the studies which bridges qualitative hazard analysis or hazard identification with that of quantitative risk analysis. Therefore, one can say it is hazard evaluation method which we all know. By this stage hazard evaluation includes risk analysis as well hazard evaluations are larger bracket. Risk analysis is a smaller bracket compared to hazard evaluation. Hazard evaluation is very generic and risk evaluation is particular.

Hazard evaluation does not or may not look in to the economics perspective, risk will and have to look into the economic perspective, however risk determination or risk evaluation seemed to be more mathematical and more acceptable to engineering community and economists compared to that of hazard evaluation hazard. Therefore, it is a science whereas risk evaluation is therefore is engineering application of science is what we say as engineering. Therefore, we are now going to include the three variables in a whole analysis and see how I can now quantify them.

So, what is severity? Severity is actually a rating which corresponds to the seriousness of an effect to a potential failure rating which corresponds to the seriousness of failure. I should say assumed perceived because a failure actually does not happen and then, if the failure happened, it is called post-accident scenario. Please understand FMEA cannot handle post-accident scenarios. It is not effective. There are other methods to do that and we will see that later, however this is at design stage. So, assume failure seriousness of assumed failure. So, it is a rating which corresponds to the seriousness of an assumed failure to as assumed failure of a component. The moment is a rating I have to give a number generally it is expressed on a scale of 10. So, for example 1 means no effect, 5 moderate effect and 7 or 8 serious effect and 10 hazardous. So, one can always give an index number to the severity depending upon how it is going to affect the overall failure of the system.

So, the second variable is occurrence. I call this is s, this as o. Occurrence actually is a rating corresponding to the rate at which the first level cause and it is failure more will occur. So, when we will you look at this, you have to apply this over a period of designing life of the system, that is a period during the design life of the system when will be the first failure mode of any component occur. Let us call the occurrence, it is not how many times it will occur; it is when it will be going to occur first. It will also talk about its demand; it also depends upon does its demand, any additional controls as I said rating again a numeric value is required. So, again it is on the scale of 1 to 10.

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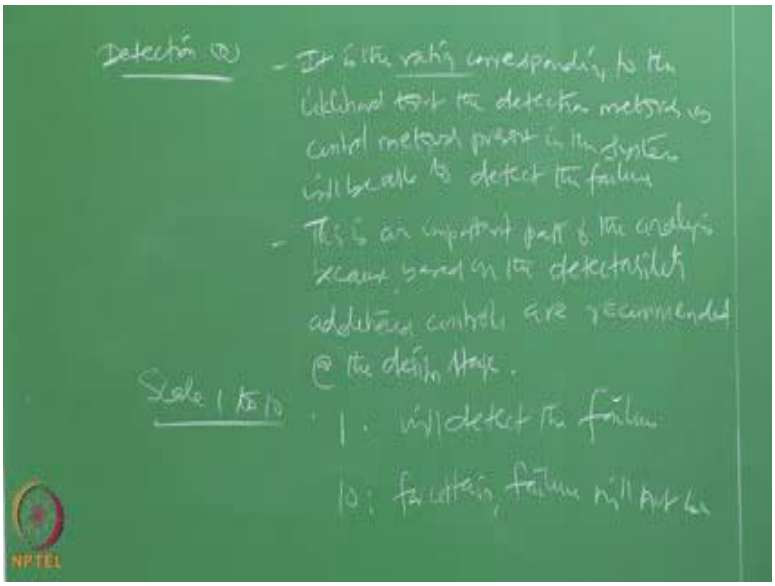

Let us say 1 fairly unlikely the component is. So, robust it will not fail at all, fairly unlikely the occurrence of failure of that component will not be there probably will not be there for the entire life of the system. So, well designed obviously 10 will indicate failure is certain. So, obviously one can say 5 is occasionally it can fail and 8 one can look at high occurrence. So, depending upon the perceived occurrence of any failure of the component, one can always associate a number to this. I call this as o as I indicated here.

The next one is a variable related to detection. It is a rating corresponding to the likelihood that the detection methods or the current controls will detect the potential failure, detection methods or control methods present in the system will be able to detect the failure. It is very important.

This is an important part of the analysis because based on this detectability, additional controls are recommended at the design stage. So, before the n product is released for commercial production, it is important that one looks in the detectability of the failure. You may attach some sensor, you may attach some alarms, you may even some l e ds to the given system that for example, if l e d is growing, then one can say this particular component is failing again in the rate of scale 1 to 10. 1 indicates will detect the failure for sure, 10 indicates not to detect the failure at all for certain failure will not be detected,

5 might detect the failure which is a guess, that is a probability and 8 high possibility of not detecting the failure.

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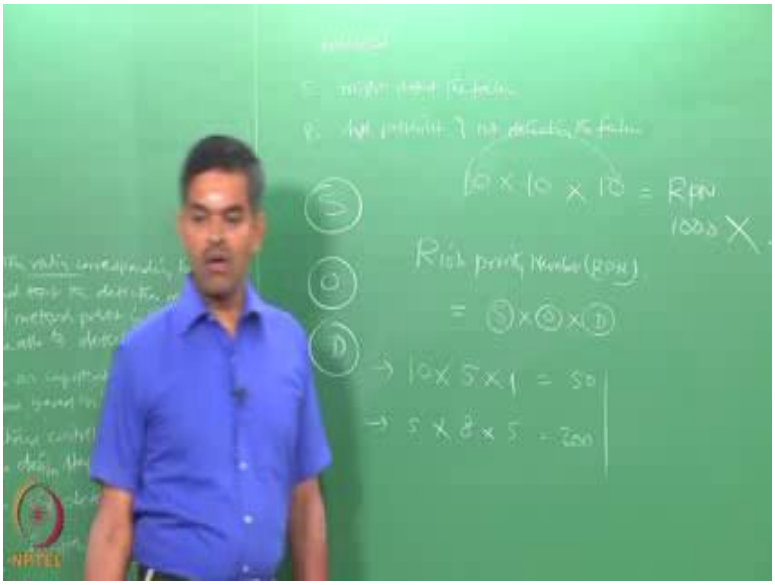

Of course 10 means for sure detection is not possible. So, depending upon this we have got three factors now i.e. severity, occurrence and detectability. Now risk priority number which I say RPN is nothing but the product of severity occurrence and detectability. There are some important issues here before we discuss further about this priority number, let us see what they are.

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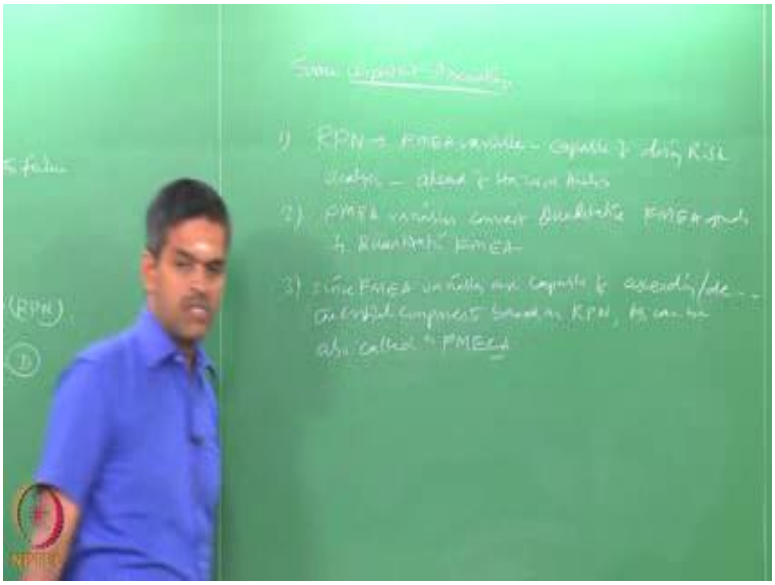

Observations one the risk priority number which is arrived from FMEA. Variables are capable of doing risk analysis which is ahead of hazard analysis. FMEA variables convert qualitative FMEA study to quantitative FMEA study. Since FMEA variables are capable of ascending or descending the critical components based on the risk priority number, on the other hand the component, whose RPN is maximum, is considered the most vulnerable component or the most critical component. This can also be called as f m e c a where c stands for criticality analysis.

If you do not include FMEA variables in a study as we did in the last example of anti-skid breaking system that is also a FMEA study, but that is purely qualitative. If you include FMEA variables into the study and try to identify the risk priority of every component, then that can be called as FMECA. It is also because criticality of the component will be also addressed. Now, based upon the risk detection or risk identification of each component and the overall performance of the failure, it is very interesting that a simple product of these three will give me r p n. It is fairly a good number of values. Let us say we know severity shows that if it is more severe, it is considered to be number 10. Let us have a component which is very severe. So, I put s value as 10 for the component, but most severe component or most sensitive component which is going to cause seriousness to the effect of the potential failure generally is designed in such a manner in a given system, they will not fail very frequently, but they may fail occasionally.

So, let us say I put a number 5 here. So, one thing you will agree with me that I will not put a number 10 here because number 10 in occurrence indicates that failure is certain. If you have a component whose severity is the highest; obviously that component will be manufactured with the greater attention. So, the failure of the component will be rare. So, I do not say 1 to this that failure is unlikely, let us take an example of let us say failure may happen occasionally.

So, let us say the number 5 I can have a number 1 to 5 here, but I think it will be not more than 5 because the component has got the highest severity. The moment the component has got highest severity, its failure should be detectable because the design will be in such a manner that you will be able to detect the failure for sure. So, obviously this number will become 1, if its detectability is very high. Let us look into the other extreme. Let us say I have a component whose failure is not will have no effect at all. Let

us say the component is there, component will fail. It has no effect or it will have moderate effect.

So, in that case s will be 5 that is the moderate severity. The moderate severity component may frequently fail and it may even certain or the failure may be high. So, I put occurrence rate as 8, then if you look at the detection, this component is not frequently failing and is not going to cause very serious effect to the overall performance in the detectability may not be sure. Let us say we put a number 5 here. So, this becomes the product of 50 and this becomes a product 200 is or not 25.

So, risk priority number cannot be 1000. Let's say 10 on severity, it means that it is certainly dangerous and it is certainly going to fail which is a very bad design and no detection is possible in this case. So, can you cannot have an r p n number 1000 at all. If you have an r p n number 1000 in a design, I think there is a most worst design you can look at is or not because if you got a component which is very severe. The detectability should be for sure you should be able to identify the component failure and it should not fail frequently.

So, therefore r p n number of 1000 is actually not a practical value. So, anywhere between these numbers you can have an example. Therefore, you should be carefully selecting these variables because this will now help you to risk rank the components that is first observation. Second observation, please understand all these variables are on a scale of 1 to 10 and they are relative. They are rating on a relative scale.

So, for example FMEA study of a component, sorry FMEA study of yeah system a should not be and cannot be compared with FMEA study of system b because the components present in system a and that of present in system in b may be different and the likelihood, the design variables and severity of components of system a may not be same as that of system b. Therefore, using FMEA studies though it is risk analysis, you cannot compare two systems. Over all we can only compare components within a system. So, it is very local. It cannot be applied on a generic sense. It is a very specific study and as we all agree whenever you adopt risk to a study, it is always specific. It is particular.

So, therefore risk priority number is one of the major important areas of concerns. It evaluates severity rating occurrence, rating detectability of the potential failure and risk

priority number is nothing, but the product of these three as we discussed just now. So, now question comes when we should take corrective measures.

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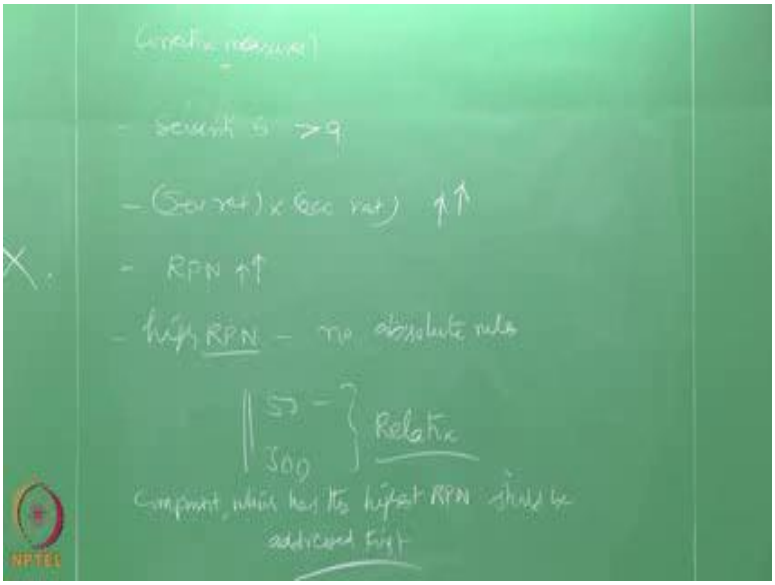

When should we take corrective measures? Corrective measures should be taken when severity is 9 or let us say more than 9. When you have a component whose severity is indicated in the report as more than 9, you should take corrective measure that is first option. Secondly, if the severity rating multiplied by the occurrence rating is very high, it means the component of severe and the failure of occurrence of a component is very frequent. Then, you should again make corrective measures. Thirdly if r p n number is very high, then you should go for corrective actions. Please understand there are no absolute rules we say what high r p n number is. So, what do you mean by high r p n number or risk priority number? There are no absolute rules for example, for you even 50 is high and for me 300 is high. So, I have to only fix myself because it is purely relative my dear.

So, there are no absolute comparisons which can be made between the systems as I just now said, but please understand component which has the highest r p n number should be addressed first. That is important. There is relative, however number you give no problem the one which has them highest number should be focused first in the design. That is very important parallel along with FMEA. One can also do a prior to FMEA

cause and effect diagram. One has to generate a cause and effect diagram to do an FMEA very effectively. Let us see what cause and effect diagram is.

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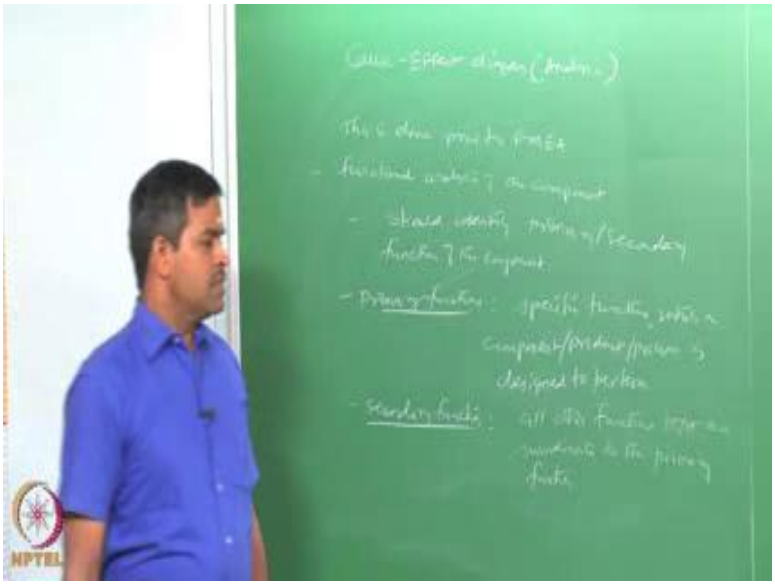

First one can ask me a question why it is essential to conduct the cause effect analysis. Cause-effect analysis is important because for FMEA, you need to identify the cause and the corresponding effect is or not therefore, it is essential. This is to be done prior to conducting FMEA.

So, this is focusing on the functional analysis of the component. What do you mean by functional analysis? We will explain this with an example. Let us say in functional analysis one should be able to identify, one should identify primary and secondary functions of the component. What are primary functions? Primary functions are those specific functions which a component or a product or even a process is designed to perform. So, it is design intent more or less. What is a secondary function? Secondary function is related to all other functions that are subordinate to the primary function. Let us take a quick example to understand easily the primary and secondary function.

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Example of a seat belt I am taking example related to this because all of us drive an automobile vehicle, may be a car and we all know the importance of every component present in automobile though we may not be automobile or mechanical engineer. However we know the functional use of these components. If we pick up that example, it will be easy for me to correlate the primary and secondary functions of a known component which I am using every day in my driving. So, seat belt. So, let us see what a primary function of a seat belt is.

The primary function of seat belt is hold the passenger in the sitting position, of course with some degree of flexibility. What are the secondary functions? The secondary functions are opening closing of the seat belt; adjusting the tension in the seat belt, adjusting the length of the seat belt etcetera is or not these are all secondary functions. So, for a given component one should be able to quickly identify the primary and secondary function which is highly comfortable and convenient to do for a mechanical system and electrical system. See it is very rather difficult to do for a process system unless otherwise we are experienced in that process line for many years. So, let us now look at FMEA cause and effect diagram for a simple example. If we talk about cause effect diagram for a simple example like this, let us say the failure mode will get influenced from.

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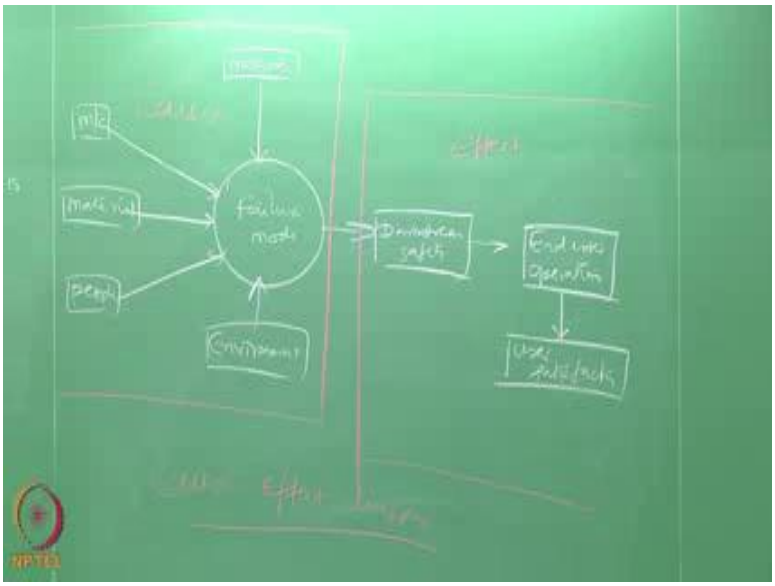

The methods of failure from the machinery, from the material used, from the people using it and from the environment, all may lead to different failure modes. The moment failure modes are identified then it comes to downstream safety. When the downstream safety is analyzed or diagnosed, it all depends on comparability of the end user operation, how it affects the operation of the end user and ultimately it may lead to what we call user satisfaction.

So, friends in this segment this part is called cause and this part is called effect. So, this is the layout of cause effect diagram. So, let us do a cause effect diagram for another example which is related to an air bag presence in a passenger car. We all know air bag is one of the important vehicle components in case of an accident or emergency brake being appeared in a car. The air bag actually gets inflated and it prevents the head injury of the passenger sitting in the front or in the back may be. Essentially in the front, so does not head his forehead, hit is forehead on the dash board of the vehicle.

So, the air bag present in the front of the steering column which inflates and protects or prevents dashing of the forehead of the driver or the co-passenger sitting in the front side from hitting his head on the dash board. So, air bags are essentially present in all most all vehicles these days as mandatory regulations of transport authority. Of course, it is not available in all models of vehicles, but almost all vehicles with more or less superior models do have an air bag in built facility available and that is the mandatory thing as far

as transport authorities are concerned. So, we will take upon an air bag example and see what are the causes and effects.

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So, we are seeing example. Two air bag in a passenger car. Once we do the cause and effect diagram of this, I should be able to convert this into FMEA study as well to find out the r p n number and then, I want to prioritize the components are very risky. So, let us say what those causes are. The first could be the method. Method is lack of proper warning. One does not know that an air bag will cause abrasion or inflation to the person.

So, lack of proper warning by the manufacturer, this can be one of the cause which can be addressed in the method which is related to the method. As we discussed here, the second can be a machinery fault. What does it mean is the regulator is not working properly; the sensor which should control the inflation of the air bag is not working properly. Let us say that could be the reason. The third could be from the material. The material can be too abrasive and that can be a cause to uncomfortability to the end user. The fourth comes from the people. If you are a small passenger, I mean the passenger is an infant or a child or may be is not of the height of the dash board etcetera, the passenger is too small. So, it will not be effective for small passengers. the other comes from the people which is passenger is too small; the other one comes from the environment passenger not wearing the belt at all.

So, all this could be the failure modes. So, before you do FMEA analysis, let us try to do first the cause effect analysis, so that failure modes can be easily detected from the given system. Once the failure modes are done, then let us say the effect it may injure light weight passenger, there is a possibility that the rear seat passenger is crushed because air bags are only for the front seat passengers. It could also be resulting in fatal injury for kids and infants. These are all the effects which arise from these causes.

So, I can say this part is the cause or the causes and this part is the effects. So, I should bridge these two, give a risk priority number to them and try to identify which are all the most important components in a given system. How they can be prioritized and how a critical component can be evaluated which will see in the next lecture as a continuation and in the next lecture, we also will talk about some example and exercise problems or exercise questions which is useful for you to review the entire course content of Module 2.

Thank you very much.