Introduction to Reliability Engineering
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Lecture 40
Summary of the Course Introduction to Reliability Engineering

Hello everyone. So, we are now towards the completion of this course. We have for two credit, you have already gone through 39 lectures of half an hour each. So, we will try to summarize what you have studied and also we will try to get little bit more information, little bit about the risk assessment also. So, initially, we will discuss little bit about risk assessment then we will try to summarize what we have learned through this course and how you can take it forward.

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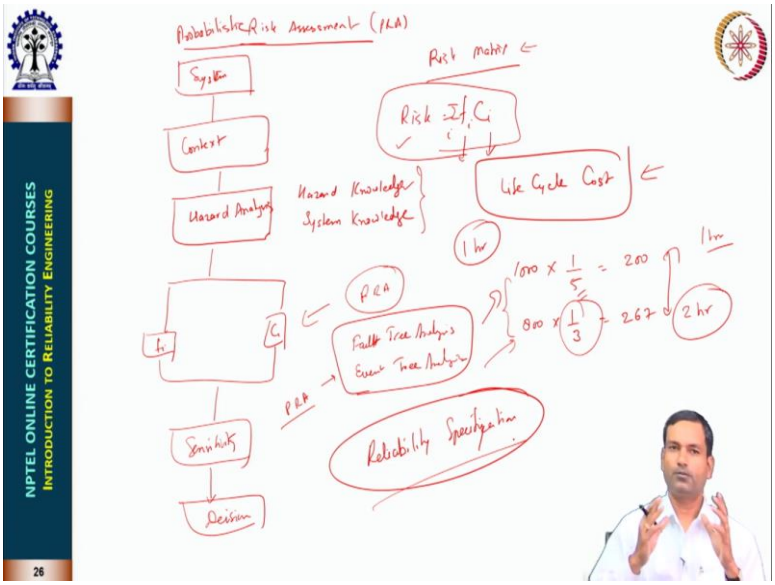

So, for risk assessment, let me just summarize initially on that. We discuss risk assessment in weak 1. For risk assessment essential requirement is that first you should know the system. So, system should be known. Then you should also have the context information. Generally, risk cannot be like general analysis. Reliability can be sometimes done as a general analysis but that also requires that you provide the context. That means operating conditions there.

Here in Risk analysis also, we have to provide the context. We have to tell what kind of conditions under which this risk analysis is being carried out. That means what are the system boundaries. That means which part of systems are considered, which part of systems are not considered for this analysis, what is the purpose of risk analysis, means whetherit is being

done for the benefit, cost benefit, whether it is done as a part of regulatory requirement on safety or we have to do it as per certain standards or the approaches.

So, this context has to be defined, that will and also we need to tell that where. So, generally, risk assessment when we are doing, the focus is mostly on the engineering big big systems, like we have nuclear power plant, we have chemical industries, we have offshore platforms, we have a various steel industries, we have refineries.

So, different kind of steel industries, all these industries they have inherent risk. Because they are dealing with the various processes which if they fail can lead to the injuries or death to the persons either operators or the general public. So, in these cases, generally, this risk assessment methodology comes into the picture. So, here we have to define the context.

So, under what context we are doing this analysis. So, that will set up that what we are trying to do here and what is the purpose of this risk assessment. Once we do this, then initially we will do the hazard identification or hazard, we can say hazard analysis. In hazard analysis, we will try to find out, like as we discussed earlier, most of the time like in RBD as we see, relative block diagram, the reliability is when everything is successful. So, that means everything is going fine, there is no problem and everything is reliable.

But the moment some problem happens, let us say something failed, someone some human made an error or some external thing, something went wrong which was not supposed to go wrong in general cases. So, something unexpected happens or some failure happens or some sort of threat happens or some sort of attack happens, in that case what will happen?

Our system will be exposed to failures; our system will be having the state change. It will no longer be the in safe state or it may no no longer be will be in the operating state. So, these events which are causing these kind of failures or the system problems, we have to find those problems first.

So, that cannot be done by the mathematics. To do that you have to have the proper brainstorming sessions. And using the brainstorming sessions, so, here we use the hazard knowledge. Hazard knowledge which we have gathered either through system, either through our own experience like for this kind of system what kind of problems we have faced or we learn from others, like other people who are running a similar kind of facility what kind of problems they have faced.

So, and there are some generic groups available, generically, there are agencies available which provides a generic list of hazards which are applicable for these kind of scenarios or these kind of systems. So, we have to find out the hazards first and we have to see which hazards are applicable for our system. Then for each and every hazard or each and every potential failure, we have to do the system analysis.

So, we use the system knowledge and hazard knowledge and we combine them together to find out the our system is specific hazards. Once you find out the system specific hazard then we can use the risk metric or we can use the, generally, we can do the this brief categorical analysis, we can do the subjective analysis and we can identify that where our hazards are lying.

So, generally, there are various risk matrix proposed which tries to segregate these results into three categories or four categories depending on the system. So, here first category could be the red zone. Here the system is not acceptable. That means the risk is not acceptable. The risk is not acceptable because there is a high consequence and there is a high probability also.

So, risk is, as we know, risk is equal to frequency and consequence, multiplication, for all hazards. And what is the summation point here? That is a hazard. So, for all hazard if we multiply the frequency of their consequences then we will get the risk. So, we identify the hazard then we find out the probabilities and consequences of the hazards. And once we multiply and sum them to be together, we get the risk, system risk. But what happens?

This risk calculation would be very tedious because this requires so many frequency values, so many hazards and their consequences, evaluating them can be a challenging because the data may not be readily available and sources of data you have to search, you have to model. So, this will be a huge modeling exercise, complete plant you have to do the model.

To before the modeling, we have to we can also do the first subjective analysis. The hazards which we have identified here, we do the subjective analysis, through the risk matrix also we can do. We can find out that on broad categorization where the hazard is lying, whether it is safe or whether it is to be observed or whether it is under unsafe category.

So, we have the red, yellow and green. Green means it is kind of safe because that kind of risk is generally seen by the society and that kind of risk generally exist in all our activities, general activities also. So, people find it acceptable. In yellow category, what happens that

risk is little higher on the border side and this may turn to be acceptable also and turn may turn into the unacceptable also, the reason being that a hazards involved are having the high consequences.

So, because of that their frequencies has to be controlled. That means the probability has to be brought down. So, they have to be continuously monitored, they have to be continuous watched over and their reliabilities has to be controlled so that you are able to have the probability of failure or frequency of failure is lower value. Once you are able to keep them in lower side then what will happen?

Your risk will be in the control. So, you are able to have the yellow zone. So, in the yellow zone whatever hazards are lying you have to provide a tight control, risk control measures, so that you are able to make sure that you are able to continue using the system. But no hazard should actually fall in the red region.

If it is falling in red region then you have to work on this using the latest technologies, processes, etcetera, so that you bring down the probability of those hazards down and you bring it into the yellow region, either. Or you can also do the, you can also decrease this or or you can decrease consequences also.

Many times like like when we wear helmet on bike ride then we reduce the chance of consequences, the chances of death are gone because most as we see that the chance of death is mostly coming because of the head injury other parts when they get injured may not be leading to the death.

So, the chances of deaths have been reduced. Or we can say the because of putting the helmet, we are able to reduce the consequence from death to the major injuries or the minor injuries. So, we can work similarly, like we recommend that everyone should put a headgear or should put proper protective clothing whenever they are going into the industry as per the industry requirement.

That is done so that even if the accident happens, the consequences will not be far, will not be very high. So, consequences are controlled. So, if we are able to establish that all our hazards are lying in green zone or many hazards are lying in red zone, our decision is clear that if it is in green zone, we allow the system to run. So, we do not need a proper or we do not need a very large risk model there.

Similarly, if the hazards are lying in red zone then also we do not have to do much because in that case that system will not be allowed to run. Because in that case it is falling outside the red zone. So, such kind of system is not feasible for the use. But when it is falling in yellow zone then we have to have the risk control.

And because of that, this yellow zone, whenever our system is falling or when we are bringing the system from red zone to yellow zone, we have to have a tight risk measures and we need to have the risk modeling done there and we are able to evaluate the probabilities here, the risk which is evaluated in quantitative manner here.

So, then we may have to do this analysis, by which we try to do the risk analysis, we try to find out f i and c I for each hazard or each consequence. Once we get this, this will give us the risk. Then we reach the decision. We can do the sensitivity analysis also here. If we do the sensitivity analysis, we will be able to find out that which system components are more contributing to towards the risk.

So, the system components which are more contributing, we can improve there. So, if we improve there then our risk reduction will be higher in lesser cost. Then we can do the decision. The decision may be that to stop functioning. That means you do not allow system to run or you allow the system to run or you say that the system is allowed to run but are under certain a kind of restrictions and frequent observations and frequent, there will be frequent inspections, frequently the processes will be checked and made sure that those processes are followed.

So, this this is general risk assessment process. And to calculate this risk using this f and c i, we use the P R A. This is mostly called as the Project Risk Assessment model where we try to calculate this f and c for all the hazards. And we also try to establish. This is generally written using the faulty analysis and inventory analysis.

So, we are not discussing those things in detail. We can discuss them in maybe in some other interactions or some other course. This is generally taught at IIT, kharagpur in subject which we are calling as Probabilistic Risk Assessment, P R A. So, probabilistic risk assessment is covering this concept how to do all this.

Similarly, like this subject, we also have many other subject in our school, School of Quality and Reliability. So, which of the school of quality and reliability, in our school, we offer

subjects like a software reliability, we offer subjects on maintenance data, repairable system data analysis.

Generally, what happens the data which we have considered, we have considered that all datas are identical and independent. But many times whenever repair happens, it may change the distribution, it may change the failure pattern. Because repair can improve the system or can degrade the system or it may leave the system as it is. So, in that case, what will happen?

Your failure pattern will change because of the repair. So, in that case that data need to be analyzed in a little different way. So, that is repairable system analysis. We have courses on like FDPM that is called Fault Prognosis and Diagnosis. So, here we can learn like what kind of different for diagnostics can be done or prognosis can be done.

We have software reliability courses where we can try to find out that if we have the software failure data available, how we can analyze and we can find out those software reliability. We have at this is the basic introductory course on reliability, this can also be further enhanced to understand that in general in industries we use the concept of design for reliability D F R process. So, this D F R includes all this but this also includes little bit more like relative prediction, F M E C analysis and the testing, goods testing, reliability goods testing, we have highly accelerated life testing.

Then with some other methods like derating methods. So, all those processes are used so that the design which we are creating is not only meeting the functional requirements but it is also meeting the reliability requirements. So, then relative design can be understood and can be is being taught in some courses at IIT, kharagpur we.

So, we offer M. Tech. courses in M. Tech. courses or that is M. Tech. in Quality and Reliability Engineering. In this course, we offer some quality courses also where we are trying to have basic quality concept, quality tools, process quality control, etcetera and from reliability side human reliability can also be there. So, so many aspects on reliability which we try to cover in various subjects.

After going through this course you can go through those kind of courses. They may not be available online now, but whenever they become available or whenever some special courses are being done by IIT kharagpur or you can or whenever we we would like that if you come and join us for M. Tech. and PhD.

So, if you join us for M. Tech. or PhD, you will be exposed to those courses you are able to follow them and you are able to do those courses. So, all these courses require some basic understanding and which is here. This course can, whatever I have taught you, whatever we have discussed here, all these things you can will help you to build up.

This will provide you the basics which are required for doing any analysis whether it is warranty analysis or any other kind of life cycle cost analysis, whatever you want to do further these concepts will become handy and all these concepts you will will help you to know that how you can do the reliability calculations.

Once you are able to calculate then how you are able to model them whether it is cost model like there is a life cycle cost model. So, in life cycle cost model generally, what happens many times we decide the cost of equipment based on the purchase cost. But actually the costing is not just the equipment cost. Cost also comes from the repairs.

Because if the equipment is failed then we have to invest money on the repair also. So, and also there is a maintenance cost, there is a operating cost. So, something which we are buying, something says, let us say if you are going to buy a LED bulb. So, LED bulb is giving you the same light, you know lesser wattage. So, efficiency is higher. Now, you can compare that generally the light bulb or the simple bulb will cost you maybe 10 rupees 15 rupees. But led will cost you let us say 200 rupees.

So, in that case, whether this or is justified or not. Because LED looks costly here but effectively the life cycle cost may come down. The life cycle cost may come down because LED can work let us say for five years, bulb may work maybe for one year or two year. So, whatever is the average life which you are getting from the equipment that will define the per unit time how much cost you are having.

Second thing is that energy consumption for LED is let us say that is 60 watt is equivalent to let us say 10 watt. So, that is one by six times. So, that means that much electricity bill you are saving. So, life cycle cost when you are calculating then that will also be counted. So, when you are seeing all these costs together then it will give you an idea that what is the life cycle cost.

So, our decision should not be based on the equipment or the face value cost, we our equipment we, whenever we are purchasing something or whenever we are selling something

or whenever we are putting something in our requirement and specifications as the tender document or something else, the cost which you are asking or the that should be based on the life cycle cost.

So, whatever is the parameter of life cycle cost, we can ask those parameters individually like we can ask what is the failure probability for the equipment because that is going to affect our repair time and repair we can also ask how much repair time it is going to take. We can also ask the manufacturer that how much cost will be there for the repairs, how much cost will be there for the spare parts etcetera.

So, all those cost when we take into account, we all together get the life cycle cost. Even after the component becomes dysfunctional, many times we may either get money back, some money back or we may have to even sometimes put money for disposal. So, disposal may be additional cost also or disposal can sometimes be rewarding also. So, that also should be counted.

Like many times we say that when we purchase of maruti car in India then the resale value is higher because those cars are easily maintainable and because of the high maintainability of those car because their spare parts is easily available, the manpower requirement is met by many people.

Similarly, that is part cost is called smaller. So, the maintenance cost comes out, comes down. So, effective cost life cycle cost comes down. So, many times people will prefer that. And when you are selling that also at that time you will get the better, sometimes people by an observation they feel that it is.

But it is not necessarily that you have one brand over another like other brands like Hyundai, we may have Honda, we may have other they may also have the same similar pattern but many times just by going with saying that this is better or that is better maybe making you biased. Because that is human approach is many time biased.

But if we have the data, if you have the data that how much is the spare part is costing, how frequently they are failing. Because the spare part even if they are costing, like we discussed earlier, let us say the same spare part made by one companies costly compared to the another one.

But that is spare part for one the company which is selling in chip that is spare part requirement is also high because that will fail frequently but the spare part given by another company which is costly but if it is highly reliable then what will happen the failure chances is also low.

So, effective cost will come down because for repair, let us say one repair for costly part let us say the cost is let us say thousand rupees and this is failing let us say once in five years. So, the cost is coming out to be 200 per year. But if you say the same thing that you are purchasing it let us say 800 rupees part but this is failing once in three years then what is the cost you are going to have?

Almost 267 which is higher. Not only the cost is higher, now, what will happen because of the repair time, that repair time, let us have taken in this part let us say repair time is taker is one hour. So, for one hour your system is not useful here but here if you see almost this is one by five almost if you say double then here you are losing two hour approximately and here you are losing only one hour in five years. So, that means the downtime is also high.

Now, this is also costly because you are not able to use your system. And there is another thing that you have to take your vehicle to the service agency again and again here you have to take two times here you have to take only one time. So, that cost also need to be included. Therefore if you are making our decision then just taking decision based on face value is not correct, just someone is saying.

If we have the data then we can evaluate the life cycle cost and we know the real cost rather than just looking at the cost which is being displayed. But for that we need to have an understanding that how much is the failure rate, how much is the failure probability per unit time and how much is the repair time, how much is the repair cost.

So, once we have this data, we can do this analysis, at least at the broad level. If you do this analysis at broad level that will also give you a very good understanding that which is actually proving you costly in during the use. Because you have to use. You are not taking something just for purchase value, it is not the showpiece that you once play purchase and place it, it will be fine. But you have to use it.

So, how long you are able to use a component that you have to see that per unit time of use how much costly of particular equipment is or particular system is. And based on that you

should be deciding that which one is cheaper system and which one is not so cheaper system. So, life cycle cost should be evaluated for deciding.

And that can also be the criteria for deciding the requirement and setting the reliability requirement or specification for your system. So, if you do not specify reliability you will not get it. So, as a customer, you should always ask like for warranty, reliability that how long you are going to have this particular system for use without failure.

That means how much is the company liability. Many times company liability only covers the part replacement but that can be a problem sometimes. Like your whole system may fail because of the failure of one capacitor. Now, capacitor cost only maybe say 1 rupee or 5 rupee but because of the system downtime you may have to replace the complete assembly that is another case.

Another thing is that system whole as a failing. So, correcting that problem will take time and because of the downtime, you have to put lot of amount of money. Because you will be losing lot of money because the system is not working. Therefore, though we are saying that on failure they are the manufacturer is only replacing component is not enough.

Whenever we have the higher reliability requirements, especially, in the competitive market or the cases where the safety concern is there, where we have the security concerns, we have the environmental concern, in that case, the each and every component, each and every system, each and every part which we are using in our system has to be having a reliability specification and they should be meeting that reliability requirement.

If they are not meeting the reliability requirement, they should not be taken in. Because whenever failure happens, someone is going to suffer and that suffering cannot be means that suffering has to be either passed on the manufacturer so that he is bound to meet the expenses when that failure happens. But that becomes very difficult to execute.

So, many times you put a reliability requirement on whatever you are purchasing from your manufacturer or the suppliers and that reliability requirement has to be met. If that requirement is not met then there should not be only the cost for replacement but there should be cause for penalty also. That means because you are going to lose.

So, someone who is saying that my reliability is this much, if their system reliability is not met, the number of failures are higher than what they have said will be there for the life duration, in that case, they should be penalized. Because you are going to suffer for that system.

So, this kind of policies need to be built and this kind of policies need to be implemented. But everything whenever you are doing this will only be feasible when you have a proper way of collecting the data. The failure data operational data has to be collected then only you are able to force these policies.

Also whenever, this data is collected, you have to make sure that this data cannot be interfered with or the any person or any organization is not able to modify the data so that the raw data whenever it is there, it is in most accurate form, which cannot be modified by some person just for the advantages.

So, that data system also need to be validated, that this is. Once you validate the system data and make sure that this will not be tempered with, in that case that data set should be acceptable to all for the decision making. So, it is very essential that reliability requirement when you put, reliability specifications when you put, this will help you to understand whole scenario.

And when multiple vendor supplier systems are there, it will help you to understand that and how reliability performance is there and you will be able to meet your goals as as promised to the customer. So, with this like there is lot to talk about reliability, there are lot to read about reliability.

It is a very wide area. It looks like a very specialization but because reliability can be applicable for everything like for civil system reliability you are doing, you may be applying the same thing but in a different way. When you are talking about mechanical system, then also basic thing is this one only, but the way you apply will be differing, because the system type is different.

So, whenever system type differs, reliability approaches tend to differ, their values tend to differ. So, all this is a very wide area, any system which you are working on, they all need to be reliable. So, they or their reliability evaluation has to be properly carried out. So, there is a

large amount of information and knowledge available in various books and papers, research papers.

You can study those and you can understand. I hope this lecture series which we had here, this will help you when you are reading those papers and books, this will help, whenever you are reading those things, you will find them more understandable and little bit easier to understand.

So, that will be the aim of. And I wish you all the best so that you are able to do well in this course as well as in future also you are able to open to lot of reliability opportunities which you can take and which you can do lot of work in this area. So, with this we are coming to an end of this course.

So, I thank you all for going through this course and listening to my lectures and I wish that you all be successful in your life and you all make some contribution to this engineering, area of engineering that is we are calling as reliability engineering. Thank you. So, thank you everyone. So, bye.