Industrial Safety Engineering
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Lecture - 22
Risk Assessment

Welcome to this lecture, today we will discuss Risk Assessment. Although you have seen that what is risk, what is likelihood, what is risk profile, also we have explain you fault tree analysis, event tree analysis, bow tie, then all the hazard identification techniques including PHA, FMA, then some other techniques also.

So, particularly in PHA we have used initial measurable risk index final measurable risk index which are basically qualitative in nature, then event tree fault tree we have used probability values to find out the top event probability and then also find out the probability of the accident scenarios. And in bow-tie, we have seen the probability of the accident paths, and the qualitative as well as the as the quantitative aspects of risk assessment particularly from probability of a top event point of view we have already experienced.

And from consequence or impact point of view we have given you the qualitative aspects that mean the severity classification or loss classification in FMA or P N you have calculated and there we have given you 10 points scale for probability calculation and severity calculation as well as repeatability calculation. And in PHA that mean 5-point and 4-point scale for probability and severity we have discussed, but as such square consequence assessment the quantitative part we have not giving to you. Because this is a although important, but it is very critical and this a difficult part particularly how to estimate the cost of accident or cost of losses arising out of any accidents that happened in industry or other say other scenarios.

And nevertheless, that although we have explained the risk assessment in fishmeal manner but the complete that picture of risk assessment not giving to you. Today, I am just actually documenting all those issues in one umbrella and we are saying it is risk assessment and then I will basically recall many of the things in my lecture what you have already known. And further basically that how to quantify the individual and

societal risk within hypothetical case I have explained here. I hope that you will like this lecture.

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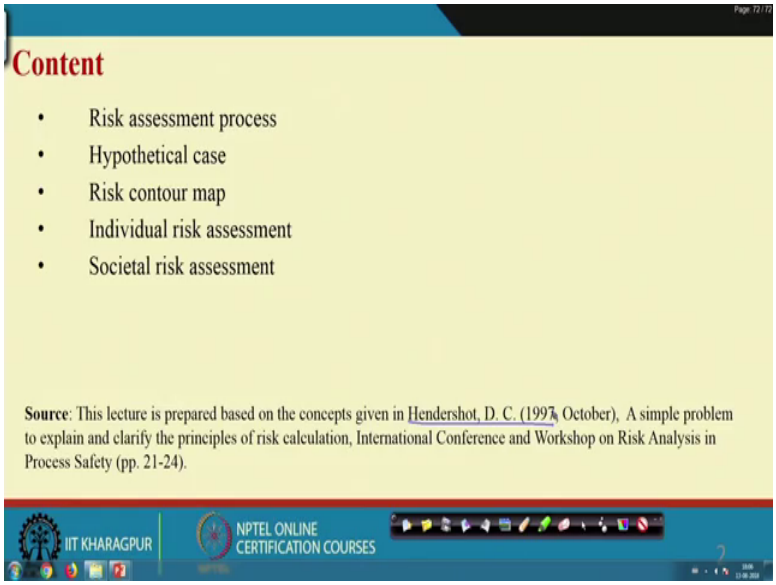

So, the contents for today's presentation a risk assessment process which we will start with then with reference to a hypothetical case. We will discuss this contour map, then individual risk assessment, and societal risk assessment. And a interestingly that these particular lecture I have prepared based on the concept given in this paper. That is simple problem to explain and clarify the principles of risk calculation by Hendershot D.C. 1997, October and this was published in a conference International Conference and Workshop for Risk Analysis and Process Safety.

Very interesting paper and it gives us lot of clarity, and based on this I prepared the hypothetical case. I have 1 hypothetical case is given in this lecture in this particular conference paper. So, you may go through these and you can get that document also and here same the same concept I will be using with a different hypothetical case similar to the one given in that paper.

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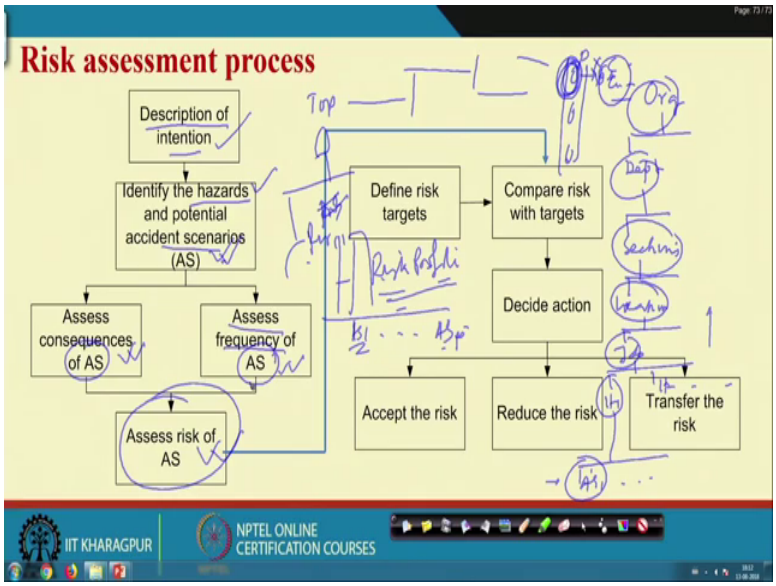

Risk assessment process; risk assessment process is very much known to you, several times we have discussed in different occasions, so formal this is basically a formal process what I am saying. So, description of intention why you are interested to conduct the risk assessment what is the purpose, what is the intention, is it to identify hazards and ranking them or is it to identify the accident scenarios; and ranking them or a it is basically maybe some other purpose as known to the risk analyst.

Hopefully, we all will agree with that in this particular lecture we are basically interested to know that there will be different hazards different accident scenarios and those accident scenarios maybe realized, may not be realized depending on where you are working. And that is why the potential accidents scenarios we can say, and will be interested to know the risk of each of the potential accidents scenario that is what is the starting point for us.

Please remember that you may go for risk per hazard also, you may you may you may identify risk for accident scenarios also. So, it is basically if you start with hazard then from hazard to all accidents scenarios you have to find out and then where then all those accident scenarios risk if you know. And then that will be to some total and will be getting the hazard or it is accident scenario.

Similarly you may be interested to know the risk of job wise. So, a job may contain several hazards and then job to hazard; hazard to accident scenario then you aggregate

the things. Finally, job wise risk you will be able to get similarly location wise risk also you will be able to get in one location there will be different jobs; so then jobs to hazards and hazards to accident scenarios again summing up. So, for an organization as such then organization then different departments then different sections, then maybe different locations.

So, again in different location, different jobs and in different jobs may be hazard 1, 2 hazard 2 different hazards and in again hazard 2 different scenarios accident scenarios. So, that accident scenario if you know the probability of the scenario happening you will be when you aggregate you will be getting this. Even you further aggregate you will be getting this, when you further aggregate you will be getting for location getting for section, so department organization.

. So, that mean accident scenario is the bottom most part for our calculation. So, whatever this may be your intention and that means, if you are interested in the department wise from scenario to department you have to aggregate. So, whatever you do, but ultimately you have you have to know the hazards and how accident scenarios are taking place. So, you all have you all have seen the fault tree and event tree; that means, we started with the top event and then we have gone to different scenarios.

So, the scenarios and top event why top event depend probability you have calculated, I am repeating what I have already discussed and then that this probability values you can calculate and this scenario ultimately lead to particular loss. So, once you quantify this loss this probability of this scenario times the loss will give you the risk. These two are coming under that probability coming in the; assess the frequency of accident scenario and the lost part is coming under assess the consequences for accident scenario.

So now, when you multiply the probability time the loss you will be getting the risk, this part is known to you. So, there are many techniques we have used and you can go by PHA with qualitative way you can go FMA with RPN way you can go for e event tree fault tree and event tree and the then find out the probability also for this. So, once assess the risk then what are the what are the steps, first is intention, second identify hazard for all accident scenarios then for every scenarios find out the consequence, and find out the frequency per year what is going to happen then multiplied the two you get the get the risk of accident scenario. And then you may find out several accident scenario and then

accident scenario and then this side maybe you can find out the probability. So this why, so this is the risk profile.

So, the risk profile also you can create. Other way wants to multiply with the consequence you will basically find out the risk then all scenarios. And the risk that also you can you can plot that is also risk profile. Ultimately we are interested in the risk.

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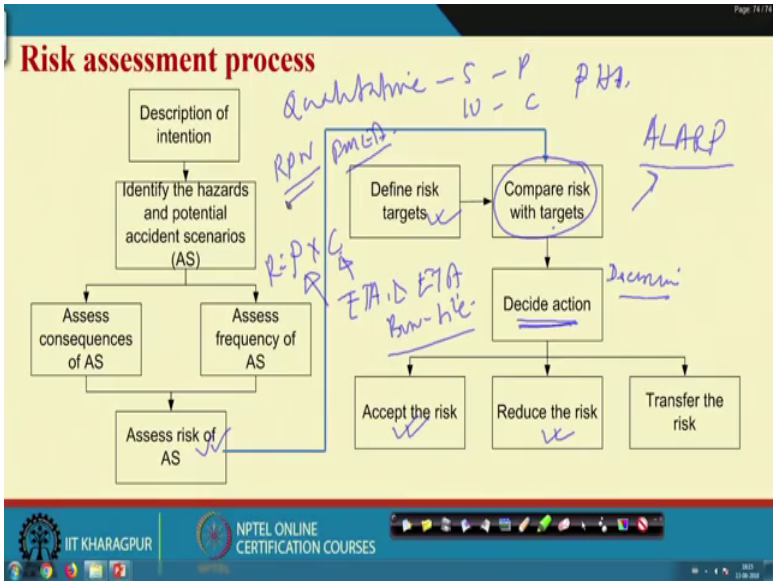

So, now once the risk is risk is assessed what is required you required to compare the risk with target. Now target can come from different sources, one of the issue is may be ALARP, ALARP as low as reasonably practicable. So, ALARP can help you to define the target or you define the risk target for your organization using any of the suitable techniques not necessarily you have to go by ALARP.

So, compare risk with risk targets this is basically that if there is any risk which is above threshold those to be to be reduced. And that reduce reduction of risk is basically the action, here decision is you have to reduce risk and accordingly what action you want to take. Now thus those decide actions may be accept the risk, if it is below the threshold, reduce the risk, if it is above the threshold transfer the risk, when you are not in a position to reduce the risk you may transfer the risk to some other parties. But please keep in mind this is the least preferred one, because even if you transfer the risk, but somebody else will be exposed to this risk that is not desirable ok.

So, maybe you will transferred to that group who are, who are having the ability to reduce the risk then it is fantastic ok. So, this is the nutshell the risk assessment process. So, to repeat that you can go by qualitative way that mean the 5-point Likert scale or 10-point Likert scale for probability and consequence like PIJ we have done you can go for that RPN value calculation the way in FMEA we have done. But in general risk assessment we say risk is equal to P into C probability and consequence and we basically will be interested to have the quantity probability value here, and some quantity value there, if not maybe some index value at the consequence level. So, here someone may be interested to use the fault tree coupled with event tree, which is basically bow-tie.

So that mean all those techniques are essentially hazard identification and risk assessment techniques. These this is the process this way. So, if you start with your organization then you find to divide the organization into departments some are smaller unit maybe division, subdivision then have division to department, department to your maybe section, section to location, location they have different jobs. And then again you find out the job wise hazard and hazard wise accident scenario then finally find out the risk related to accident scenario and you aggregate to higher level to get the risk per job, risk per location, risk you department, risk per you organization. So, that is it.

Now, that is what you have to do so that is what is our formal methodology for risk assessment ok.

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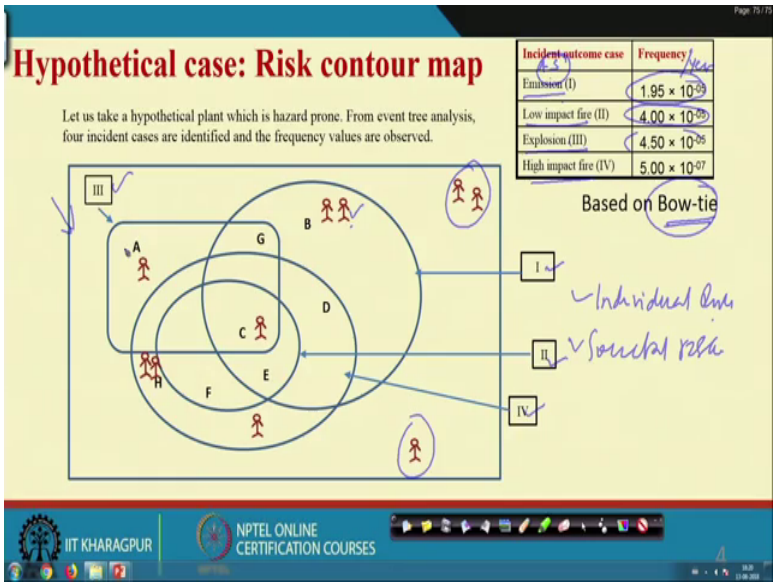

Now, let us see that how we will do this risk assessment with a hypothetical case and assume that actually what does it practically mean risk assessment in the in the plant. So, hope that the hypothetical plant we have considered this is my plant boundary and there are different people working at different locations.

So, there are different locations which are also very important like A, B, C, D, E, F these are the locations and late that we know the source of hazard. There can be 1 hazard source, there can be multiple hazard source and we know that the hazard to accidents scenario that path is also known mean. That means you have bow-tie available for your plant bow-tie available for your plant if bow tie is available for your plant; that means, you know that what are the accident scenarios that would happen in your plant that is the potential accident scenarios.

And interesting to say that that even if there will be multiple hazards, but maybe many hazards will ultimately result in the similar accident scenarios. So, for the timing you just think that this in this plant there will be some gas emission, there will be low impact fire, there will be explosion, there will be high impact fire ok. So, that mean these are the 4 that is the finally, accident scenario or incident outcome scenario I am saying that accident scenario sometimes we use in accident scenario that is developed.

There can be some more accident scenarios, but we are assuming that this is basically complete for this plant. Then using fault tree we know that the hazards we know how the hazards lead to these scenarios. So, that mean the fault tree is known to us, event tree is known to us that mean bow-tie is known to us. Using this bow tie concept whatever we have discussed earlier we have identified the frequency per year. So, that mean emission frequency per year then emission frequency means emission to the to the for example, 1 here that this is area. So, emission to this area this much this much area will be affected that is what we are seeing emission, so then low impact for with this frequency high impact for with this frequency.

Please remember that these frequencies are also hypothetically in nature. So, there is no practical meaning here practical value here it is basically is meaning is that these are these are the frequencies per year that could happen. So, with this information I you want to know what is the individual risk and societal risk. Individual risk means suppose you are working in this plant suppose you are working here you are this person ok. So, what

is basically going to happen to you what is the risk you are exposed to? So, we will not consider these people because they are not affected. So, if you see that these are the first scenario, second scenario, third scenario, and forth scenario. These are the accident scenarios and first scenario is this is the affected area. So, emission take place this many this much area will be affected, then second scenario is this, so this much area will be affected, third scenario is this, this much area is affected and fourth scenario is this, this much area is affected.

So, suppose we are interested to know people working at location A, location B, location G like this at different location what is the individual risk. This is number 1. And another one is suppose we have see you have taken all the location in the damaged area only where affected area, we have not taken location out of the affected area. So, out of the affected area you consider location. And if you assume that these are the scenarios only then definitely they at that place people will not be individually they are not going to be effected.

So, another one is the societal risk the definition I have given you earlier. So, that in a group what is the effect these 2 things we will calculate.

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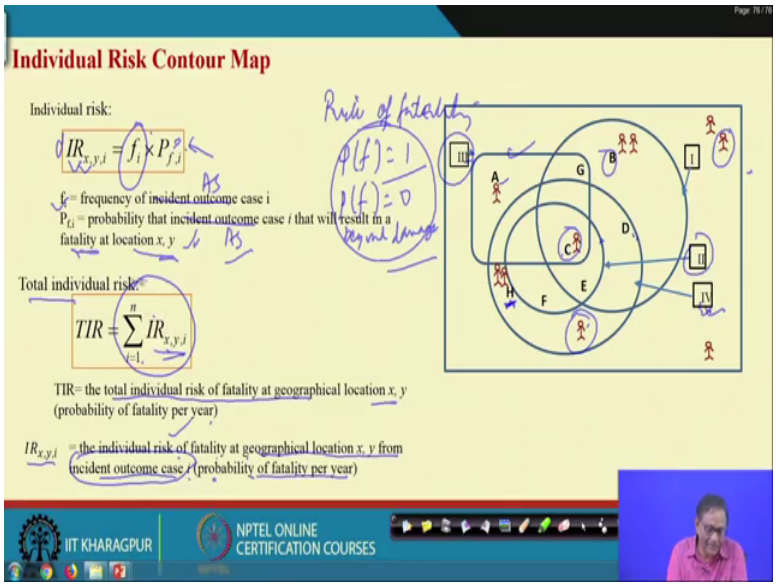

So, what is our further assumption is that, assumption that mean we are basically talking about the here our risk is basically risk of fatality; fatality risk ok. So, if a the damage within damage area the fatality probability of fatality equal to 1, beyond the damage area

probability of fatality equal to 0 beyond damage area. So, that is another simplification, but it is not true always, because the location at which the accident has taken place people affect will be affected they are more and then slowly when you go away from the accident zone the affect will be less.

But, we are expecting that the as the accident scenarios are very fire exclusion and emission of gases they are really a fatality prone accident scenarios or other way I can say that we have considered only those accident scenarios which are fatality prone. So, then this is these assumption is valid, so then if I want to know what is the individual risk fatality risk then what is the frequency and its probability. If the location at which i we are interested to find out the fatality risk if the location is out of the damage area this will be would be will be 0, but that value multiplied by 0. So, the individual risk 0.

. So, here f i is frequency of accident out incident outcome or accident scenario 1 i probability of incident outcome or accident scenario that result in a fatality at location x i suppose you are here at B. So, it is within the damage area, fatality probability will be one, you are here beyond the damage area fatality probability is 0, so that is what is given here. Then what is the total individual risk individually i equal to 1 to n or r i i (Refer Time: 21:35) this how many that mean in every area suppose that every location it may be affected by 1 1 accident scenario may be affected by multiple accident scenario. So, that is to be taken into consideration. Suppose you are working in C what is happening C is affected by this one; that is impact 3 C is affected by these. This is impact 2 as well as this C, C is also affected this one this one is impact 4 and C is affected by 1 also impact 1.

So, someone who is working in C is affected by all the 4 accident scenarios. So, the probability or I can say individual risk will be sum of impact accident scenario 1, accident scenario 2, accident scenario 3, accident scenario 4. For examples suppose someone who is basically working at H, H if you see that it is basically effected by this one scenario 4. Someone working at location H his probability or in the fatality risk will be related to the scenario four only others will not be considered ok. So, that is then total this that is why the total individual risk of fatality at geographical location like this.

So, what is I R X Y the individual risk of fatality at geographical location x y from incident outcome case i probability fatality per year. Here, we are using incident outcome

case, but again I am repeating it is nothing but accident scenario i. I hope you have understood may let me repeat you are interested to know the probability of fatality of a person working at any place of these at a designated place in this plant that designated place may be A, B, C, D, E, F, G, H, I; or any other, which is not designated. So, then what you want to know; you want to know what is the individual risk of a person working at location A.

First what you require to know you required to know what are the accident scenarios or what is the affect zone what this place is under which affect zone, is it is it is it affect zone 1, 2 3, or 4 or any other if here we have four different effects 4 different scenarios. So, then you just find out the frequency; frequency means basically that number per year that through the bow-tie you will find out. So, if the particular location is affected by many of the accident scenarios then their sum will be they will be added up and that added that risk value this formula will be added up here that is the individual risk.

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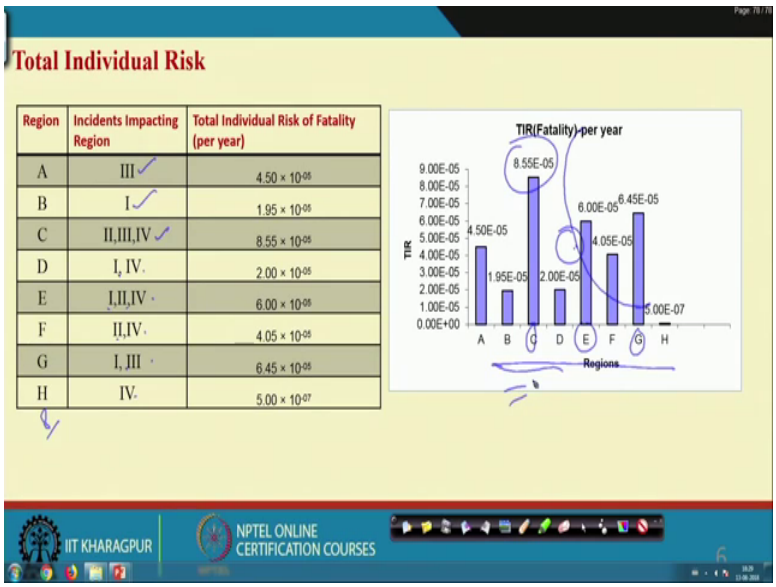

Now, let us see for example, if we consider this one A, B, C, D, E, F, G, H. So, A, B, C, D, E, F, G, H so we have considered 1, 2, 3, 4, 5, 6,7, 8; 8 locations we have considered. A is affected by 3, B is affected by 1, C is affected by 2, 3, 4, 1, 2, 4, 2 4, 1 4 like these, but I think I have to just check here, C is affected by 2 sorry C is affected by these this is C. So, this is affect this one, this one, and this one ok; so 4 and if all affect is there.

So, when you are summing up all will required to be summed up. For the timing i as it is a hypothetical case, so i k what we have written that C is a 2, 3, and 4 what is 1, 1 is this 1 is this. So, 1 is this; so that means, I can write like this then this place will not be affected by 1, if we consider like this. I hope you understand something mistake is good. So, then what happened if this is the case and we have you have to find out basically the incident impact in zone. And then all the corresponding probabilities are the probability values are summed up and then this is the plot, this is the plot.

So, C and C is the most problematic one then G then E like this ok. So, this is your individual risk. Now we will be interested to know the societal risk.

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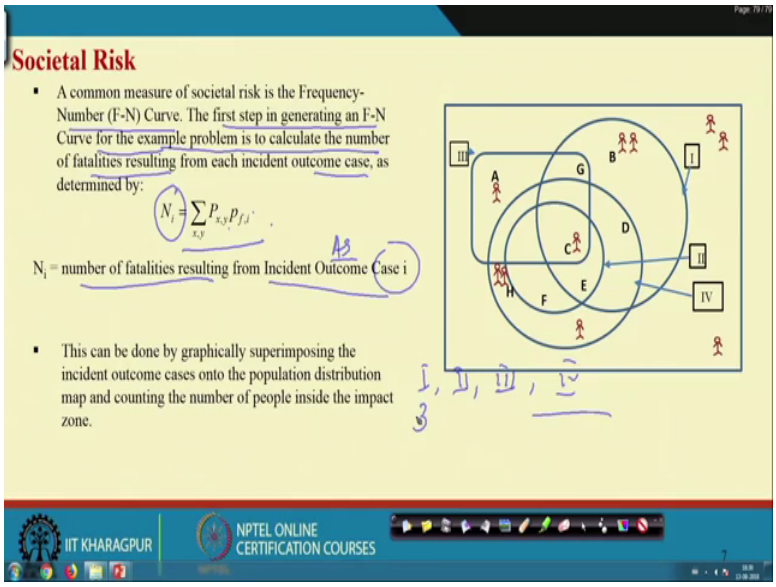

What is societal risk here a co, societal risk means a group of people affected by the risk. So, what will be the here we will be using f n curve, what is F-N curve basically we will discuss the first step of F-N curve e for the example problem is to calculate the number of fatality resulting from the incident outcome case as determined by N i that probability x i, y i, p f i where N i is the number of fatality resulting from incident outcome case i.

That mean you have to find out how many people are exposed to accident scenario i. So, far in individual case we have not discussed how many people are exposed to how many scenario used they are 1, 2, 3, 4 scenarios are there. So, what you required to know you required to find out the number of people that number of people resulting from each of scenario as determined by the number of people exposed to each of the scenario. That is

basically the if they are exposed to their fatalities also they will be fatality affected ok. So, how many exposed to 1, here 1, 2, 3. How many exposed to 2, how many exposed to 3, how many exposed to 4 like this you have to find out. So, then so, if there is calculation mistake you please rectify, but this is what is issue.

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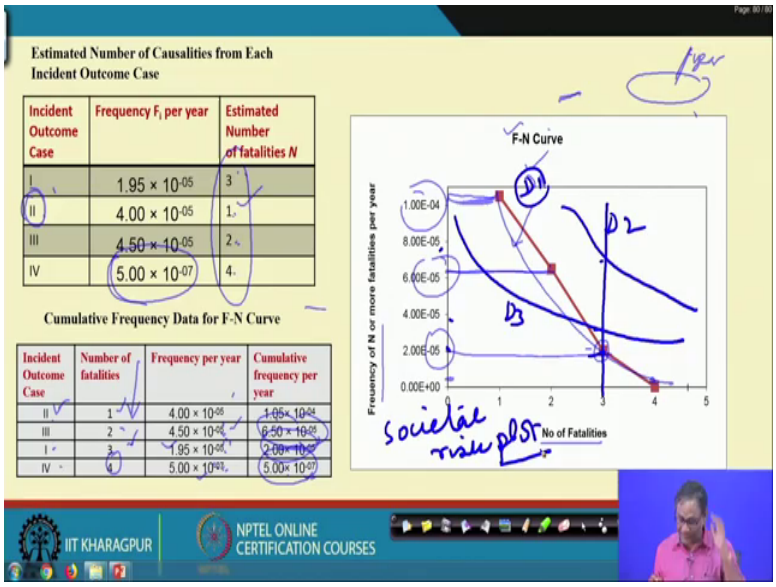

So, you see that number of people exposed to 1 is 3, number of people exposed to impact zone 1 is 1 2 3 1 2 3, number of people exposed to 2 is 1. So 2 means this one. So, number of people exposed to 2 is 1, number of people exposed to 3 is 2, number of people exposed to 4 is 1 2 3 4.

Fine, so, 3 1 2 4, so, where is no computation calculation mistake here. Now what is the frequency per year for the incident outcome 1. So, if you if you go back what is this frequency per year. So, you have found out frequency per year. So, first one this is the frequency, second one this is the frequency. Third one this is the frequency. So, like this, so other as it is per year that you measuring frequency sometimes you may say this is probability also. So, we are using interchangeably this one. So, this one is your c that 1 then 2 then 3 and 4. So, this is the frequency or other way I can say basically probability of fatality. So, then what we are plotting here this side number of fatalities and this side frequency n or more of fatalities per year, this is frequency per year.

So, what you will do you just arrange these in ascending order. So, which one is having which impact zone having the less number of fatalities 1. So, it is incident outcome 2.

So, 2 1 what I have done 1 2 3 4 that way ascending order we have arranged. So, 1 relates to 2 then 2 relates to 3, 3 relates to 1, 4 relates to 4. So, this is what is basically in ascending order means 1 fatalities, 2 fatalities, 3 fatalities, 4 facilities, so then their corresponding probability values. So now 4; what is the probability or frequency per year frequency of n or more fatalities. So, frequency per year 5 into 10 to the power this, if it is in first one zone it is 1.95 into 10 to the power this, if it is in zone 3 impact zone 3 4.5 into these, if it is 2, 2 means 4 into this. So, what we required to know we required to know that frequency n or more that means it is cumulative 1.

So what is the maxi maximum number of fatalities here it is 4. So, if you want to know that frequency 4 or more then what will be what will be the means number of fatalities 4 or more what will be the cumulative frequency that this part per year, it will be 5 into 10 to the power minus 7. So, that is what is the point here 5 into 10 to the power minus 7, then we are going to 3 or more. So, that mean what happen these2 will be added and ultimately the result will be this 2 into 10 to the power minus 5. So, 2 into 10 to the power minus 5, then when 2 or more then the first this 3 will be added; so these in plus this, so ultimately 6.5 into 10 to the power minus 5, 6.5 into 10 to the power minus 5.

And finally one or more 1.5 into the power minus 4 1.5 into 10 to the power minus 4 ok, so like this; so what is happening here that 1or more fatalities what is the frequency per year this, if you say 2 or more these, 3 or more these, 4 or more some value here. So, this is known as frequency number curve. So, this way the societal risk is measured.

And I hope you have understood ok. So, you may be wondering that why this kind of curve, because here what happened we have considered the probability of fatality if it is probability is 1 if it is under the impact zone, but if we; that means, a step function we have used probability either 1 or 0. But, if you know all the actual probability with reference to distance or with or some other probability with reference 2 that, that abstract probability values you may be thinking that your curve may be something like this.

So, if I say now this is my F -N curve for the organ department where I am working maybe this is department one like this once. Similarly you can create your F-N curve for some other department also which may be like this some other department may be like this. So, these will that that is the interesting part. So, that mean now this is department 1, this is my department 2, and this is my department 3. So, if I want to know the

probability that 3 or more fatalities or frequency of three or more fatalities. So, if you do like this you see that here probability frequency value is less, here it is more, here it is even more so that means, D 1 your department is performing better in terms of that societal risk. So that is why for all department, all jobs, all locations, your organization should have some societal risk that plot societal risk plot.

I hope that this is meaningful to you. And I also hope that a given such F-N curve or individual risk plot you will be able to interpret the results. And ultimately also you will be able to develop matter that the some kind of excel sheet to calculate this kind of to computation curve.

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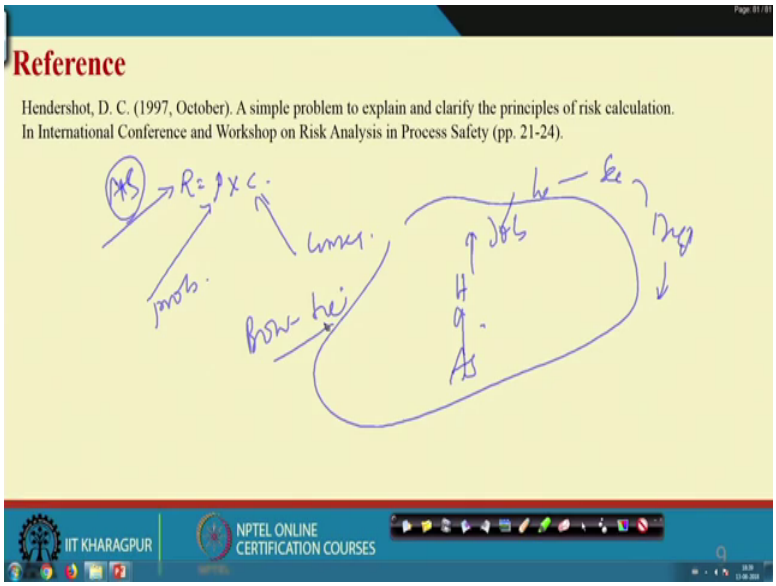

So, this is; what is the totality in terms of risk assessment. So, let me repeat that in risk assessment risk is in general P into C. So, that mean there will be one model for probability computation, another one for consequence estimation, but this risk for what, is this risk for hazard or risk for accident scenario or risk for department.

It is actually we finish we will start with risk for accidents scenario like fire is a accident scenario risk for fire. So, in your big organization big organization, so there can be multiple places or locations, there can be multiple jobs, there can be multiple departments. So, whatever you do there can be n number of hazards; obviously accident scenario will be identified from the hazards only, but accident scenario is the first a as

then hazard then your job then your location then your section then your department then your organization.

And in order to identify hazards whatever hazard identification techniques were told to you please do it. And in order to accident scenario using bow-tie, in order to compute the probability and consequence values go qualitative or quantitative approach follow this and then for societal risk. And, you are your individual risk the approach what mentioned here today it is better you follow this one.

Thank you very much. I hope you enjoyed it.