**Industrial Safety Engineering**
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**Lecture – 04**
**Key Concepts and Terminologies - Risk Assessment and Control**

Welcome, we continue the Key Concept and Terminologies. In this lecture, we will primarily concern about the terminologies related to risk assessment.

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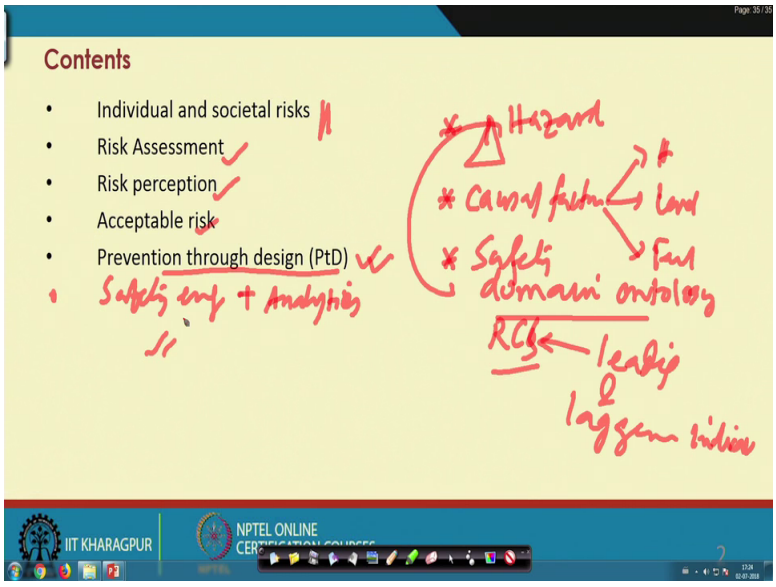


And, then under risk assessment individual and societal risk, then we will discuss about the assessment process, what is risk perception, what is acceptable risk, and another very important concept PtD prevention through design.

In addition, I will try to cover one more important topic here, that that is basically the in detail what will be the safety engineering, and plus some touch of analytics related to safety. So, I hope that by 40 minutes time we will be able to cover it, otherwise let me try how much it is possible; but to relate to my previous 2 lectures where the basic concepts and terminologies are discussed.

So, you have seen that we started with some key definitions, then what I have given you I have given you hazard triangle and then the causal factors 3 level causal factors: one is at the hazard level, then the level 2 where the system component, and again the level 3

the further breaking down into the failure modes failure mode this level. And, I also talk about safety domain ontology, in safety domain ontology with reference to with reference to construction at not construction working at height. And, there we relate this accident triangle sorry I say that hazard triangle, we will use of what hazard triangle not accident triangle hazard triangle.

And, then under this I talked about also the risk control system, RCS and a hazard actuation, hazard perceptions all those things we have you know. Actually, you are now in a position to understand the key terms terminologies, what safety engineers looking to do? And how the hazard element to the accident path and what are the different measures that can be taken? You do not know the specificity of those measures, but you know the ab in abstract level, what are those things you know? And in addition I told that with reference to RCS I told that leading and leading and lagging indicators lagging indicators very important topic.

So, now we will see little more concepts, that under individual and societal risk, and also there are different kind of other issues. And, then what is prevention through design? And, what is in totality industrial safety engineering? That is the topic.

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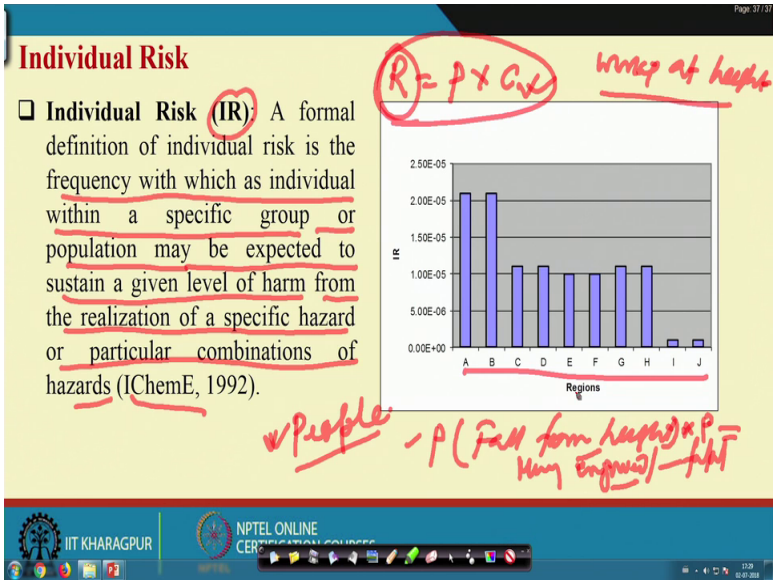


So, let us see what is individual risk? What is individual risk IR? We will go by the definition of IChemE. A formal definition of individual risk is the frequency with which an individual within a specific group or population may be expected to sustain a given

level of harm from the realization of specific hazards or particular combination of hazards ok.

So, do you know what is the risk: yes, by definition you know the risk is the quantification of hazard potential. So, what is the harm that the hazard contains and if the target is exposed to that harm, that is what is the risk level for that target. By individual risk, we talk about target specific risk. For sake of simplicity, we will say that suppose people or human is the target. In that case a person working for a particular job, what is the amount of risk is exposed to? That is, what is individual risk. and individual within a specific group or population may be expected to certain level of harm, so R risk equal to probability time consequence probability means suppose let person working at height; person working at height.

So, let us consider that working at height is the hazard element. What will you will meet an accident fall from height fall from height is the accident. So, he can meet fall from height accident or because of system failures, system level failures. Means suppose the platform which is carrying that person it may be deteriorative. Or he might have not used the safety belt other things which are required to be used at that place particularly. So, all those initiative mechanisms will lead to fall from height.

So, then if the fall take place, then what will happen the person may injure depending on the preventive measures the injury may be at that level he may he may circum to death also fatality. So, probability of fall from height times, if we consider that we are interested in fatality risk times the probability of fatality consequence or simple consequence value, this will give you the risk value.

A welding person he is doing some kind of welding in the machine shop, he is also subjected to some kind of risk ok. So, there can be electrocution. So, what is the probability that he will be get into touch of electricity and then what will happen; that two combination will give you individual risk. This is related to people. So, suppose hypothetically you consider that in your plan there are A B C D E F I J, 1 2 3 4 5 6 7 8 9 10 different locations, people are exposed to people are exposed to different locations.

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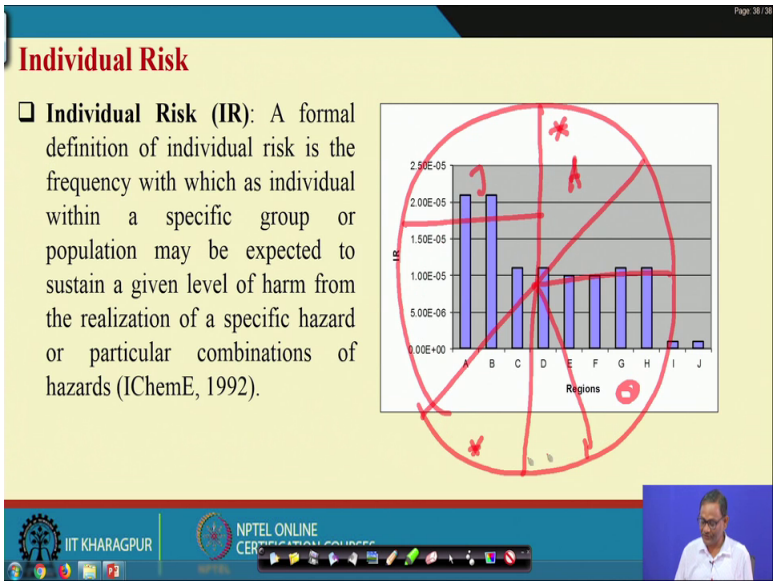


Suppose I draw the location chart. And, I am drawing also like this, so like this, may be this. So, in this way A to suppose this one assume as J 10 different locations are there, someone working here, someone working here, other person working here are they exposed to same amount of risk no. It all depends on many other factors, what amount of risk is expressed to depend on the, what hazard elements? How the hazard element will be ultimately through different and initiating mechanisms will lead to what kind of accidents? And, then to then probability of that accident and if that accident what will happen to him? Whether there is a cos cos case of nearness or there is a case of LTI or there is a case of fatality or there it is a serious injury. So, all those things ultimately may be different from different places. So, as a result job wise also there will be difference. So, that is what we are talking under individual risk.

So, as a result suppose person working at A B location or J location, they are not exposed to same amount of risk this two high risk compact waters. These two and these two another group this also another group, but can be same. So, we can say cluster risk cluster 1, risk cluster 2 and this is risk cluster 3.

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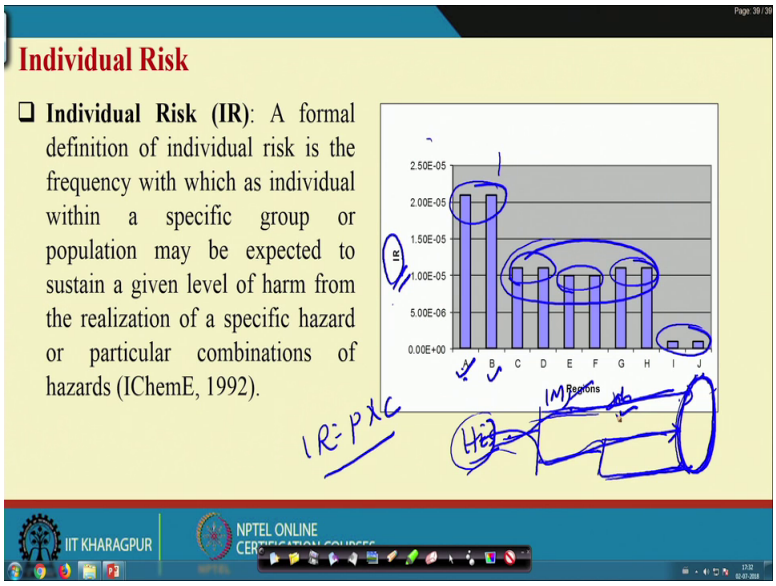


If I replace region by job, then I say the job group A and B have been same level of risk then C D E F G H sharing in a same level of risk and I J same level of risk.

Now, you may be worried about that what is this IR, that is the individual risk how do I quantify all those things. For the time being I told you that this I R is P cross C, probability. Now if I say it is job then you have to add this for a-th job, what are the different hazard elements, you may be exposed to different hazard elements, there can be multiple paths for initiating mechanisms, different paths for initiating mechanisms. And finally, the different consequences also at this path one level at this 3 depend. All those, this occurring of this the probability the path or probability of this path, probability of this path, probability of this path, probability of this path all those path ultimately will give you this IR there will be some total.

So, need not be that for a particular job or a particular location that there will be equal number of paths, it is not. It is the safety engineer who is designing this job or the designing this facility for people to work they must understand much before what it is and accordingly take action ok. So, those issues will be discussed little later. For the time being individual risk means an individual exposure what amount of risk. Where I am working here at any point in time I am exposed to risk at any point then time I may have some con face some consequences. So, that is what is individual risk.

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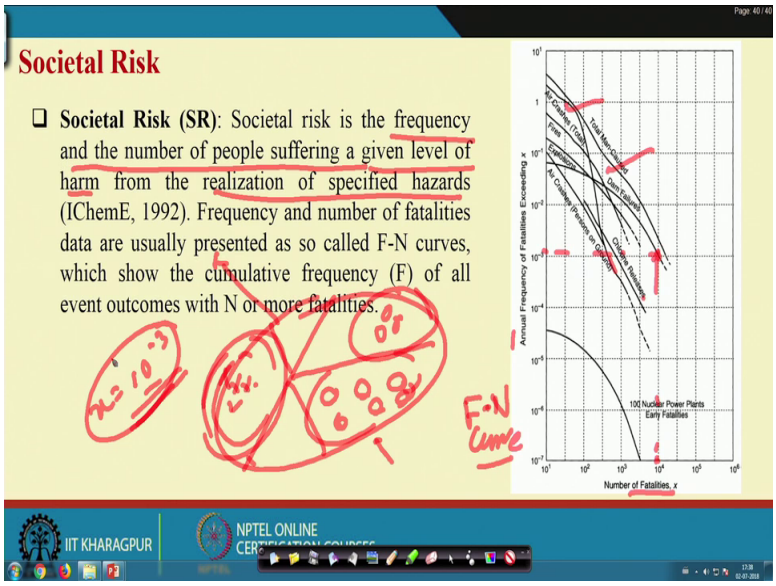


So, but individual risk is not the only thing that the safety engineer should look into the societal risk is another very important one, because societal risk is more problematic one. So, whatever may be let us first you understand, what this also tell this here? Societal risk is a frequential number of frequency and number of people suffering a given level of harm from realization of the specific hazards. That means, we are not talking about individual, we are talking about people with reference to suppose this is your dia plant; this is your plant.

So, there are different locations. Here suppose 3 peoples working, here let will be 10 people working, here may be 25 people working, should they then if I say that what is the amount of risk? For this location considering all group the total set all group of people or here considering these three people are here or collectively for the plan considering all employees together. Or you may go beyond this that the plant also create hazards or risk to such other people who are basically out of the plant, but within the society nearby.

So, that is why the concept of societal it is basically we are not talking about individual, we are talking about the group as a whole. For example, everyday there is there is fatality in Indian roads. Now, when one people die in such conditions and when there is a suppose train accident many people dies. So, the even though the number of may be the number of people died in train, then real is less than number of people die in on roads,

but the rail accident creates more awareness more concern to people. So that means, there are situations where many people will face the problem. So, if you are the planned in charge, you must know what are the what are the hazards, that are specific to individual risk and what are the hazards that basically once occurs will create the caters I can societal the group of people will be affected.

You must have this knowledge that is why this is important it is not that important, because group of people will be affected or individual will be affected some kind of contribution it, because you must know the hazards which cause individual risk and which cause a societal risk there will be hazard, which cause a societal risk that may cause individual risk it is quite likely. So, as a result when was a society at large is more important than individual of course.

So, we basically create a curve called F-N curve. What is F-N curve? That you we will discuss later, but for the time being that this is a measure of societal risk not like the individual part, what you have seen earlier. Where you see that 100 nuclear power plant early fatalities so, this is risk this one is Air curve which one this is basically explosion. I think the second this one this one is what is this chlorine something and similarly then in total man made risk this one.

Second one all classes this one, but what is this why this kind of curve is coming here, what is number of fatalities? What is this annual frequency fatalities exceeding x? So, x or suppose my fatality number of fatality is this exceeding that fatalities. So, you see that this fatality here for this one is much less, but if I consider this you got up you will find out this is the this is what is you dam failures I think. So that means, the corresponding probability is available. So, F-N curve basically talks about x or x or more failure what is the probability, you may be in there say you may find that if there are one fatality, it is may be few row, but if there 10 to the power minus 3 fatalities it may be acceptable.

So, then you understand what is the probability in my plan, that my fatality number of fatality x equal to 10 to the power minus 3, which may be acceptable by the community ok. So, we will during this quantification time we will discuss, how to calculate a F-N curve and how to compute the individual risk and other things?

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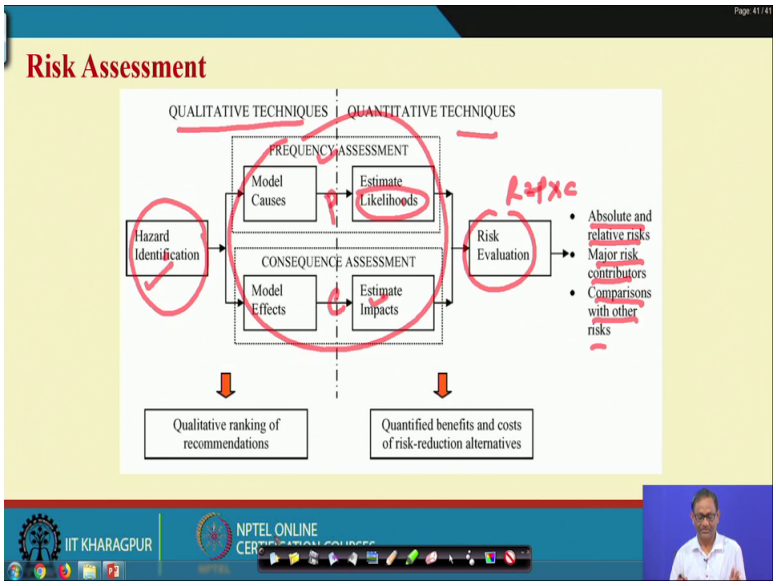


So, after risk assessment and understanding the individual and societal risk, after understanding the hazards, after understanding that how the ultimate when hazard occurs the paths leading to accidents. You have to do one another important issues called risk assessment, what is the value either individual risk or societal risk, what is the value? So, that value will be further compared or evaluated either with certain acceptable standard or with benchmark risk or we with other similar situation what kind of risk is there and so, that you can take actions for what actions risk mitigation action risk prevention action ok.

So, that process is known as risk assessment process. Now, please understand what is risk process? In this process you see one is hazard identification. Then this is basically risk quantification, you must know the probability or frequency and the impact that is basically likelihood here probability mean likelihood impact; then evaluate the risk. So, R equal to if this side give P this give C R equal to P cross C. And, there will be absolute risk major risk contributors comparison with other risk as I told you this one will be compared and we will get like this.

So, there are these particular process one side is qualitative, another side is quantitative. If you go by qualitative risk assessment, we will get qualitative RR qualitative ranking, when you go for quantitative you will be you will get quantified benefits ok. So; that means, what is the process of risk assessment, you have to first identify hazard then that

hazard how it contribute both contribute to accident? Then there will be model of causes which gives you the probability, there will be model of fx which gives you the impact or consequences and then these 2 multiplied gives you the risk. And finally, this risk will be used for different purposes later on I will show you that risk quantization the now, how Pareto chart will be used for risk prioritization? But, anyhow risk assessment is important step but at the same time please understand it is both qualitative as well as quantitative in nature.

Suppose for industry people may be interested in qualitative ranking, but the phase engineers the student they may be oriented as to in quantitative assessment ok. So, we will see later on, but for the time being you understand there is a process called risk assessment. It is primary purpose is identification of hazards and how it will leads to the different kind of accidents. And, then there will be there will be some model of causes and there will be some model to find out the effects, the cause and effect will be multiplied and then you will get risk, once you have the risk for different hazards there will be prioritization. And, there will be comparison that is what is known as risk evaluation and you can do it qualitatively as well as quantitatively.

Quantitative one is better, but as it is costly or time consuming. So, for all larger plant or all industry prospective initially qualitative risk is done. And, then for safety critical syst events or safety critical subsystems that you can go for quantitative risk assessment not for all.

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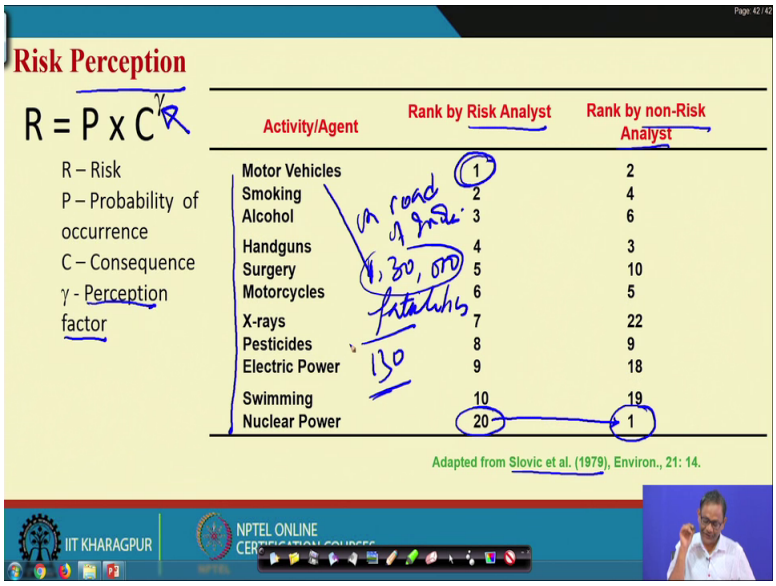


When you when you when you develop risk ok. So, I can say when you basically either qualitatively or quantitatively you know the risk, then what happen you rank it? Show should here some points are give some activity and assumptions given motor vehicle smoking alcohol to nuclear power and you are a risk analyst.

So, do I see that motor vehicle primarily accident on roads and nuclear power which is important one another one. So, these 2 what are the why the place this one I have wrote it from this. So, we get out. So; that means, motor vehicle risk is one rank is one high highest level nuclear power at twentieth. Suppose you are not a risk analyst known risk analyst, what do you see? You will tell nuclear power is more risky compared to many others. So, the ranking you see it is the twentieth to one, first rank, what is this is perception ok.

So, you cannot ignore this important, this is a psychological issue you cannot ignore this. So, that is why when you come you identify the hazards leading to societal risk, there what will happen? This gamma parameter plays a significant role, because what happened in nuclear power accident not only national phenomena, it is international issue.

Similarly, you are a very good you your industry is extremely popular industry lot of people like your industry because it is a brand one accident may lead to loss of reputation. So, that gamma factor the perception factor is extremely important.

One road to the best of my knowledge every year in India there will be a 1, 30,000 fatalities, that is what is happening on road of India ok. If you consider 130 crores people that is the different bolge altogether may be per million may be one fatalities, but please understand the amount of fatality. So, high we tolerate this ok, but we will not tolerate may be a bridge failure killing 10 people. So, this concept is so, important this is important for decision making ok.

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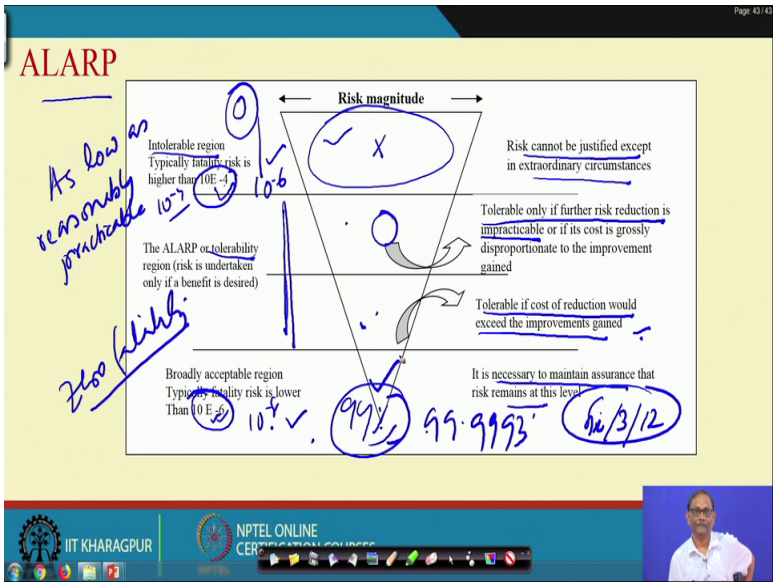


Another important concept ALARP; what is ALARP? ALARP is as low, as reasonably possible or practicable. This is basically a guideline to understand the acceptable risk there are 3 regions; region 1, region 2, and region 3. This is intolerable region, when you identify risk quantify not identify quantify risk. For your sys job for your location or for your planned as a whole whether the risk value falling here, falling here or falling here.

So, this one is intolerable region risk cannot be justified except in extraordinary circumferences. This is the tolerable region, now this is the top one this is the bottom one tolerable only if further risk reduction is impracticable. And, it is tolerable if cost of reduction exceeds improvement gain cost benefit. And, this one is the broadly acceptable regions, which is necessary to maintain this one. One great region may be that if your fatality risk is 10 to the power minus 4 means at any point in time, or it is basically 10 to the power minus 6 or less in between when we entered that is under tolerable region this is acceptable, tolerable intolerable.

So, once you identify the risk values, quantify the risk values, what will happen; you put where it is falling. And, this figures 10 to the power minus 4 10 to the power minus 6 these are the criteria, that this value must be means if 10 to the power 4 people exposed, then one fatality per 10 to the power E 4 unacceptable, but per 10 to the power 6 people it is acceptable.

It is a one subscribed area it is so, for it is a Dutch criteria, but please keep in mind you can create your organization specific criteria, you may not accept this 10 to the power it can be it may be you may say no it should be 10 to the power minus 6 and it should be 10 to the power minus 8. For your case it such that the 10 to the power minus 3, but whatever you do if it is a fatality risk I will be always interested in the value of 0 0 fatality.

So, that you crea you identify all hazards find out the risk value, than totally you create the alert matrix for this. How many jobs falling under this category? How many locations falling under this category very very important, how many job is it so, that 99 percent of your that all jobs are falling under this or it is 99.9993 percent, is it what kind of process it is 6 sigma process from safety point of view or it is a 3 sigma process or it is 12 sigma process. So, do you have any idea you defined it all these things.

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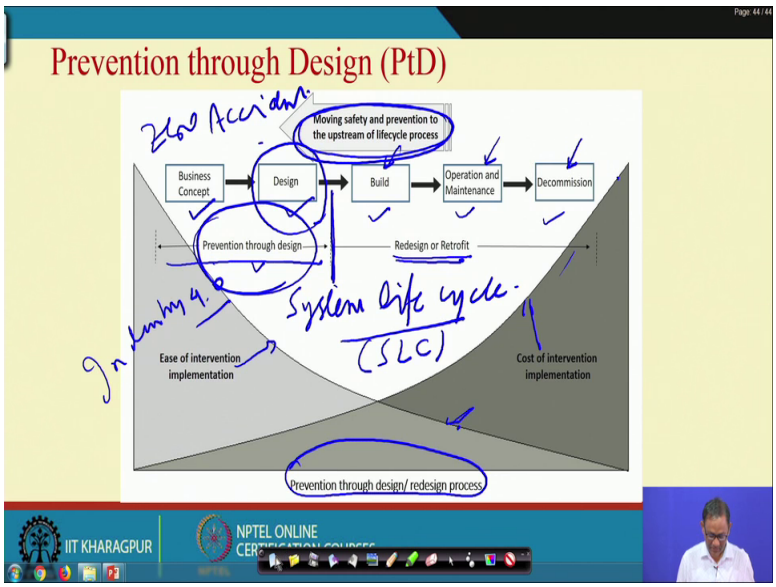


I told you many things, I told you hazard, I told you hazard actuation, I told you state return hazard transition, for more I not I told you the causal factors, I told you safety

domain ontology to know the accident paths, I had discussed individual risks, I have discussed societal risk so many things we have discussed. So, all those things what is the need of knowing at the engineer at the graduation level, when you are in the in the engineering student level. Primary region in that, when you design a product or a process, please keep that safety not during the design only, the safety of people property environment entire lifecycle of the design. During entire lifecycle or your of your design. So, traditionally what are the design steps?

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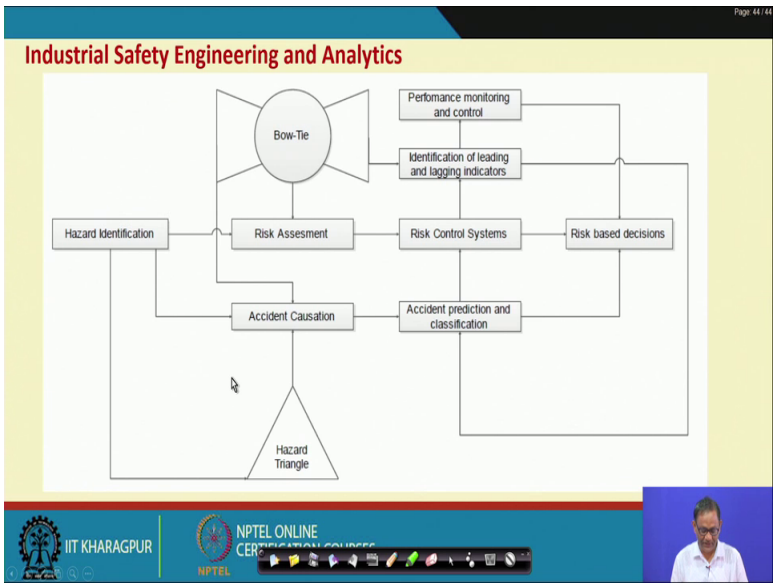


First one is your traditionally, first one is your that business concept idea. Then you will go for design, there will be preliminary design detail design, there are stages of design, then this will be build and finally, it will be under operation maintenance one and then decommission. Any branch we will go through all those stages. The entire stage from business concept to decommission is known as the system lifecycle, what I am saying system lifecycle system SLC system lifecycle.

So, you must understand as a designer safety engineer, what are the hazards that may occur during operation and maintenance? During decomposition, decommission and during built erection all those things must understand and during design all those hazards will be properly addressed this concept is known as prevention through design.

The prevention through design concept whatever you do I will in the report design during design that, that ultimately not only helps you that ease of implementation, but

also your cost of intervention cost of intervention this is basically ease of implementation, this is a cost of intervention cost that is ease of intervention. So, your safety for the people at work for the property for the environment as whole will be much better, if you think all those things much before putting to operation.

So, you whatever you do within this design these are prevention through design. Otherwise the design retrofit and moving safety prevention to the upstream of lifecycle, that is the work of safety engineer this subject is important because of this. Not because that during operations and accident has taken place and you want to analyze it and then say this has happened it will not happen. That is the last result you why you have not understood it during design you to understand it. If, you cannot understand then you cannot design for it. And, unfortunately we do not have any such training in undergraduate level, how many colleges included that safety engineering as a important subject of their basic engineering structure? I am sure I do not know.

So, that is very important. So, prevention through design, during design you understand all hazards, you understand what are the initiative mechanism that may take place? You understand who are going to be affected and what is the amount of affect? That you must know what are the different accident that takes place? You must know that, what are the risk barrier risk prevention measures risk control system will be in place? So, that ultimately accident will be prevented, mitigation is also require prevention may not be successful all the time because there is a probability concept ok, but we want 0 accident our concept also should be 0 accident.

Now, in under industry 4.0, industry 4.0, 0 accident this is very important. So, what are you doing? Are you thinking that one day accident will take place? So, you should not you should not wait for accident to happen, you must do prevention through design. That this particular subject will help you in understanding hazard, hazard actuation, different techniques for hazard identification, risk quantification, blueprint for prevention and all those things together with qualitative and quantitative methodologies techniques ok.

So, this is what is the concept, I will end this lecture now the concept part just I want to tell you what are the take homes for you; one each from concept point of view you understand the basic terms.

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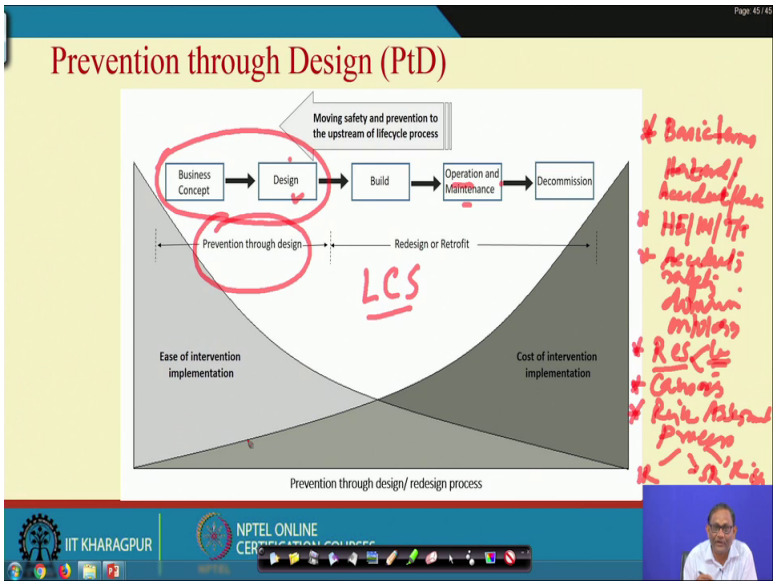


What are the basic terms? One is hazard, second one is accident or mishap, third one is risk minimum basic terms; hazard, accident and risk. You have understood hazard triangle with hazard element initiative mechanisms and target and threat.

You now know that the hazard triangle will give you accident paths through safety domain ontology. You know that there is concept called prevention and mitigation measures under risk control systems. There are many risk control systems starting from maybe even 10 inspection and maintenance, land design, competency of work all those things. You know that that there are causes of accidents, because accidents is not a one factor phenomena it a multiple factors are together.

Under risk control system we also discuss leading and lagging indicators, you must identify what is leading and lagging indicators? Ok. We also discuss under risk assessment that; what is the risk assessment process. Obviously, within the conceptual level not quantitative way risk assessment process. Then I talk under risk assessment individual risk then societal risk and risk perception risk perception.

We are also inter interested to know that, whether though all those things, we will be doing when it is needed to you must know what is the lifecycle of a system. And all those things that hazards how it will happen? Ultimately all those things you must understand in the prevention through design stage which is basically under the under design. Build during build, during erection, during installation, you know during operation and

maintenance, during decommissioning or otherwise I can say disposal every activities must be thought of in the design stage.

And the total risk con it a lifecycle of a system must be understood and prevention or mid and mitigation must be put into perspective through safety protection measures different safety protection measures. The early you do the better is the result the reason, it will be easy for implementation, it will cost will be less. So, safety engineering under prevention through design is understand everything, if you get the de design stage incorporate all protect possible protective measures the design stage. So, that people at large when they are at the workplace they will not get into they will not meet into any accident.

Thank you very much.