NPTEL

NPTEL ONLINE CERTIFICATION COURSE

Health, Safety & Environmental Management in Offshore and Petroleum engineering (HSE)

Module 1
Safety assurance and assessment
Lecture 4
Safety Assurance (continued…)

Let us now continue with the lecture on safety assurance this is lecture 4 on module 1 safety assurance and assessment in the last lecture we have learned that safety cannot be quantified but risk can be quantified and risk and safety or contemporary if you are able to quantify risk you are indirectly quantifying safety so now let us see how logically risk assessment can be carried out.

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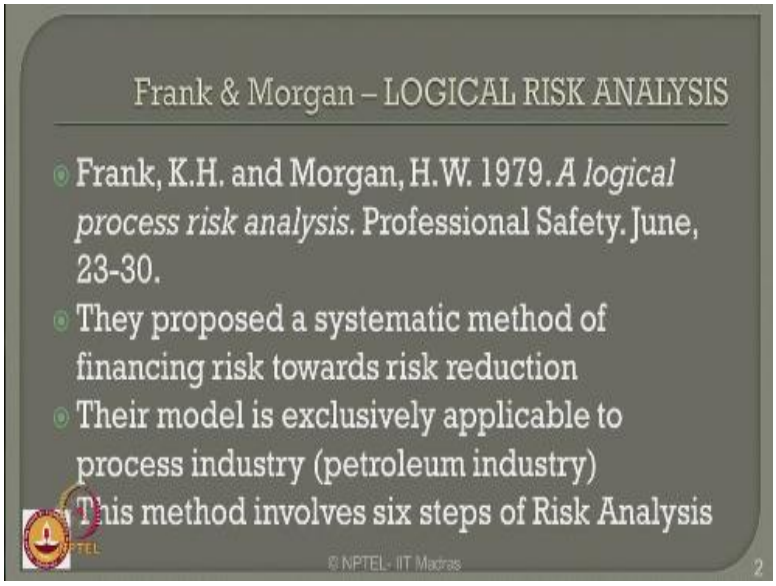

Frank and Morgan has given a very interesting technique how to logically do risk analysis this was suggested by them in the year 1979 a logical process risk analysis published in professional safety journal June 23-30 PP number they proposed a very systematic method of financing risk towards risk reduction now I want you to pay attention to this specific statement as when we talk

about logical risk analysis you will see that the focus instantaneously is addressing of course risk reduction which is an important aim or objective of any risk mitigation program but you will see that logical disk analysis also focusing parallely on how to finance risk it means the risk analysis has been given an economical coverage.

Risk is not told as a number but asset time attempted to certify or attempted to quantify through economic terms because loss is always a important measure of risk and if I am able to measure loss in economic terms if I think we have addressed risk in a more quantifiable manner so let us see how to finance risk please do not misinterpret the statement that to make risk assessment we are creating finances there is a wrong interpretation also do not think that we are financing risk occurrences these two misinterpretation should be eliminated.

We are deriving a method how to assess the financial loss through risk assessment that is what the method is their model is exclusively applicable to any process industry and we all agree that oil and gas industry is a process industry therefore one can apply this method to oil gas industry very interestingly this method of course has six steps of risk analysis.

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Let us see one by one quickly in step number one you compute risk index of each department one can ask me a question what do we mean by department you know every production unit has got different segments for example inventory, stores management, sales, personal safety etc… production unit drilling so there can be different departments in every production unit so let us say I want to assume or I want to calculate risk index of every department the next step I estimate relative risk of each department.

Now I will compare every department with one another and try to estimate a relativity factor between each department. Then I will compute risk index in percentage that is why it is called present risk index for each department. Then one will compute the composite exposure dollars for each department now in this step we are converting the analyzed risk to that of economical terms that is why we say exposure dollars then you compute composite risk for every department once you do this in the last step you rank the departments base up one relative risk score.

So one has to actually rate the department depending upon the risk score we will take up an example and solve and see how the different departments can be relatively ranked on terms of purely risk analysis.

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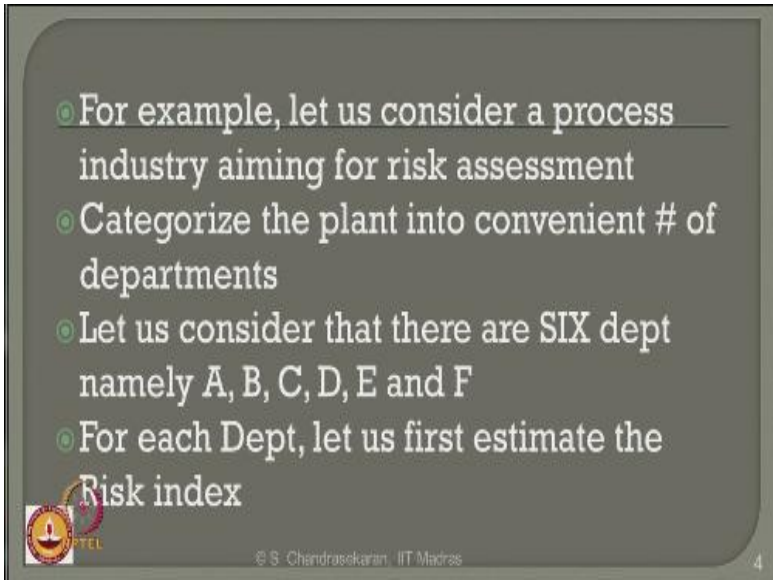

Let us consider a process industry aiming for risk assessment categorize this industry or the plant into convenient number of departments let us call A, B, C, D, E either or five departments or six departments in a given plant let us say the departments are named as A, B, C, D, E and F there are six departments each department let us first compute the risk index.

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Now the question comes what is a risk index each department inherently has a risk level this is to be first Identified can be done by evaluating hazards present and the control measures available within the department, so every department has hazards scenario in their presence there are of course control measures available within each department comparing these two I can always create or calculate the risk level of each department.

This is also a very is called first level of risk assessment in every department generally it is done by ascertaining this from a checklist a sample checklist developed by Morgan will be shown in the next slide so based upon this one can establish an hazard score and a control score.

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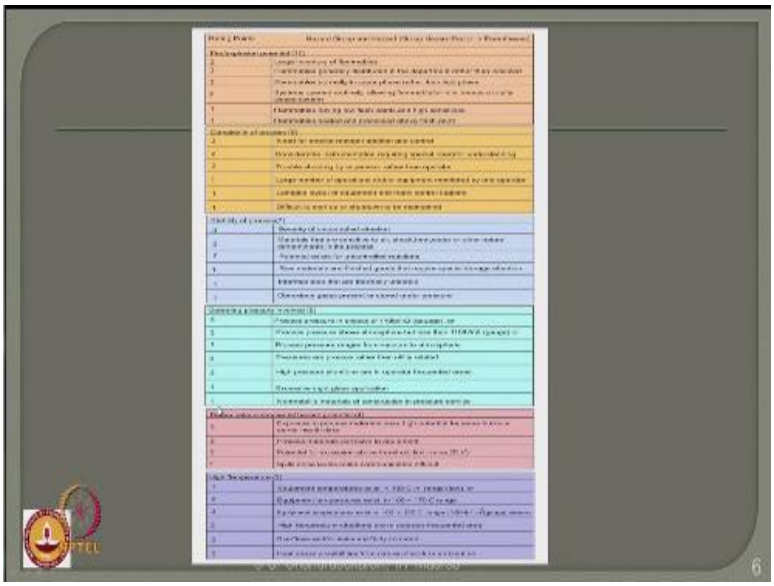

This is a sample list which is shown to you to ascertain the hazard score and the controls score the hazard score or the hazard group there are six groups here 1, 2, 3, 4, 5 and 6 groups for example the first group is on a 10 point scale of weight age which and fire and explosion potential the second is on complexity of the process on 8 point weighted scale stability of the process operating pressure involved personal environmental hazard potential existing and high temperature problems.

Each division has a specific weight age of 10, 8, 7, 6, 4 and 2 respectively each one of them has got different categories within them each category as relative weight age so what I have got to do is if my specific department in a given plant has a large inventory of flammables then I will take that score as 2 multiply that as10 and form this value as 20 if I have large inventory flammables and also they are generally distributed within the department and they are not localized then my square will be 2+2, 4 multiplied weight age it becomes 40. So for every group I can now find out the score of hazard.

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Once they do this then I will estimate what is the control scope similarly for control group also I have different control mechanisms available in place in every department there can be fire protection systems for a weight age 10 electrical integrity systems for the weight age 8 safety devices present in the system for the weight age of 7 inheriting and deep piping systems present in the department for a weight age of 5 there can be ventilation open construction systems available in the department for a weight age of 4 there can be accessibility to the department or with a separation which can be weight age of 2.

So there are again 1, 2, 3,4, 5, 6 groups within each group there are different parameters then for example if your department has an automatic sprinkler system in position then your control score for that group will be 4 since the weight ages of fire protection is 10 your control score for this group now becomes 40 if your department also has adequate distribution of fire extinguishers in the entire area of working then you have an additional score of 1 so your total score becomes 5 because 4 +1 5 multiply this with 10 you get 50.

So for every group one can easily calculate these course as a control scope from the previous slide can calculate the score as an hazard score.

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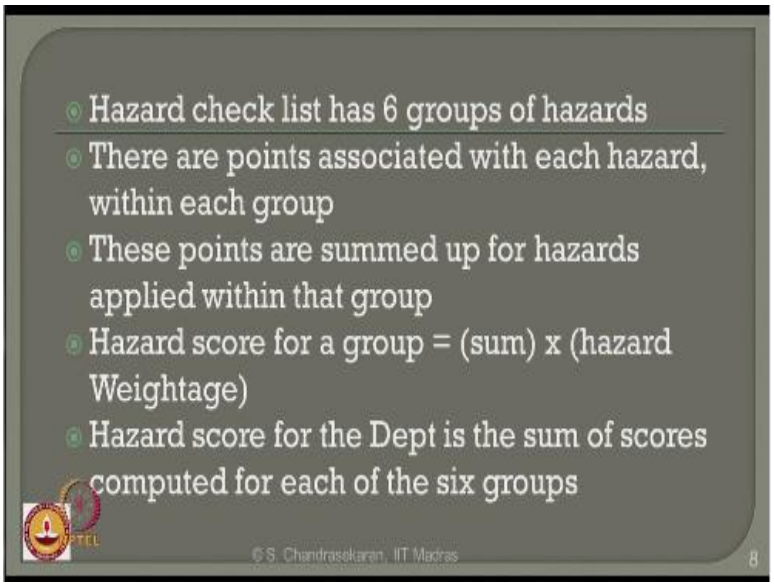

Compare these two scores force to form the risk index so hazard checklist as six groups they are associated with each HR these points are summed up within that group therefore hazard score can be simply the sum multiplied by the weight age for each group as he explained just now so hazard score for each department is now sum of the scores of all the 6 groups as you seen in the last table.

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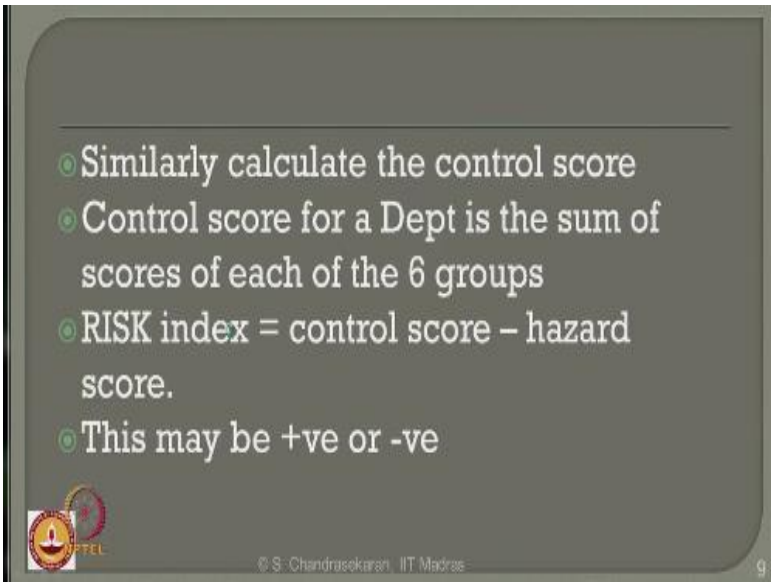

Similarly you can also calculate the control score the control score for every department is again the Sum of scores of each of the 6 groups therefore now the risk index can be computed for each department risk index is control score minus hazard score please understand it is not the difference between the control score and hazard score it is control score minus Hazard score one can ask an interesting question here if my control score is higher than the hazard score for a given department risk index will be positive if we control score is lower than the hazard score for a given department risk index can be negative.

So it is very simple risk index can either be positive or negative if the control score is exactly same as that of all score of the department risk index can even become zero?

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Now I calculate relative risk one can ask me a question why I am interested in calculating relative least so far I have been calculating risk index of every department in a given plant individually but of course I want to compare the departments one can ask me a question why should I compare the risk of every department within a given plant now get back the definition of safety, safety is not only violation of individual personal but also the group of violation getting aligned for organization together, therefore I must now compare the risk of every department and try to find out your relative ranking in terms of risk within each department of a given plant.\

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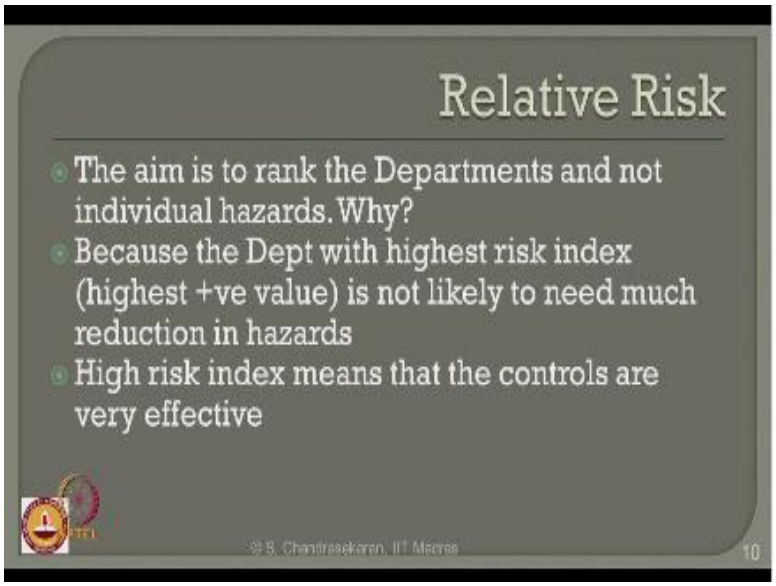

To aim the rank of the department we must not only see the individual risk but I must look at the relative risk because the relative risk will now give me the relative ranking of the department but it not focus on individual hazards of the department. Now the question is why it is so, why individual hazard of the department is not important? Because the department with highest risk index that is highest positive value does not require additional reduction in hazard mechanisms.

Because risk index is controlled score minus hazard score if the risk index becomes positive therefore the department is safe, the control measures taken with the department is much higher compared to the envisaged hazard score of the department, therefore that department may not require or do not have to pay much attention in terms of reduction in hazards. So I must compare all the departments together that but I am not interested in knowing the individual hazards of each department.

Because risk is not individual capacity it is a group issue. High risk index means the controls are very effective it means the department has better control mechanisms compared to the hazard scenarios present in the department.

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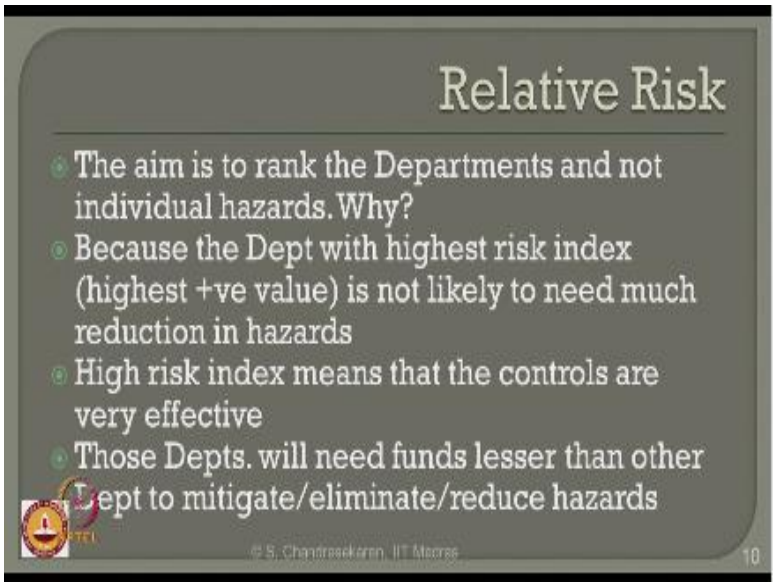

So those departments obviously will require less funding than other departments either to mitigate or to eliminate or to reduces arts because these departments already have enough control mechanisms in place but can you make the finance assistance to this department is a zero, if you do that then I will not be able to maintain the existing control mechanisms, so I cannot make the financing risk to the department whose score is best as zero.

I must fix a minimum amount of finance given for risk reduction to this department. Now interestingly if six departments are present in your plants if department A for example has got the maximum positive risk index compared to the other five departments that this department is considered to be a better department amongst all present in the plan, what is the weight age you give to this department?

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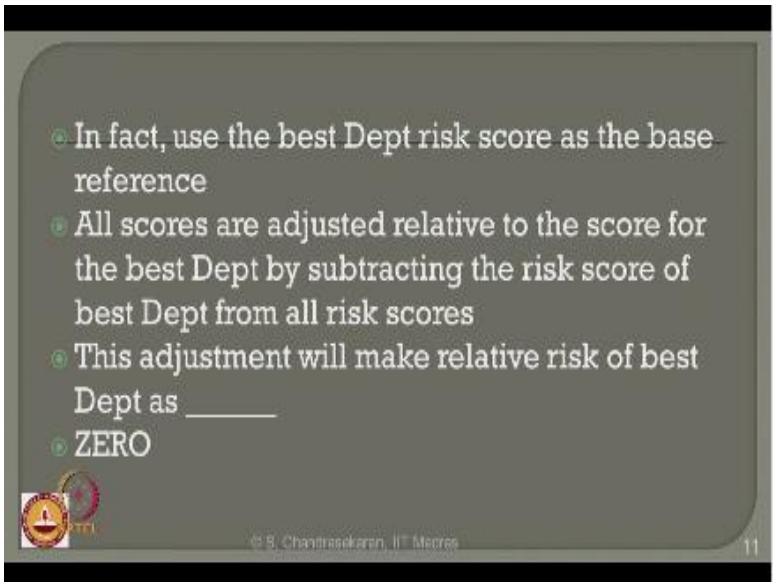

You must consider this department as a base department, which we call here as the base reference for risk analysis. Now all scores of other department should be adjusted relative to the score of the best department. So what you should do is, subtract the risk score of best department from all other risks scores, now the risk score of the best department will be the maximum, the risk score other departments will not be as high as this.

So start subtracting the risk score of the best department from the risk score of all the departments to make them relative, this adjustment will make the relative risk of the best department as the guess is very easy. Now since the best score is same as that of the reference score the relative risk of the best department obviously will be 0, that is taken as the base reference for the problem.

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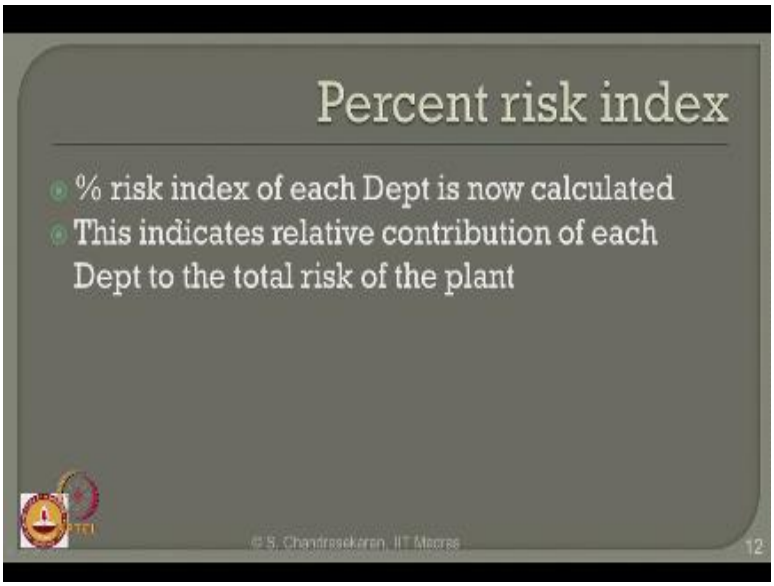

When you compute percentage risk index of every department it is very easy you can compute this value in percentage you will know the risk score of every department divided by the total you will know the percentage risk of every department, therefore you will also know was a total risk of every plant, ladies and gentlemen it is very important to know here that every department will know its own contribution of risk for overall plant.

For example A contributes 10% of risk, B contributes 20% of risk, so the department which contributes to the maximum will have to be paid more attention by the organization. So at this level itself you will easily understand which department should be focused in terms of safety assurance programs or which department should be revisited for improvising safety in stringent terms.

So this level of analysis will also help the organization to ascertain the level of safety being practiced in each department as a control mechanism for avoiding or rewarding each department.

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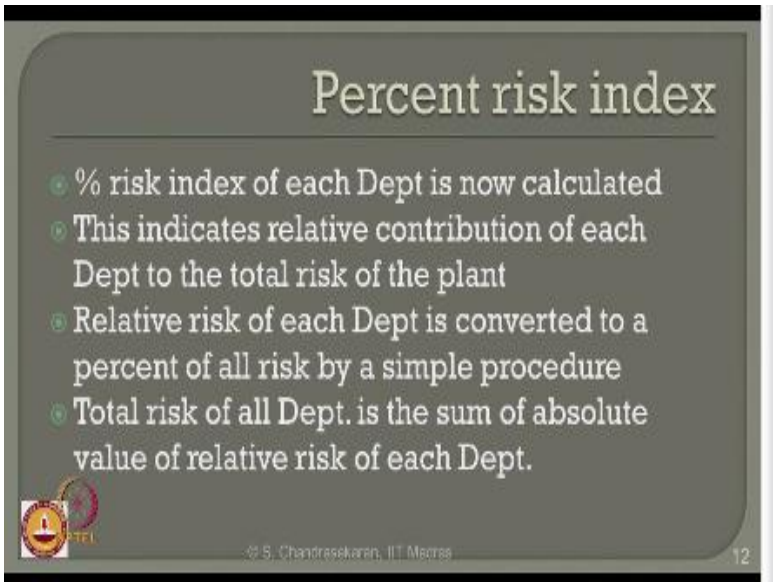

Relative risk of each department is then converted to a percentage by a simple procedure, the total risk of all department will be the sum of absolute value of relative risk of each department.

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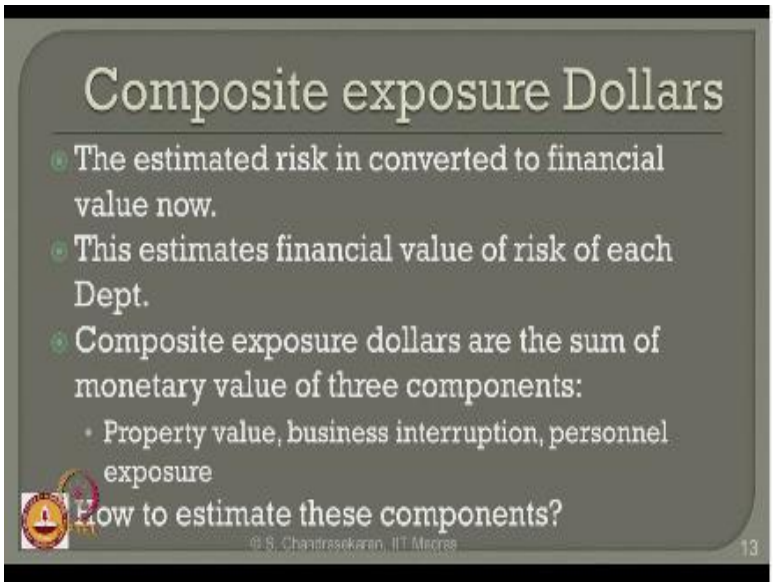

Which will amount to 100%, no one can ask me a question so far we have certain risk of individual departments compared them put them on a relative scale, where is the finance part entering here because Morgan focused on financing risk, Franken Morgan, where is a financing part coming here. Now the financing part is coming in this area of risk analysis where I am going to say composite exposure dollars.

There are three terms available here, why it is composite, where is the question of exposure, why it is in dollars? So dollars indicate it is a financial aspect economical purview of risk analysis whereas composite and exposure is going to explain you how risk is converted in terms of economy. The estimated risk is converted to financial values now this estimates financial value of risk of each department, composite has got different segments involved in this canalizes.

Like property asset, business interruption and personal exposure. So three segments are involved in ascertaining risk, each one of them is played and have value separately, so that the total risk involved in terms of economy is also focused. Now the question is how to estimate these components in terms of composite exposure dollars?

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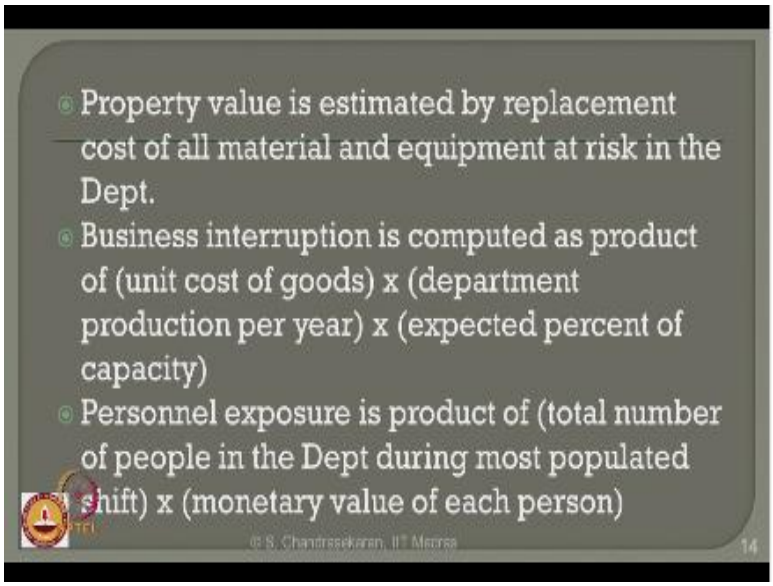

If you talk about property value it is actually the estimated value by replacing the cost of all material and equipment which are at risk in each department, business interruption is computed as a simple product of (unit cost of goods produced in the department) x (the department production of every year) x (expected percentage capacity) present in the department, whereas personal exposure is a product of (total number of people in the department during the most populated shift) x (the monetary value of each person).

Therefore ladies and gentlemen it is very interesting for us to understand that in composite exposure terms we are not only including the asset value we are also including inventory value we are also including the personal value as well as salary pay to each person in terms of working hours. So we are integrating all these components together to bring the financial color to that of the risk involved in the plant.

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So for a department it is going to the product of (composite exposure of dollars) x (the percentage risk index) which have completed in the previous step, this represents the value of relative risk of each department. The units of composite risk of course will be in currency herein this case is in dollars.

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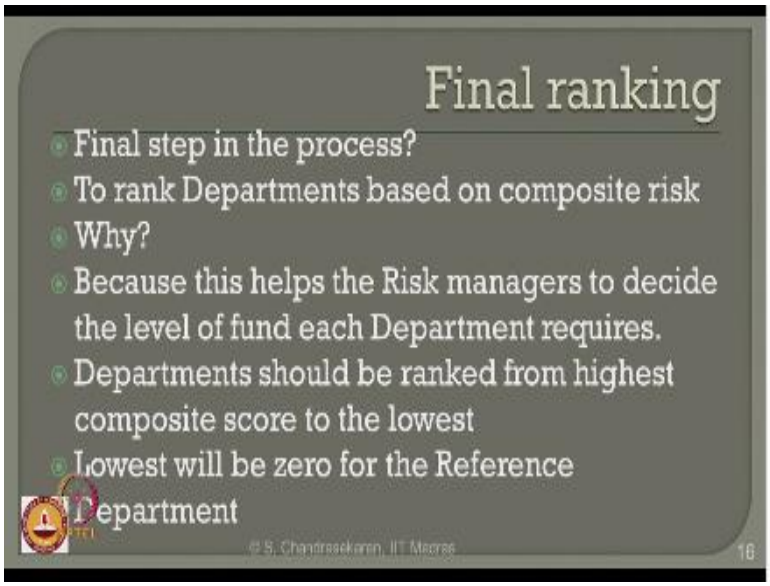

Then you do a final ranking depending upon the final step in the process, now this will help us to rank the department based on composite risk, you already done a ranking in the earlier case which is purely only on risk. Now you do a final ranking which including risk and the composite exposure of every department, why because this helps the risk managers to decide the level of funding to be given to each department is require to mitigate risk.

Departments then should be ranked from the highest composite score to the lowest, lowest will be of course 0 for the reference department.

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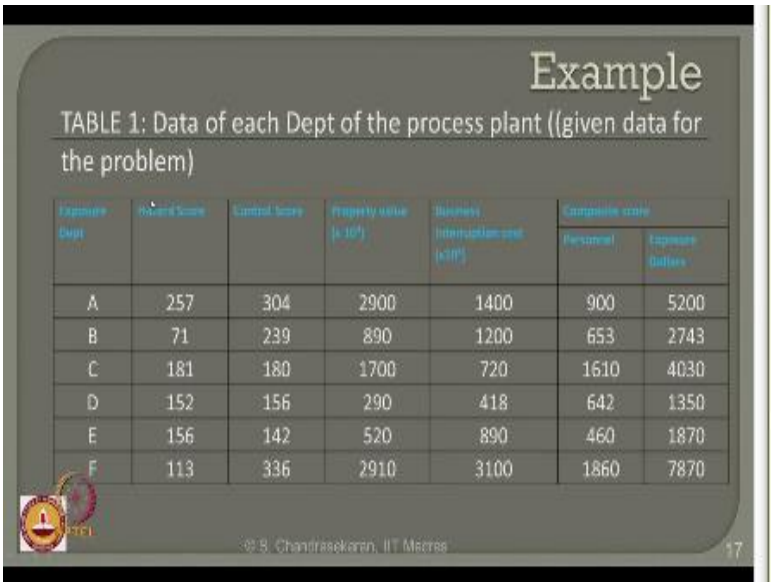

There is an example here, there are six departments a, b, c, d, e and f where the hazard scores has explained earlier or computed, the control score as explained earlier are computed, the property value the business interruption and the composite score are computed and this becomes an input table to do the risk analysis, either you can use Frank and Morgan's charts to compute the hazard score and control score of a department.

Or can also prepare your chart so that can use these Department score separately. So this becomes an input data for each department therefore I say it is a given data for the problem, once you have this data with you.

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Move further to calculate the risk index we already know that the department which has got the maximum positive risk index or positive score is considered as the best department, so the maximum positive score is 223 where for the department f is considered as the base department in this example therefore the relative risk of the department essentially becomes zero and all other departments are actually subtracting the risk values from this.

So 47 minus so and so you give these values and the total amounts to 9, 11 as an absolute number then you calculate the percentage this index for each department because you know what is the value of this divided by this multiplied by 100, therefore you get the percentage risk index of each department. So at this level you will know that which department is contributing to the maximum risk for the entire plant.

So in this example I understand that department E is contributing to the maximum risk for the given plant whereas Department F the does not contribute risk at all because the department F is considered as the best department, the best department in the given plant. Now I attach the values of these numbers.

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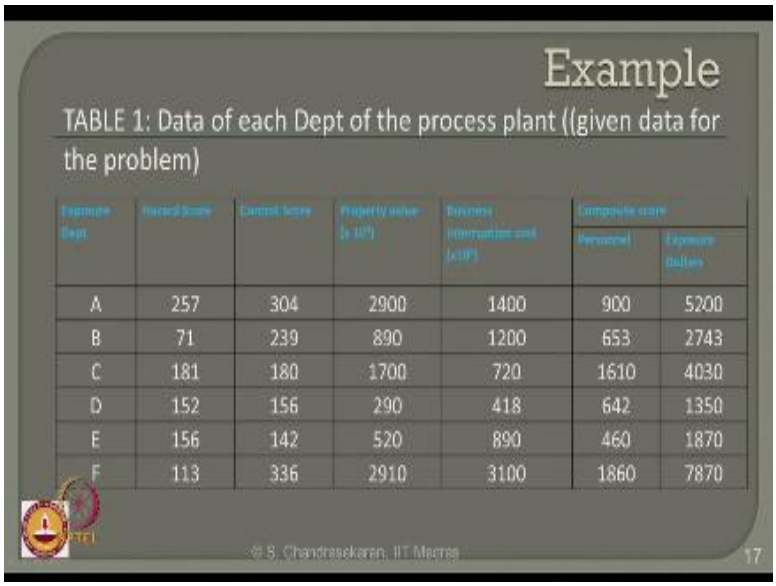

Which it took from the previous table because for example plant A I mean Department A has 5200, the exposure dollar scores of each department for example A, B, C etc are word out as a input data which it transferred.

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To the next table so all these values what I got are essentially input data which are computed from the known chart for every department. So now we have two levels of analysis one we now know amongst the given department which department is contributing to the maximum risk of the whole plant, we also know what the asset and involvement of the department in terms of money here it is exposed dollars and for our realistic figures I am multiplying these numbers to 10^3. So these numbers are not simply 5200 dollars they are 5200 10^3 US dollars so that is what the value is in terms of commercial meaning of these numbers.

So now I compute composite risk how this is then composite risk is nothing but this value multiplied by the percentage in terms of absolute number. So 19.31/100/5200 will give me 1005. Now once I get this I will know which department in terms of finance loss is contributing to the maximum. Now very interestingly if you look at here department E had the maximum percentage risk, since the inventory or the property asset or the manufacturing or the personnel involved in department E amounts to only 1870 compared to the top department A which has got the highest.

Therefore, the contribution of department A in terms of financial loss compared to department E in terms of financial loss is different. Therefore, you will see that in terms of risk ranking department A contributes to the maximum compared that of department E because department E gets a score of 3 whereas department A gets a score of 1. It is contrary because very interesting when you do only relative ranking based on risk alone probably department E would have been contributing maximum for this number.

When you convert risk in terms of financial figures then the real risk picture is C, therefore you do risk ranking finally not only based on only the risk index but the amount of financial loss proposed by the department to the plant in terms of commercial value that is why it is called financing risk, risk is converted to economical picture by this table.

Now look at department C, department C has got a negative score compared to the department A, what does it mean department A has better control scores compared to hazards score that is a risk index is positive because risk index is control score minus hazard score, it means the control mechanisms available in department A is far better compared a department C.

But you will see that department A gets a risk ranking 1 whereas C whose controls cause an inferior compared to department A still gets rank 2. Interestingly this transformation is occurred because the economical perspective of risk is covered in this analysis. So this analysis not only discusses only the risk involvement in the department, it also tells me how this can be converted on economical terms which is very important for any production plant like oil and gas industry.

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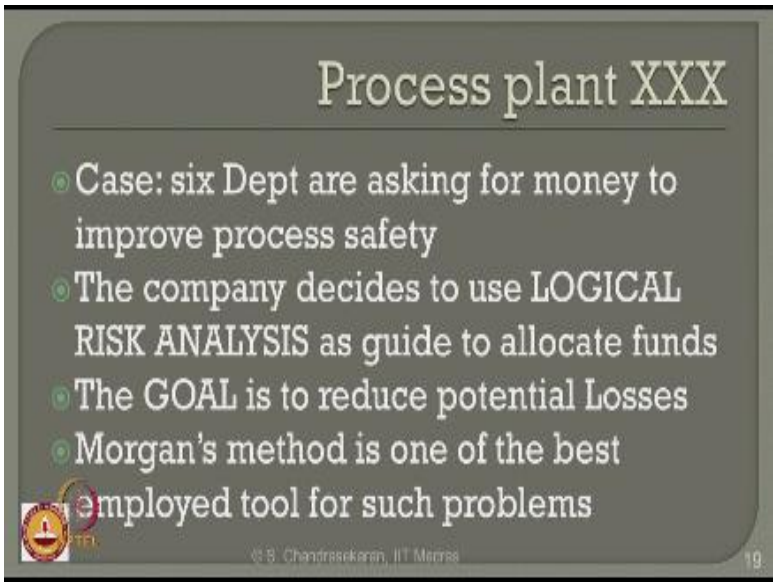

Let us take another example as a process plant XXX six departments are asking for money to improve process safety in a given plant, the company decides to use logical risk analysis as a guide to allocate funds from the budget. Now the goal of the company is to reduce the potential loss. Morgan's method is one of the best employed tool for solving such problems.

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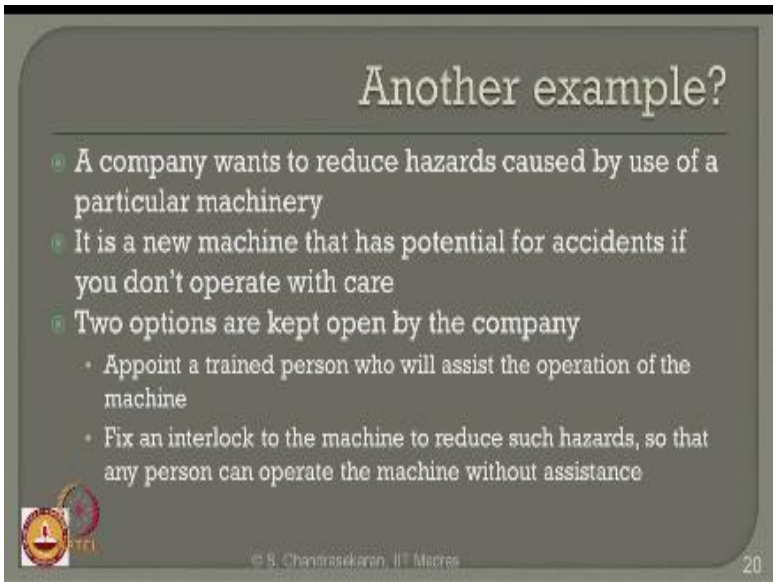

Let us take another example a company once reduces hazards cost by use of a particular machinery, it is a new machine which has got high potential for accidents if you do not operate the machine with care. There are two options available with the company one option A the company appoints a trained person all the time 24 x 7 who will assist operation of that machine was he will be trained etc. Next the company also fixes or proposes to fix an interlock to the machinery which will reduce such hazards, so that accidents can be reduced.

So company have got two options it can either higher a trained person round the clock, so that the machine operation is done through the person or by the person under the direction of instructor or the mechanism can be with interlock. Let us see which is a better method mechanism by which we can this can be reduced.

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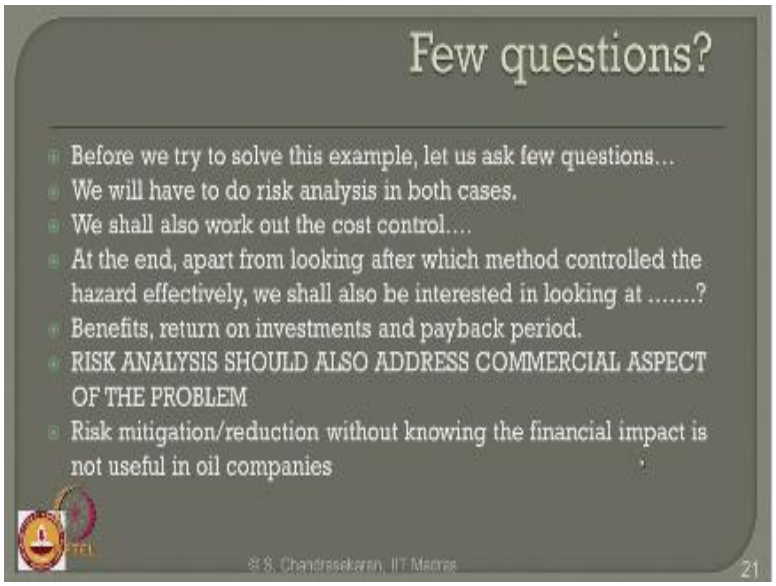

Now there are few questions asked before you solve this problem, before we try to solve this problem, we will have to discuss in both the cases option A option B, both risk analysis mandatory, we shall also workout the cost control in both the cases that is important, and again apart of looking after which method control the hazard effectively we should also see what this another factor which is very important for an investor, whatever the factor the factor is what is the benefit I derived, what is the return on investment I get, what is the payback period I get on investment that is very important.

The risk analysis therefore should also focus on the commercial aspect of the problem risk mitigation and reduction without knowing the financial impact is not useful in oil companies.

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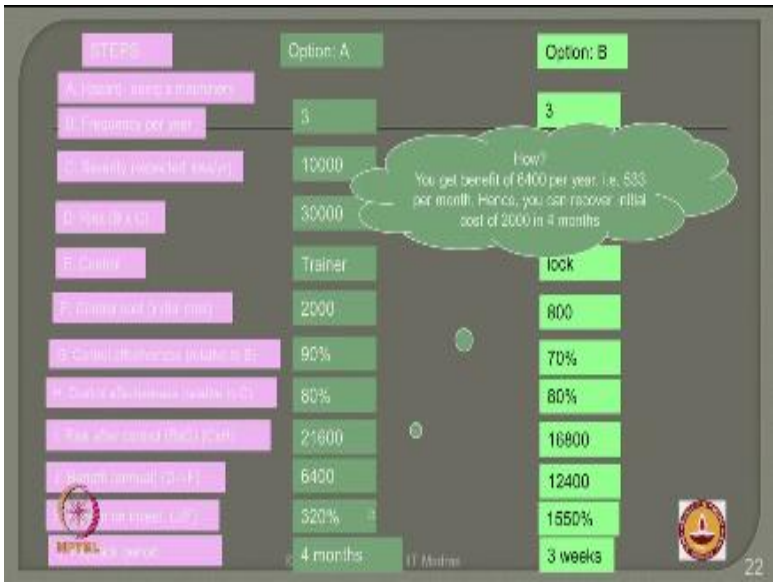

So let us solve this example I have got two options steps option A option B, step A says hazard using a machinery, frequency per year in both the cases it is three and three I want to maintain both of them same, so that there is no difference between option A using a trainer option B using an interlock to the machinery. Let us see what is the severity of an accident that is expected loss every year I want to keep the expected loss in both the cases same so they can compare them very easily.

Now I want to see what is risk involved in each case risk involved is actually the product of these two because we know risk is a product of frequency and consequence, I want to keep both the risk level same where I really know now which option will be better for a financial investor as well as for a manager. Then I say what is the control mechanism available, the control mechanism available in option A I employ a trainer in option B I put an interlock. Therefore, the control effectiveness in both the cases should depend on what is the initial investment, the investment is higher in option A because I want to hire this person around the clock.

Whereas cost of this lock can be cheaper because this can be bargained when you purchase the machinery. Therefore, I want to make a significant difference here I have made this cost

approximately three terms of this because I think this person will be employed at least run the clock in three shifts. Now let us see what is the cost effectiveness related to B, the B is a frequency I want to keep the effectiveness by applying a person higher than that of an interlock because this person is trained, this person is available around the clock he will instruct the users.

Therefore, the effectiveness of cost in the control will be much superior compared to that of a missionary because this lock can be even defective, can be non-functional, can be a power failure. Therefore, I take this effectiveness slightly lesser compared that of the option A. Let me see what is the control effectiveness, the control effectiveness using instructor or the mechanism I want to keep it seeing, so that I do not want to create the discrepancy at this stage of my problem.

Let us see what is the risk after control where I did not know what is the risk before control that is 30,000, risk after control is nothing but the product of effectiveness of the cost and effectiveness of control so B product G multiplied with C product H, I compute this and now there is a seeming a difference and risk after control is higher in case of option A compare it of option B. Now what is the benefit annual which is drawn from this, so it is nothing that the risk involved minus the investment minus the control effectiveness I get this value as 6400 whereas the benefit I draw from option B is much higher than that of option A.

Now what is the return on investment that is very interesting, I made there a higher benefit, but I am I able to get the return much higher. I have calculated this as percentage, one can ask a question how you have done that okay. What is the payback period how do you do that. It is very interesting, I have derived a benefit of 6400 in a year that is 533 per month. Therefore, I have invested 2000 rupees approximately I will get this money back in four months, whereas here I have invested only 800 rupees I get this money back in just three weeks.

So return on investment or payback period becomes very important aspect of any mechanism or any plant or any investor who controls about risk. So this is a very interesting example where risk control mechanism has been given a complete illustration in terms of economic perspective.

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Once we understand this we should also agree there is some acceptable level of risk in oil and gas industry. Risk is acceptable under regulatory agency and also to public. According to US EPA criteria a lifetime risk of one in million is defined as acceptable risk given by or developed by carcinogens. For non carcinogens this acceptable level of risk is hazard index of less than one, according to UK health and safety executive the acceptable FAR is 1.0.

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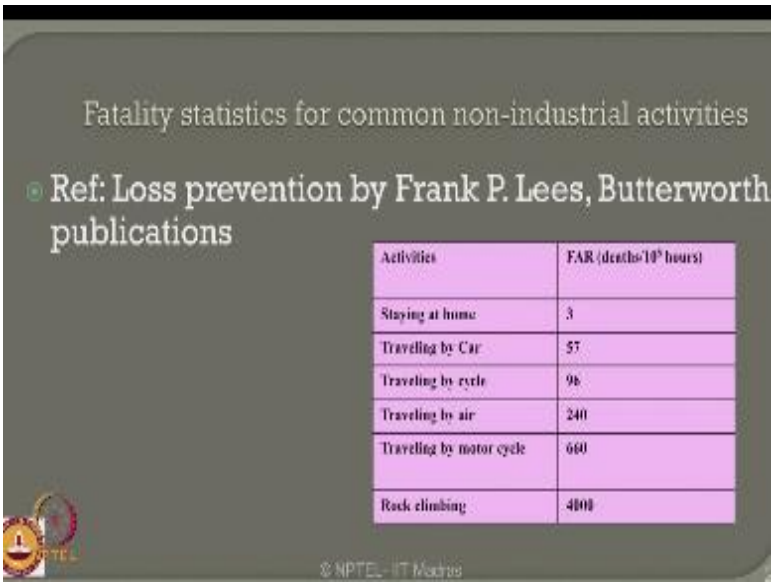

These are acceptable risk statements. Now let us see the fatality statistics for common non industrial activities, this is given by loss prevention, Frank P. Lees, Butterworth publication I am drawing the table from their activities and different FAR are listed, you will see your FAR can be as I has 600 even autonomy motorcycle if FAR can be as low as 3 if you stay at home. On the other hand even if we simply stay at home there is always an risk involved.

So risk is symbolic with every work of life ladies and gentlemen risk is not only related to oil and gas industries. Now one can ask a question why traveling the motorcycle compare that of has got an higher risk index or let us say FAR. So remember FAR depends upon what the exposure time of risk in the expose time of risk if the person involved in exposes larger and larger the FAR goes higher and higher.

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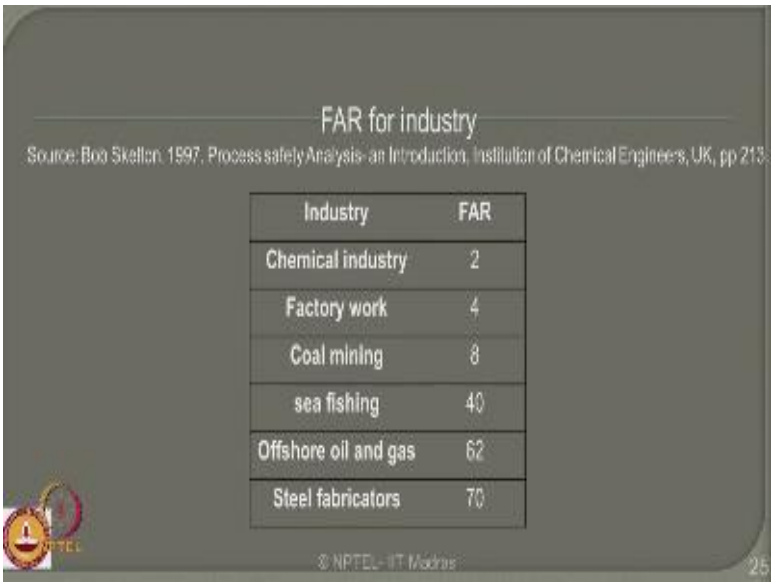

FAR for different industry is also given, chemical industry is 2, oil gas industry has got a very high FAR of 62.

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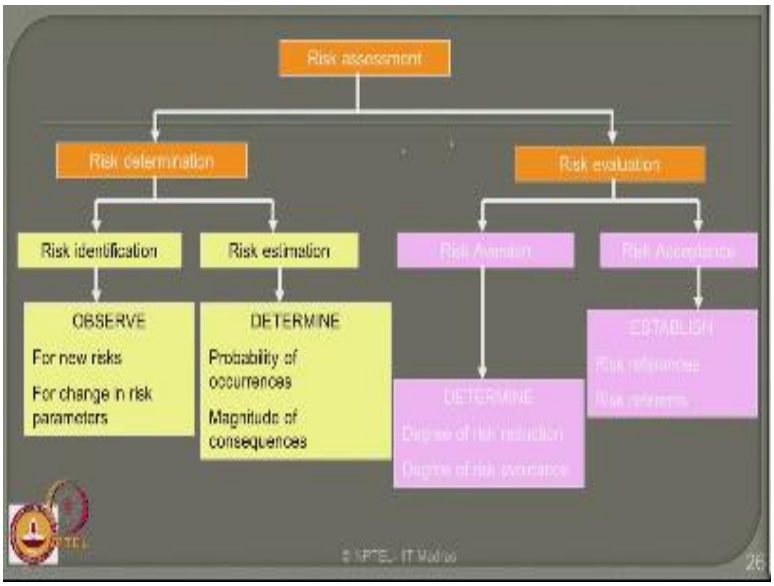

Let us see how do we actually do risk assessment in terms of an flowchart risk assessment has got two segments one is risk determination, other is risk evaluation, determination is got two components, identification and estimation, identification has got two segments one is observed which is based upon new risks and change of risk parameters, whereas risk estimation is essentially depending upon how do you determine risk, determination becomes the problem of probability of occurrence and magnitude of consequences.

Risk evaluation is done in two stages one is risk aversion other is risk acceptance, risk aversion has got determination where you do find out degree of risk reduction and degree of risk avoidance whereas risk acceptance is depending upon how will you establish the risk levels, risk levels can be based upon risk references and risk reference. So you have risk assessment as a complexity of two essential stages of determination and evaluation.

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Let us now take a specific case of risk assessment, let us take an example of a process plan is a chemical plant, national academy of sciences is identified four steps in chemical risk assessment hazard identification, dose-response assessment, exposure assessment and risk characterization.

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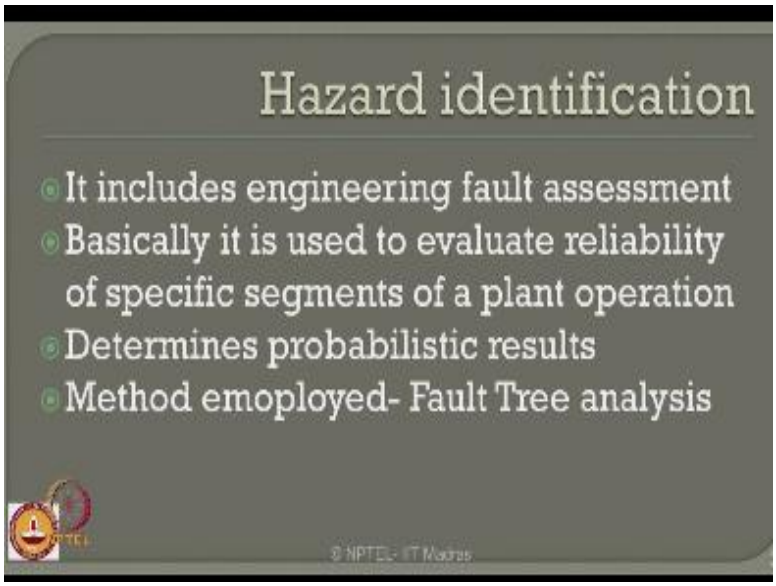

Hazard identification includes engineering fault assessment, basically it is used to evaluate reliability of specific arguments, segments of the plant operation, determines probabilistic results, and method of employed is fault tree analysis.

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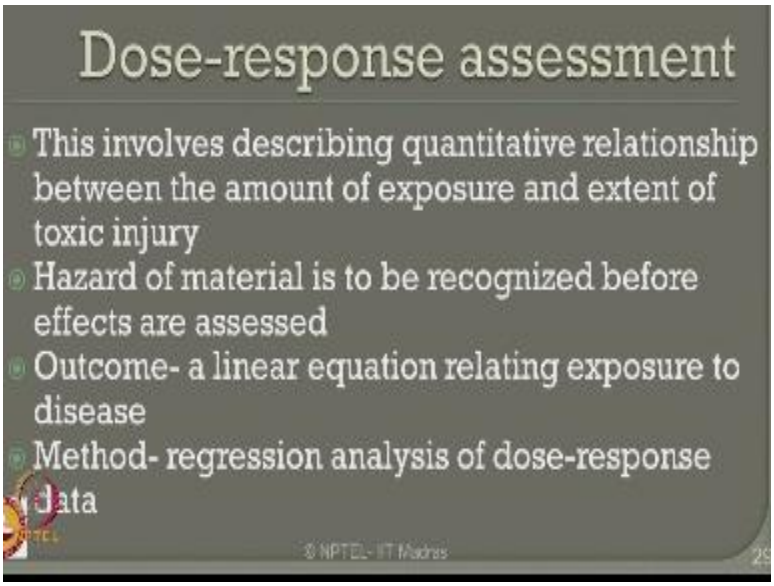

Dose-response involves describing quantitative relationship between the amount of exposure and extent of toxic injury, hazard of material is to be recognized on hand before they are assessed, outcome is a linear the equation relating exposure to diseases, method is regression analysis for dose response data.

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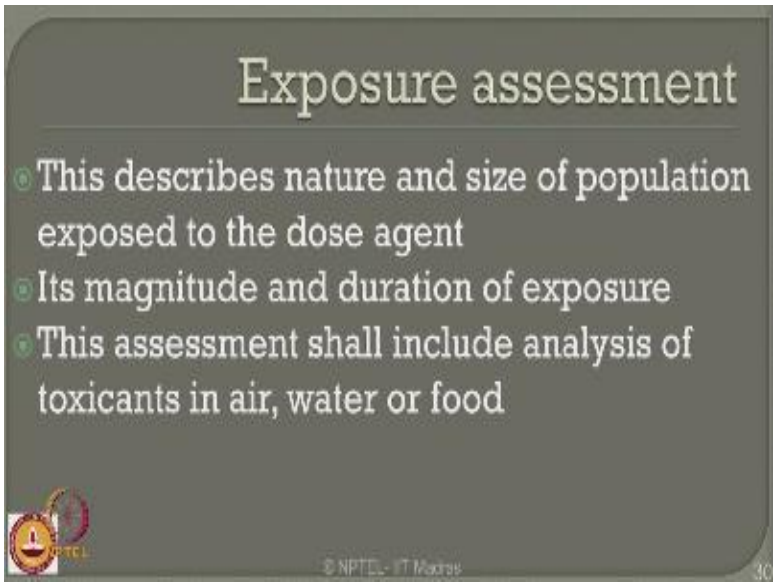

Exposure assessments depends on nature and size of population, its magnitude and duration of exposure, assessment includes analysis of toxicants in air, water or food.

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And risk characterization depends on integration data and analysis. It determines whether people will experience effects of exposure or not, it includes estimating uncertainties associated with the entire process of risk assessment.

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There are certain issues when you start applying this risk assessment in reality, risk assessment often relies on inadequate scientific information or lack of data. For example, any data related to repair cannot be used for newly designed equipments, it means even though the data available is less still available data all of them cannot be used because they do not quantify the risk in a proper manner.

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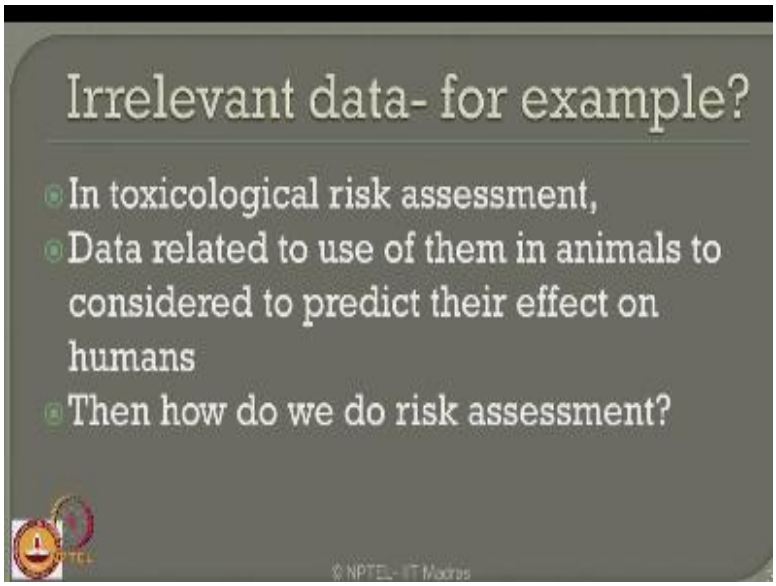

There are some irrelevant data also available, for example, in toxicological risk assessments we generally find data related to use of them in animals but we cannot use them directly to compute the effect on human beings. So then how do we actually do risk assessment.

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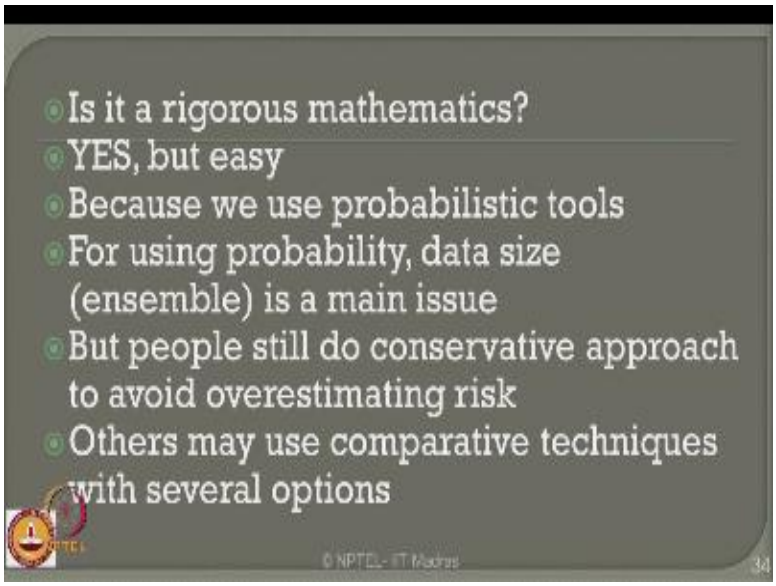

It is a rigorous mathematics, is it so the answer is yes that is very easy because we use probabilistic tools to solve them, for using probability, data size in symbol is the very main issue, but people still do conservative approach to avoid overestimating risk, others may use compared to techniques with several options.

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What is the conservative approach how do we do quantitative risk assessment, we identify frequency of an event, its severity, we calculate risk rankings, we ascend them to get risk order they got risk management.

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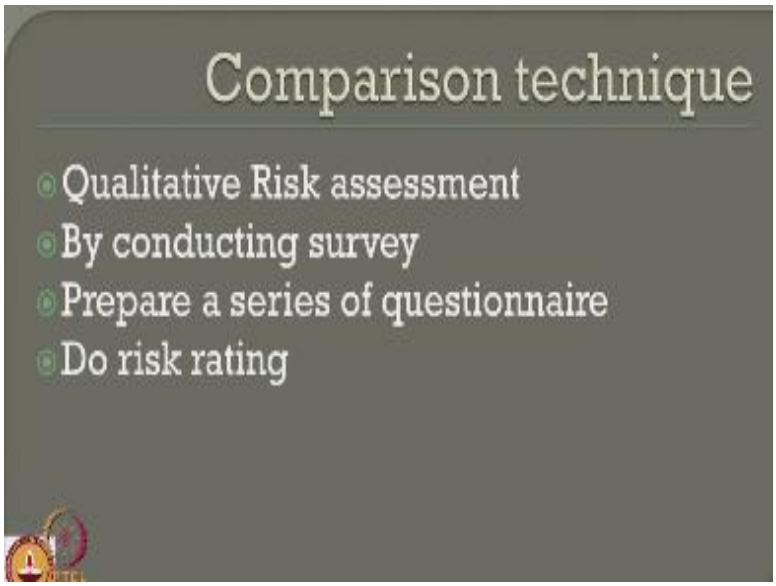

And then we use comparison technique upon qualitatively do risk assessment. We do conduct surveys for qualitative risk assessment, we prepare series of questionnaire, we do risk rating based on this.

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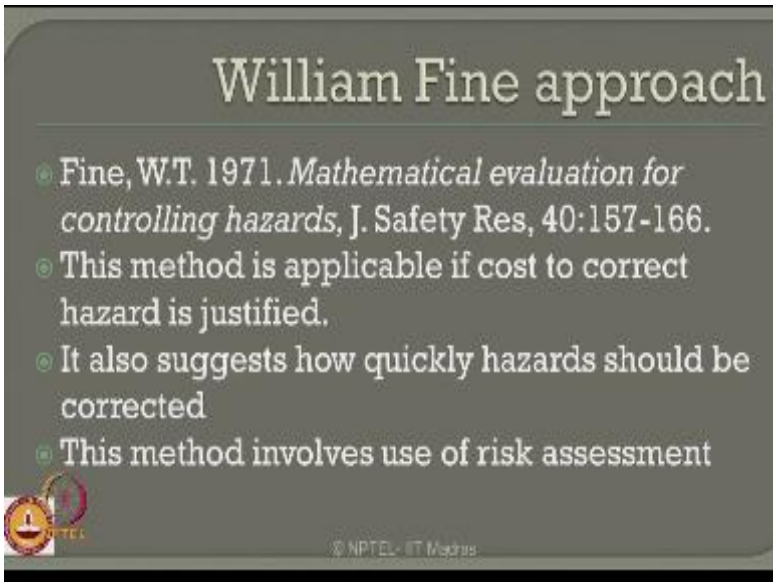

And do QRA, William Fine has given a very interesting approach to quantify risk assessment interestingly in 1971 as the reference is available there, this method is applicable only if the cost to correct hazard is justified. It also suggests how quickly hazards should be corrected, this method involves use of risk assessment interestingly by an example.

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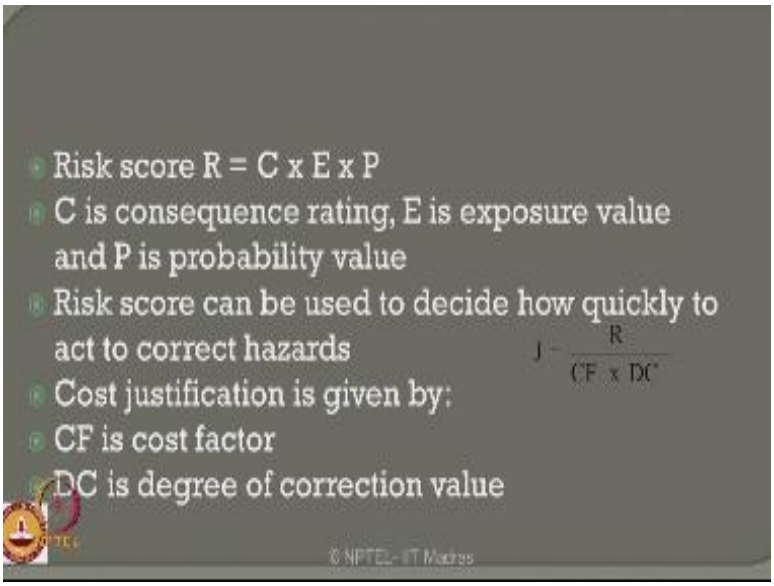

It estimates risk score which is multiplication of C E and P where C stands for consequence rating, E stands for exposure value and P stands for probability value, risk score can then be used to decide how quickly you have to correct the hazards, cost justification is given by a simple equation as you see here which is R divided by product of CF and DC where CF is the cost factor and DC the degree of correction value.

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Now to estimates C E and P we have a table available here, P is a probability, E is exposure, and C is the cost factor. The term is suggested by the gentlemen where there are regions available and each region has got different divisions, each one of them has got different weighted scores. So based on this use the risk rating score and compute the risk score if the risk score falls between 200 to 1500 you must have immediate correction action, if it is between 90 to 199 it requires attention as soon as possible, if it is less than 89 hazard should be eliminated without delay.

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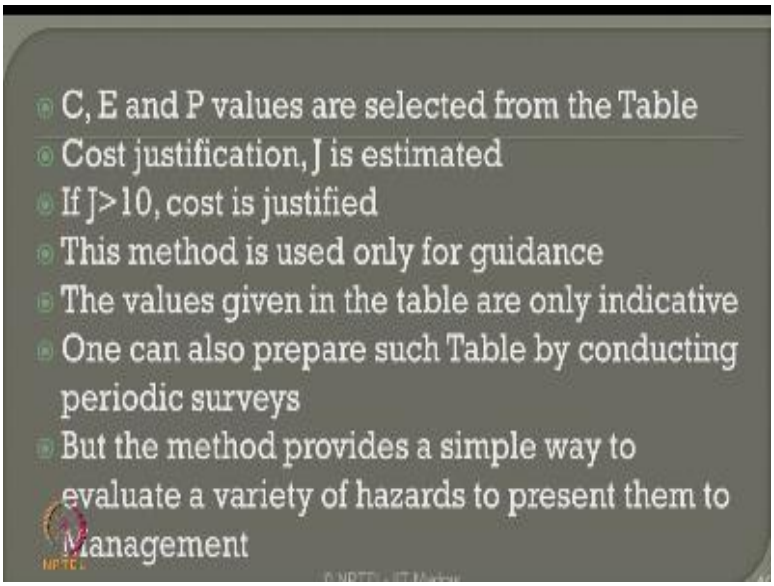

So let us do an example of this CEP values are selected from the table, cost justification is estimated, if J is greater than 10 then cost is justified, this method is used only for guidance, the value is given the table are only indicated you can also prepare your own table depending upon the surveys what to conduct periodically. We will apply this method now.

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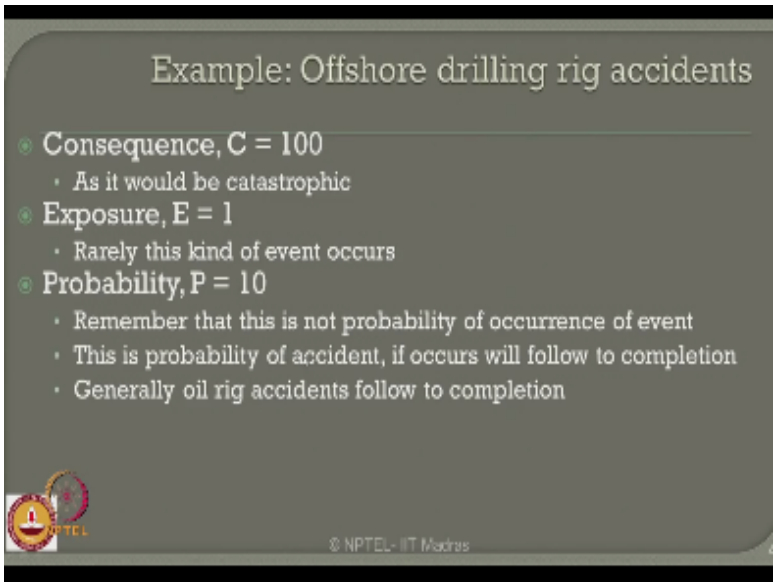

For a simple offshore drilling rig accident, consequence for this accidents 100 because the accidents are catastrophic, the exposure is one because they are very rare and its even these values are taken from the table, probability of accidents is 10 remember this is not probability of occurrence of the event, this is probability of accident, if it occurs it completes in general. So every offshore accident generally rig accident when they are initiated they are completed totally therefore a number of 10 is given here.

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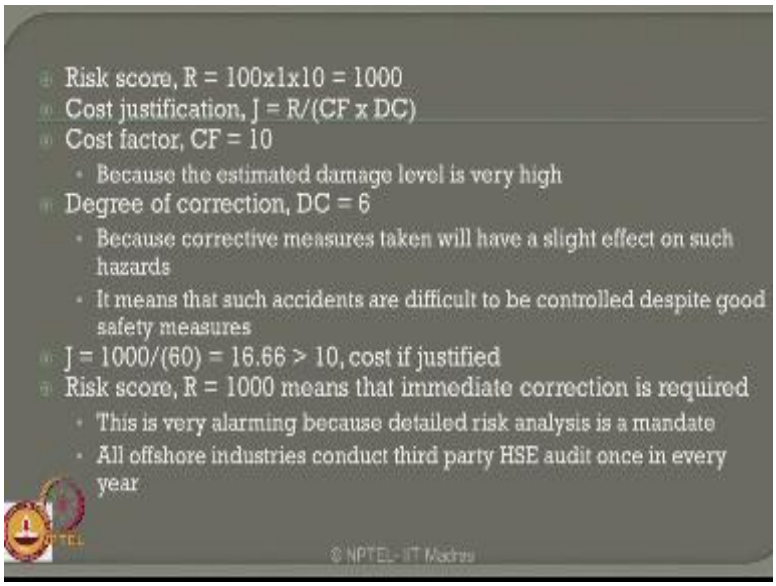

So risk score is a product of CEP which gets 1000, J is computed as R divided by C and F though cost factor is 10 in this case, and degree of correction is 6 in this case. Therefore, my J comes to 16.66 which is greater than 10 it means that the cost spent on this reduction on drilling accidents is justifiable. Since the risk score R is thousand which means that immediate correction is required, therefore it is very alarming because detailed risk analysis is a mandate in this case or offshore drilling accidents and industries should conduct third party HSE audits once in every year to assess risk assessment.

So this example easily tells you how to compute the hazard score, the cost factor, and cost justification because cost justification becomes a very important parameter in case of risk investment in any industry.

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So thank you very much.

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