Risk and Reliability of Offshore Structures
Prof. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module – 03
Risk assessment and Reliability applications
Lecture – 08
Logical Risk analysis

(Refer Slide Time: 00:20)

Friends, we are discussing on lectures module 3 of the course on Risk and Reliability of Offshore Structures. In module 3 our focus is risk assessment and a few applications in reliability today we will discuss about the lecture 8, where we are going to discuss logical risk assessment. As I said and we have now understood categorically the difference essentially between risk and reliability in actual is this gives an economic perspective to the top probability of failure which is actually seen in reliability as one of the important outcome.

So, the probability of the success of a given system is what we look at reliability, but to be more chronic if the system fails what would be the consequence of the failure on the overall performance of the system in terms of economic perspective is what we see in this. So, risk is starting to take off from the reliability outcome and then taking on to the economic perspective. So, is there any method by which we can do a logical risk analysis

that is what we are going to see in this lecture now frank and Morgan in 1979 prescribed a method, which can help us to know the economic perspective of risk analysis. So, this talks about what we call financing risk that what is frank and Morgan said essentially this is going to give me the economic perspective of risk assessment.

It is going to help me to analyze a given system it is useful to analyze any given system for the risk present in the system as suggested by Frank and Morgan. This can be successfully applied to any process industry. You can apply this to any process industry any way we are looking for an application in oil and gas industry, which is also one of the prominent process industry in the industrial sector, before applying this method for targeting this reduction.

(Refer Slide Time: 03:31)

So, this method actually targets two things one risk ranking, two risk reductions. So, in a given system under the presence of various hazards what would be the ranking of risk of different components or elements present in the system. If at all we can perceive the risk present in the given system based on the risk perceived by different components of that system, then we can rank them. Once we rank them we also like to know what would be methods and recommendation which we can suggest, so that the risk can be reduced please recollect important statement risk mitigation is not possible. And offshore

structures or let us say in general offshore process industry are nonzero risk members it means the risk will be always inherently present in the system because the various uncertainties evolved in the process, manufacturing, production, material assisted environmental, loads, commissioning, handling, impact loading etcetera ok.

Now, interestingly this particular method of logical risk analysis helps us to look at the risk on functional aspects especially in administration point of view. If you recollect the statement what I said in the previous lectures risk can be only studied when the system is in operation or the system remains functional. Therefore, risk actually is a practical aspect of looking at the consequence of failure; whereas, reliability can be a window through which you can always perceive an expected failure probability of failure and also use that as a design tool. So, risk actually is a practical aspect which will look only the functional characteristics of a given sets. And more or less risk is a proprietary of administrative point of view it is not scientific point of view; it is lower on the scientific point of view and very, very higher on the administrative point of view

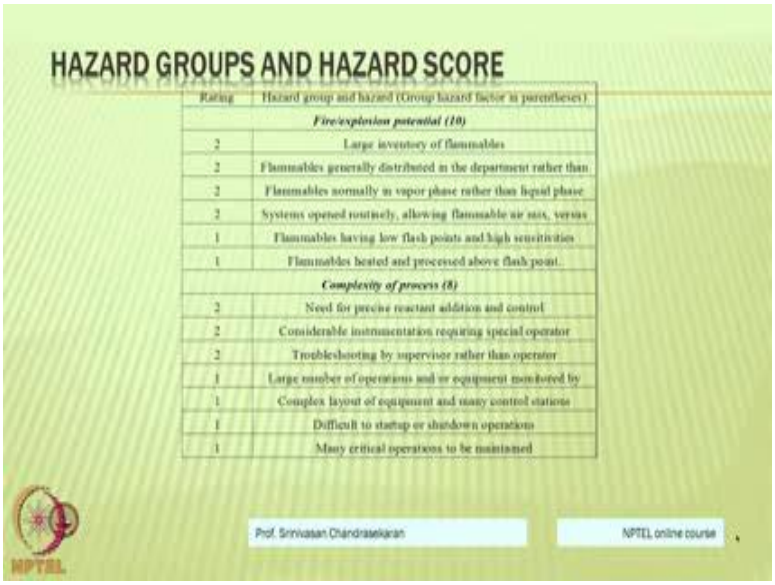
So, let us now look at the method proposed by Frank and Morgan and do a numerical problem to understand this. Let say what are the steps involved in this particular logical risk analysis why it is called logic risk analysis there are six steps involved let us say step number 1. Let us write down this step. In fact, I will write down all the steps there and keep on doing it here it is better.

(Refer Slide Time: 06:37)

So, let us do it here. So, let us say step number 1. In first step, I have to compute the risk index of each department how to do that each department present in a given process system can be identified for an inherently present risk level which is to be identified first. So, you can do a survey a what if analysis, prepare a checklist based on which you can identify the risk present in the department. Now, the question is how do you actually identify the risk index of a given department or a given element in a system. This can be done by evaluating the hazards present in the system and the control means by which the system is going to be or intended to be protected by the design.

So, step number 2, once I know the risk index then I try to get the comparison of these risk indices of different departments. Now to get the hazard score and control measures Frank and Morgan actually suggested a specific type of what if list and he has also converted those aspects of hazards present in a process industry to a numerical value.

(Refer Slide Time: 08:21)



Please pay attention to the table shown in the screen. Now for example, there are different hazard groups shown in the screen like fire and explosion potential complexity of the process let us for example, take one instant let say fire and explosion potential which is having the maximum hazard score as 10. So, now if you have a large inventory of flammables present in the system as seen here then you can identify an hazard score for that particular activity as 2. If your process industry or the offshore structure has flammables generally distributed in the department rather than concentrated one specific place then you can give me a hazard index or rating of 2 and so on.

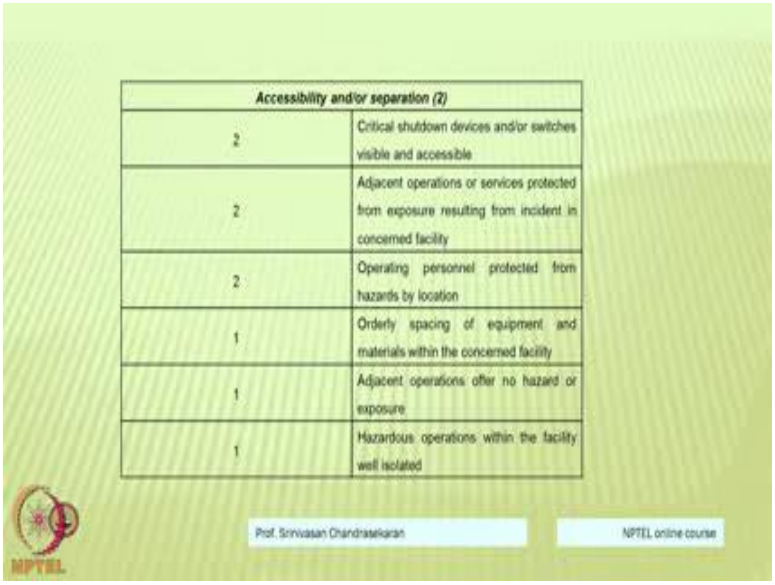
So, one can always use this existing table as recommended by Frank and Morgan which is available in one of the references as we gave you in NPTEL website or essentially one can also prepare this checklist based upon their experience and expert team available in the industry. Usually, it is the general practices every industry prepares a checklist identifies hazard scores based on their experience and expertise available on the subject and these checklists are actually prepared by the industry personnel from the safety department and they are available for any analysis.

Let say I have a table like this which is present to start with I can always identify the hazard score. Similarly, we can always have the table for control means for example; if

my fire fighting system is present in the given plant then I can put a index of 2 on a scale of ten and so on. These tables are available as a guideline to starter as given by Frank and Morgan. For example, let us say look pay attention to the screen again. Now, if you look at say that I have a complexity in the process which needs for precise reactant addition and control then I give 2, I also have a trouble shooting with the supervisor rather than be the operator.

Let say both of these are present I can always add them. So, the hazard score which is arising from the second group that is complexity of a process can be now 2 plus 2 can be 4. So, one always group the hazards in such a manner we can sum them in the hazard score and for every department can always get the individual hazard scores and the control scores which are available. For example, if you look at the every suggested way Frank and Morgan in the screen.

(Refer Slide Time: 10:52)



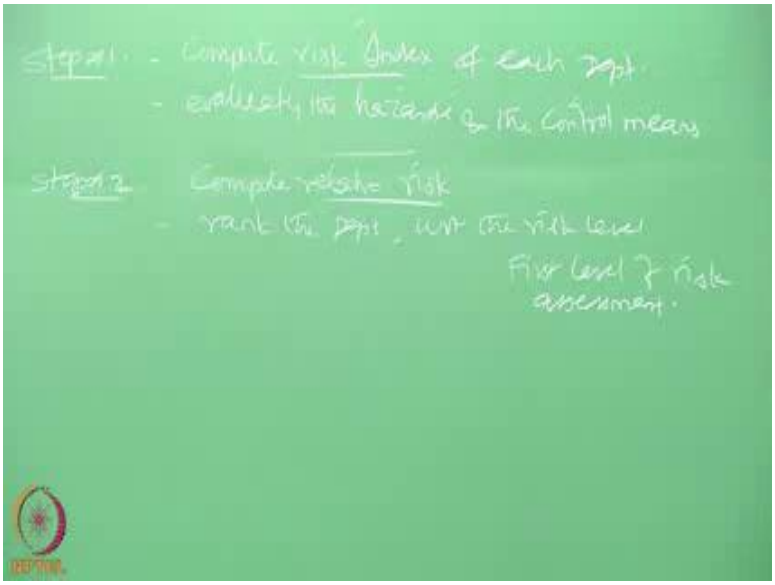
Now if you have an accessibility and separation process available if you have a crucial or the critical shutdown devices available and visible then the control score for them can be 2. If the adjacent operations or services protected from exposure then the control score is again 2 if the operating personnel is protected from the hazards with the location itself then again the control score and so on. So, one can either prepare the control scores

based upon the experience and expertise what we have in the plant or in the process industry or 1 can use a readymade charts available by Frank and Morgan suggested for any process industry in general.

So, in the first step, one should be able to actually divide the whole plant into different departments. For every department one should be able to identify the hazard scores and the control scores based upon either the expertise and experience available on the checklist prepared and based on the checklist values sum them the scores and get the hazard scores separately and control scores separately. For each department depending upon the type of process, the complexity of process, the flammables available in the control measures, which are designate in the design etcetera. Please understand the hazard score and control scores are actually prepared based on the functional requirements of the plant; it is not based on the design requirement for the plant.

For example, the design says you should have the sprinkler system as one of the control measure. But in reality the sprinkler system is not present in the department or in the plant then you should not take that advantage of providing a number or a control score of 2 thinking that as per the design sprinkler system must have been there, sprinkler system is assumed to be there and I have a score. So, the control scores and hazards scores are to be given to each plant only based on the physical inspection and then compare the state of level of existence of the department with respect to the checklist prepared then prepare the summary of hazard scores and control scores. I think I am making it clear how to get the hazard scores and control scores. Once I get that in the second step I will do what is called relative risk.

(Refer Slide Time: 13:00)

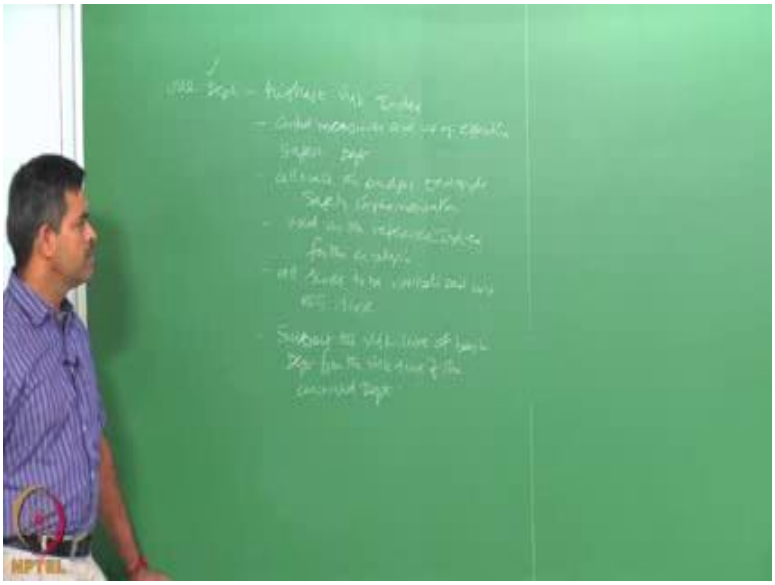


So, compute relative risk once you know the hazard score and control score one can get the risk index I will show you how it is done it is very easy. Then you compare the relative risk of each department. Now interestingly the aim of this particular step is to rank the department and not the individual hazards present in the plant. So, this will help you to rank the department with respect to the risk level, it will not rank or prioritize the hazards present in the plant in the whole. So, once the risk index is prepared which is respect to every department individually then you are going to only compare the department you are not going to compare the level of hazard a severity of hazard etcetera are present in the plant. So, this is going to do a relative risk which is going to help me to rank the department now. So, this is what we call as first level of risk assessment.

Now, one can ask me a question where is the economic perspective available here one can always understand that the hazard scores and control scores given by you inherently include the economic perspective of creating the control facilities and neglecting those facilities and creating a hazard facility in the given department. So, the economic perspective is implicitly present in these kinds of course or the charts what we prepared based upon the inspection or based upon the expertise. So, this is what we call as first level of risk assessment. And I am able to rank the department by using the relative risk index score. So, essentially, if I get the department of the highest risk index, Let say I

have a department whose risk index is very high.

(Refer Slide Time: 15:10)

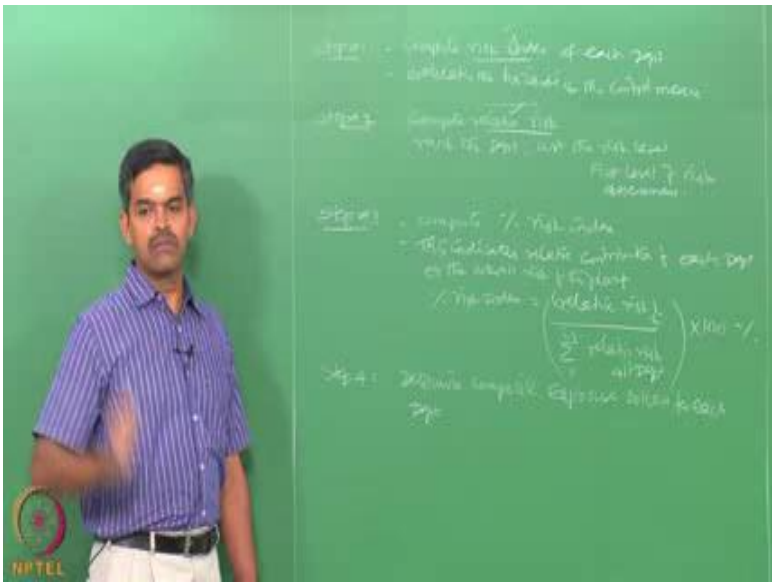


Let say based upon the comparison I find out that once specific department has the highest risk index. So, what does it mean higher risk index means that the controls are very effective highest risk index means the control measures are very effective it means the department is considered to be the safest department among thus all present in the plant. So, we are talking about financing risk. So, this will help me or the administration to really understand what would be the fund transfer to be allotted to this department to maintain the safety or risk reduction in the coming year. So, this will also help me to allocate the budget towards safety implementation ok.

In fact, the best department score is used as a reference index the best department score is used as a reference index for the analysis all scores of other departments are to be normalized with respect to this. So, all scores to be normalized with respect to this department that is what we generally do or try to do in step no 2 based on which I do a relative risk index or comparison. So, how do you do this is done by subtracting the risk score of the department. So, you subtract the risk score of the department risk score of the best department from the risk score of the concerned department. Obviously, when you apply this to the best department the adjustment for the department will become 0,

because the reference score is taken as that of the score of the best department step number 3.

(Refer Slide Time: 18:05)



I compute percentage risk index. I would like to know which department is contributing in terms of risk to the maximum for the entire system. So, the whole argument of department wise can also be applied to element wise in a given structural system, but as the structure is not remained functional without the operational features you cannot apply a logical risk analysis assessment to a structure. You can always apply to a system where structure is a part, so that is why we are saying departments here because I can apply risk analysis only to the functional issues not to the design, which are not functional issues. So, I compute the percentage risk index in step number 3. This indicates relative contribution of each department to the total risk of the entire plant. Relative contribution of risk relative contribution each department to the overall risk of the plant the relative risk what you obtained in the previous step is converted to a percentage risk index by a very simple procedure, which you will understand when you do a numerical.

Now, interestingly, the total risk of all departments summed up with an absolute value of each department that the percentage risk index can be easily obtained as relative risk of the ith department by the relative risks of all departments all departments multiplied by

100 because I want to express this as a percentage. In step number 4, I will like to determine the composite exposure determine composite exposure balance for each department. Now this is where the risk is now converted to economic perspective in true sense by the Morgan's method.

(Refer Slide Time: 21:08)

In this particular method, this step actually converts the risk into financial aspect. Let us see how why it is called composite. The estimates of financial value of risk of each department are done in this step. Composite actually he has got three components the composite exposure value of each department has got three components let see what are they. One is the property that is the asset value of the department is the book value. Second is what would be the business interruption cost; on the other hand, if one department is subjected to very high risk and the department remains nonfunctional, the business would be affected. What would be that interruption cost contributed by their department to the overall revenue of the entire plant, you would like to know this. And third would be what is the personal exposure. For example, a department A has got about 10 people let say department A has got 10 personnel at different capacity 3 may be safety managers 1 may be the chief safety executive. So, you are going to pay some salary for these people and some perks. Suppose in case the department has got the highest risk, and this personnel safety is challenged you may have to pay insurance to these people in

case of any accident what would be the cost by putting these 10 personnel on exposure.

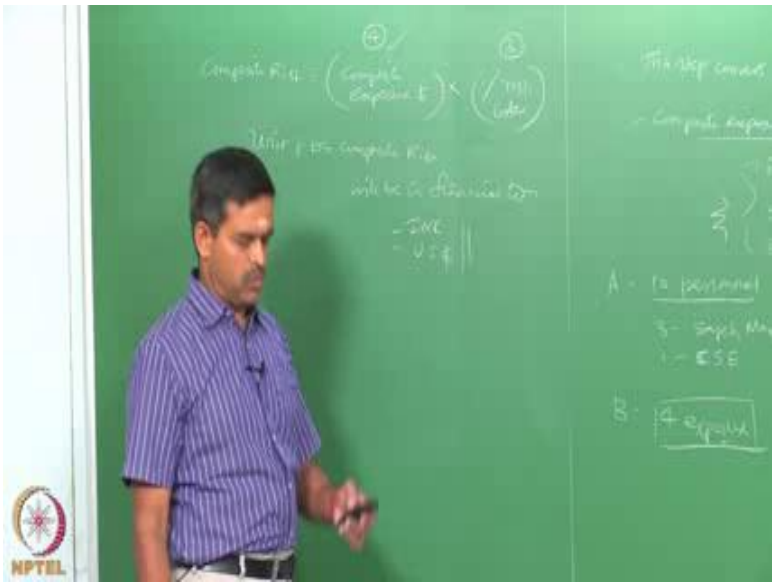
On the other hand, if you look at department b there are only 4 people who are exposed during the process and the contribution of this personnel exposure of department b will be fairly less in comparison to that exposure cost by department A. So, now, all these 3 put together we have to sum them up will give me the composite exposure in terms of dollars because that is what Frank and Morgan suggested the name. But however, we are not interested about the unit of this measurement, we are interested to know that all these three put together will add to the financial aspect of the whole problem, so that is what we are trying to do in step number four. So, we will determine the composite exposure for each department separately which will be the sum of the asset value, the business interruption cost and the personnel exposure cost of each department independently.

The property value can be estimated with replacement costs of all materials and equipments at risk in the department. The business interruption cost is computed as the product of unit cost of the goods and the production per year and expected percentage capacity that is what we can compute the business interruption cost, whereas, the personnel exposure will be the product and the total number of people in the department during the most populated shift and the monetary value of each person. So, one can easily calculate this separately sum them up and get the composite exposure dollar value of each department independently.

(Refer Slide Time: 25:01)

In step number 5, I will compute the composite risk for each department.

(Refer Slide Time: 25:24)



So, what exactly do here is for each department composite risk is nothing but the product of composite exposure dollar and the percentage risk index. So, this you had from step number 4 that is what we had and this you compute in step number 3 that is what we

have. So, multiply these two and try to get what we call composite risk for each department now this value which is computed in step number 5 represents the relative risk of each department units of composite risk will be in financial terms maybe in Indian rupee or maybe in us dollars etcetera does not matter. The composite risk is given by simple product of this which can be computed and the unit of this of composite risk will be essentially in financial terms maybe Indian rupee maybe us dollars whatever maybe the case. So, one can compute this.

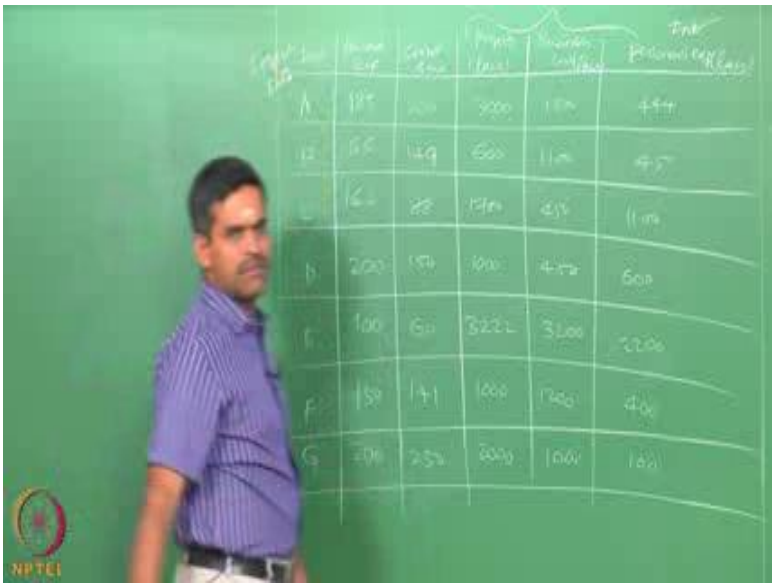
So, friends, please understand the risk computed because of the presence of hazard and control is relative ranked for each department and then the commercial value of the each department is included. Now I am able to compute what would be composite risk of each department in the overall plant. So, I am now converting the risk present in the departments or on the plant to financial terms. So, risk is an extension of study of reliability of probability of failure in terms of it is financial perspective.

(Refer Slide Time: 27:30)

In step number 6, I do the final risk ranking which is based upon the department which is having the maximum composite risk will be ranked number one. So, that department is going to contribute to the highest risk in the overall system in terms of financial perspective please understand the departments are also ranked relatively in the first level,

but in the first level of risk assessment while ranking the department we relative risking we have not included the commercial aspect at all. Indirectly, to some extent, we have included them in the hazard and control scores, but ultimately the extent of which like property value business interruption cost and personnel exposure, this kind of detail commercial aspect is not included in this step while we are relatively ranking the risk of each department. But when this has been converted in terms of financial aspects in this step then this step based on the results we will able to get the risk ranking. Once we know the risk ranking department should be ranked on the highest composite score to the lowest. Once I know that then I will be able to advocate recommendations for mitigating or controlling that risk present in the department there are six steps involved. Let us pick up a quick example and try to solve this.

(Refer Slide Time: 29:05)



Let say I have 6 departments I am marking them here department, Let say I am calling them as A, B, C, D, E and F. Let say the hazard score and control score of each department based upon the checklist prepared by the experienced person in that departments or in the plant is indicated. Let us assume that these values are known to me and they are 185, 65, 162, 200, 100, 150 let say we have one more department and 200, 185, 65, 162, 200, 100 150 and 200. The control scores present depending upon the control scenarios or the safety measures available each department we can sum them up

and we have a score here which is 200, 149, 88, 150, 60, 141 and 250.

Friends, this is the real time example where a study has been conducted on a process industry of a refinery plant of crude oil and the departments are cannot be named I have given them as A, B, C because of strategic reasons. And the controls scores and hazard scores are actually evaluated based upon the checklist prepared by that company and we got these scores one can also do this at your own level or use the suggestions made by Frank and Morgan for this. Interestingly, we also have the property value the business interruption cost and the personnel value. So, the property asset the business interruption cost and the personnel exposure for each department separately given by people.

So, let say these are all in lakhs Indian rupee, these are all in lakhs, this is also in lakhs in Indian rupee. I am using units as Indian rupee. So, the values are 3000, 1500 and 444 for plant of a department A. 600, 1100 and 450 for department B. 1700, 450 and 1100 for department C. 1000 again 450 and 600 for department D. For E, it is 3222, 3200 and 2200. And for department f it is 1000, 1200 and 400. And for department g it is 2000 1000 and 100 these are available based upon the financial figures given by each department. We know how to estimate the how what we mean a property as a cost of the particular department. We also know what is business interruption cost we also know what is a personnel exposure we explained it earlier. So, one can these figures these are all units or in Indian rupee in lakhs 10 power 6 these are nothing, but simple indications of scores this is an input data which is prepared for the given analysis. Now, we want to apply the steps for logical risk analysis and try to do them let see how it is done.

(Refer Slide Time: 33:57)

So, let me compute the risk index let me do it here I am extending it. Let me do it here. I am doing risk index. Risk index is the hazard score minus control score. I have the hazard score I call this HS or this control score minus hazard score. So, control score minus hazard score, one try to do this quickly. So, 200 and 180, 15 or let me do it here. So, it is control score minus hazard score. So, it is going to be 15, 84, 88 minus 162 so minus 74, minus 50, minus 40, minus 9 plus 50.

I also want to find the relative risk index that is what the step number two says I want to find the relative risk index step number 2. I have to identify the best department score let us say look at this scores this is control minus hazard. If the controls are better than the hazards then the department is safe. So, we must look at the positive scores. Let us look at the positive scores among these three departments which have got the positive score the department B has the highest positive score. It means that the department B has more control scores than the hazards it means the control measures obtained in this department or followed in this department are far superior compared to department A and department G.

So, we call this department as a reference department. So, identify the reference department and then rank the department based on this takes that as a base score. So, the

base course for this going to be 0. Then I will compute the base score or the relative risk index of other departments like 15 minus 84, so going to be 69. So, that is why I will get similarly this is going to be minus 74 minus 84 which will be minus 158 and this going to be minus 50 minus 84 which is minus 134 this is minus 40, minus 84, minus 124 minus 9 minus 84 minus 93 and 50 minus 84 minus. So, minus 69, 0, minus 158 minus, 134, minus 124 minus 950 and minus 34 that is what we do in step number 2, this is what we did in step number 1.

Step number 3, I want to compute percentage risk index. I make the absolute total of this make the total absolute value. So, I want to find the percentage risk index. So, I want to compute this going to be minus 69 by minus 612 into 100 which will be 11.3 and get 11.3 percent or 11.27, 11.3. And of course, this will be 0, because this is base department not having risk at all. Similarly, this is going to be 158 by 612 which is 25.8, 134 by 612 which is 20.9; 124 by 612 which is 20.3 which is 15.2, 5.6 this is expressed in percentage. So, this can easily tell you that the department which is contributing to the maximum risk is going to be having the highest risk index number which essentially in the department C.

It is also evident that the department C has the risk index which is highest negative it means the control scores are much inferior compared to the hazards present in this department with respect to all other department that is why it is having a maximum negative score of risk index. So far this is the stage I have ranked them and I have identified that department C is going to the highest contributor in terms of risk for the whole plant, but the economic perspective is not still included in this specific discussion is it not. So, we will discuss this example again in the next lecture further to discuss more interestingly the financial aspect of this or the economic perspective of this, and then we will talk about the application of this more in detail for better understanding.

Thank you very much.