Health, Safety and Environmental Practices in Offshore and Petroleum Engineering

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Module – 02
Operational Safety
Lecture – 09
Risk Assessment and Accident Analysis

Friends welcome to the virtual classroom on the online course titled Health, Safety and Environmental Practices in Offshore and Petroleum Engineering. This an NPTEL course from IIT Madras. We are discussing lectures on Module 2. I am sure you must have gone through the lectures on module 1 and of course, eight lectures on Module 2 as well. In module 2, we are essentially focusing on operational safety.

In this lecture which is 9th lecture in module 2, we are going to talk elaborately about the risk assessment and accident analysis. Prior to that, we will also solve a small example on Frank and Morgan Risk Analysis.

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So, in the last lecture we discussed about Frank and Morgan model which actually gives a risk picture in economic perspective and we all agree now that if the risk picture is not given with an economic perspective, it has no commercial sense of meaning as far as offshore industries are concerned because offshore industry business activity is one of the vital activity in the government sector or in any nation in the economic growth.

Therefore, one should really know what the influence is or what the consequence of an accident or risk picture in economic perspective is to really gain importance. So, if risk is connected to economic perspective I think we all agree as an engineer and technicians that risk will gain more importance. The moment risk gains more importance, the window is widen. Obviously, risk propagation can be controlled and risk mitigation measures can be initiated and all catastrophic accidents which are happened unintentionally really, where accidents in offshore industry, they could all be avoided at least in the coming future. So, let us take a very interesting example and see how Frank and Morgan model can be simplified tool to apply risk analysis and the interesting outcomes of this example.

As I said let us take a process plant. I will take an example of a process plant. Without naming the plant and without naming the departments, I would divide the plant into different departments a b c d e and f. So, there are six departments. As we all know we want to find the hazard score and control score of each department which actually depends on the check list prepared by this industry or this plant based on which we do an inspection.

We did an inspection, we tried to identify the hazardous situations in each department in the given plant and of course, we also inspected the control measures what each plant or each department had in position in place and then, we also estimated the composite exposed value of each department in consideration with the people working in the department as well as looking at the stock and inventory of the department and so on and so far. So, I will not be going into the detail of what inspection was conducted etcetera because that is not the part of this particular discussion, however we all know as an experienced professional, this can be always consulted and this can be obtained, however

let us have a summary what we already had. So, the summary is what I am presenting here. Let us say the exposure department is table 1.

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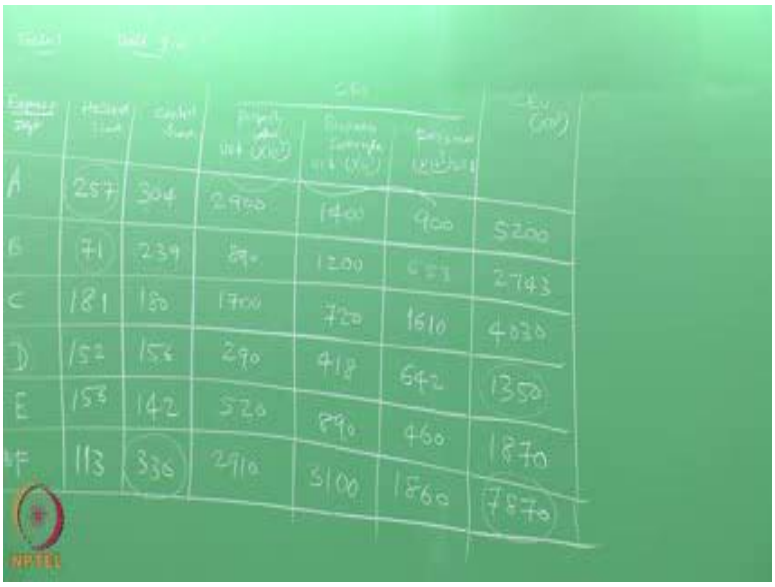

I should see the given data. These are given data for the problem. Let us say the exposure department I will always use a term exposure here because risk is always effective only when the person is exposed to risk is actually handling the risk management. Then we will talk about the hazard score and of course, the control score which has been obtained by each department after conducting detailed inspection meetings etcetera, preparing a check list all has been done. Then, property value that is asset of each department I will put this asset in terms of US dollars and multiply this value with 10 power 3 and this is in US dollars.

Business interruption cost again I will multiply this with n power 3 again. The value is given in US dollars and then, I will also have the personnel exposure value. Then, all put together this may composite exposure value which will enter here in US dollars. So, maintaining the CEV value in US dollars is of course 10 power 3. Let us prepare a table. Let us have this data known to us for six departments. So, let us say the departments are a b c d e and f. The hazard scores are entered here. Let us say this is 257, this is 71, this is 181, this is 152, this is 156 and this is 113.

The control scores available in each department have inspection was found out to be the following 3, 0, 4, 239, 181, 56, 142 and 336. Then, the property value is given again in US dollars 2910 power 3 that is the asset value then 1700, then 290 and 520 and 2910. If you look at the business interruption cost of each department in terms of US dollars 10 power 3, this is 1400. This is 1200; this is 720, 418, 890 and 3100. Similarly, the personnel exposed value 900 here, 653, 1610, 642, 460 and 1860. So, I want to combine and these three to make this sum. So, if you add them up, I get this as 5200 and this as 2743 and this as 4030 and this as 1350 and this as 1870 and this as 7870.

What is the data given to me for doing the risk analysis? Let us quickly diagnose this data and see what observations we can make from the data. The observations what we make from the data are the following. We make from the data one the department a compared to f, let us say the composite exposed value of the department f seems to be the highest. So, it seems to be the most important department in the whole production line, where as the department d seems to be the composite exposed value seems to be the lowest and therefore, the contribution or the influence of this department on the whole production line is least.

So, please understand the statement carefully. We are not comparing the department depending upon the importance. All departments are important, HR is important, drilling is important, production is important, store inventory is important, marketing is important, all departments are important. We are not saying anything about that. Please understand the contribution of this composite exposed value comes from the three segments as you see here. Reasonably the business interruption cost as expected is highest here. So, it indicates to be very clearly that this department has may be the life line concept of the whole production system. So, that is the first observation you can make. So, one we can easily find the most important department looking at the composite exposure values. One can look at this. The second observation one can make is looking at the hazards scores. One can feel now the department a seems to be most hazardous compared to department b.

Then parallel look at the control scores department b which is having the least hazard is reasonably having a better control score also. So, it is expected to qualify for something

like a reference department because the control scores are very good, however the highest controlled score is on the department f, which is also one of the important department in the life line or the production system of the product line. The hazard levels are also not reasonably higher compared to a. So, it is lower. So, one can easily see from this picture the department f is able to manage hazard on the risk management in a proper manner in the past years, so that even though they become the life line of the product system because of the composite exposed value, they have reasonably a very good control score. So, this is a very quick analysis what we can make. So, one can simply see which department has done better in the past I mean one can get this inference also, ok.

We will extend this table. Now, I want to get what we call. So, friends let us try to now compute the risk index in step number 2 etcetera. So, step number 1 we have just quickly tabulated the value. In fact, we have able to get the c e v is of different departments and we are able to get some quick information only from the data. I mean this itself can be a first level of hazard assessment because we have able to relatively understand which department was performing better, which department is highly vulnerable, which is most important in terms of production line. All we get information from this and experience personnel looking at this table will be able to make out some more information also from the data, however we will proceed further to step number 2. So, step number 2 I want to compute the risk index. I will do it here itself.

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In fact, step number 1 itself is actually the risk index. Let us compute the risk index. Step number 1 we will get the risk index itself because this is the data only. This step is only the data. This is only the data we could make some information on the data with that is irrelevant that is, but let us try to do step now a risk index. So, risk index we already know that it is a control score minus hazard score. So, let us try to do that 304 minus 257. So, I get 47 positive. So, I do not write positive because we know that, but negative we do write negative. So, 239 we have a better control score here. So, I expected to be positive. So, that is going to be 168. Similarly the next one is going to be 180 against 181. So, I get minus 1 here. It means it is bad control scores are inferior compared to the hazard scores. Similarly here it is going to get plus 4. So, I am writing simply 4.

Similarly, here it is going to be the control scores are lower than this. I must get minus 14 and 336 is far better than 113. Therefore, I get plus 223. So, a best control score or the best risk index is seen in department f as expected in the first information because department f had a very good control mechanism. It seems in place compared to other departments relatively. So, please understand you cannot use this table for comparing two different plants. Please understand this. This is relative ranking, relative risk indexing only within the plant various departments. So, you cannot compare two different plants because the operational, the seasonal variations, the composite exposure

values because exposure values as we saw from the first module, they also depends on climate, temperature, weather, humidity, sunlight. There are many factors.

So, one cannot simply compare this data for two plants a and b, locate a different latitude longitude and I am going to compare. No, it cannot do this relative within the plant because these departments, please understand are connected to a single production line of the same plant. They are all, they should be anyway directly or indirectly connected to the production line, otherwise there is no composite exposure value meaning at all, ok. If this is some head office somewhere located elsewhere, I cannot connect the head office to my risk analysis of a plant because this is no way involved directly or indirectly in the production line. There is exposure is what we are looking at. So, all these departments are located in the same campus where the production is happening. Therefore, exposure is a concept here. Please understand this we are not looking only the values of this.

So, I compute the risk index. From the risk index, I do the first table hazard management. I can easily understand the departments which have the negative numbers are dangerous because hazards are far higher compared to that of the control scores. They should be paid attention. So, I can develop an inference here from step number 1.

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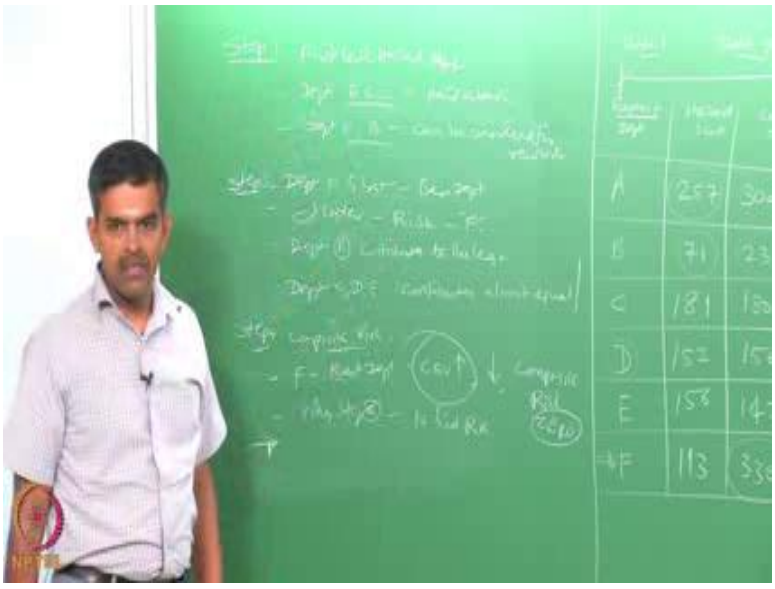

I do first level hazard management departments. Let us say e and c should be paid attention. Let us put the mark like this here and department f which is the highest. Department b can be considered for rewards because the risk index is positive. It means the control scores are far higher. This is the first information we have from step number 1. Let us see how they again redefined. So, after doing a risk index in step number 2, we are supposed to compute the relative risk. Let us do that to compute the relative risk. I have to identify the base reference department which is the best department. The best department is that department whose risk index is maximum positive. Positive indicates the control scores are far superior. Positive number highest indicates the department is the best.

So, if you look at this figure of risk index here, 223 is considered to be the highest positive number in the given data. So, department f is considered to be the base reference department. So, if I do the control score of I mean the risk index of the department with that of the base reference department, deduct that I will get zero here because 223 minus 223 will be 0. Now, what I should do is here to compute this is should say 47 minus 223. It should not be the other way, ok. It is this department should be compared with the best. It is not the best department compared with this. Please do not do that. So, it is interesting that all the relative risk scores what you will be getting in calculation should be negative. So, it is an indication in the table that all departments are inferior compared to the base. So, zero is negative if you look at it mathematically. All departments are inferior compared to the base reference department and therefore, 47 minus 223 and so on and so far.

Let us do that. So, this is going to be minus 176. So, this is minus 55, this is minus 224, this is minus 219 and this is minus 237. You will always notice in check the one which are already negative will have further increase than this number. They are further worse because they are already worse and they still worsen compared to department f. So, relative risk can be easily computed and the check here is let me write is equal to minus 176. So, all will be indicated negative and we can do that in the step number 3. What we are expected to do is the percentage risk index. How do you do that? So, let us sum up the relative risk. Let us add this and take a mode value of that. So, the sum is going to be 911. If the sum resolve I mean neglecting the negative sign, sum is going to be 911. I

want to compute the percentage risk index of this department. This can be easily said as risk index of the department which is relative risk index of minus 176 by 911 into 100. So, it is going to be let us say you can calculate this going to be minus 19.31.

Similarly, you can calculate for all the departments minus 55 by 911 into 100. So, that is going to be minus 6.04 minus 24.59 minus 24.04 minus 26.02. In this way it is 0 and if you add them all, it should become 100. Now, in step number 3 that is this column, let us name the columns. I am leaving these columns data. I say this is column number 1, column number 2, and column number 3. Risk index is nothing, but control score minus hazard score, ok. This is control score minus hazard score. So, if you want to really get the breakup of 47, it is nothing, but 304 minus 257. That is how we got 47. That is how we got 47. So, is remaining all can be worked out like that. So, let us write information. Now from step number 3, we get further information. Step number 3 indicates that department f is the best. So, base department in fact rather we got it in step number 2, itself does not manner, but anyway we also know that all other departments showing a negative index indicating they are at risk compared to department f is obvious because department f is best reference department.

Now, let us compare the percentage relative risk index. Now, these are relative. Now, I am comparing a with f, I am comparing b with f. That is what I am trying to do here is or not and comparing a with f. That is why I go this this number belongs to f. That is why I got this. So, now one can see here, they all are going to be the percentage contributors to the overall risk. The overall risk in the plant is 100 and the base reference department does not contribute to any risk at all. That is why it is 0. So, one can see here from this that department b contributes to the least and departments c d e almost contribute equal. I mean contribution to risk I am saying contributes almost equal. Please understand the composite exposure values of these three departments are significantly different.

The control scores of these departments are also different. The hazard scenario may be equal, but they are different, but when you apply the percentage and compare relatively they become more or less close contributes to risk easily. This is how departments risk will get aligned to the risk of the plant individually. They are not because all of them you

see, all of them have good especially let us say it is very pretty to see the department d in this dialogue because department d had a positive score.

It means it has a better control than the hazard in comparison to these two departments, but department d is also dragged in the same line as it of c and e. When you start relatively ranking them that is the problem here. So, risk actually is an alignment of mistakes. Individually you may be good, but a small error committed by you will overcome the positive contribution of the other department and you get aligned in committing to risk. So, accidents are alignment of mistakes. You may feel you may say that my contribution is very good. Sir it is positive, but your positive will each and away by the negative aspects of the other department that is the difficulty here.

Then one can ask me a question, sir how these not eaten away by this department because the positive feel of this department is so significantly high even the negative issues could not even go near by them. So, you as a department representative should perform extremely well towards risk management, so that other even they do a mistake you cover up that mistake and avoid accidents is like a multi-legged race. You are one of the legs in the race, but you carry the remaining legs along with you and even though they may not run in the same phase as you are running you still win the race because it is a multi-legged race. So, have relative understanding between the departments.

That is why we say so. This method is very interesting. It also debugs the weakness and strength and brings out cordial understanding between the departments and tells where the department stand compared to the reference department. That is very interesting which is required as HSE manager is important. So, step number 3 gives me a relative risk index in terms of percentage. All these are percentage values I have indicated here and it is sum up to 100, ok.

Now, we will hear this risk assessment which is conventional, which is mathematical, which is probabilistic, which is frequency based etcetera whatever you want to feel it is all fine here, but in oil and gas industry being a very vital sector in economic participation of the economic growth of the country or a nation or let us say world’s economy, we cannot simply stop risk by a number here. I want to convert this risk in

terms of financial figures, otherwise I am not happy. I have to tell my board members that what does this actually plant tells in terms of risk assessment, in terms of financial figures. My stake holders will be interested to know will it cause an economical damage dent in my investment. They would like to know this.

So, my risk assessment should converge to economic perspective, otherwise in oil and gas sector risk assessment will have no meaning, but please do not ask me a question later when you do a qualitative risk assessment why this an economic perspective. There are qualitative risk assessment as well we have to do that, but if the risk assessment converges to economic perspective, it is easily understood by the investor insurance agencies etcetera, stake holders because it is convenience of understanding. Therefore, it is very popular. So, step number 4 I will like to convert this in terms of composite risk. That is what I am going to do here.

So, step number 4 let us say composite risk I want to complete this. How do we do it is very easy. I have the percentage risk multiply this with the composite exposure value of each department and get the composite risk. So, forget about the negative figure. Negative figure indicates it is risky. It is at risk compared to the base department. All are negative. You can see here except this right. So, this figure is now going to be 19.31 by 100 because there is a percentage multiplied by 5200. Is it right? So, if you work out I will get 1005. I have rounded up to the nearest possible number. Why? It is because I am talking about money.

Now, I will multiply this with 10 power 3 and say this is in US dollars because I am now converting risk in terms of finance statements, if you do that for remaining departments, I will get this as 166, this as 991, this as 325, this as 487 and of course, this will be 0. Now, I have a question here to the viewers. The question is very easy here, but you have to think it over. Department f is the best department. The composite exposed value is a highest of this department. Because the department has no risk as a base department, the composite risk has become zero or naught, but please understand the question is why the composite risk is becoming zero even though in the department had a very high composite exposed value. So, that is the question. Even though the department had a very high, a decently high composite exposed value in US dollars multiplied by 10

power 3, why the composite risk has become 0? Think it over. It is very easy from the inference. You can easily find out that I compute this in step number 4. I can do this.

I have to the ranking now risk ranking I should call risk ranking let me do the risk ranking may be I will rub this because already I have used this value here somewhere I calculated I will rub this because for a positive of space. So, I will rub this particular column and replace this column with the risk ranking. Excuse me for that, but I think in your sheet please do not do that. This has to follow on the other side, but I am rubbing this for my convenience in the black board. So, please allow me to do this. So, this is going to be a step number 5 oblique 6. What are you saying? I am going to do risk ranking here.

Obviously the department which is having the base reference, the best should rank the least. It is the best in terms of protectional control. It is the least in terms of indicating intuiting influencing the risk for the whole plant. So, it is the lowest rank. Why 6? There are only six departments. When you now look at the number 1000 and 5 etcetera, compare them this is the highest. So, I get this as my rank number 1, rank number 2 will be 991, rank number 3 will be 487, rank number 4 is going to be 325 and obviously, it is going to be rank number five of all ranking.

I repeat again very quickly. Rank number 1 is obtained comparing this figure with that of the remaining, we do not compare anything else. I have a second question to the viewer here to really get the risk ranking. Why we need to go to step number 4? Why cannot get the risk ranking directly from the percentage risk index itself? Why we have go to the step number 5 or step number 4 to really get the risk ranking? That is a very interesting question I can even get the risk ranking just looking at the control in hazard score itself. I can get a ranking that is the first level risk assessment.

We said we have to pay attention to each department. Interestingly there is a second question I have for you. First question already said why this is 0? The second question I have is why step number 4 to be looked to find risk ranking? It can be obtained from previous steps also. What difference this would make? I will tell you the difference here, but you have to answer me. Please listen to this step. Memorize carefully a step number

1, 2, 3 and 4 you will see that the department a is nowhere commented. We are saying e and c should be paid attention, f and b can be considered for rewards, f is the best department and so on. B contributes the least. We said all arguments about all departments. A is nowhere in the dialogue here, but unfortunately department a is ranking top in the risk.

See this is very interesting example is a very interesting example. So, this is a hidden contributor. Please understand why I am saying hidden contributor compared to these departments. A was contributing less to the risk percentage risk in the flow line of the production, but in the overall risk ranking relatively, it took the first rank. So, there are silent contributors who also cause risk to the whole plant. So, our job is to also debug that and find out this example and hats off to Frank and Morgan's method is able to diagnose this kind of issues very deliberately very clean very simple and explicit.

So, I should appreciate. In fact, I loved that this method is able to give me very interestingly here. Risk analysis in various changes in economic perspective very interesting model, department a is nowhere in the argument here, but it picked up the first rank in risk relative risk. Please understand you have to really find out why. So, the example has been chosen in such a nice manner I mean it was formulated automatically. This is a real life example and it has been done in a specific site. I will not be able to disclose the source of the information because of the strategic issues, but this is a real case study that done in one plant of a processing plant of crude oil.

So, the department a b c cannot be named for some reasons of the client. This has been done in very example. So, this result was amazing even for the execute authority of the company to really know. So, for he was bating and saying that a is the best department because it not contributing much compared to these three, but when you saw this result is amazing is very interesting that is the question asked for you. So, the answer is anyway hidden. You will be able to make out the answer had have done the risk ranking in the earlier steps. The hidden agenda which was contributed by department a would have not been explicitly brought out.

So, you must do the relative risk ranking only after associating the commercial value of this. So, that is the very important task which is emphasized by Frank and Morgan in this method, though do risk assessment without associating economic perspective to this it has no meaning. So, economic perspective is to be associated to risk assessment to really know amongst the players who is most vulnerable. So, that is what I was insisting in the previous lectures. The economic perspective gives actually a sensible meaning. It makes more sense about the risk ranking or risk assessment or risk mitigation etcetera. So, it is very interesting.

Now, let us compare quickly departments c d l e. You will obviously see c d e follows ranking next to next which was expected in the previous steps also. Now, very interesting question number 3 in this problem c d and e do not have the same composite exposed values though I have rubbed it off. They do not have the same composite exposed values and the percentage risk index is almost equal, but amongst this if you notice the one which is having the positive index got a lower rank compared to these two, but very interestingly department e had more negative score compared to b. It means the control is worst in comparison to b, but if you look at the ranking b became the second rank and this became the third rank. This is very interesting. It is puzzle, no because it is very difficult to really know how this is happening. It is expected.

You are happy that it is on 4 compared to 2, 3. It is on 4 because it has a positive score. Good observation, agree, but on the same line if I see this has 2 and this has 3, I would be happy, but that is not happening. This is 2 and this is 3 if my calculations are right. So, again that is the question asked how this is happening. This will happen only friends when you attach economic, this prospective to risk assessment otherwise you will not be able to get this at all, ok. Now, let us come to the decision. Let us say decisive outcome.

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One just because f is the best, can we stop funding towards safety practices in department f. The answer is big no if you do that in the next assessment of this sequence f will become a and a will become f. So, you should not stop the basic. Funding should not be stopped that should be given in addition to that. You have to reward by department f that is the first observation here. The second observation even though department a had a positive score which indicates the control measures are better, how come department a is ranking 1. So, it is very important. So, you have to diagnose the problems and fund for risk mitigation to department a.

That is the second decision we can make. More experience people watching this classroom can derive more information from this and you would like to share them in the NPTEL website for the business some for the viewer's benefit. In the discussion forum I will be rather happy and try to answer those questions which I asked in the class, so that we can share your experience in terms of understanding and the very interesting model what we had which I think you can now immediately apply this in a department and see or in a plant and see where do you stand is very interesting has a manager as a participant etcetera. You can see this which is very interesting model, very interesting example which we saw.

So, I close the class with this and we will talk about the accident modeling in the continuous lecture, the next lecture. So, I think you I believe that you have understood how the economic perspective in risk assessment becomes very interesting and important, so that the hidden contributors can be brought to lime light in terms of risk contribution to the whole plant on the production. Please understand this is applicable only to process industry. Why? It is because I am taking about exposed values term related process and production of course, not related to any HR or any management systems where this no exposed to risk.

Here the whole exercise leaves a very interesting homework for all of you how to prepare the check list to estimate the hazard and control scores for different groups in a given plant. That is first homework. You have the second homework is how to align the data you have related to the composite exposure value of a department terms of these three segments and keep it ready. That is important. They will help you to really do a risk assessment in more interesting manner in the near future.

Thank you very much.