Health, Safety and Environmental Management in Petroleum and Offshore Engineering

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Module No. # 01

Lecture No. # 02

Safety assurance and assessment

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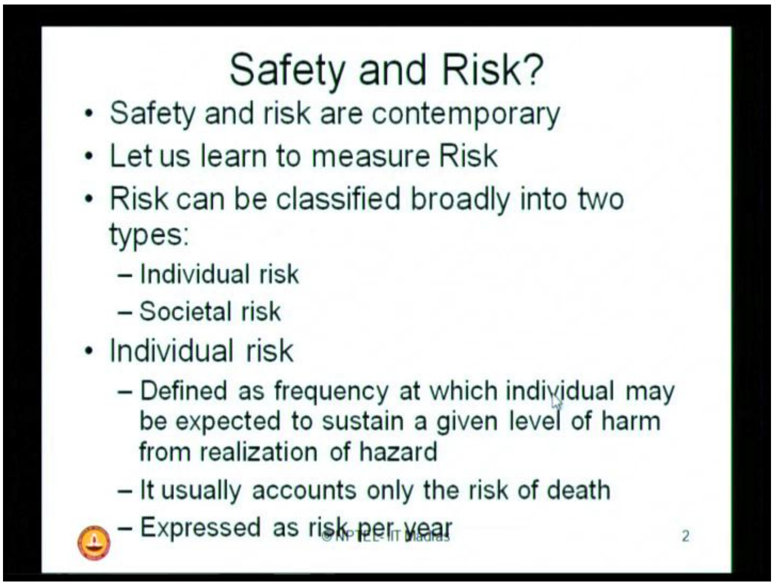

Dear friends, we discussed about health, safety and environmental management in petroleum and offshore engineering. In the last lecture, we gave you introduction to HSE; we also discuss some basic terminologies and their definitions as applicable to HSE in petroleum and offshore engineering.

Today, in this lecture two of module one, we will talk about safety assurance and assessment methods. Just for the sake of completion, I will again overview, what are the topics we will be covering in module one, like safety in design and operation organizing for safety hazard, classification and assessment, hazard evaluation and hazard control, and importance of safety in petroleum and offshore industry.

Gentleman, let us ask a final question, how do we differentiate safety and risk? They are actually contemporary instead of discussing safety. We will start discussing about risk, ultimately, we will connect risk and safety at the end. Now let us learn how to measure risk? Risk can be classified broadly into two types namely, individual risk, societal risk. Individual risk is defined as frequency at which every individual may be expected to sustain a given level of harm from realization of hazard. It accounts usually for risk of death only. It is expressed as risks per year remember individual is related to an individual person, which encounters or has risk of death.

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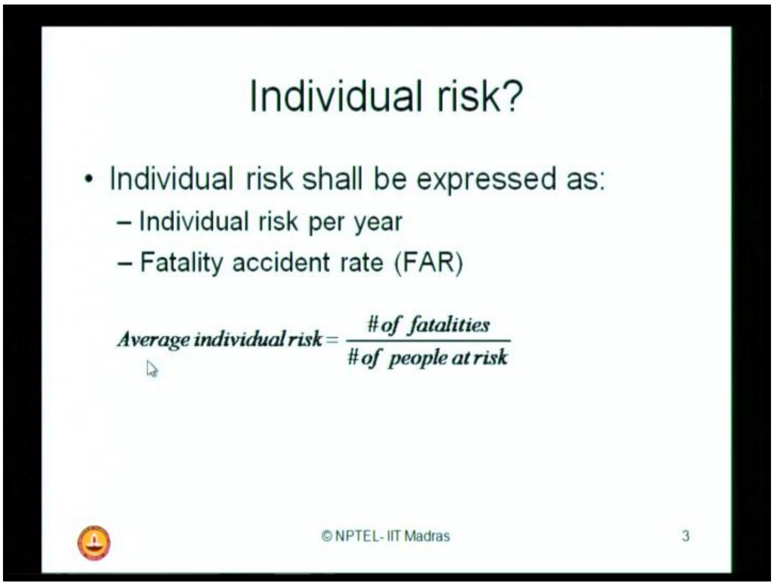

On the other hand, individual risk is generally expressed as risk per year or fatality accident rate - FAR in the literature. Average individual risk is given by a simple equation, number of fatalities divided by a number of people at risk.

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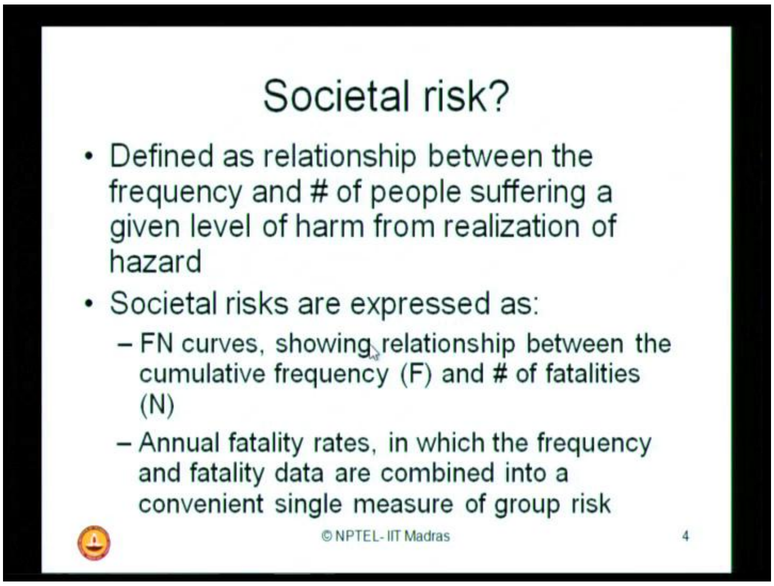

You can also look at risk in the other angle, that is called societal risk. Now the word itself very clearly categorizes the risk is for the society. It is defined as relationship between the frequency and the number of people, suffering a given level of harm from realization of hazard. Societal risk are expressed as FN curves, showing the cumulative frequency which is F with respect to the number of fatalities which is N. Annual fatality rate is an outcome of this kind of study, in which the frequency and fatality data are combined into a convenient single measure of group risk.

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Now, the question comes how to measure accident or loss? Unfortunately there is no single method available which is capable of measuring accident and loss statistics, with respect to all required aspects. There are three systems available in the literature in offshore industry, which addresses accident or loss measurements – OSHA, FAR (fatality rate or deaths per person per year).

OSHA is an international body, expanded as Occupational Safety and Health Administration, by United States Department of Labour. They have their own method of classifying accident or loss. The other method of classifying this, is by a common phenomenon called fatality accident rate. Fatality rate or deaths per person per year is expressed. All the three methods have commonness in them. They report the number of accidents and/or the number of fatalities for a fixed number of working hours, during a specified period. Gentlemen, the emphasis is generally given on fixed number of working hours, that is very important.

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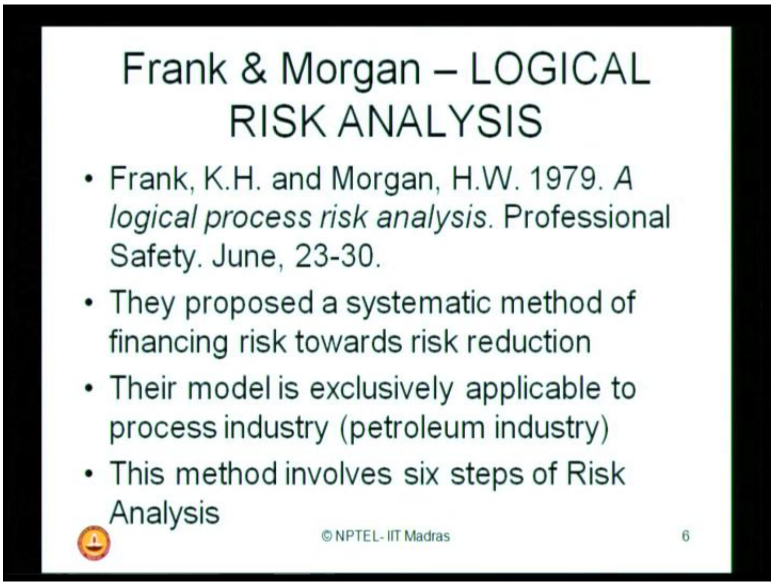

Extending this philosophy, Frank and Morgan gave a method of logical risk analysis available in the literature. Frank and Morgan proposed this method in 1979, the reference course as a logical process risk analysis, Professional Safety, June 1979 pp 23 to 30. They proposed a systematic method of financing risk towards risk reduction. You may wonder why one has got to financer risk towards risk reduction. I can give a very classical example of this statement for example, if you want to reduce your risk in life you generally go for health insurance. So, insurances are nothing but financing risk towards your risk reduction. The model suggested by Frank and Morgan is exclusively applicable to process industry, for example, in our case, a petroleum industry can be a user end of this kind of logical risk analysis. This method involves six steps of risk analysis.

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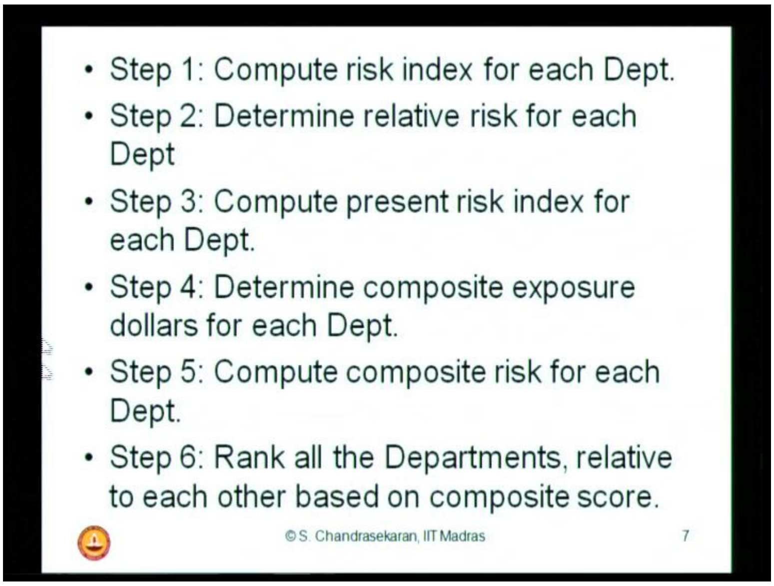

Let us see this in detail today. Step number one - compute the risk index for each department; step number two - determine relative risk for each department; step number three - compute present risk index for each department; step number four - compute composite exposure dollars for each department; this is the financial aspect of converting risk into money; step number five - compute composite risk for each department, and step number six - the last step, rank all the departments, relative to each other based on composite score.

Gentlemen, you may be wondering in this particular method, what do we actually mean by each department, first question? Secondly, you will be eager to know how this method ends up in financing a risk for a given process industry. We will take an example to explain these questions in detail.

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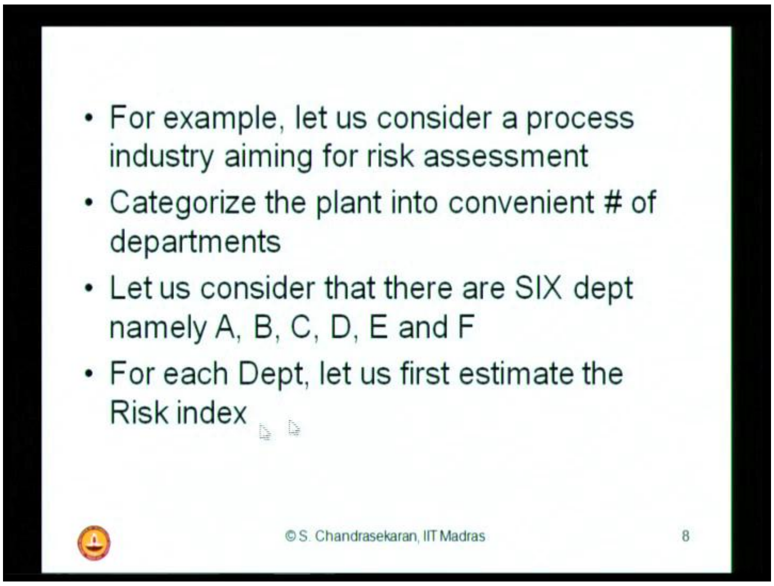

Let us say, I consider a process industry which aims for risk assessment. I categorize the plant into convenient number of departments. This is not a very difficult task, every process industry has designated departments which is enclosed in the industrial umbrella. For example, research and development production maintenance inventory etcetera. So, this data of categorizing the plant into different departments is already existing in industrial management.

Now, let us consider one such example of process industry, and say that this industry which I am considering now as six departments, we will name them as A, B, C, D, E and F. For each department, let us first estimate the risk index.

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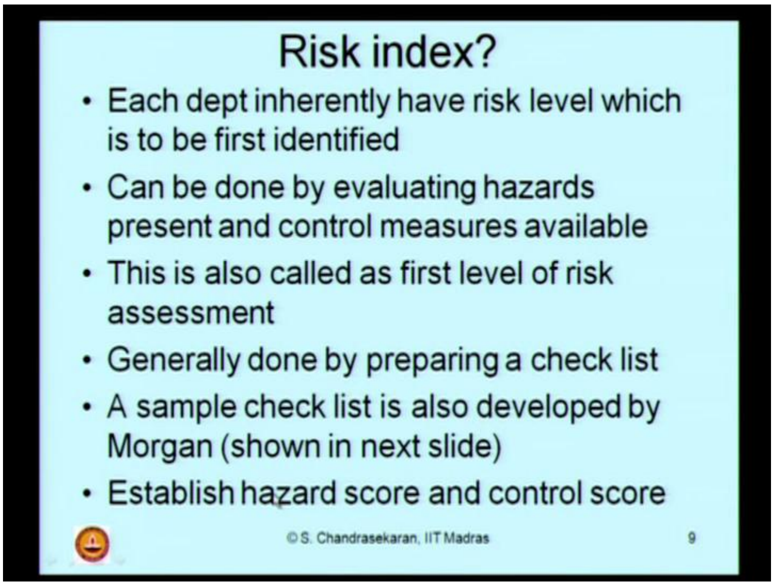

So, each department inherently have risk level, which is to be first identified. This can be easily done by evaluating hazards present and the control measures available. This is also called as the first level of risk assessment. Generally, this is done by preparing a check list. Now to make it very simple, a sample check list is also developed by Morgan which I am going to show you in the next slide. Based on that kind of check list prepared, establish what is called as a hazard score and a control score.

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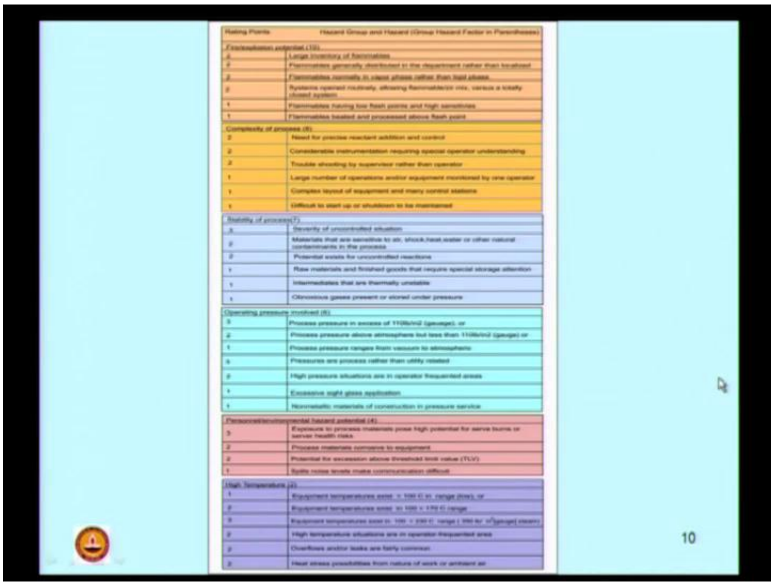

Look at this slide. This a sample slide presented by Morgan, for example, the check place gives different rating points for different hazard groups. For example, if you have a hazard group of fire and explosion potential, if there are large inventory of flammables available, you give the rating point as two. If the flammable beated and processed above the flash point, give the rating point as one. Looking at the complexity of the process, the maximum score will be eight. If you need for precise reactant addition and control, then you give the rating point as two. If it is difficult for start up or shut down to be maintained, give the complexity of the process rating as one. Look at the stability of the process, if it is severity of uncontrolled situation, give the rating point for stability of the process as three; otherwise if it is obnoxious gases present or store under pressure, give the stability of process as one. Similarly, you can look, the rating points for operating pressure involved personal and environmental hazard potential available and high temperature scenario.

So, based on different kinds of hazard groups, you can easily fix up a rating point and of course, these values are subjective, you can also, out of experience, can prepare a similar check list.

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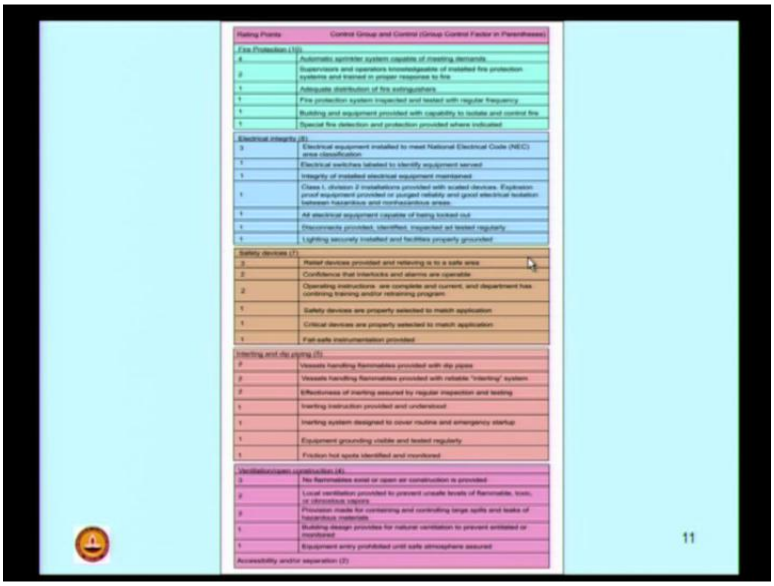

Once this is done, look at the control group and also try to give the rating point for different control activities present in the plant, for example, look at the fire protection, if there are automatic sprinkler systems capable of meeting the demands available in the plant, give the rating point as 4.

If the fire protection system is inspected in this state, with regular frequency, give the fire protection rating point as ten; these are all control group points. Look at the electrical integrity, look at the safety devices inserting and deep piping and ventilation present and so on and so forth. Depending upon what kind of control measure is available in the plant for safety, for inserting, for electrical integrity, for fire protection, keep on trying to give different rating points for your simplicity.

These rating points are all given, and the sub groups are given in different colours, for example, Morgan suggested a checklist where the control group is divided into 1, 2, 3, 4, and 5 divisions like fire protection, electrical integrity, safety devices inerting and dip, piping and ventilation. So, if you have an experience of auditing a similar plant earlier, you can also prepare a similar check list and have different more than five groups as well. The idea is, try to give different dating point for different existing control mechanisms.

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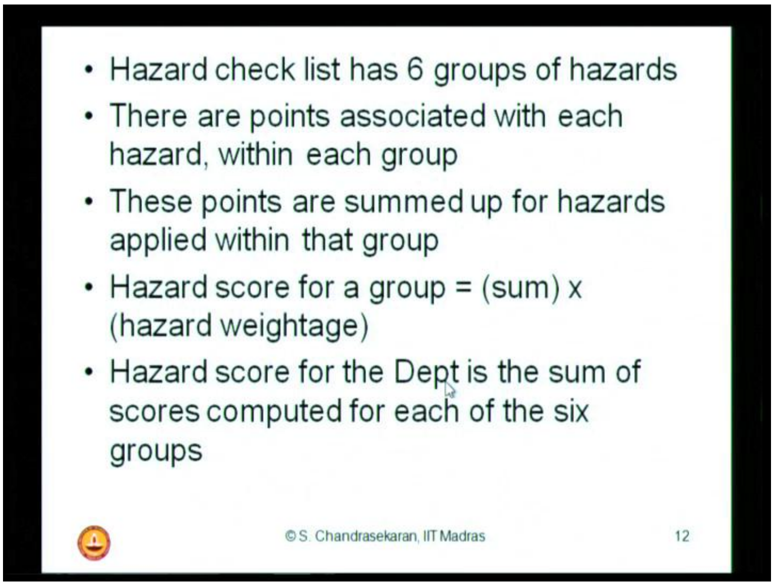

Now, hazard check list has six groups of hazards. There are points associated with each group, as you have just seen in two different tables. These points given under each group or summed up for the hazards applied within that group. Now, hazards score for a given group is sum multiplied by the hazard weightage for that particular operation. In this manner, you can easily identify or determine the hazards score for each department, which is nothing but the sum of scores computed for each of the six groups.

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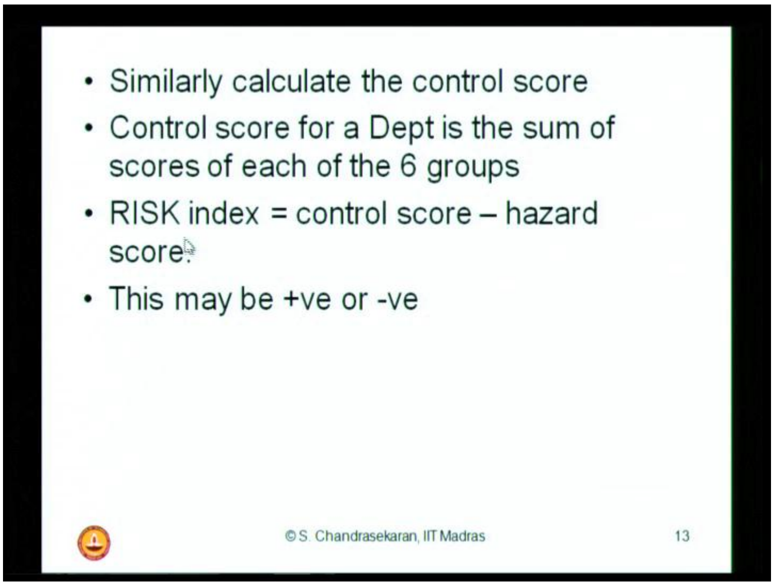

Similarly, we will do it for the control score establishment as well. Control score for a department is again the sum of scores of each of the six groups, as you see in the table. Now, it is very simple for me to estimate risk index - risk index is the control score minus hazard score. Ladies and gentlemen, please note that the risk index can be a negative number as well, for example, your control score for the department is very poor and the department has a very high hazard potential; obviously, the risk index can become a negative number. Any department, which has a positive risk index, is comparatively safe with respect to the other department which has a negative risk index. So, the risk index score may be positive or negative.

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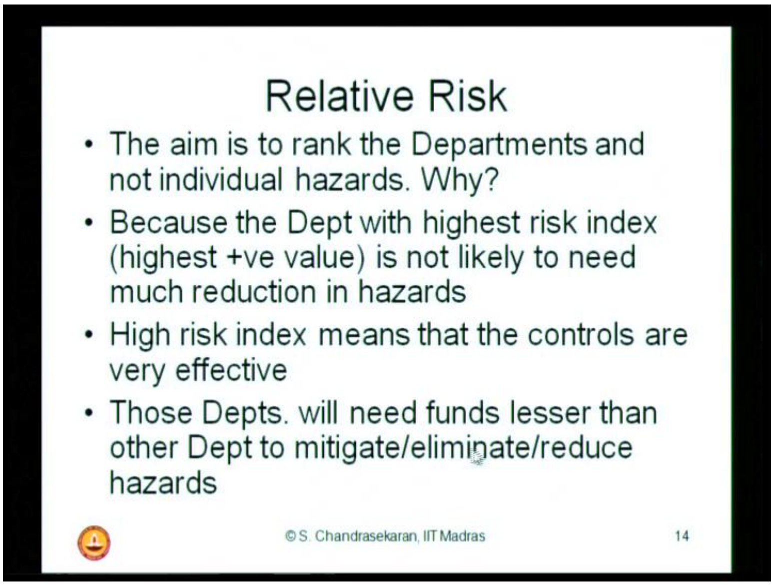

We now estimate what we called as relative risk. Yes, your guess is right; I am trying to estimate the relativity of the risk between the departments. The aim is to rank the departments and not the individual hazards, each department is facing, I am interested to rank the risk departments and not the individual hazards. Can you tell me, why the reason is very simple? Because, the department with highest risk index, that is highest positive value, is not likely to need much reduction in hazards; it means we are talking about financing risk reduction. The department which has a positive score of maximum, does not require much more methods to reduce hazards. High risk index means that the control measures are very effective. Those departments will need funds lesser than the other departments to mitigate, eliminate or reduce hazards - is that clear?

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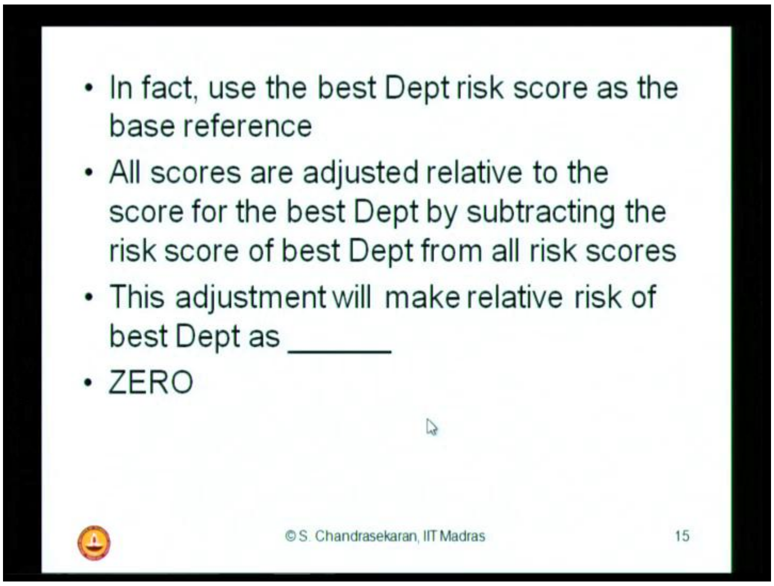

Once we estimate relative risk, we will now say, use the best department risk score as a base reference. I think we have no confusion identifying the best department based upon risk score. The department which has highest positive risk score is considered as the best department. All scores are then adjusted relative to the score of the best department, by subtracting the risk score of best department from all other risk scores. I am coming up with an example in the few slides later; this will be illustrated step by step for you. This adjustment will make the relative risk of best department as… Can you fill in this blank quickly?

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Yes, your guess may be right; the best department will have a relative risk as zero.

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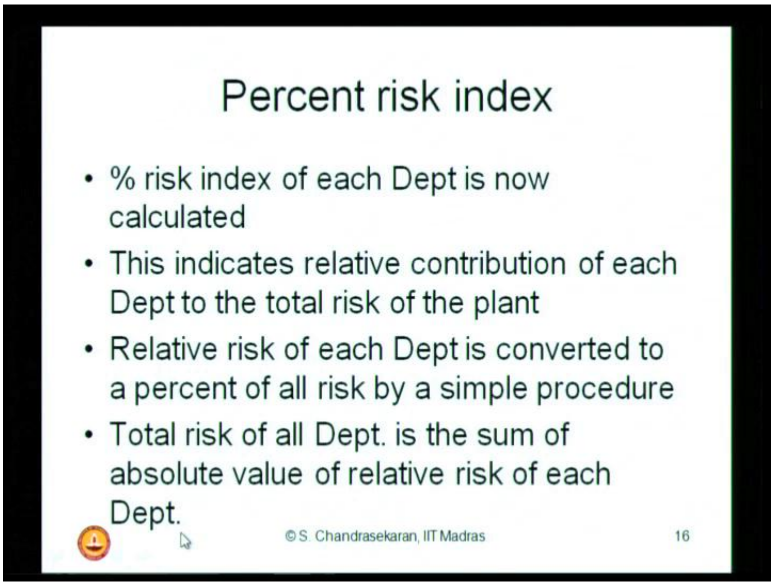

After doing this, now we will work out what is called percentage of risk index. I am interested to now know, what is a percentage of risk index of each department? This indicates relative contribution of each department to the total risk of the plant. Remember, this is a very important stage of calculation of Morgan's value because, this will tell me which department is most vulnerable or which is contributing to the maximum of the total risk of the complete plant.

So, I am trying to compare a percentage contribution of each department to the overall risk scenario of the whole plant. Relative risk of each department is converted to a percentage of all the risk by a simple procedure. Total risk of all department is a sum of the absolute value of relative risk of each department. I emphasize the word absolute value, because of a simple reason as we saw in the previous slide; the relative risk can be a negative number as well. You take the absolute value of risk of all the departments, sum them up, then subsequently estimate the percentage.

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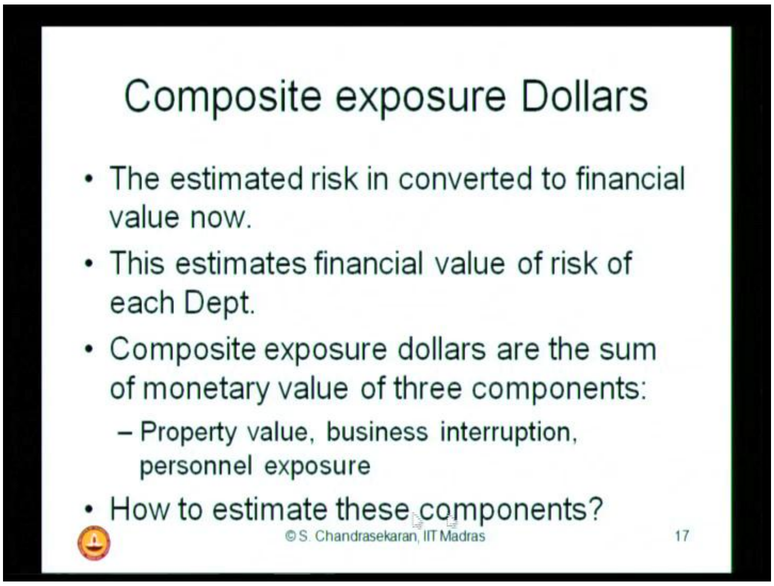

Now, this risk is converted to financial terms - what we call as composite exposure dollars. The estimated risk is now converted to a financial value, because we are now looking at financing risk reduction. This estimates financial value of risk of every department. Composite exposure dollar is the sum of monetary value of three components of every department. Every department has a property value, every department can contribute to a loss, if business in the department is interrupted, and of course, every department has different classes of personnel and the exposure level of this personnel can also be different. I am now associating a simple exposure dollar value to each one of them separately. How to estimate these components?

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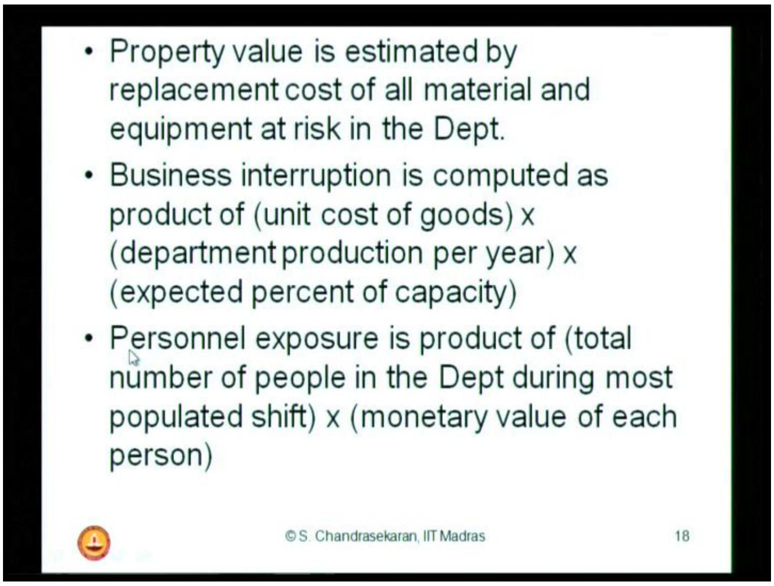

Morgan suggested a very interesting process by which this can be done. The property value is simply estimated by replacement cost of all material and equipment at risk in the department. For example, if a department has respective material and equipment at risk, simply put that value of the material and equipment to be called as property value of the department in terms, of course, dollars.

Business interruption, as I explained you earlier, is computed as the product of unit cost of goods multiplied by the department production per year multiplied by expected percentage of capacity. So, if the business in the department is interrupted, this would be the total loss the department will contribute to the overall loss of the whole plant.

Personnel exposure is simply the product of total number of people in the department during the most populated shift, multiplied by the monetary value of each person. I think, you very well understand that the monetary value of each person involved in the department may be different, and the populated shift we can have a mixture of such kind of people, so the product of these two carefully evaluated, will give me what is called personnel exposure.

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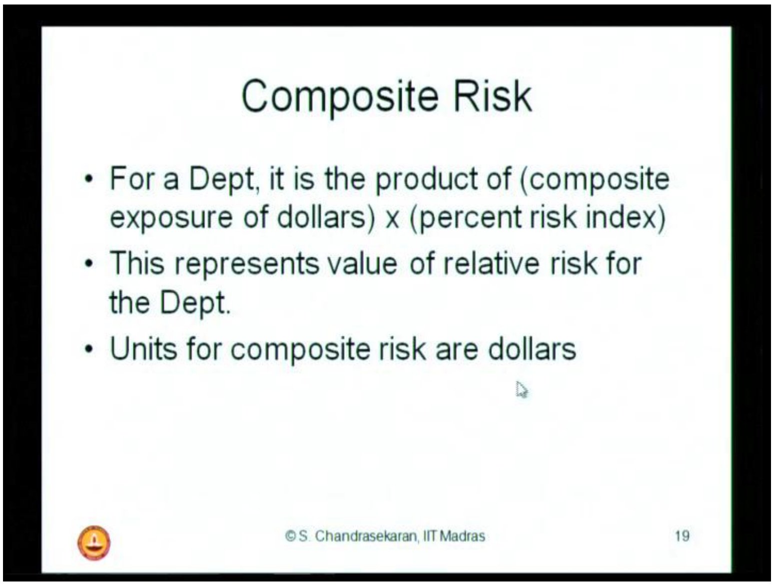

Then I estimate, what is called composite risk. For each department, this will be a simple product of composite exposure dollars multiplied by percentage risk index of every department. This represents the value of relative risk of every department. The units for composite risk are generally financial terms, in this example, I have taken them as dollars.

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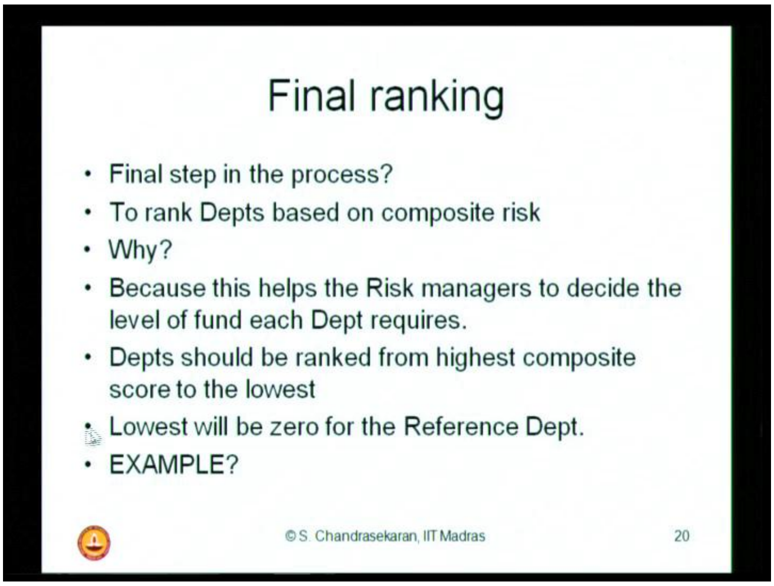

Then, I will land up in what I called as final ranking. The main objective of the Morgan's method is, to rank the departments depending upon the risk involvement in the production process.

This is the final step in the process. To rank the departments based on the composite risk what the department has. You may wonder a term, why I am introducing a term called composite risk? The answer was present in the previous slide, can you look back them and try to understand the reasoning for why calling the risk as composite risk. It is because, this helps the risk managers to decide the level of fund each department requires. So, the ranking of a department is mandatory as a risk manager, you should be able to decide what level of funding you should give to each department, for of course, risk reduction or risk mitigation. Therefore, it is inhabitable that the department should be ranked from the highest composite score to the lowest. The lowest will be; obviously, zero, which is considered as the reference department. You may recollect that the reference department is that department which had the maximum positive risk score. I would explain this whole process of Morgan risk assessment by a simple example of a process industry.

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TABLE 1: Data of each Dept of the process plant ((given data for the problem)

Exposure Dept	Hazard Score	Control Score	Property value (x 10^3)	Business Interruption cost (x10^3)	Composite score	
					Personnel	Exposure Dollars
A	257	304	2900	1400	900	5200
B	71	239	890	1200	653	2743
C	181	180	1700	720	1610	4030
D	152	156	290	418	642	1350
E	156	142	520	890	460	1870
F	113	336	2910	3100	1860	7870

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Let us consider a process industry which has got departments A, B, C, D, E, F. For each department, I have conducted a survey and I know the hazard score of each department, which I taken from the table. And the control score present in each department, which I also have taken from the table. Now, for each department, I know what is the property value of the department, what is the business interruption cost of the department and therefore, I will now work out what is a composite score, as based upon personnel and exposure in dollars. This final column is what I am interested in for each department, ultimately my aim is, each department should be ranked depending upon their risk exposure level. So, I am looking for financing the risk - that is why ultimately the hazard and control measures are converted or expected to be converted in terms of dollars.

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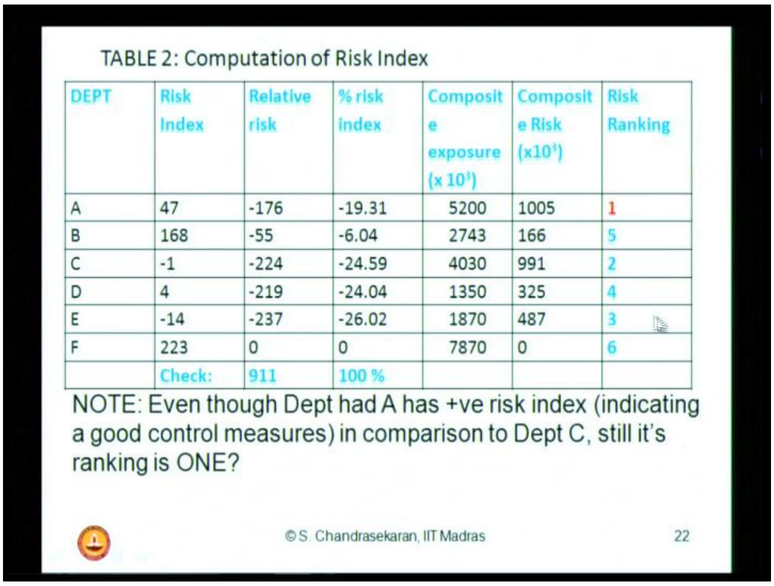
TABLE 2: Computation of Risk Index

DEPT	Risk Index	Relative risk	% risk index	Composite exposure (x 10^3)	Composite Risk (x10^3)	Risk Ranking
A	47	-176	-19.31	5200	1005	1
B	168	-55	-6.04	2743	166	5
C	-1	-224	-24.59	4030	991	2
D	4	-219	-24.04	1350	325	4
E	-14	-237	-26.02	1870	487	3
F	223	0	0	7870	0	6
	Check:	911	100 %			

NOTE: Even though Dept had A has +ve risk index (indicating a good control measures) in comparison to Dept C, still it's ranking is ONE?

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I know to compute what is called risk index. I have the same departments scored as A, B, C, D, E, F. The risk index, what I get from each department, is indicated here 47, 168, minus 1, 4, minus 14, 223. I think you should be in a position to identify the significance of these negative numbers, and the significance of the positive numbers, and the significance of the department which has the maximum positive number; it means, this tells me that the control measure of this department is the best. Now, I take the department as may reference department therefore, the relative risk for the department will be zero.

I now estimate the relative risk of each department. How do I do that? Get back to the previous slides and try to find out on your own, how relative risk can be computed for each department. Once I compute, then I take the absolute sum of all these values and put a check measure as 911. Now, I am interested to work out what I called as percentage risk index. I pick up the value of the respective department, divide this by the total and multiply by 100, I get percentage risk index. I can simply work out this value for every department, as shown in this column of the table. You can also check that the total percentage risk index should come to hundred.

Now, each department has a composite exposure in terms of money, of course, this value is multiplied by 10 power 3 in terms of dollars. Oil industry is one of the most expensive process industry, therefore, these values are very, very high. This value, ladies and gentlemen, we can remember that I have taken this column practically from the previous table; this is expected to be a given data for every process industry.

Once I have the composite exposure of each department placed in the table on this column, I can easily estimate the composite risk of each department is simply multiplication of the risk index of the department to the cost, of course, on absolute multiplier there is no negative element. Remember, that the department a had a positive score of risk index 47, which is not of course, the highest; the highest is department F which is considered as a reference department. I now work out for all the departments, the composite risk index; obviously, for my department it become zero. Now I do the risk ranking; if I look at the risk ranking, the department which has the maximum composite risk is considered as rank number-1. It means, this department is expected to receive the maximum allocated budget of fund for risk mitigation or risk reduction.

Now, you may wonder that what would be the finance given to department f, because the composite risk index of this department f is practically zero? It does not mean that the department f should not receive any funding at all. You can fix a basic value of funding for the department, may be 10 percent of the budget.

Then, remaining 90 percent you keep on distributing as per this rank. This problem has a very interesting outcome; I recollect that outcome once again for you. Department A had a positive risk index compared to that department C which had a negative risk index; it means that the department C had less control measures compared to that of A. If you look at the final ranking, department A is rank 1 and department C is rank 2. Please note that all the time the department which has a negative risk index may not be ranked as number 1; this is where Morgan has played a very interesting role in mixing this risk index with the money environment. So, I simply read a note here, even though department A had positive risk index indicating a good control measures in comparison to department C, still it's ranking is number one. You can very well understand why it is so.

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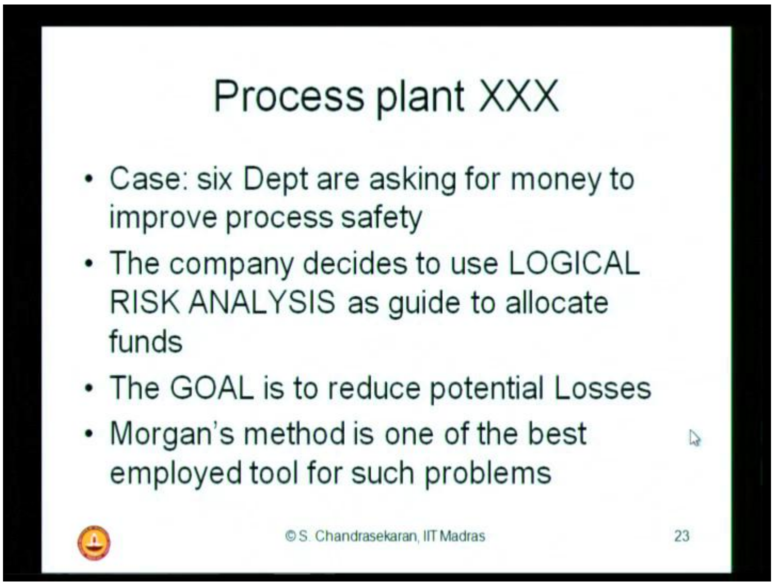

Let us take another example of process plant triple X. The case is a process plant. The process plant has six departments, six departments are requesting for money from the management to improve their process safety. The company decides to use logical risk analysis as proposed by Frank and Morgan, as a guide to allocate the funds for each department. The goal is to reduce potential loss the department could inquire, which will attribute to the total loss to the company as a whole. Morgan's method is one of the best methods employed for such problems.

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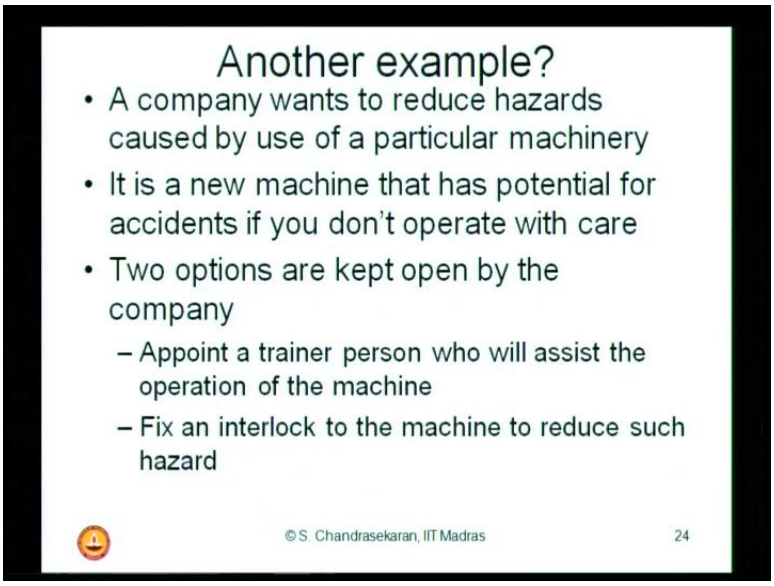

Can we look at another example? A company wants to reduce hazards caused by use of a particular machinery. I have a company; I have a process plant; it uses specific machinery; use newly placed machinery in the process. Trainees are available for this machinery, but the company looks actually to a goal of reducing hazard only because of this particular machinery, may be a drilling rick, may be a BOP - blow out preventer etcetera. It is a new mechanism found in that machine, which has a potential for accidents; this is true when you do not operate this with care.

Now the company has two options; number one - appoint a trainer person, who will assist the operation of the machine. You understand the consequence of this term; you have got to have a team of training people who is known how to operate this machinery. Put them on shift. Whoever wants to operate this specific machinery, should be instructed by this people every time before they use the machinery. The goal is to reduce the potential hazard because of this machinery. The other alternative the company had is to fix up a lock to the machine to reduce such hazards. There can be a siren; there can be an alarm; there can be interlocking mechanism in the device, which will stop the machinery whenever the machinery is not put to proper use. One option is purely a mechanical based system; one option is purely a physical or personal based system. The goal is to reduce hazard or to reduce risk or to mitigate risk.

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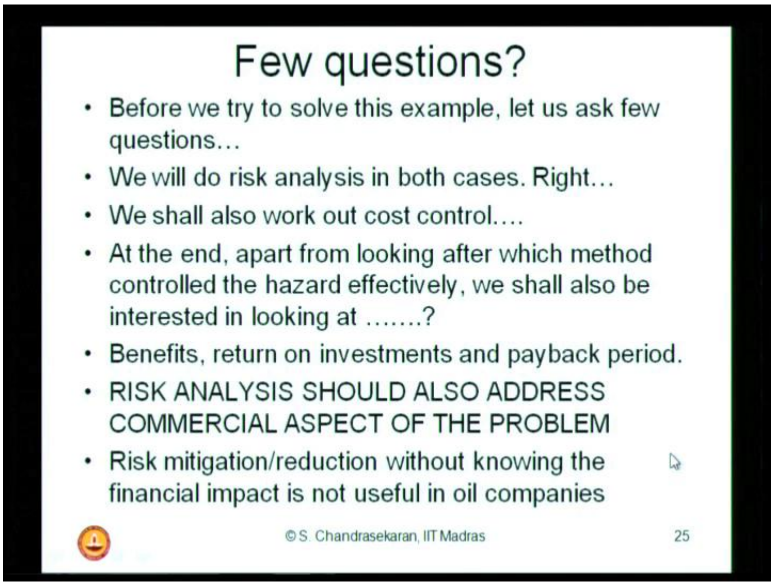

Let us see, how this will be effectively working which is going to be cheap. Before we solve this problem, let us ask few questions to ourselves. We will do risk analysis in both cases, both options? We will do risk analysis.? We shall also work out the cost control in both the cases, because any risk mitigation method, if it is not financially controlled, one will not be interested to employ that kind of risk mitigation methods. At the end, apart from looking which method controlled the hazard effectively, we shall also be interested in looking at another point. What is that another point? The benefits or the return on investments and the payback period.

You know, in both the options, either you employ a trainer or you put an interlocking mechanism, the company will be investing on that particular method of mitigation. What would be the benefit of that investment; what would be the return of that investment if at all the company gets the return, what would be the payback period? So, this is a financial aspect of risk reduction. Risk analysis therefore, should also address commercial aspects of the problem; otherwise, it would not be appealing for oil industry. Risk mitigation reduction, without knowing the financial impact, is not useful for an oil company.

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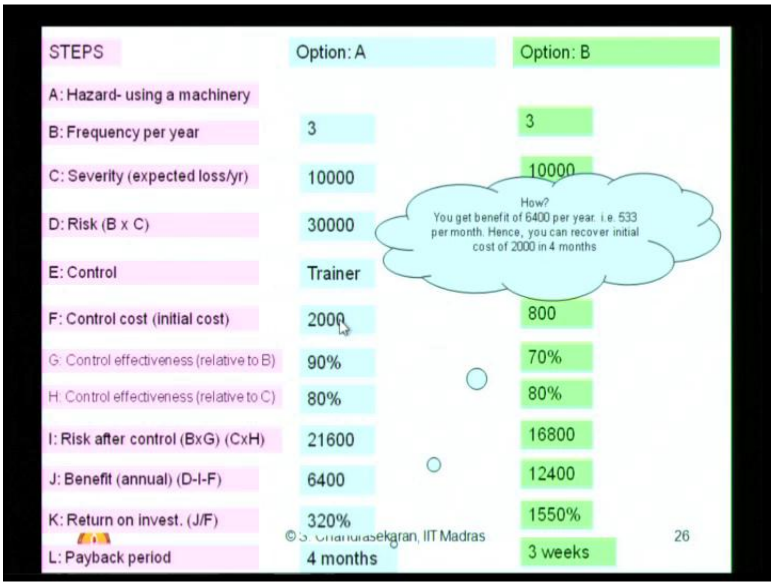

Let us take a simple example and try to solve this problem. Let us say I have option A and B given by the company. Option A you have a trainer whose going to teach people every time when the machine is to be operated; option B you have an mechanical interface system, which I called as an interlocking in the machine, which avoids any kind of risk while miss operation of the instrument.

The hazard of using the machinery frequency per year for this problem is, three for option A and three for option B. It means, even if you have a trainer accidents related to this, miss operation can be three times in a year. I keep it same for interlocking three as well, just to have no relative measurement between these two options. Severity is what we say expected loss every year; I keep the expected loss is same in both the cases, whether the functionality of putting in interlock fails or the functionality of putting a trainer fails, the expected loss to the company every year is considered to be tenth thousand units may be dollars, may be rupee, may be euro.

Now, the risk is a simple multiplier of frequency into severity - that is a classical definition for risk, which we saw in the previous presentation. So, I simply get the multiplier of these two, I get the risk for option A and option B. At this stage you will appreciate that the risk on both the options are same then what does the company do? What is a control measure the company is putting? In option A the company wants to appoint trainer, in option B the company wants to put the lock to the machinery; it is a mechanical interface, it is an human interface. The risk involved in both is same. The control cost, the initial cost what the company has to invest on these two options are now different. The lock cost only 800 units whereas the trainer - his employment, his graduate, etcetera cost much more than that, so here the difference starts. Now, let us see the company will look for option A or option B. It does not mean that option B is cheap, therefore go for option B or option A is expensive still the control measurement are better, let us go for option A. It does not mean like that.

Let us look at the cost control effectiveness. How effective is the control related to B? For example, you put a trainer the frequency initially was three accidents per year as the trainer instructs people very closely every time, the reduction is about 90 percent only ten percent of this happens, whereas the interlock present in the device, works effectively only for about seventy percent.

Now, the control effectiveness related to severity. For example, if you reduce the frequency of occurrence 90 percent, but still the control effectiveness in terms of severity is remaining same let say 80 percentage. You may wonder, why the control effectiveness of 90 percent on frequency should result in 80 percent of severity? These are subjective values, this I am deliberately keeping different because; obviously, you may expect that a trainer will closely watch or train people to operate the machinery therefore, this method can be effective in reducing the frequency of accident, but if at all that accident occurs, a severity is about the same. So, therefore, I am keeping these numbers same, but these number deliberately different because, I am investing more on a trainer compare to investing less on a lock of the machine.

The risk after control is simply B into G crossed by C into H I get this value for a trainer and for the lock. The risk, after control, is this much. Now, the benefit what the company will draw, will be simply the risk minus the control minus the investment what the company made. The risk is 30000 units, the eye value is 21600 the company invested 2000 units. Therefore, the company has benefit annual of 6400 units, where as the benefit annual in this key is more than this.

Now, can you guess which will be the best option by the company should follow. The return on investment is simply this value divided by the initial cost. So, the return is only about 320 percent whereas the return on this case is 1550 percent, how this is first of all estimated. The payback period for this case, is four months, and for this case, is just three weeks. So, the company gets back this money faster. The company gets back money slower, risk after control is higher; risk after control is lower. I think, you would have now guessed which option the company should follow, but before telling you that, let us see, what could be the procedure to arrive at this number. It is very simple. You get the benefit of six thousand four hundred units every year, that is 533 every month, hence, you recover initial cost of 2000 units in four months.

Similarly, you can also workout for this figure and the answer will be three weeks. Now, as a HSE manager, you should be in a position to decide which option you should follow. My goal was not to guide you which option you must follow; my goal was, if you have two options, how to systematically analyze which option will be better. So, there should be a logical method of analyzing both the options. So, this method which is present now as an example, was just to make you to understand, how one can logically analyze both the options present under different phase.

If you have any queries based on this examples, you are most welcome to give your feedback and a question to NP-TEL at IIT Madras. We will now break for short while for this lecture. We will continue with a same module later.

Thank you.