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NPTEL ONLINE CERTIFICATION COURSE

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

Module 1
Safety assurance and assessment
Organizing safety (continued)

Dear friends we are continuing on the lecture module one which is focused on safety assurance and assessment in the lecture 8 today we will talk about organizing safety with another example. In the last lecture we discussed about how safety organization could prevent or intelligently reduce economic loss in case of a nuclear reactor disaster that has happened recently in Japan.

Today I will take up another interesting example which is resulting from or which could result from a man-made disaster, let us talk about how organizing safety or risk management can help to assess and minimize the loss in such cases. Now we shall take an example.

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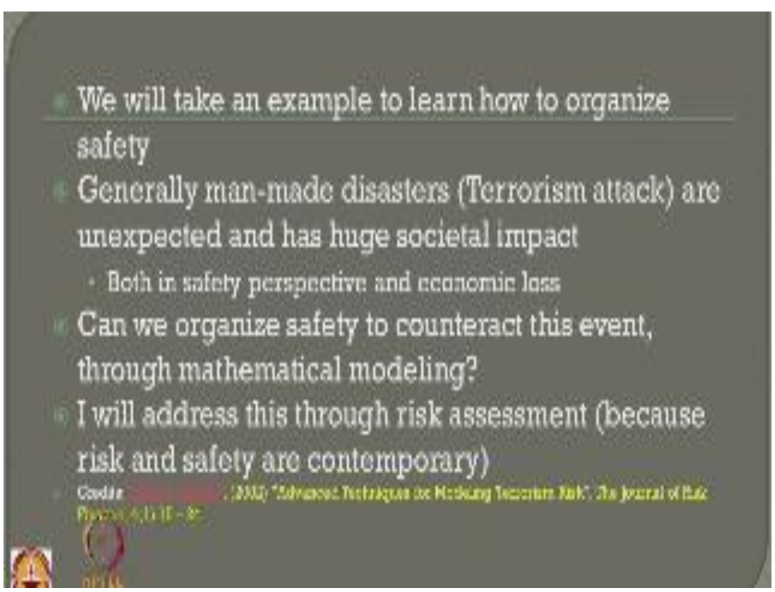

To learn how to organize safety generally man-made disasters like terrorism attack are unexpected and as huge social impact, the impact is in both sense in safety perspective as well as huge economic loss to the country. The question now comes is can we organize safety to counteract this event through mathematical modeling one can also ask a fundamental question in case of health safety and environmental management why are we talking about risk management related to terrorism attack

There is a very interesting answer I will give this I will address this risk assessment they cause risk and safety or contemporary we already know that and we want this credits to John imager who has published a paper on the specific topic based on which the extract of this lecture is dependent on.

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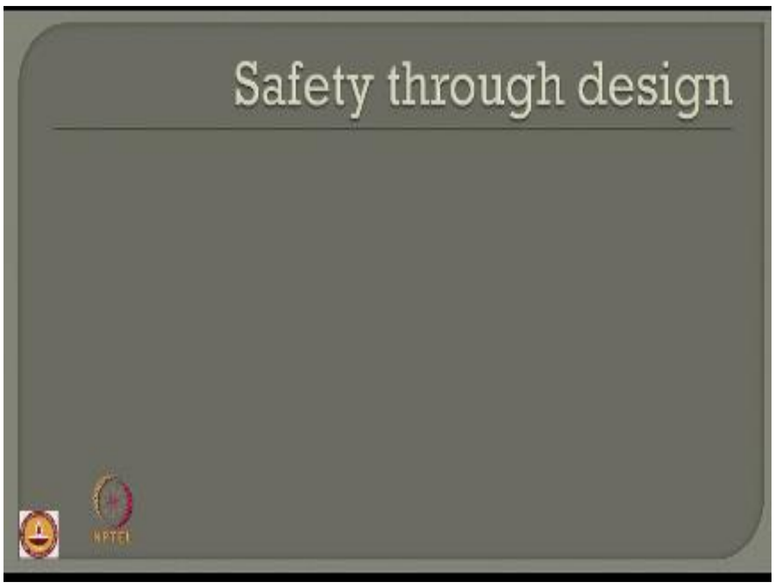

Before we take up an example to understand how risk management or risk assessment or safety assurance through risk assessment can be done for an example like a terrorism attack. Let us try to recollect some of the points which are related to safety through design.

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Now the best way to minimize injuries, illness, and fatalities is to design the plant with minimum hazards and risk, by design try to eliminate hazards and control the risk to an acceptable level at the source itself, control risks as early as possible in the life cycle of the plant in the workspace so that they do not get matured to become a very serious problem. If you find any difficulty in the design or if you revisit the design and find out that hazards are enormously high because of aging of the plant then in that case redesign retrofit existing work place, facilities, equipments, tools and plants and machinery and the work processes if required.

So that tried to bring down the hazard level and improvise safety to an higher improved standards and all these can be essentially done through the design.

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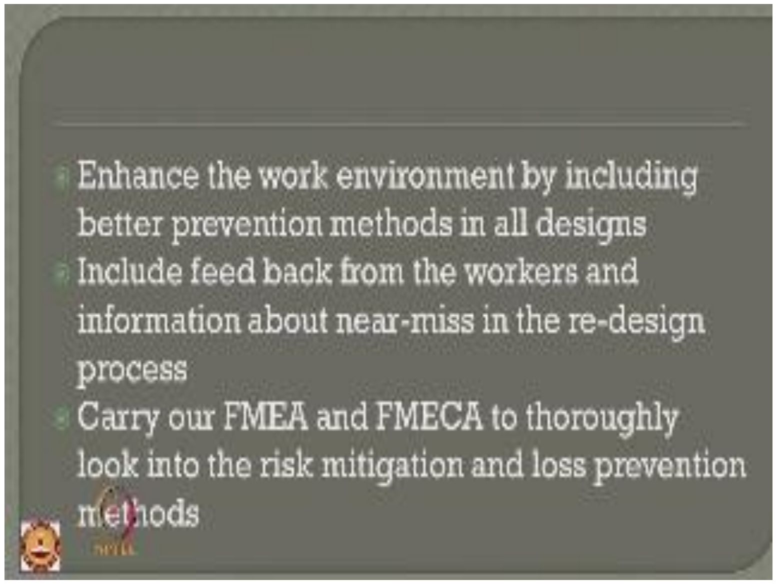

One should also plan to enhance the work environment by including better prevention methods in all the designs. Try to include feedback from the workers there is a very important aspect because the personnel who are on board will give lot of reports on near-misses which could become an important item to add to safety improvement in the whole program. So therefore, I strongly encourage that one should include feedback from the workers and the information about the near-miss what they have encountered and try to redesign the entire process or the plant, so that the safety level is always on the improving side.

If it is a mechanical based problems if it is related to equipment failure anticipated as one of the design phenomena then one can carry out failure mode effect analysis which is abbreviated as FMEA or one can also do FMECA which is abbreviated as failure mode effect and criticality analysis to thoroughly look into the risk mitigation processes and the loss prevention methods by which you can improve safety definitely be redesigning the plants in equipments itself.

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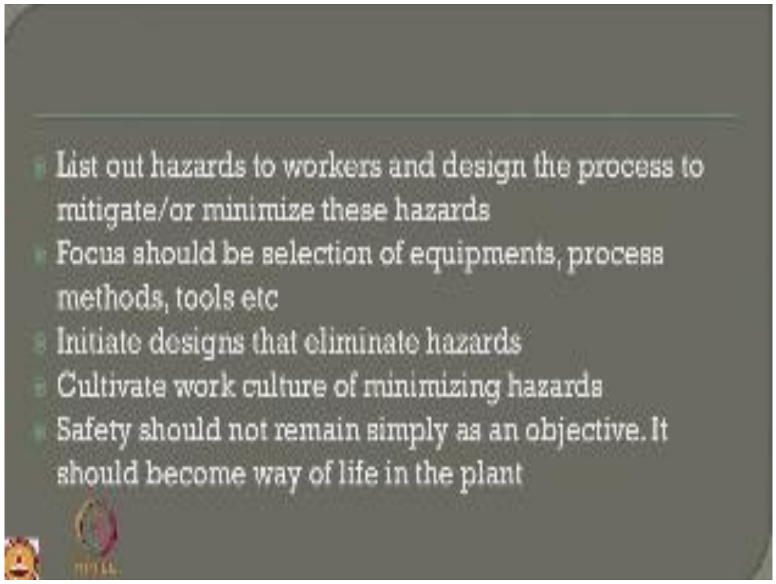

While doing so try to list out the hazards to the workers and design the process to mitigate or to minimize these hazards, while doing so one focus should be on the selection of equipments carefully, alteration or deviations suggested in the process methodologies, tools and plants in machineries etc, so that all put together with a minimal contribution from each one of them can result in improving overall safety of the process as well as the plant by itself.

So initiate designs that eliminate hazards, cultivate a good workculture of minimizing hazards, safety should not remind simply as an objectivein the plant it should become a way of life in the plant that is the important role what a safety engineer has to play inculcate a good work culture habits which improvises safety as a part of the life in the plant.

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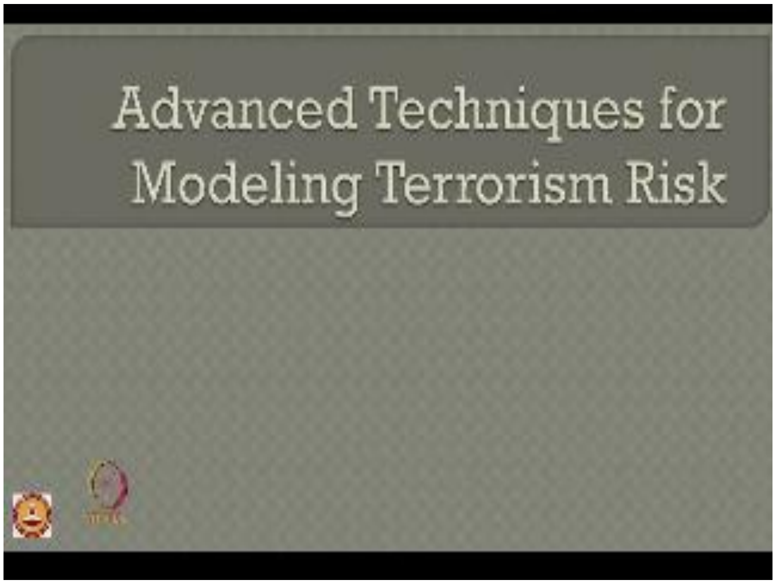

Now as I said in the beginning there are man-made disasters cost to the plants nevertheless process industries of I importance like oil and gas industries like nuclear reactors or no exemption. Let us see what are the advanced techniques available for modeling terrorism risk so that one can minimize their economic loss encountered from such activities.

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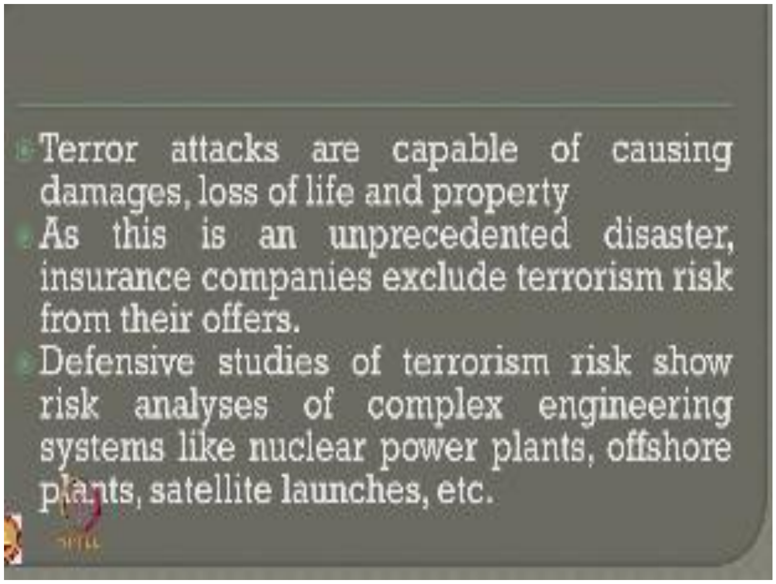

Terror attacks are capable of causing damages loss of life and property as this is an unprecedented disaster insurance companies generally exclude terrorism risk from their offers, defensive studies of terrorism risk show that risk analysis of complex engineering systems like nuclear powerplants offshore plants, satellite launches etc, do definitely get included in this kind of unexpected disasters which are caused by the mankind.

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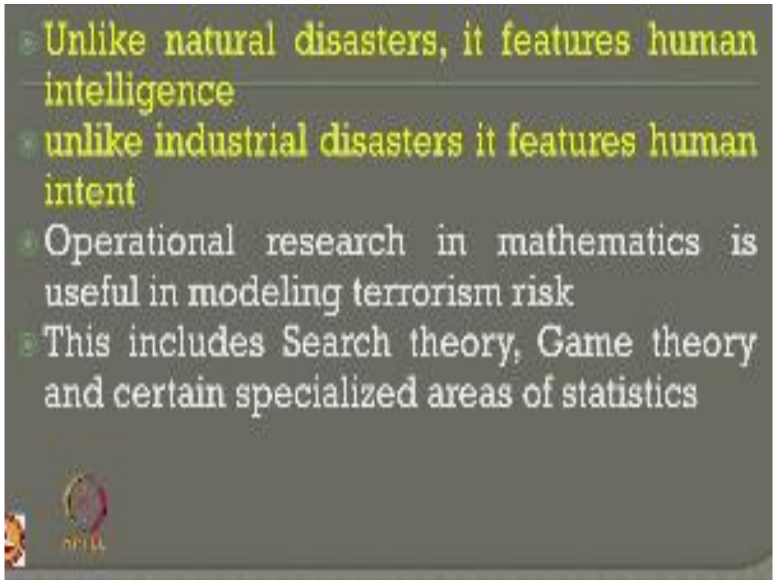

More importantly unlike natural disasters these kind of disasters feature human intelligence, unlike industrial disasters they feature human intent. So therefore, it is very difficult to model the complex algorithm of an human intelligence because as you all understand human intelligence is the most powerful criteria what God has created. Natural disasters can be predicted but of course the economic loss is beyond your control but human intelligence cannot be even predicted.

What would be the circumstances under which a attack can be programmed and plant is a very difficult compress algorithm, but there are few advanced mathematical techniques available so that if this is practiced and understood properly oil and gas industries and the process plants can be easily saved by minimizing the economic loss caused by such unprecedented activities operation resaearch in the field of mathematics is a very useful tool in modeling terrorism risk. This includes such theory, game theory and certain specialized areas of statistics which I will discuss now.

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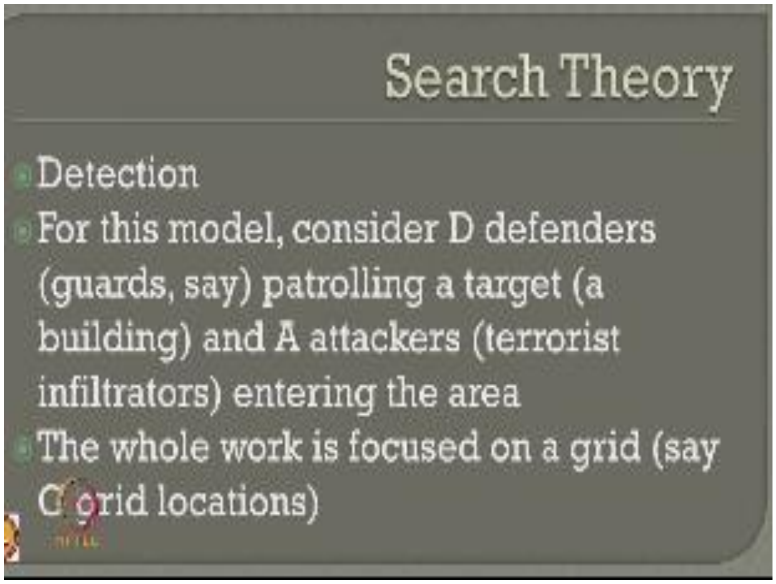

Let us discuss about to start with the search theory, search theory discus sabout detection for this model let us consider D as defenders let us say the security guards patrolling a target maybe a building, maybe an offshore plant, and let A be the attackers who are infiltrators entering the area. The whole work is essentially focused on a grid says G grid locations let us say we identify the grid locations as G and D are the defenders and A are the attackers.

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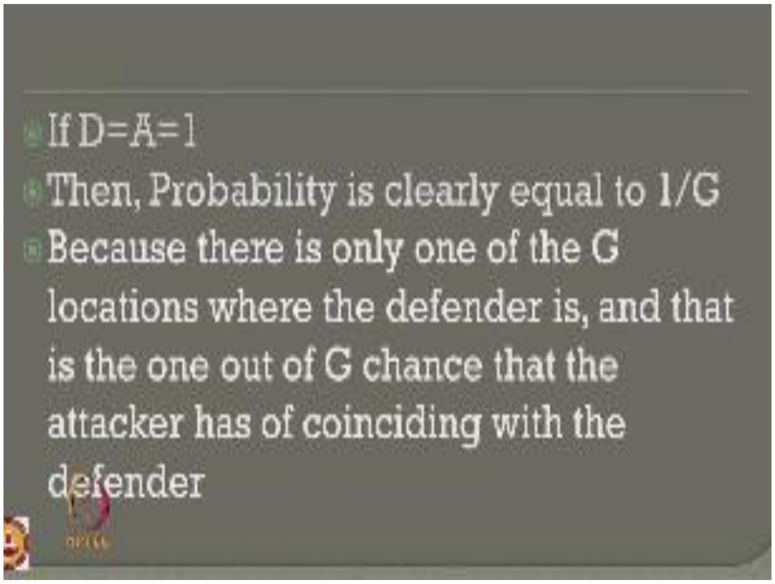

If the defenders and attackers are equal in number let us say they are equal to 1 then the probability is clearly 1 over G why because there is only one of the G locations where the defender is and that is one out of G chance that the attacker has coinciding coincides with the defender.

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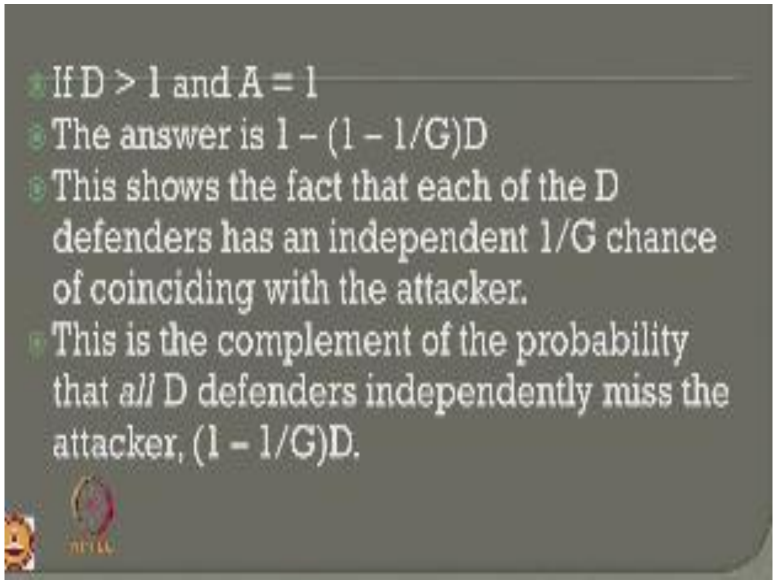

If D is greater than 1 and A is 1 on the other hand more defenders less attackers in that case the answer could be 1 minus of 1 minus 1 over G(D), this shows the fact that each of the defender has an ipendent 1/G chance of coinciding with the attacker. This is the complement of probability that all defenders independently miss that occur and that is going to be equal to 1 minus of 1/G that is why we say (1 - 1 / G) D, whereas 1 / D is the probability of the defenders being that and (1 – 1) / G will be the defenders independently missing the attackers that’s why we say (1 - 1 / G) / D.

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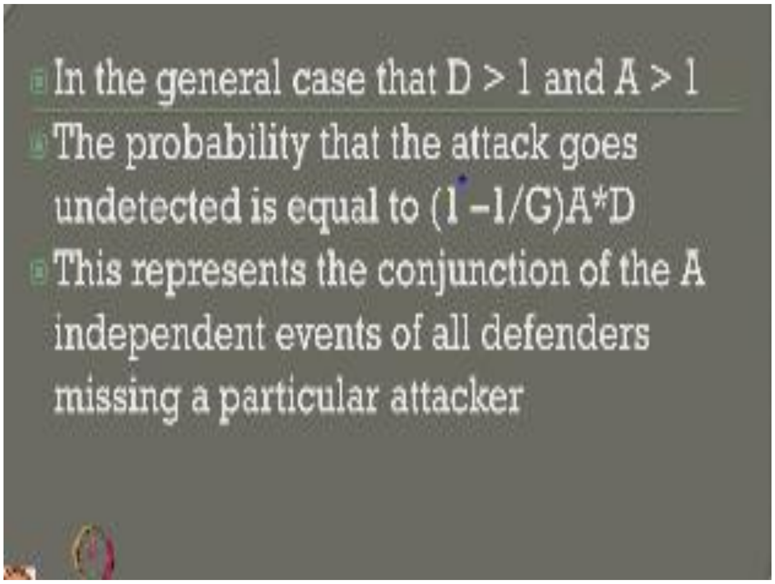

As a general case if more defenders and more attackers let us say D is more than one and a is also more than one in this case the probability that the attack goes undetected will be obviously equal to (1 - 1 / G) A* D this represents the conjunction of A independent events of all defenders missing a particular attacker.

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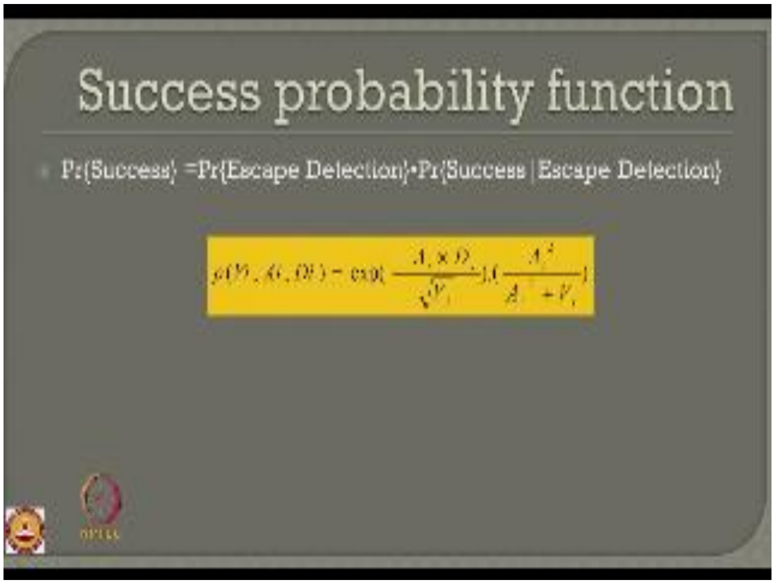

Now let us see what could be the success probability function as given in this slide. The success probability function is given as a product of two, the probability of success is the probability escape detection with probability of success given escape detection.

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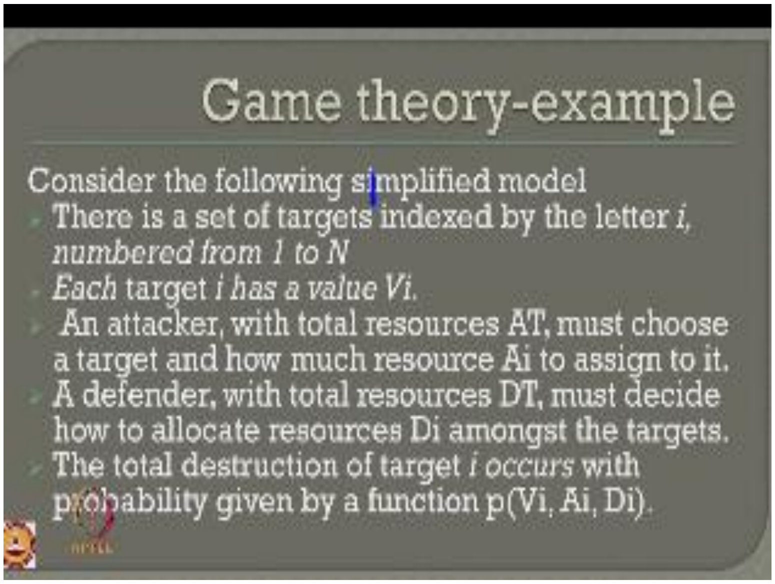

Let us take an example of this, consider the following simplified example there is a set of targets indicated by a letter I which is numbered from 1 to n each target I has a value which is given as Vi an attacker with total resources AT must choose a target and how much response Ai to be assigned to it is to be decided by the attacker, whereas a defender with the total resources DT must decide how to allocate the resources Di amongst the given targets, the total destruction of target I occurs with the probability given be a simple function which is including of Vi, Ai, and Di where Vi is a target value Ai is attacker and Di is a defender.

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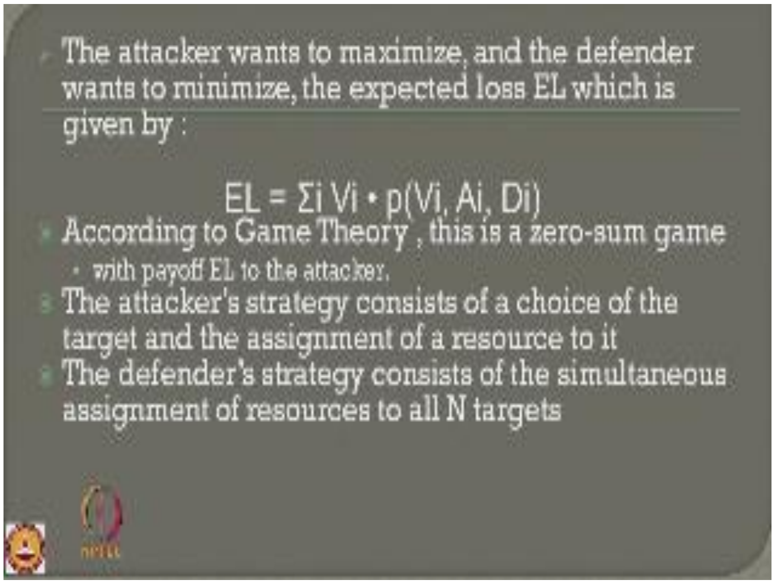

Now it is obvious to understand that the attacker wants to maximize and the defender wants to minimize the expected loss which is given by a simple algebraic sum as you see in this particular equation. Now according to game theory this is a zero-sum game that is without pay off economic loss to the attacker, the attacker strategy consists of a choice of the target and the assignment of a resource to it, whereas the defender strategy consists of simultaneous assignment of resources to all N targets.

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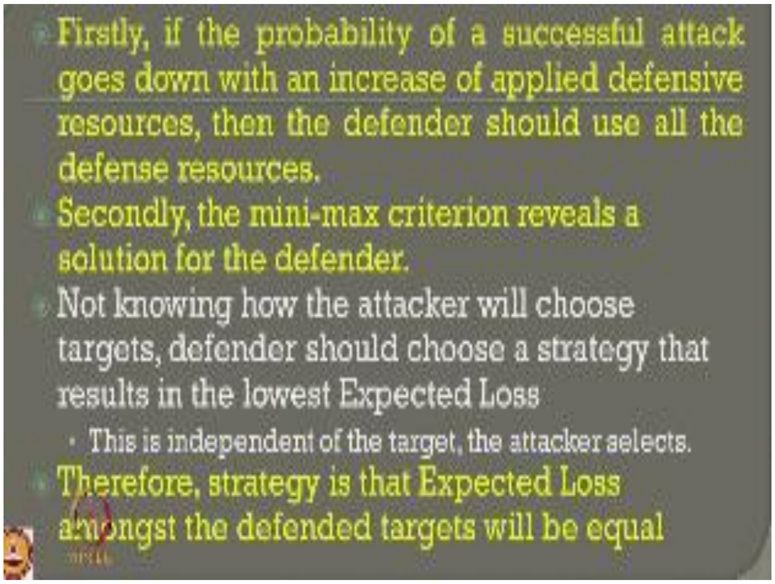

Now interestingly let us say first step by step as a first step if the probability of a successful attack goes down with an increase of applied defensive resources. On the other hand if the successful attack is defended with an increase of applied defensive resources, then the defender should use all defence resources to do this. Alternatively is a second step the mini-max criteria reveals a solution for the defender. Not knowing how the attacker will choose targets defender should choose a strategy that results in lowest expected loss that could be the focus for the defender that even the attacker is successful the expected loss created by the attacker should be the minimum.

So this should be independent of the target the attacker selects because you do not know what would be the target selected by the attacker. Therefore, the strategy is that the expected loss amongst the defender targets should remain almost equal on the other hand the attacker selects any target the loss expected from the target or any missed of target should remain almost equal.

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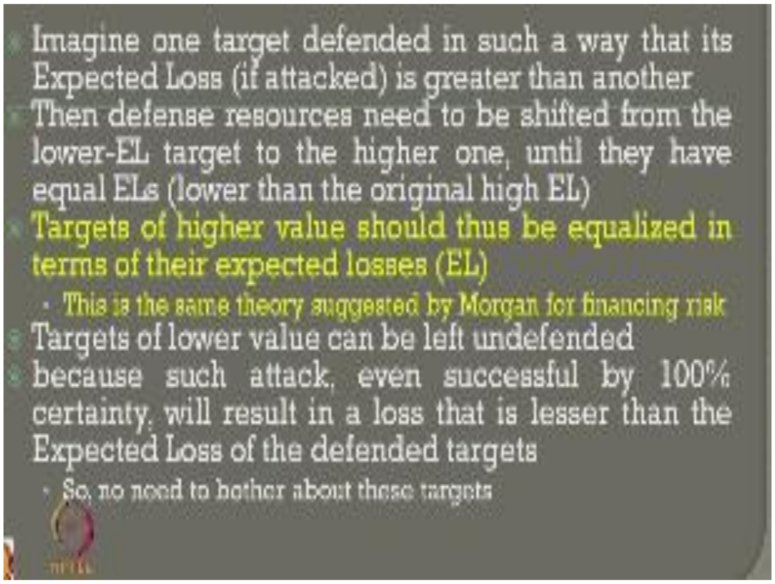

Imagine one target defended in such a way that it is expected loss is greater than another if that is a situation then defence resources need to be shifted from the lower expected loss target to that of the higher one. For example, if you have many targets where the expected loss from the each target is different from one another and if you feel that the attacker is aiming at the higher expected loss target then the defence resources need to be shifted from the lower expected loss target to the top the higher which may not be a good problem.

Because in that case you have to keep on guessing what would be the target achieved by the attacker. On the other hand if all targets have equal expected loss and that remains fortunately lower than the original high EL value then targets of higher value should thus be equalized in terms of their expected loss. On the other hand you must focus one important point here even though the attackers guess is not very clear, the strategy followed by the attacker is not clear, the defence people do not know how to follow a strategy to maintain the minimum economic or expected loss.

The main focus in this risk management is to minimize the expected loss. On the other hand friends please understand in risk management or risk assessment it is not the strategy which is important the focus is on reducing or minimizing the expected loss. If you understand and recollect the example problem what we solved the previous lectures this is exactly the same theory suggested by Morgan for financing risk where different plants of ABCDE have been suggested and recommended for some financing budget based on only the economic loss achieve or attain or projected by the department in case of encountered risk.

The targets of lower value therefore can be left undefended very important if the attacker tries to understand that there are some targets which are not given more importance even though they are attacked as the expected loss arising from the attack on these targets are much lower than the expected loss encountered by the design then they can be still left undefended. Because such attacks even success by 100% will result in a loss which is much lesser than the expected loss of the defended targets.

Therefore, no need to bother about these targets. Ladies and gentlemen interestingly instead of chasing the targets as expected by the complex geometry which can be programmed and initiated by an attacker intelligence what we can try to do is we try to equalize the expected loss in all the targets and keep the higher expected loss balanced from the targets. So if any untargeted or undefended targets are left over as it is even though that attack can be 100% successful we will understand that the expected loss arising from that target would be much lesser than those balanced expected loss which has been proposed by the manager or the defence team. Therefore, one need not have to bother about these targets.

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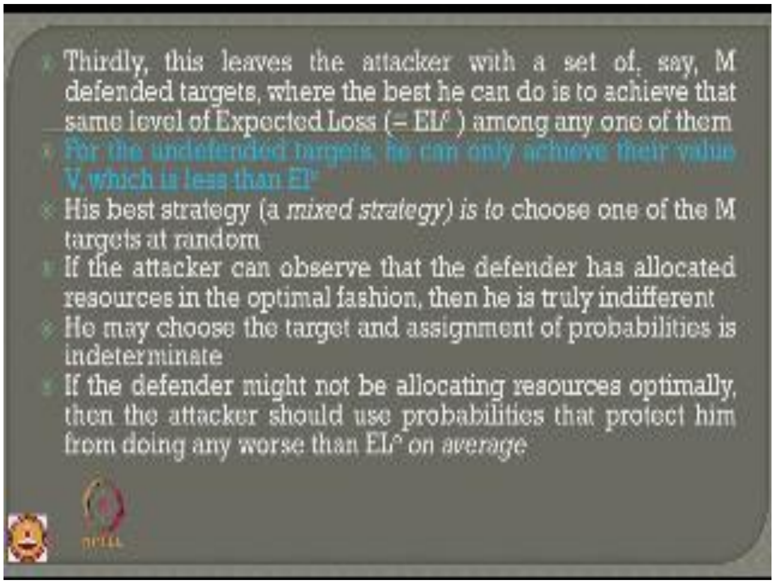

The third step is very important this leaves the attacker with a set of say M defended targets, because the attacker would now like to know which are those defended targets because he would be interested in creating the maximum economic loss or the expected loss. However, the defender would always interested in minimizing the expected loss or making it a balance in any target irrespective of what the attacker chooses.

Therefore, the attacker will now have an option of M defended targets where he can the best he can choose is to achieve that same level of expected loss among any one of them. We call this expected loss as let us say EL^0. Now for the undefended targets he can only achieve their value much lower than EL^0 his best strategy which could be a mixed strategy is now to choose one of them targets at random.

Dear friends please understand now there are N targets, now based on these N targets you have made an equal distribution of the expected loss in the M targets where M is much lesser than N and there are some undefended targets whose expected loss would be much lower than that of the expected loss on the M targets. Now we are intelligently able to minimize the targets from N number to that of M number where M is much lesser than N which is now going to be the target for the attacker.

If the attacker can observe that the defender has allocated resources in an optimal fashion then he will behave or he will plan in a truly in different manner, he may choose the target and the assignment of probabilities is indeterminate in such cases if the defender might not be allocating resources optimally then the attacker should use probabilities that protect him from doing any worse less than EL^0 on an average.

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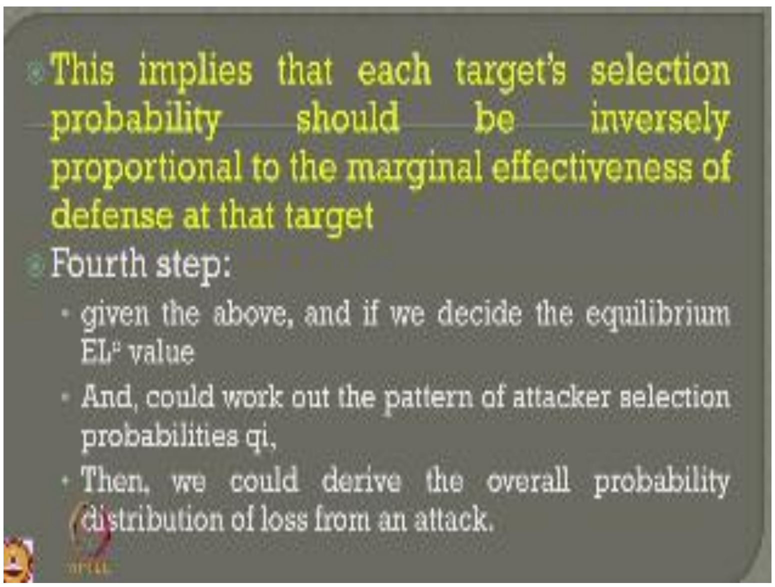

This implies a simple statement that each target selection probability should be inversely proportional to the marginal effectiveness of the defence at the target. Now as the defence people cannot be able to anticipate what is the strategy plan of the attacker similarly the attacker will not be able to guess what would be the strategy followed by the defence people.

So therefore, it is very interesting to know that the target selection now becomes inversely proportional to the marginal effectiveness. So if the marginal effective is higher and higher the target selection will become lower and lower followed by which is the four steps as given by the above if you design the equilibrium EL value to all protected or defended targets then one could work at the pattern of attacker selection probability which is given by QI then we could derive the overall probability distribution of a loss from an attack.

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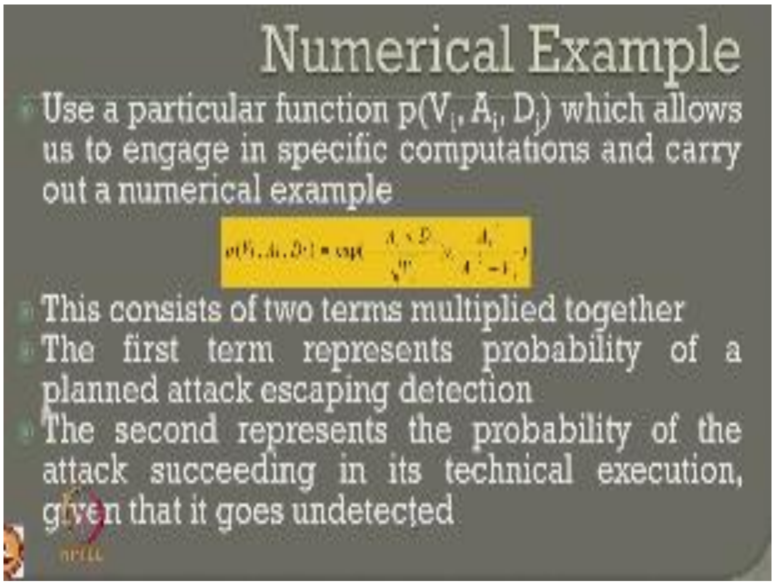

Which is given by this equation through a numerical example. Let us use a particular function probability function Vi, Ai and Di which allows us to engage in a specific computation and carry out numerical example. Now in the above equation the equation has got two terms, now multiply to each other the first term which is seen here represents probability of a planned attack escaping detection, it means success rate that is why it is A, D and route Vi.

Whereas the second term represents the probability of attack succeeding in its technical execution given that it is undetected. Remember this is escaping detection this is successful only when it remains undetected.

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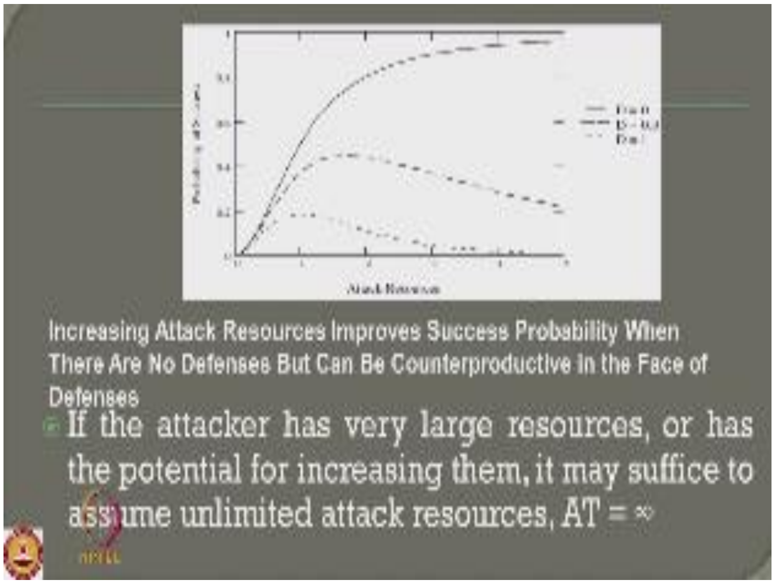

If you apply the probability distribution and try to see a plot between the attack resources versus probability of success as seen here by John Major increasing attacked resources, improves success probability, if you increase the attack resources it improves the success probability because as it moves from 0 to 5 the success probability goes to close to 1.

However, in this case the success probability is close to 1 only when the defence is practically zero, the moment you start putting defence in place you will see that has attack resources keep on higher and higher, as you keep on playing a defence attack also in the appropriate manner you will see the profit of success will initially look like higher well stabilize and becomes decreasing.

However, if a defence mechanism is much powerful then however maybe the attack resources the probability of success will be much lower than that of the earlier case and you will definitely come to 0 whereas the profit of success for an attacker will become practically not possible. If the attacker has very large resources or has a potential for increasing them it may then suffice to assume unlimited attack resources where AT practically becomes infinity.

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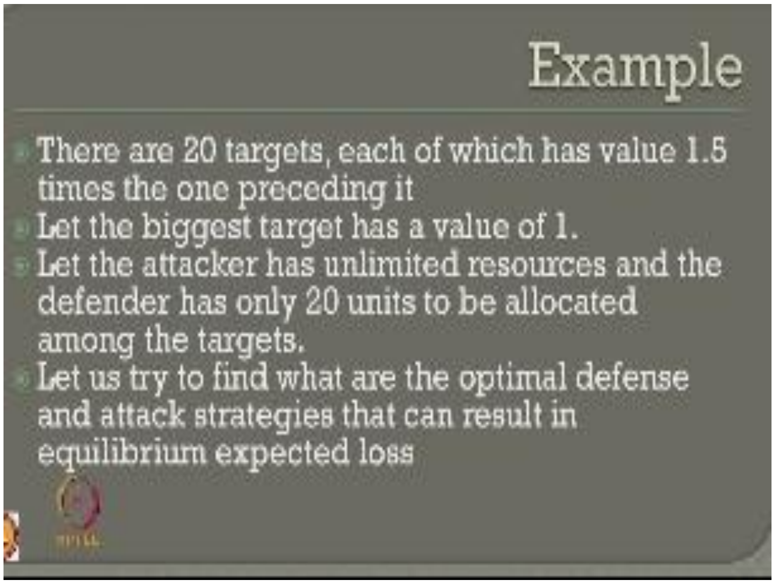

Let us say there are 20 targets each of which has 1.5 times the value than the preceding one. For example, target A the values 1, target B is 1.5 of A, target C is 1.5 of B and so on, each target value is increased. Remember we already said that the target value of an higher order should always be distributed equally so that there is always an expected loss from these targets which are more or less balanced or equilibrium.

Let us say now there are 20 targets whose values are 1 over the other increased by a factor of 1.5. Let the biggest target be having a value of one for our simplicity in mathematics. Let the attacker has unlimited resources and the defender has only 20 units to be allocated amongst these targets. Let us try to find out what are the optimal defence and attack strategies that can result in equilibrium expected loss, because as I said we are focused not on the strategy of the attacker neither strategy of the defence people but we are focused on minimizing the expected loss if the attack would remain successful.

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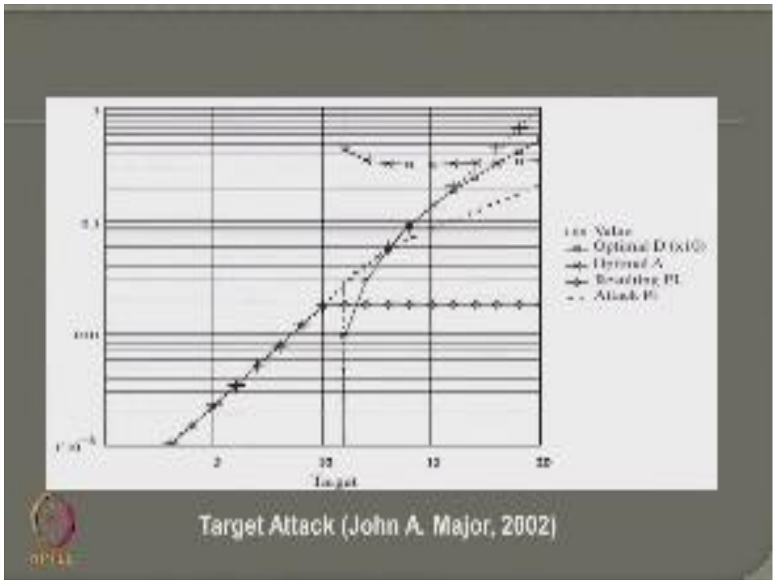

As plotted from here you will see that the, this particular plot shows let us say there is an optimal value, the target success rate keeps on increasing as there is no difference mechanism. Once the difference comes in place the expected loss is stabilized and does not increase. Whereas the attacker probability wants to make it maximized wants to make it maximized as far as desired whereas the optimal defence mechanism after the 10 targets are reached will try to get the attack probability more or less stabilized, which results in a minimum economic loss or expected loss even though that I become successful.

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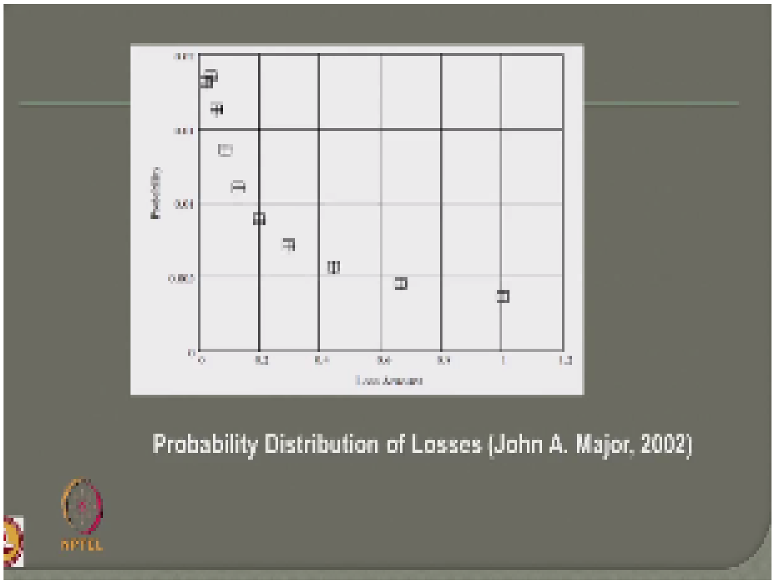

If you look at the loss amount compared to the probability as the loss amount keeps on increasing the probability of that loss amount increasing is very nominal. Whereas the probability of success becomes very higher for a very low probability or very low loss amount that is what we said the different targets which is having a very high expected loss should have a more focused and the study simply says they one which has got a loss amount higher will always have a lower probability of success rate.

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So in this example it is seen that there is an overall 89.3% probability that the attack is not successful. The remaining 10.7 is not spread evenly over the defender target values, it is more likely to be successful attack on a very smaller target whose expected loss is much more lower than the one which has been assigned by the defender. Therefore, the probability of largest loss a value of one from the largest target is only 0.36%.

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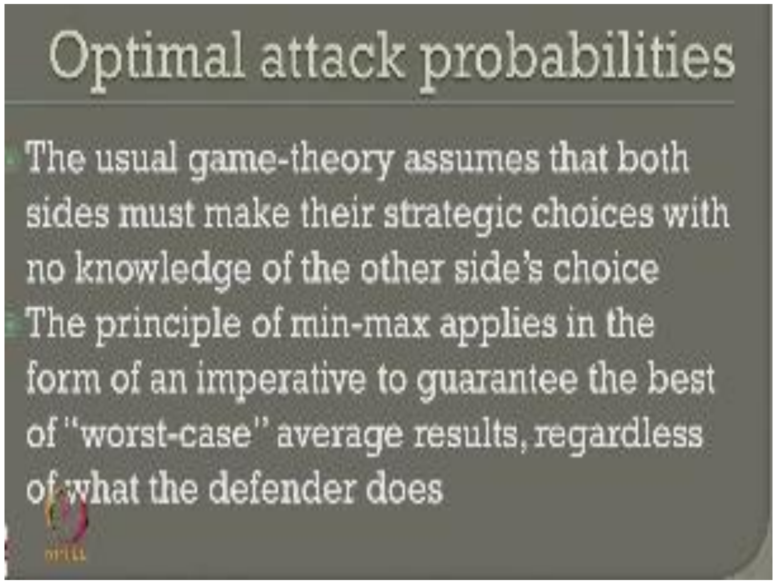

There is another methodology by which you can say optimize attack probabilities the usual game theory assumes that both sides must make the strategic choices without no knowledge of the other sides choice. However, the principle of mini-max applies in the form of an imperative to guarantee the best of the worst case average results regardless of what the defender does.

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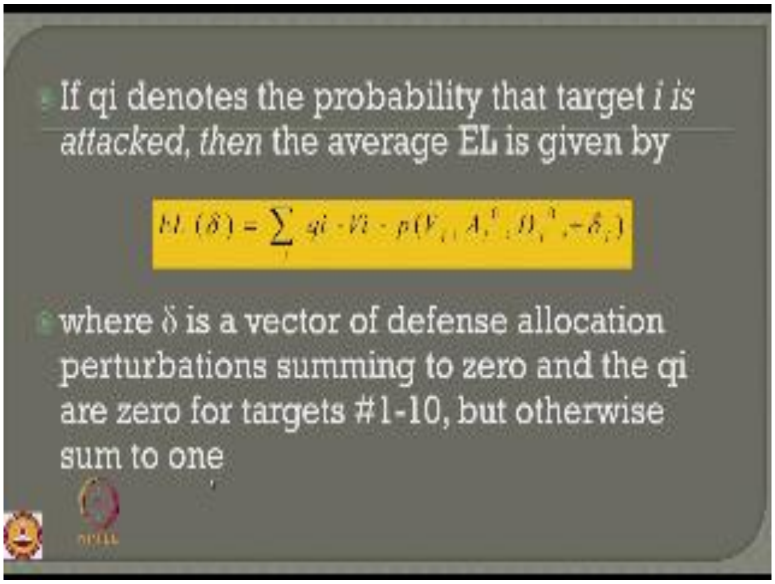

When we focus the expected loss if QI denotes the probability that I is attacked target then the average expected loss is given with the equation seen in the slide here in this case Delta is a vector of defence allocation perturbations summing to 0 and the QI are zeros of targets 1 to 10 but otherwise the total will make to 1 whether it is the highest value we have taken in the study.

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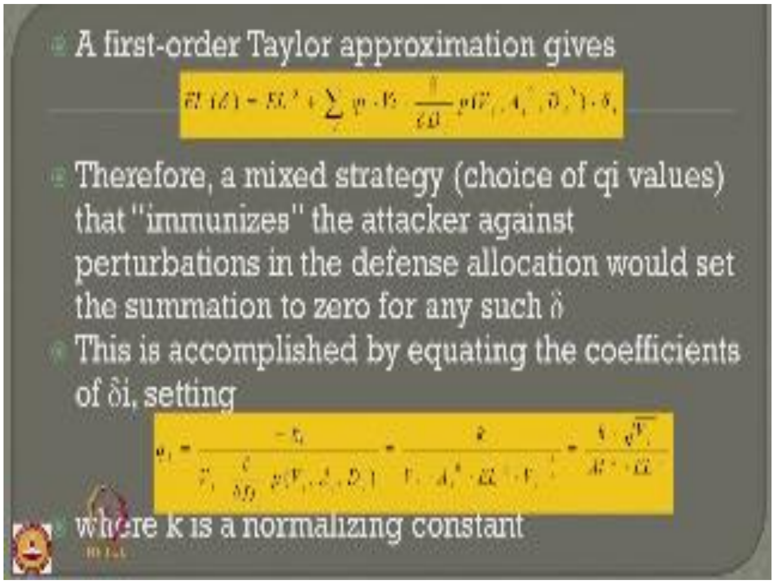

A first-order Taylor approximation can also be used to compute the expected loss which is given by the equation above. Therefore, a mixed strategy which will help us to choose QA values which immunizes the attacker against the perturbation is the difference allocation would set the summation to 0 for any such deltas, which is given by the equation here which is accomplished by equating the coefficients of delta I setting Qi as the equation on the right-hand side given here where in this equation the K is called a normalizing constant.

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Dear friends it is very important to understand and that a problem which is highly complex in nature can also be handled in a very simple manner by using the strategies available in mathematics like game theory. In modeling terrorism risk as we just now saw probability is not enough, analysis techniques borrowed from wartime operation research especially game theory or highly valuable, risk management can be also applied to such unexpected activities with an improved assurance of safety.

If that is an agreed statement by all of us then why cannot we apply this to oil and gas industries where the process is much well defined, thank you very much.

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