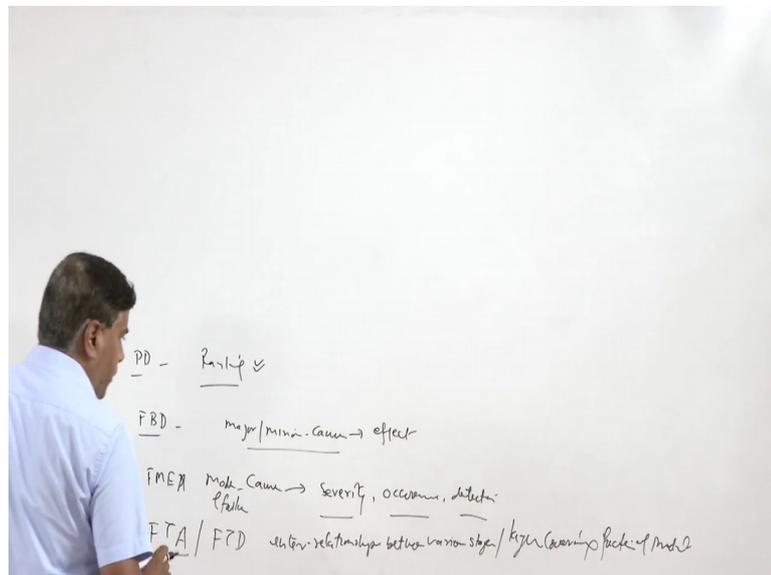


Failure Analysis & Prevention
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Lecture - 15
Industrial Engineering Tools for Failure Analysis: Fault Tree Analysis

Hello, I welcome you all in this presentation, related with the subject failure analysis and prevention and we are talking about the industrial engineering tools and their possible applications in the failure analysis. So far, we have talked about the Pareto diagram.

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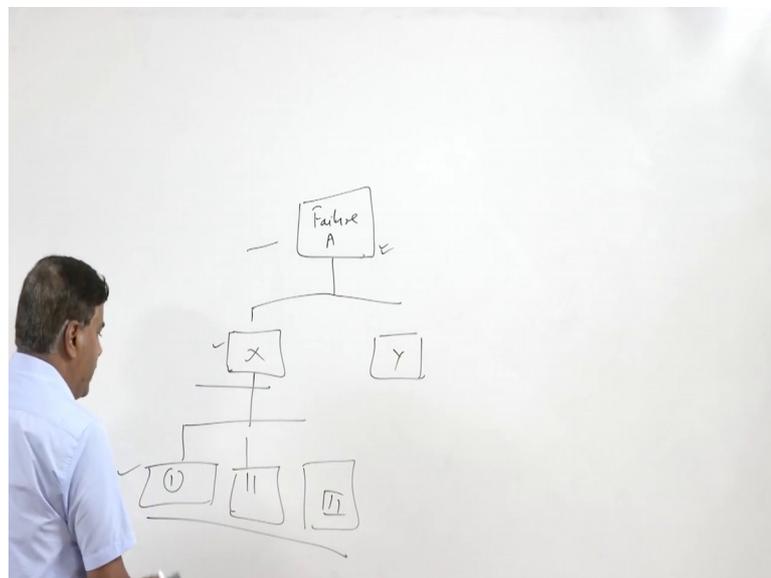
We have also talked about the Ishikawa diagram and in the last presentation I have talked about the failure mode and effect analysis. Actually the Pareto diagram talks about the ranking of the various factors or the causes, which are more important to have a particular kind of effect. While the Ishikawa diagram or that is also known as a fishbone diagram actually helps to identify the various major and minor causes for a particular kind of effect.

There is no severity there is no occurrence possibility, which is taken care of in case of the FMEA. FMEA talks about the various the modes of the failure the causes, and then the severity of the effect of failure, the frequency of occurrence, and the detection possibility how easy to detect or difficult to detect to avoid the failure.

So, it is simply relative ranking of the few causes or few factors with regard to their importance, maybe it is good or the bad effect, it simply talks about the various major and minor causes for the particular kind of effect. Here it provides the better insight of the kind of severity, if a particular cause leading to a particular failure mode and then it is occurrence and the detection possibility. And if we talk of the FTA fail fault tree analysis, or the fault tree diagram, it talks about the interrelationship; between various stages, or layers governing the function of a product or process function of product or process.

So, this is more important to see the sequentially to see sequentially, the various stages which can lead to the fault or improper functioning in a particular process or the product. So, the interrelationship between the various layers of a process or product can be understood in much better way, while understanding the different layers related with the product and the processes. It also explores the way by which a particular layer or particular function or particular step can fail so, for example like there is a failure of a one particular aspect A.

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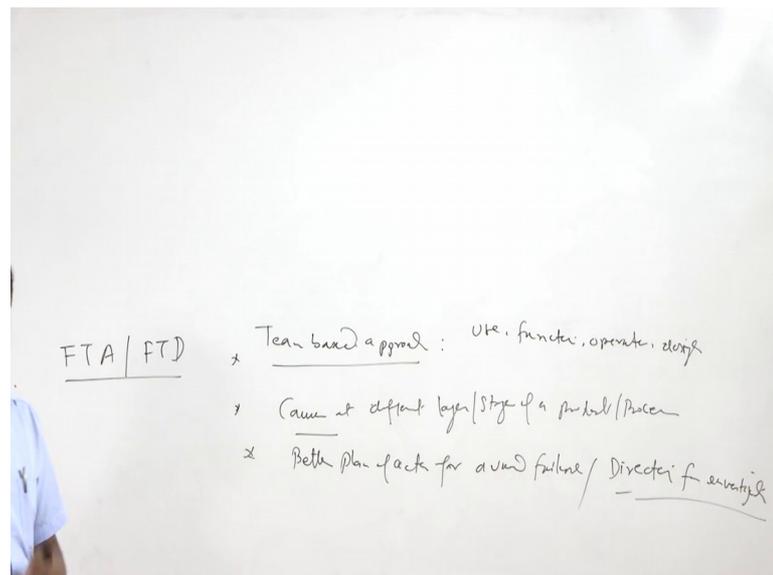
So, the failure of a can occur due to the various regions. So, like so in that case the region X and the region Y can be mentioned. But the X can effect, X can be caused by some other regions like 1, 2, 3, like this. So, the these are the three possible ways or one of the one of the three possible ways, or presence of all these three regions or just one

region is necessary for the for failure of the X and if X phase then component means the system is a whole, starts to perform starts to perform poorly.

Similarly, so, here if we see there is a like this is one layer, this is another layer, this is third layer, which is delivering the output. So, it helps to analyse a particular layer with regard to the causes which will be leading to the improper functioning of the particular process or the product. So, it helps us to provide the better insight with regard to the different stages, and with regard to the different layers; which are present in a product and which will also give us insight of the various ways or the causes by which a particular layer can fail.

So, this is what will be, this is what is in the just of the FTA or the fault tree analysis or the fault tree diagram.

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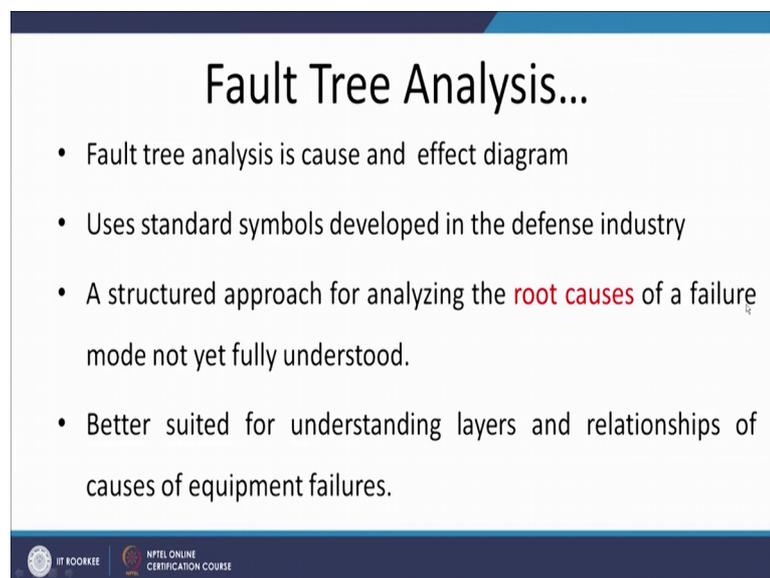
So, basically fault tree diagram is developed for this purpose. So, if we see this is also a basically team based approach; means, we need the people from the different the sections and the groups, who are concerned with the given product or a given process; means, they are familiar with the different aspects related with the use, function, operation, design, etcetera.

So, the people from the different groups are brought together and when it is applied it helps to identify the various causes at different layers or the stages of a product or

process, which can lead to the failure. And at the same time it also helps if we know the various causes and their interrelationship with the various stages, it helps in help us in developing the better plan of action plan of action for avoiding failures or it will give us the directions in which the investigation should be carried out. Direction for investigation of the failure analysis; so that the suitable root cause can be identified so, better understanding of the root causes of the failure and the better developing the better plan of action for avoiding those root causes so, that the failure can be taken care of.

So, going by this the fault tree diagram, basically it talks about the various causes at the present at the different layers which can lead to the failure of a product or of the process. So, fault tree analysis is a cause and effect diagram. And for this diagram for developing this diagram we use standard symbols. It is used extensively in safety in the field of safety and in the field of the defence industry in order to see what can go wrong at a particular stage so that the corrective action can be taken. It is a structured approach for analysing the root causes of the failure.

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Fault Tree Analysis...

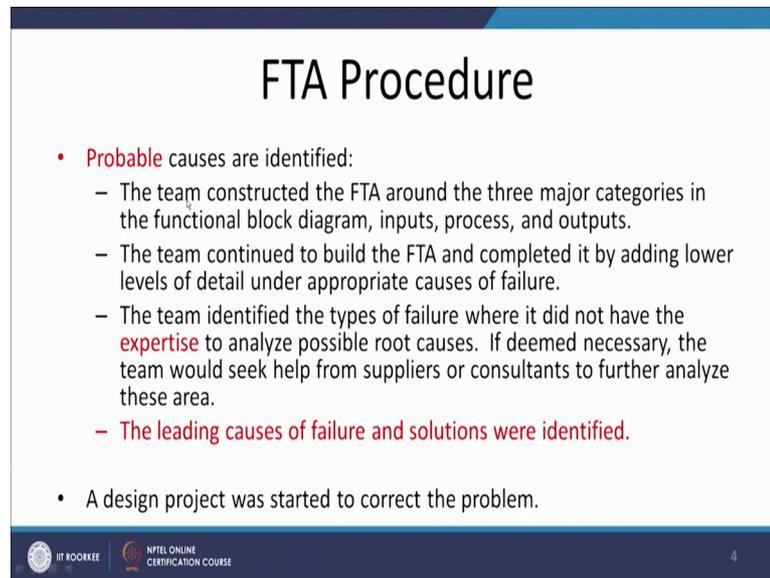
- Fault tree analysis is cause and effect diagram
- Uses standard symbols developed in the defense industry
- A structured approach for analyzing the **root causes** of a failure mode not yet fully understood.
- Better suited for understanding layers and relationships of causes of equipment failures.

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And especially those modes which are not yet fully understood and it is better suited for understanding the different layers, stages of particular process or product. And also helps in understanding the relationship between the different layers, and the relationship between the causes which can lead to the failure of the component.

So, the procedure of developing the FTA procedure for FTA fault tree analysis or developing the fault tree diagram, it basically relies heavily on the identification of the different components and the ways by which those components can fail.

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FTA Procedure

- **Probable** causes are identified:
 - The team constructed the FTA around the three major categories in the functional block diagram, inputs, process, and outputs.
 - The team continued to build the FTA and completed it by adding lower levels of detail under appropriate causes of failure.
 - The team identified the types of failure where it did not have the **expertise** to analyze possible root causes. If deemed necessary, the team would seek help from suppliers or consultants to further analyze these areas.
 - **The leading causes of failure and solutions were identified.**
- A design project was started to correct the problem.

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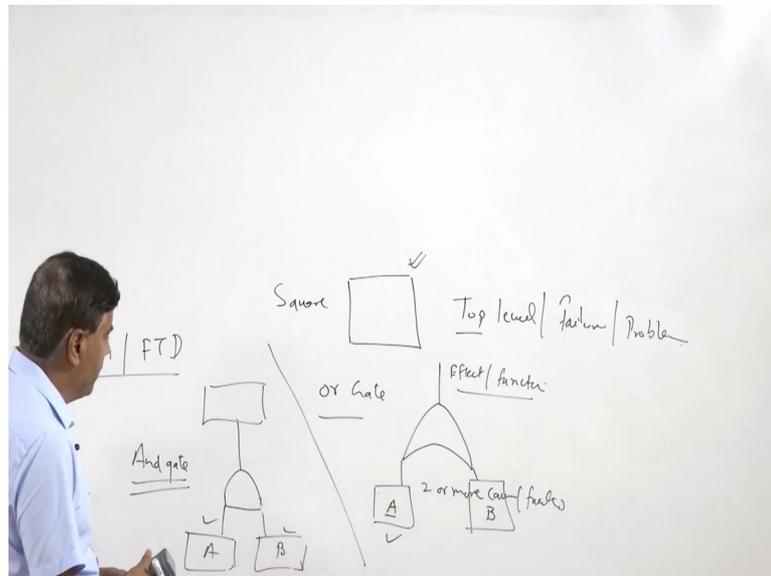
So, a sequentially we try to develop the flowchart or the functional body diagram to see what is the sequential way by which information flows or the product flows or the process flows for performing the process or the product performance effectively.

So, here team in for FTA the team is constructed or team is developed around, the 3 aspects like the functional block diagram, we need to see what are the different stages by which information regarding the product or the process flows in, what are the various inputs how the process works in, and what kind of the output is achieved.

So, then team develops the different causes for each of the layer. Like, at the input and at the process and output level. And then team identifies the types of failure where it did not have expertise to analyse the root causes. So, those areas which are difficult to be analysed in view of the expertise in view of limited expertise. So, the things can be left on also for certain sections, if they find that it is a difficult to analyse. So, if team necessary then team can take the help of the consultants for further analysis.

This when the FTA is carried out, it is it leads to the causes of the failure, and based on that solutions can be developed in order to avoid the failures in the service. So, basically the fault tree diagram uses certain standard symbols.

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One is like the square symbol which is used to define the top level, it is we can say the kind of failure or the problem which is to be addressed.

Then there is another symbol which is termed as or gate is indicated with the help of diagram like this. Or gate shows that this kind of effect particular effect, or particular function, failure of a particular effect or the function can be due to the presence of either of the two things or two or more thing. So, two or more causes or the factors needed for or gate; means, like this is the one factor, which we can say, this is this is one, and this is another.

So, what it says that if there is a like A and B component. So, failure of either A can lead to the malfunctioning or failure of the B can also lead to the main malfunctioning or improper functioning of the product. When this is the situation then we use or gate, and then there is and gate. These are symbols and gate is used when we work with the and gate symbol is like this.

So, and gate is used when we have certain factors or the components, like A B or C. It can be any there can be any number of the components or the subcomponents A B C. So,

the product of or improper functioning of a particular stage can occur when the all three causes has to be present, or both these two causes has to be present. So, if we see if they are just two components, then failure of the both will be needed for improper functioning, otherwise component can keep on working well.

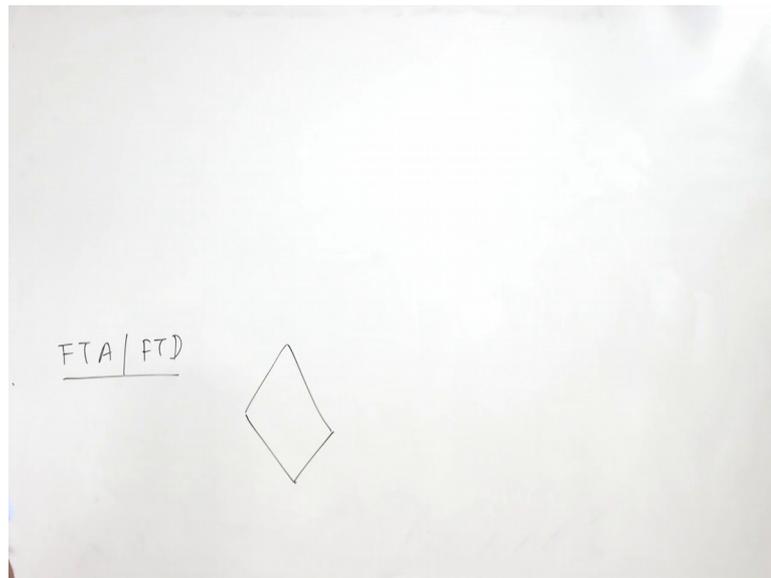
While in case of or gate, if failure of any of the two occurs, then it will lead to the improper functioning of the particular stage, or particular part or particular process. So, here then the another symbol. So, this one is used at the top level, or at the bottom most level. this one is used to show the relationship between the various causes and their functions. Like, if both causes are present both causes or more than two causes should be present for improper functioning, then they will be connected with the and gate. If one of the so many other causes; need to be present for improper functioning of the product then or gate is used.

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So, this circle is used for identifying those events or steps which cannot be broken down, broken down further into the lower elements. So, means these points become the actionable points and the action is taken on these steps in order to avoid the problem or avoid the failure which has taken place. So, that system can be brought in to the working condition. So, these are the few symbols there is one more symbol apart from these and gate or gate circle and square.

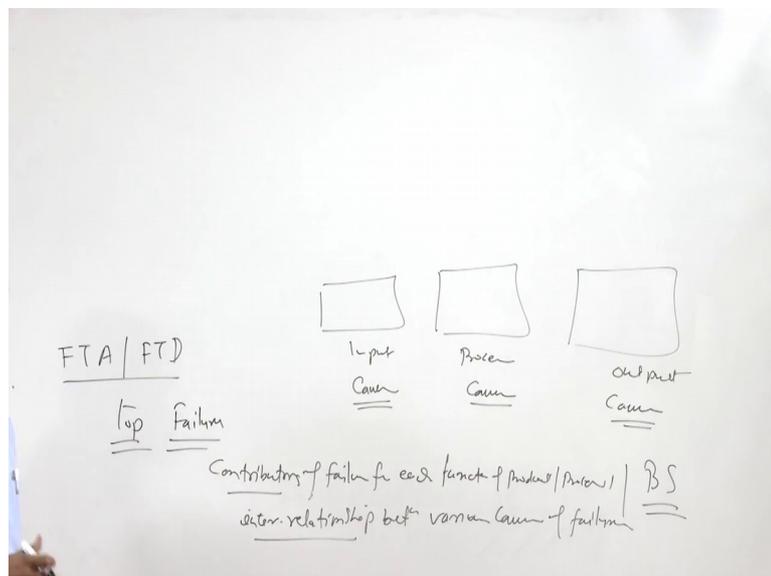
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And this one is the diamond shape. Diamond shaped is used to for those events and the activities which cannot be analysed either due to the limited expertise or due to any other reason.

So, this activity these are the diamond is used for showing those activities which are not analysed, due to various reasons. So, these are the symbols which are used for developing the fault tree diagram. So, for developing the fault tree diagram, important step is identify what is the kind of failure that is to be investigated.

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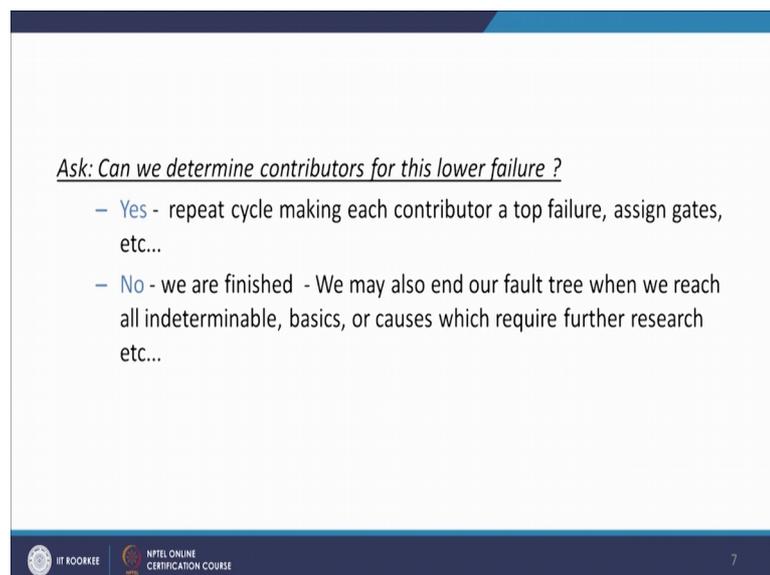


So, at the top we mention the failure. And thereafter we try to see the we try to develop the functional block diagram for a particular product or for the process for which fault tree diagram is being developed.

And in light of this these are functional block diagram, we try to list the causes of failure. So, like if there are three broad components in a product. One is taking input, second is processing the information, and third is giving the output. Then the various causes for the failure of the input things are identified, various ways by which the process can fail are identified. So, the causes for failure of the process are identified and the causes for failure of the output are identified. And all these may be independent of each other.

So, these causes are the we can say the contributors of failure for each function of product or process are identified and for this purpose, only we need the brainstorming so that the each function or a step can be analysed sequentially. And also, here the interrelationship between the various causes is also identified; interrelationship between the various interrelationships between various between various causes of failure is also identified. So, and then this information is used to subsequently to develop the fault tree diagram. So, link the contributors to the top failure with the correct kind of gate which can be and gate or gate.

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Ask: Can we determine contributors for this lower failure ?

- Yes - repeat cycle making each contributor a top failure, assign gates, etc...
- No - we are finished - We may also end our fault tree when we reach all indeterminable, basics, or causes which require further research etc...

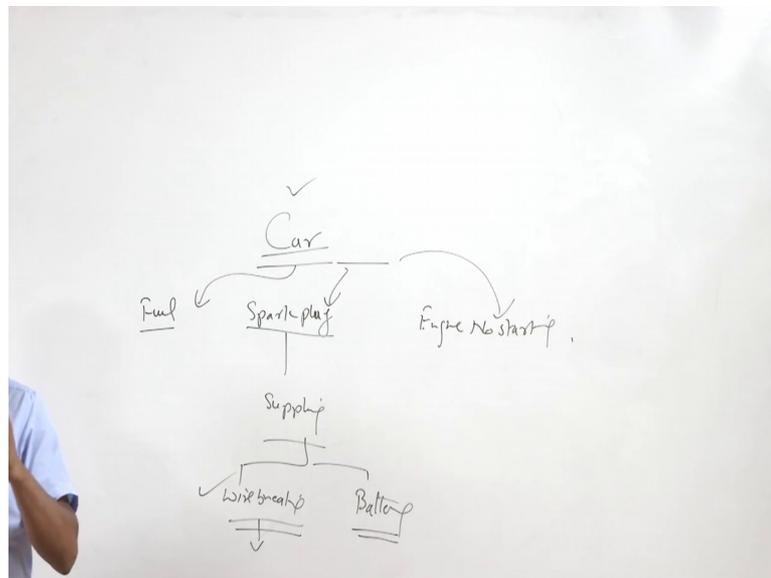
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Now, you see we need to ask certain questions like; we need to from the functional block diagram, the different there can be the different components which will be providing the

input for proper functioning of the product. So, we need to keep on breaking down the various causes to see up to what extent these causes can be break broken down, and which will be coming through the improper functioning of the various subcomponents.

So, we need to ask during the breaking down of these causes, we need to ask can we determine the causes or the contributors for this lower failure because the top failure which is really is stopping the working due which can stop the working due to the various reasons.

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For example, say if it is car can stop working due to the various reasons. Like, there is no fuel or spark plug is not working or engine not starting or; so, say broadly these are the three. One fuel is not there, or the spark plug is not working or engine itself is not starting or there is some breakage of the wires. So, this is one thing say this spark plug is not working, because it is not getting supply. Now supply it is not which can happen due to the wire breaking of the wire or even if the wire is intact the battery, battery is not well charged.

So, likewise this is the top cause that the car is not working; which may not work due to the improper functioning of the spark plug. And spark plug may not function due to the proper due to the lack of the power supply is not getting and supply it may not get due to the breaking of the wires. And or it can happen also due to the battery is not charged or

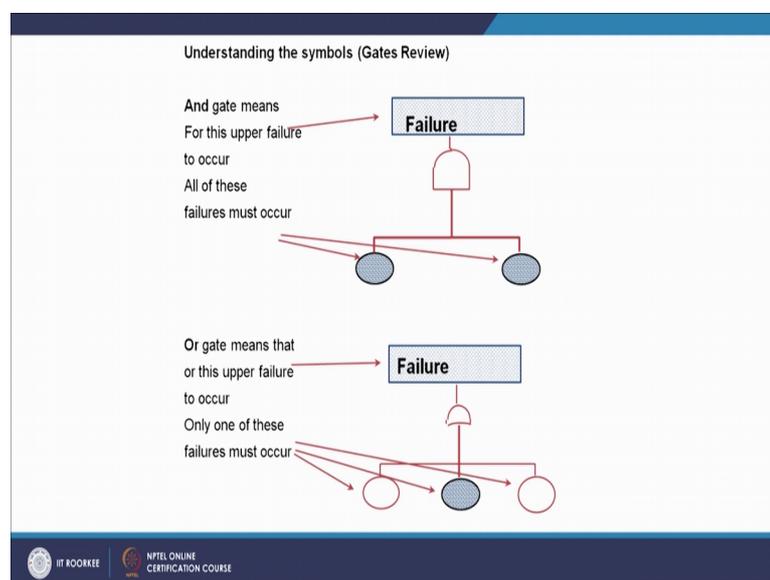
say the wire can break again due to the number of reasons related with like insulation circuiting has taken place.

So, means for the top cause there can be number of the lower causes, or the lower failures. And we need to keep the lower failures breaking down until we find that now we have reached to the actionable level of the lower level of the failures, where we can take the action in order to avoid in order to bring the system in proper working condition.

So, so, we need to ask like can we determine the contributors for this lower failure, and if we find no then we need to stop there. Otherwise if we can if we get the answer like yes, then repeat the cycle of making each contributors as a top failure and then assign gates, and then same thing will be repeated if the answer is no, means we are finished.

And now we may also end our fault tree diagram, when we reach to the all determinable, indeterminable basic or the root causes on which we can take the action further or on which we can do the investigation to find out the cause. So, this is what is there in schematically what has been shown what I have.

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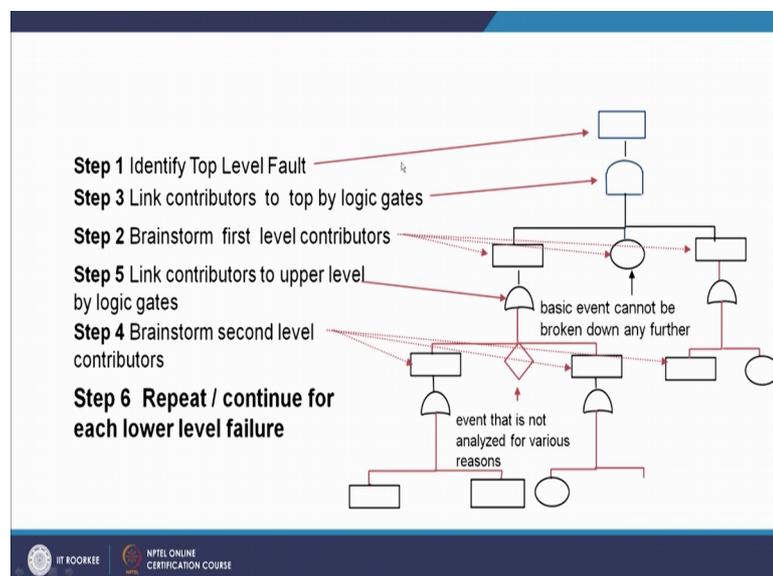
So, this is the same what I have described in form of and gate and or gate.

So, this is the top-level failure. The top-level failure in case of gate both these lower level functions and both these lower level failure should occur for occurring the top-level

failure. So, here when this is the case like. There are two lower level failures, and both should occur for the failure of with one this top level.

So, and gate means for upper failure to occur all these failures must occur. So, both these failures must occur for the failure of this top-level failure. While in this case, in or gate is used when for the upper failure to occur one of these failures must occur; means, any of these three failures can lead to the failure of the upper level failure. So, this is how the various causes are related with the various related with the functionality of a particular level of the failure.

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So, this is the like say is schematically it has been shown the different the layers of the fault tree diagram, and the how it is developed. For example, at the top what will be mentioning identify the top-level fault? Like system is not working; which may not work due to the various contributors. So, link the contributors to the top level failure by the logic gates. So, logic gate here is and gate. And gate means, there are 3 contributors 1, 2 and 3. So, these 3 contributors in this case, the presence of all these 3 is needed means all these 3 contributors should fail for improper functioning of the top failure. failure of the top level failure.

So, here in this case these have been related with and gate. So, through the brainstorming only this will be identified if failure of any one of these parts or the component can lead to the improper functioning or failure of all these three is needed for improper

functioning. So, that is what is identified through the brainstorming. Then these, these will again be considered as a top-level failure for further breaking them down.

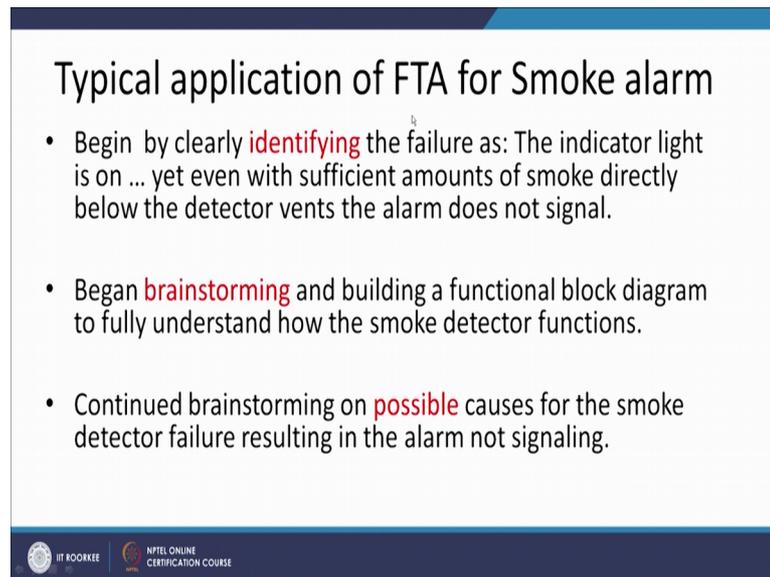
So, here if this one is broken down further we find again then or gate. Here of means different contributors for or gate are identified. Means, different contributors are identified and they are corrected accordingly. Say, for here for this level failure for the failure of this component in the in the sequence, there is or gate which means the failure of either this one, or this one can lead to the failure of the component. This is the second level contributors. And in this case, they are connected through or gate; means, if any of these two fail, then it will not be means this also one of the function and if this fail then it will be leading to the failure of this upper level contributor, upper level component.

And then, here it is further broken-down like this second level contributor is further broken down through or gate, and we find that there are two more components. And failure of any of these two can lead to the failure of this level of the contributor and this can lead to the improper functioning of the component as a whole.

So, so, if we see all these are actually in this schematic indicating that this is the main system which is showing that the system has failed and which can occur due to the various level of the failure of the various level of the contributors, and the various causes are identified for each level of the failures and they are interrelated with each other to see.

If both failure of one or failure of more than one components is required for failure of the system or just failure of one of the components can lead to the failure of the system. So, accordingly and gate and or gate are used. And this cycle is repeated until we reach to the situation; where we reach to the situation where we get the circles means circle is indicating that we have reached to the situation where it cannot be broken down further.

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Typical application of FTA for Smoke alarm

- Begin by clearly **identifying** the failure as: The indicator light is on ... yet even with sufficient amounts of smoke directly below the detector vents the alarm does not signal.
- Began **brainstorming** and building a functional block diagram to fully understand how the smoke detector functions.
- Continued brainstorming on **possible** causes for the smoke detector failure resulting in the alarm not signaling.

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So, there is one example where the functional tree diagram in fault tree diagram, is applied for the smoke along improper functioning. So, indication is that indication here is that despite of the smoke in the room, alarm did not smoke alarm did not give the siren this was the; so, the fault was the no alarm despite of the smoke in the room, smoke alarm did not give any siren.

So, for this purpose for the brainstorming was carried out and the functional block diagram was developed to understand how the smoke detector functions. And thereafter brainstorming was further carried out to see what are the various causes for the smoke detectors, means due what are the various causes possible causes for the failure of the smoke alarm at the input level process level or at the out-output level. So, there must be some presence of some cause because of which the alarm did not give the signal.

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FTA Example: Smoke Detector

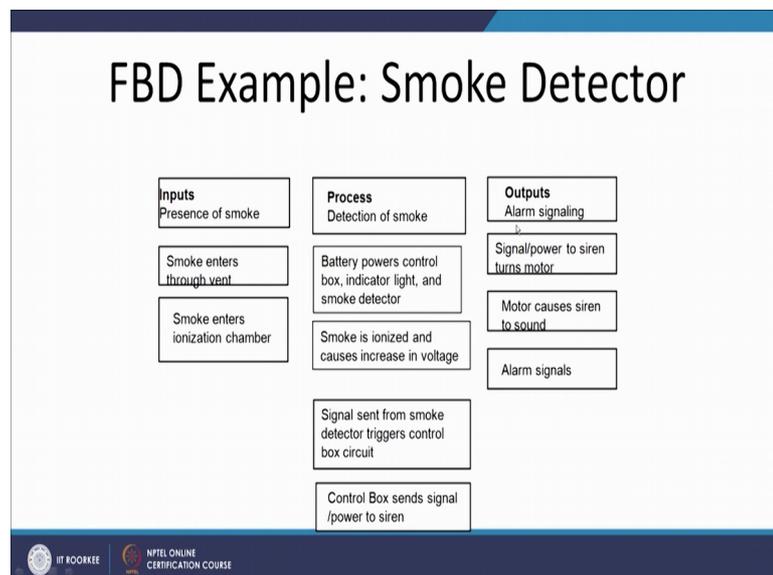
- **Failure:** The indicator light is on... yet even with sufficient amounts of smoke directly below the detector vents the alarm does not signal.

Before we begin a Fault Tree Analysis, our first step should be to construct a Functional Block Diagram.



So, here the failure was like an indicator light is on; yet even with the sufficient amount of the smoke directly below the detector, vents the alarm does not signal. Means, there was no siren. So, for this purpose to analyse this failure, the fault tree analysis was carried out, and first step in this is the development of the functional block diagram.

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So, functional block diagram for the smoke detector was developed, through the brainstorming and it was found that is smoke detector gets the input from the inputs in form of the smoke. And smoke is smoke reaches into the detector through the vents,

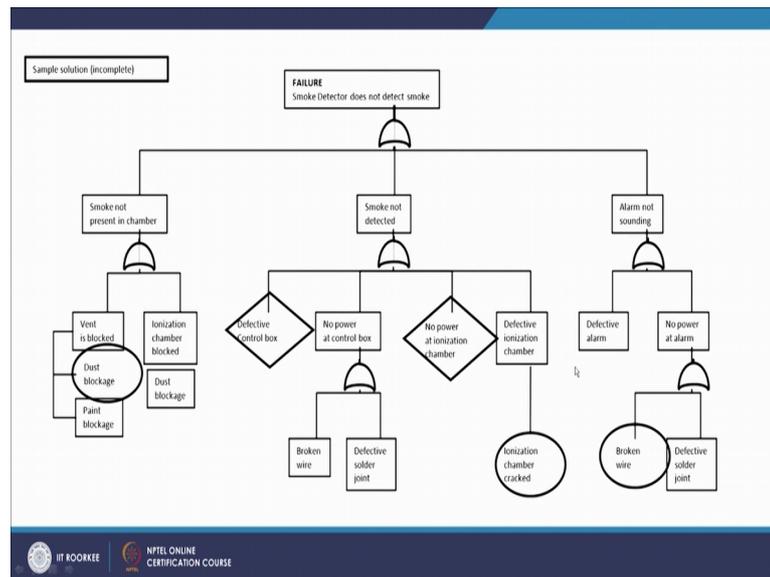
smoke enters through the vents into the smoke detector, and smoke enters the after entry through the vents smoke further enters the ionization chamber.

So, smoke is there outside in the outside the detector. It enters through the vent into the ionization chamber. And the process is what the smoke detection of the smoke is the processing of the information. Like, battery powers battery powers the control box indicator light smoke detector smoke is ionised, causes the increase in voltage. Whenever there is a smoke in the ionisation chamber smoke is ionized and which in turn increases the voltage. And which in turn gives the signal, signal is sent from the smoke detector, triggers the control box circuit. And box circuit sends the signal to the power to the siren. And output appears in form of the alarm signal in form of siren.

So, signal or power to the siren turns the motor causes siren to sound and the alarm signal is achieved. So, this is the functional block diagram, which shows that is; so, first smoke should enter into the vent. And if the vent is blocked, then smoke will not enter into the vent. And if the vent ionisation chamber is blocked then smoke will not enter also into the ionisation chamber.

So, finally, smoke has for a smoke to be there in the ionisation chamber, it should enter first into the vent, and then it should enter into the ionisation chamber. Any blockage will lead to the improper functioning. The same history here power is not there or a smoke is not ionised, or the power control is a problem. And therefore, it is not able to send the signal. So, this is the sequence, or signal is not I mean signalling system is not working motor is a problem, because of which it is not giving the signal.

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So, this is the kind of chain which needs to be looked into. So, the failure is here smoke detector does not detect the smoke. So, these are connected through or gate. Or gate means either smoke is not present in the chamber, or smoke is not detected or alarm is not sounding. These are the through three possible cases. Because of which we are not able to get the smoke detector is not able to detect the smoke.

So, here we see the smoke is not present in the chamber despite of being present in the room. So, there can be various causes, again it is they are connected through or gate because presence of any of the cause can lead to the absence of the smoke in the chamber. Like, vent is blocked, or ionisation chamber is blocked. In both these cases, the smoke will not enter into the chamber for the ionisation purpose.

In the processing section smoke not detected. Again, it happen it can happen due to the various reasons like, defective control box no power to the control box, no power for no power at the ionisation chamber or defective ionisation chamber. So, things are not working in the ionisation stage or detection stage.

And thereafter no power no power at the control box means again there can be two regions, broken wire or defective shouldering joint, or here defective ionisation chamber can be due to the ionisation chamber crack or any other similar kind of the regions. So, here it shows that it cannot the crack the cause cannot this one cannot be lower level cause cannot be broken down further. So, it has been shown by the circle alarm signal is

not working means, again it is connected through or gate. And here alarm signal cannot work may not work due to the two reasons. One is alarm is defective, or there is no power to the alarm no power to the alarm can be due to the two regions one is broken wire or defective shouldering joint which is giving supplied to the power.

So, likewise, we can keep on breaking down the various lower level causes, and until we find that we have reached to the some actionable step and things cannot be broken down further. So, this is how will be able to show the interrelationship between the various sequentially steps through which particular system works in two. And once if this one is established it will help us to pinpoint the kind of things, which are not working properly so, that we can take the corrective action on that particular part.

So, now I will summarise this presentation. In this presentation basically, I have talked about the quality analysis or the fault tree diagram. We talks about the various steps and the methods which are used for the fault tree analysis or for developing the fault tree diagram. The fault tree analysis helps in understanding the relationship between the various causes at the different levels. And also helps in understanding the interrelationship between the various causes which can lead to the improper functioning of the component.

Thank you for your attention.