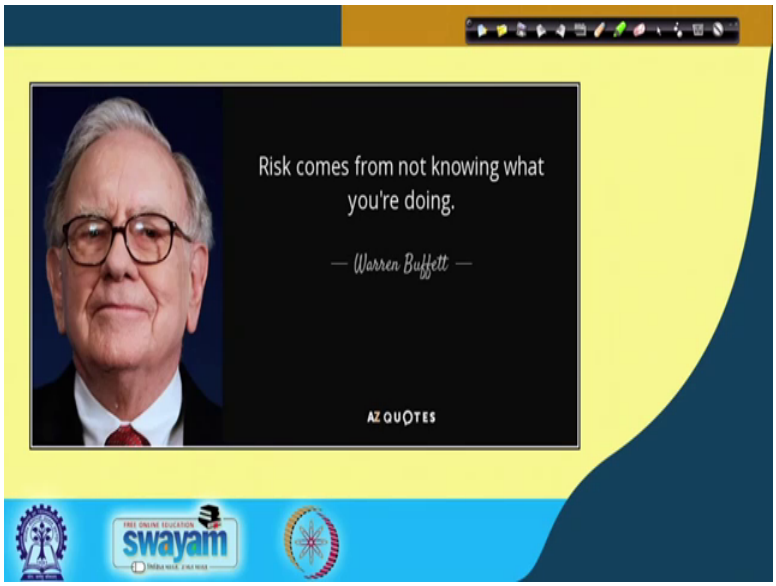
Six Sigma
Prof. Jitesh J Thakkar
Department of Industrial & Systems Engineering
Indian Institute of Technology, Kharagpur

Lecture - 37
Failure Mode Effect Analysis (FMEA)

Hello friends I welcome you to our ongoing Six Sigma journey. And we are in the analyze phase of our DMA IC cycle which is used for achieving the six sigma level in manufacturing and service industry.

As a part of analyze phase we have talked about various topics like; hypothesis testing, ANOVA analysis, multi vari studies. And so on. And now as a part of lecture 37 we will talk about a very important and interesting topic that is; Failure Mode Effect Analysis, typically called as FMEA.

(Refer Slide Time: 00:59)



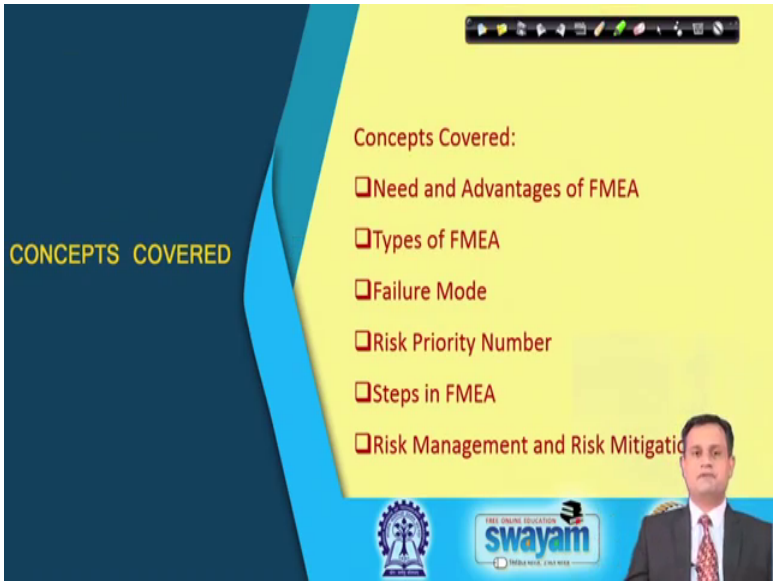
So, let us begin with a very good quote given by Warren Buffet “Risk comes from not knowing what you are doing”. So, this is very true in all the facets of the life that when you are not aware of what you are doing then you are inviting very high level of risk.

So, this is something where we need an approach like FMEA that can help us to even address many critical issues right at the design stage design of the product or design of the services.

(Refer Slide Time: 01:36)

So, we had a long discussion on multi vari studies which can be used as a complementary tool for ANOVA analysis. You can screen out the important and unimportant factors. And then can only focus on important factors as a part of ANOVA analysis. And we had seen the construction and mini tab application of multi vari charts.

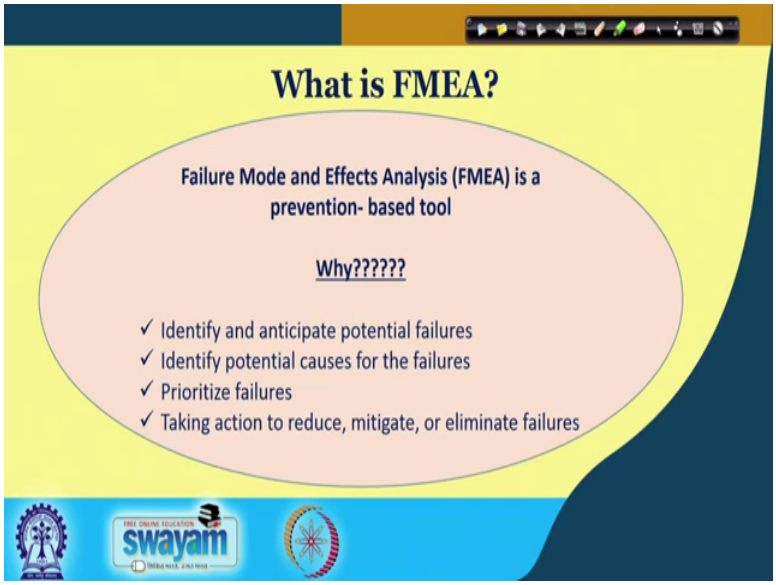
(Refer Slide Time: 01:59)



Now, as a part of this lecture FMEA we will talk about need an advantages of FMEA, types of FMEA, failure mode risk priority number steps in FMEA. And how do you

basically derive risk mitigation and management plan. And this we will try to see through a case study.

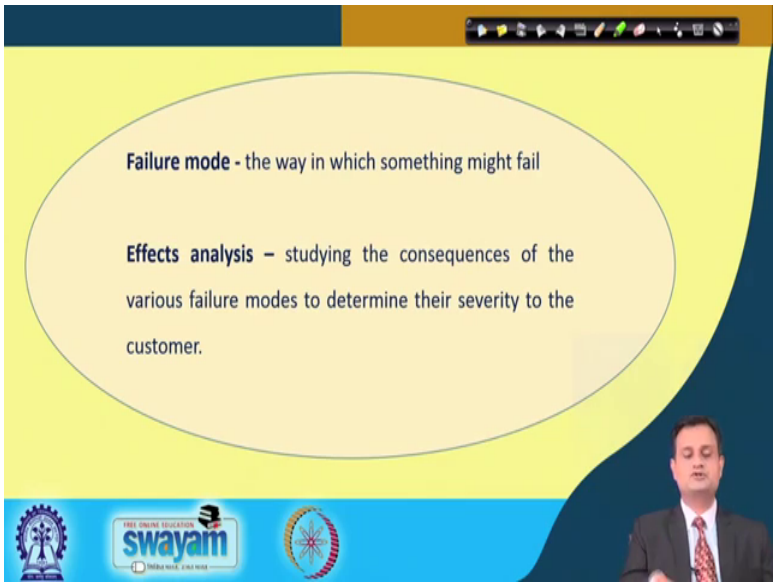
(Refer Slide Time: 02:24)



So, what is the FMEA the first question? If you just look at the name it is failure mode effect analysis. So, you can just say that I am trying to analyze something called failure mode. And what is it is effect on the entire system and when I conduct this analysis I call it as FMEA. So, you can derive the meaning through the name also.

So, typically FMEA in a technical term is a prevention based tool. And then the question comes why? So, we want to identify and anticipate the potential failures before actually we go for the actual manufacturing of the product design of the process or services. Identify potential causes for the failures prioritize the failures. And taking action to reduce mitigate or eliminate such failures and hence it system wide say implication system wide impact.

(Refer Slide Time: 03:29)



So, this is what exactly we try to do as a part of FMEA. Now the first thing is to understand what is failure mode. So, failure mode the way in which something might fail. So, we do not know let us say at present I am delivering a lecture and now there is a sudden interruption and I am discontinued. So, there could be many reasons maybe failure of electricity, maybe recording system, ahead gone out of control or many other thing.

So, I need to identify that what is the way in which something may go wrong or might fail. Effect analysis studying, the consequences of the various failure modes to determine their severity to the customer. So, now, it is not only to identify the failure mode, but what is it severity. So, for example, again if my recording gets interrupted maybe because of some say problem in the recording system or electricity problem. Then what is the consequence or severity? Because this is an offline recording fine I can start again and I can do it.

But assume this is online and directly I am delivering the talk to the people then such kind of interruption say may hinder the knowledge acquisition process. And student may not say feel comfortable with the too much interruption. So, it all depends that what is the situation and what is it is effect and we need to analyze the impact system white consequence of this effect. And then we can do some rating for a particular failure mode and try to appreciate the severity.

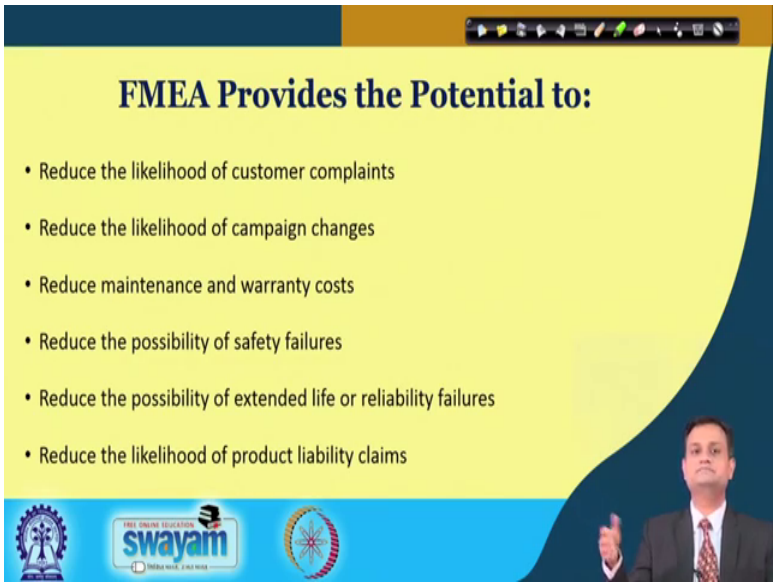
(Refer Slide Time: 05:18)

So, there are various reasons for FMEA get right the first time. I do not have the time to go for rework rejection failures at the customer end loss of brand and so many things. Identify any inadequacies in the development of the product. So, right at the product design and development stage we all already seen one of the important tool QFD.

Now many a times QFD and FMEA they are used as an integral approach even to help people industry to design their product processes manufacturing or service in a more robust manner. Tests and trails maybe limited to a few products regulatory reasons. We cannot say exclude many regulator reasons like safety norms environmental norms government say various regulated policies. And we need to also incorporate these in the design of the process or product.

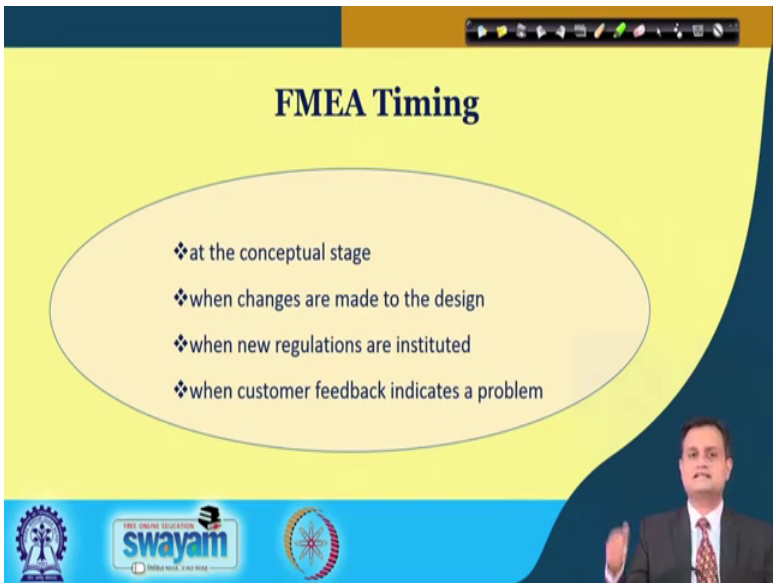
Continuous improvement is my strive and that is why we are talking about six sigma. Preventive approach I am trying to prevent as much as possible by addressing the potential failure modes. Team building because you need the cross functional knowledge people need to come together and then they try to conduct the FMEA analysis. And required say procedures that can even be laid down. So, this is the importance and reasons why we need FMEA.

(Refer Slide Time: 06:54)



There are many potentials benefits when you conduct the FMEA like reduce the likelihood of customer complaints already you have taken care couple of things many things at the design stage because of which failure may take place at the end of the customer and this will help you to minimize the customer complaint. Reduce the likelihood of say campaign changes, then reduce maintenance and warranty costs possibility of safety failures possibility of extended life and product liability claims can even be reduced.

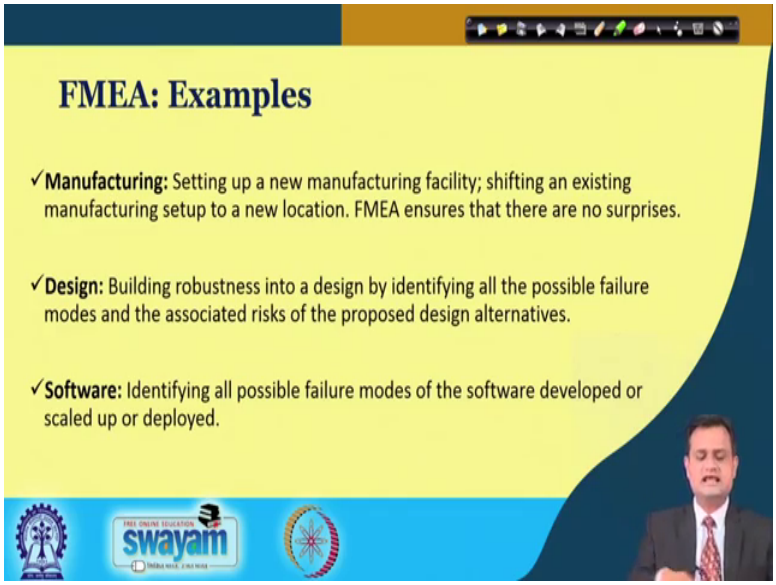
(Refer Slide Time: 07:31)



Now, as I mentioned that FMEA can give you the best advantage if it is employee if it is conducted at the right time. So, the first is right at the conceptual stage when you are conceiving a product at the conceptual stage or process it is very important that you do the FMEA analysis in order to get rid of many constituencies as an outcome of certain failure modes. When changes are made to the design now you have the design you want to modify the design again.

This is the juncture where you need to supplement or support your process with the analysis like FMEA. When new a regulations are instituted whether at the organizational level it is technical HRor maybe the national level then again you need to see that what could be the consequences. And when customer feedback indicates the problem then you may revisit your FMEA and try to dig out that where the failure mode and consequences are not properly addressed.

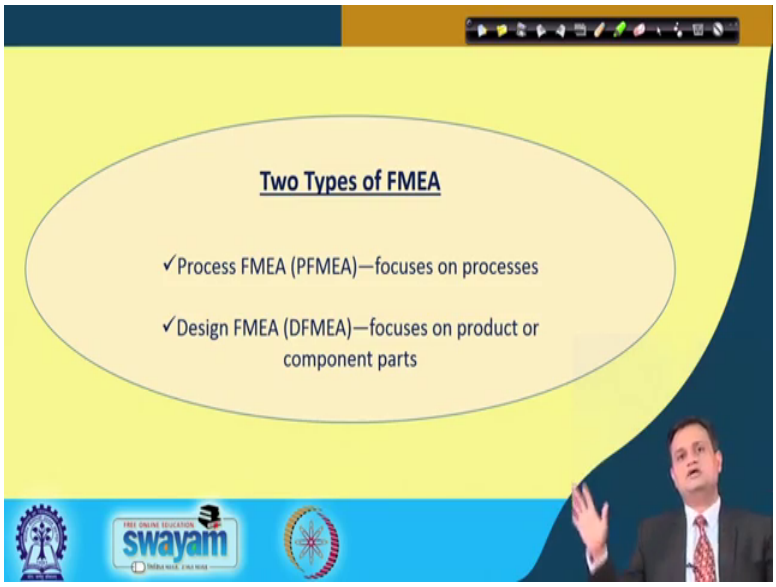
(Refer Slide Time: 08:45)



Just see the example as I mentioned you can use of FMEA in manufacturing and service industry. And it will reap the equal advantage in all the facets. So, manufacturing let us say setting up a new manufacturing facility shifting and existing manufacturing set up to a new location. And FMEA ensure that there are no surprises it means you can go ahead execute your plan without much disturbance and you feel more confident in going for the change over.

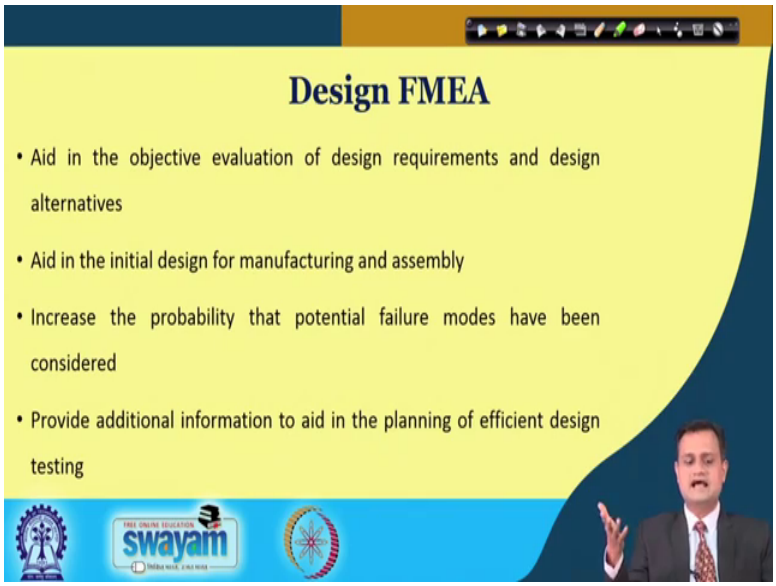
Design you want to build the robust product it means it is less sensitive to the noise and external factors. So, again if you address some of the potential failure modes right at the design stage this can be achieved. Software identifying all possible modes of the software developed or scaled up or deployed. Again many software companies they develop fantastic robust software which can give the uninterrupted service and make the user friendly experience to the user and this is where again FMEA can help.

(Refer Slide Time: 10:00)



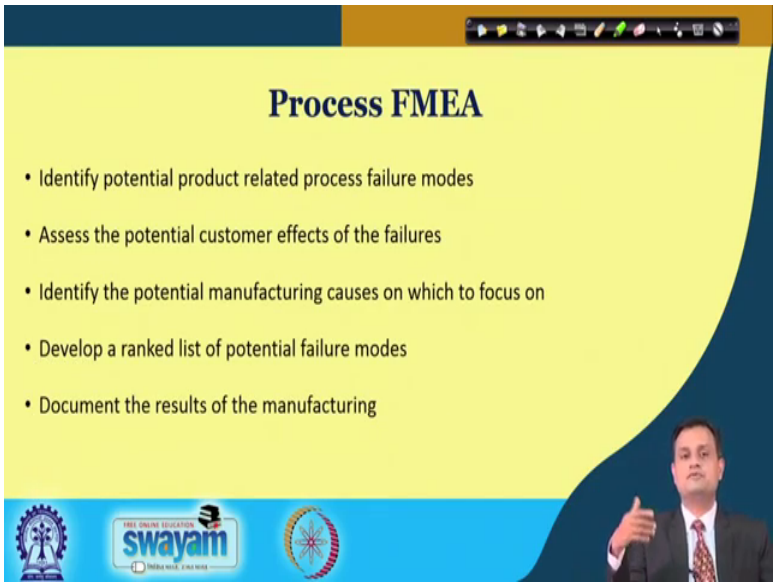
So, broadly you have two types of FMEA number one is process FMEA and typically name suggest it focuses on the processes and number two is design FMEA. So, I would use this FMEA for the conceptual or the design phase of the product.

(Refer Slide Time: 10:20)



And design FMEA the objective as I mentioned is to address the failure modes right at the design right at the concept stage. And it increases the probability that potential failure modes have been considered.

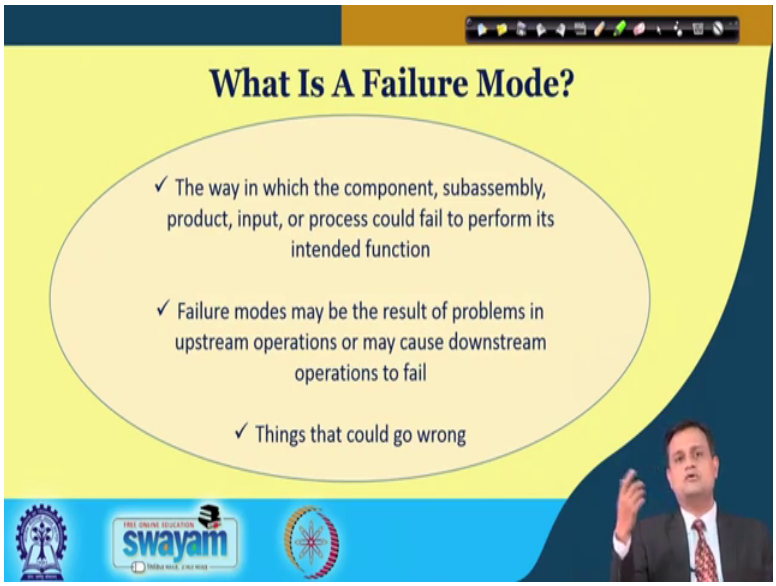
(Refer Slide Time: 10:36)



So, my product would be robust. In case of process FMEA identify potential product related process failure modes. Now you have a product to be manufactured, but this product cannot be manufactured smoothly if your process cannot work uninterruptedly. And then you need to identify what could be the probable failure modes.

And who will address this failure modes or take the ownership of this failure modes. So, whether you need to modify the design of the process you need to have the redundancy in the process or you need to say have better preventive maintenance plan. So, these are the issues that you can address when you talk about the process FMEA.

(Refer Slide Time: 11:19)



So, now let us try to see the technical term failure mode and how it is expressed. So, the way in which the component sub assembly product input or process could fail to perform it is a intended function. So, suppose you are using the washing machine. Now; obviously, the purpose of washing machine is to ensure the best possible cleaning and the dirt removal.

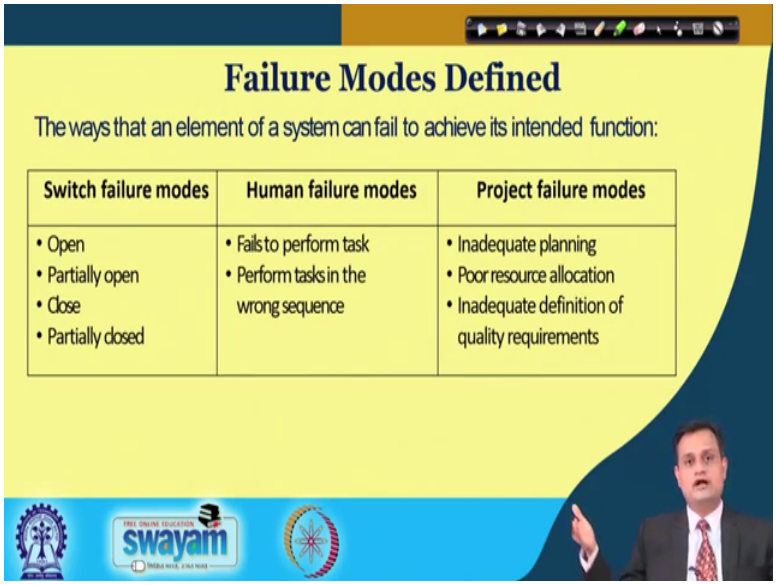
Now because of some error you may see you are using fully automatic machine sometimes there is some error and your laundry washing is interrupted. So, now these are some of the things whether it is because of electronic circuit or maybe something got strucked and your drum is not rolling.

So, this is something where failure mode analysis can help you to design your product in such a way that such kind of interruptions failures can be avoided. failure mode may be the result of problems in the upstream operation or may cause downstream operation to fail. Please remember it is not only about your organization manufacturing, but if something very typical not addressed right at the supplier end then downstream will also suffer.

I just give you an example that suppose you are purchasing the steel plate for manufacturing fuel and breaking tubes and this steel plate has some thickness within certain tolerance limit and it is supplied by some vendor. Now, if there is a too much variation if the thickness then when you will use the steel strip for manufacturing tube it will get stucked somewhere.

Either in the stretching rolling meal or maybe the any link chamber somewhere. And then you will find that your production is getting interrupted and there are too many breakdowns and every time you will encounter a setup time and the cost. So, in brief I would say that things that could go wrong and this is something which is called failure mode.

(Refer Slide Time: 13:33)

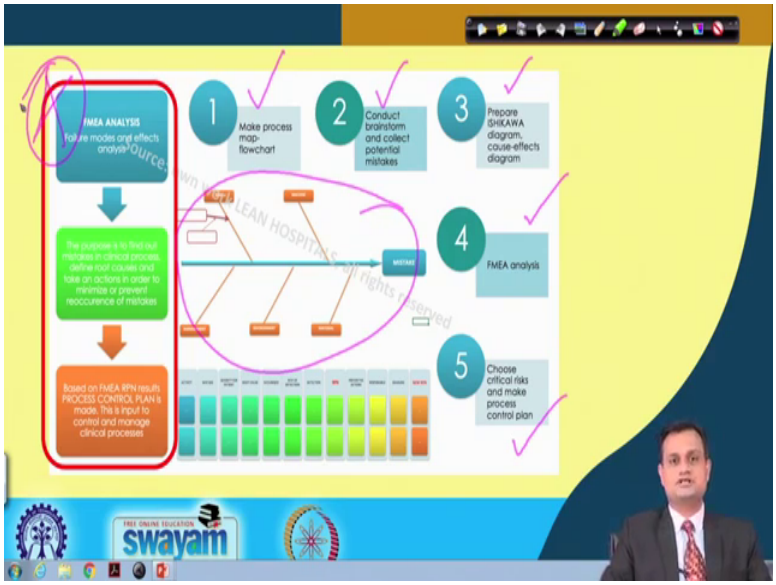


You can have some examples also so let us see failure modes define. So, switch failure mode open partially open close partially closed. These are the possible ways in which a system can fail. Human failure modes fails to perform task perform task in the wrong sequence your operator, your manager, and this is where the possible failure modes we can figure out.

Project failure modes inadequate planning you have not created your charter appropriately your blueprint is not strong. Poor resource allocation, inadequate definition of quality requirements and there could be later on conflict between the client and the

project executing agency and this may lead to some of the failures. So, we have a typical FMEA process.

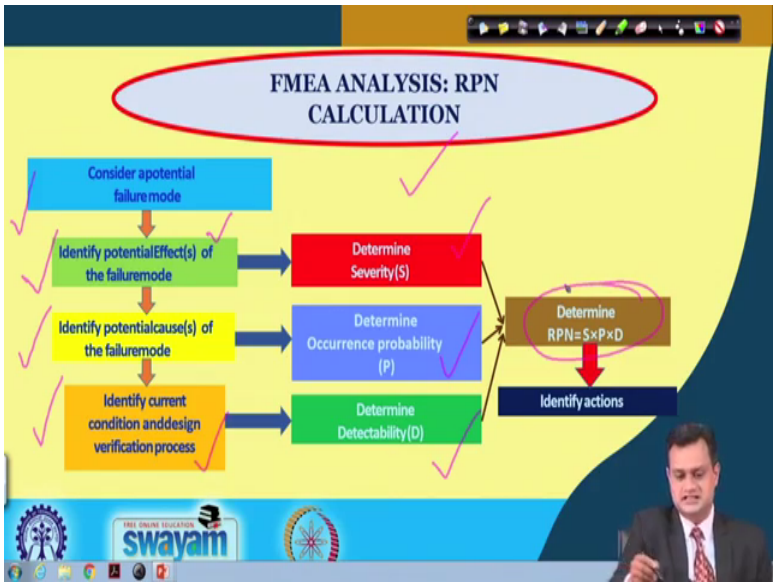
(Refer Slide Time: 14:29)



And what you can see here that you have make process map flowchart. Second is conduct brainstorm and collect potential mistakes prepare ishikawa or fish bone or cause and effect diagram. This is what it is shown here. And then you conduct the FMEA analysis and choose critical risks and make process control plan.

So, this step four physically is explained here. So, this is my FMEA analysis. And typically I try to figure out that what could be the potential failure mode what is it severity what are the consequences. And this is we try to do by having some very simple calculation like this.

(Refer Slide Time: 15:20)

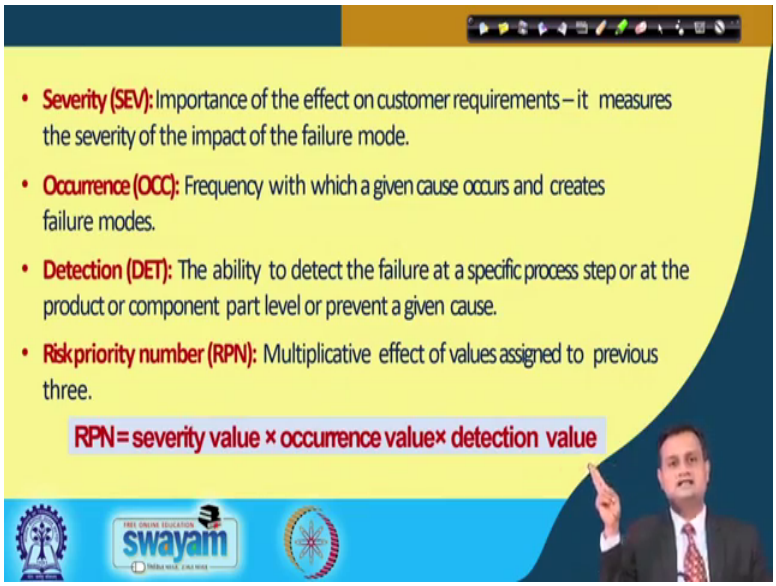


So, this is my FMEA analysis and typically RPN calculation. So, you consider the potential failure mode you have already conducted the cause and effect ishikawa analysis. Now from machine point of view material point of view person point of view you have collected the various potential failure modes.

And now consider the potential failure modes then identify potential effects of the failure mode then identify potential causes of the failure mode. And then identify current condition and design verification process. When you do this identify potential effects of the failure mode what you get is the severity denoted as S. When you do this identify potential causes of the failure mode what you get is the occurrence probability.

And when you identify current condition and design verification process what you get is the detectability. So, you have three terms to calculate your risk priority number called RPN that is severity, occurrence probability, and detectability. So, this is something which is very interesting that I consider three different important factors and just see this.

(Refer Slide Time: 16:43)

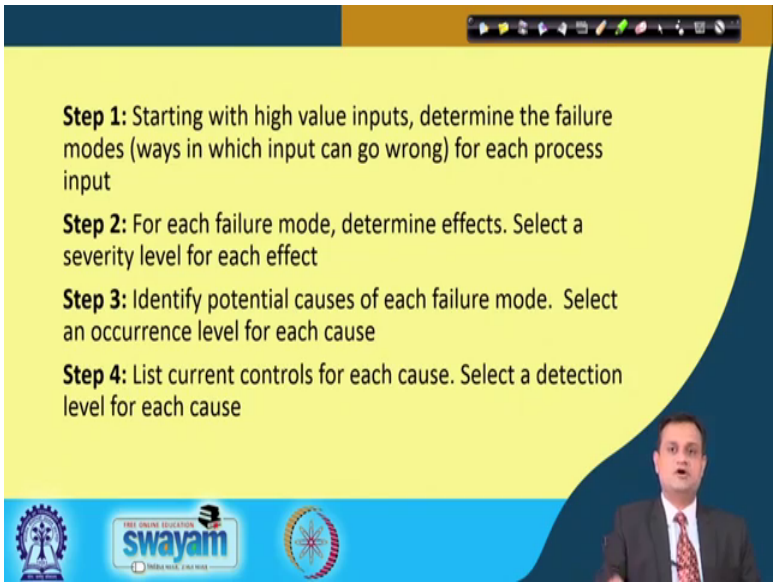


When I say severity then importance of the effect on customer requirement. And what is the severity in terms of it is impact on the customer requirement or satisfaction of this particular failure mode. So, how severe my failure mode is occurrence frequency with which a given cause occurs and creates failure mode and how many times you encounter such a failure occurrence.

Because many a time something may happen once in a 100 years or 50 years then that particular probability is very less. And detection the ability to detect the failures in many a times somebody will have an heart attack let us say. Now it is very complex phenomena and many a times you are not able to detect it.

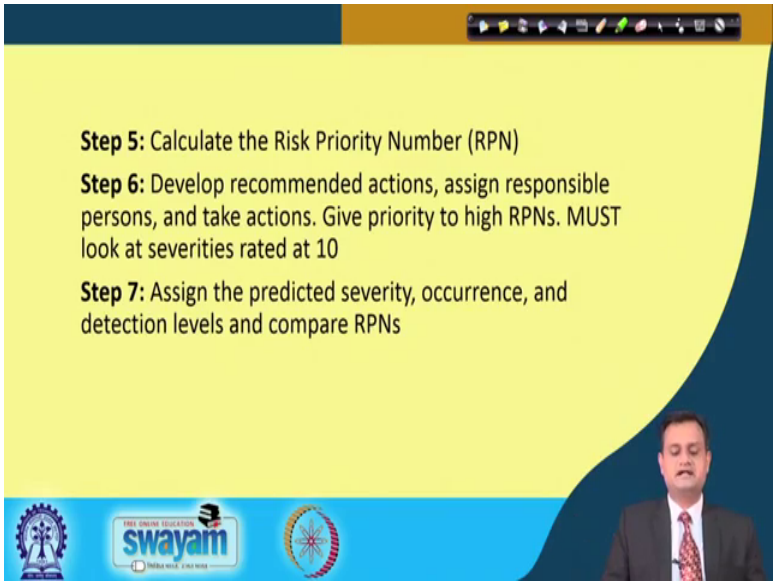
Even person would not feel uncomfortable and the day he will feel uncomfortable he will encounter an heart attack. So, many a times it is very difficult to detect and we should also consider our ability to detect that is detectability in calculating the risk priority number. So, typically it is a multiplicative effect of values assigned to three that is severity occurrence and detectability or detectable values.

(Refer Slide Time: 18:07)



So, FMEA steps are very simple to follow. Step one, start with high value inputs have a cross functional team for each process input. Step two, once you have identified the failure mode determine the effects select the severity level. Step three, identify potential causes of each failure select an occurrence level how many times it can occur. Step four, list current tools controls for each cause select the detection possibility or detectability.

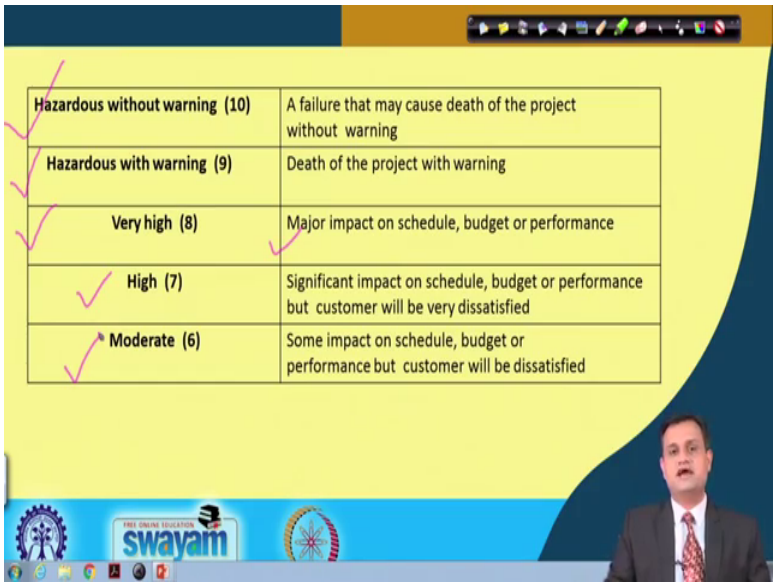
(Refer Slide Time: 18:40)



Calculate RPN, develop recommended propose, your mitigation and management risk mitigation management plan. And assign the predicted severity occurrence and detection

level and compare RPN's. So, how to define severity I will just give you some standardize table, but text to that is there could be some variation, but it hardly matters. So, let us say severity.

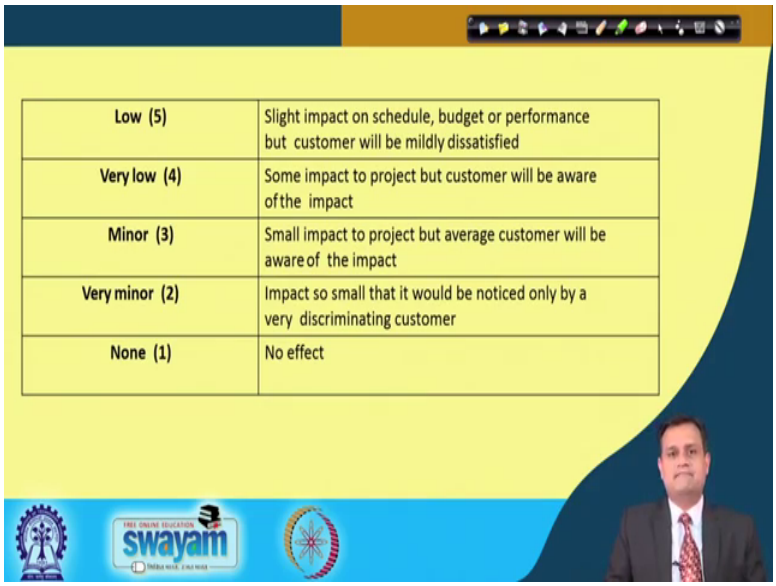
(Refer Slide Time: 19:09)



I would say azardous without warning. So, a failure that may cause depth of the project or the person without warning there is no warning available. Hazardous with warming death of the project with warning very high major impact on schedule budget or performance. Here I just tried to relate it with the project you are doing six sigma project high.

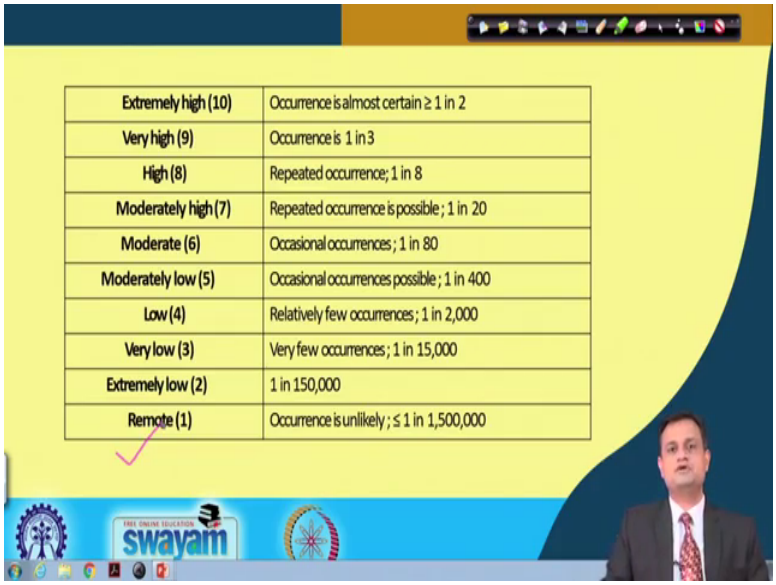
Significant impact on schedule budget and performance, but customer will be very dissatisfied and moderate. Some impact on schedule budget and performance, but customer will be dissatisfied. So, depending upon it is severity impact on the customer satisfaction we try to rate it; 10 means it is very high and severity must be considered at the highest level.

(Refer Slide Time: 20:03)



Same way you can interpret for low very low minor very minor none means there is no effect even if it will happen it hardly matters. So, this is about my severity.

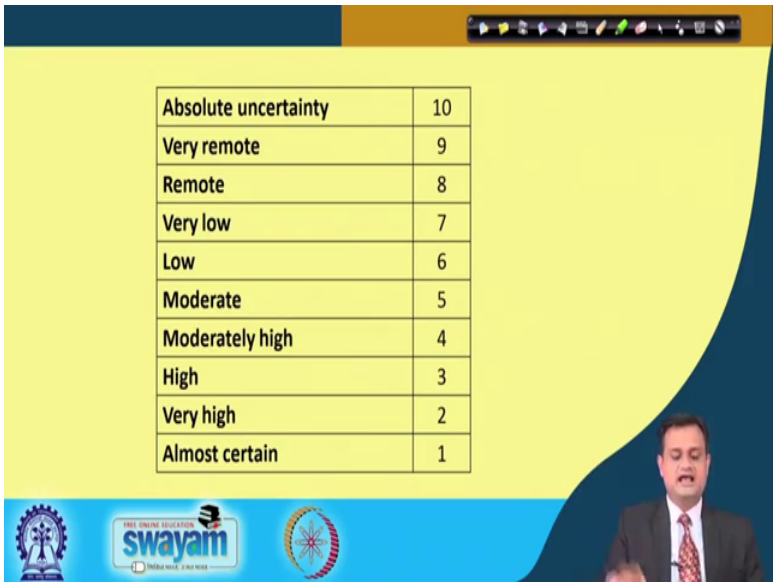
(Refer Slide Time: 20:21)



Now how to define occurrence probability? So, you can use a particular table like this that extremely high 10. So, I will say occurrence is almost certain it is bound to happen if you will not address this failure mode it is bound to happen means greater than one in two. So, out of two times one time it will happen or more than that very high occurrence one in three out of three times one time it will happen high repeated occurrence one in 8.

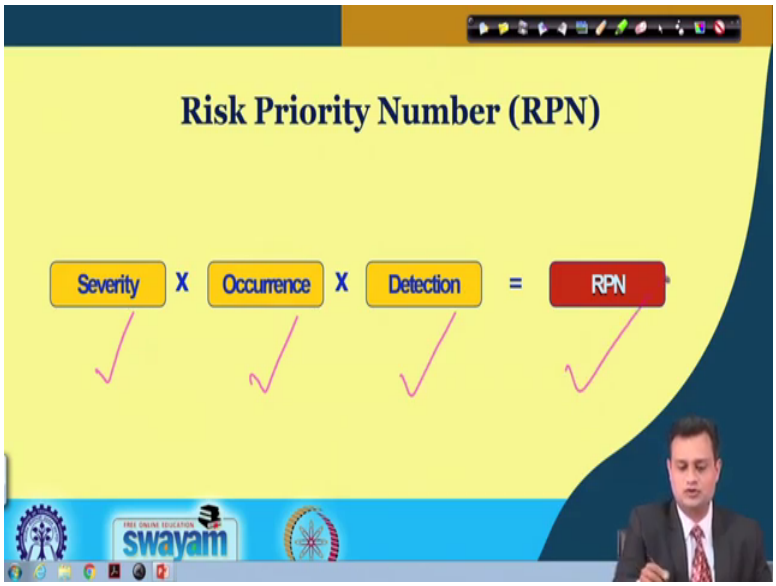
And then you can see that if I look at the final one remote occurrence is unlikely less than or equal to one in say maybe 15 lakh. So, it is very less and we need to be considerate as far as the occurrence probability is concerned and this must be used in computing my RPN. So, now the third element is the detectability. What is my capability to detect? Can I really detect a particular failure mode? If I cannot then my consequences would be very high so let us just see that.

(Refer Slide Time: 21:32)



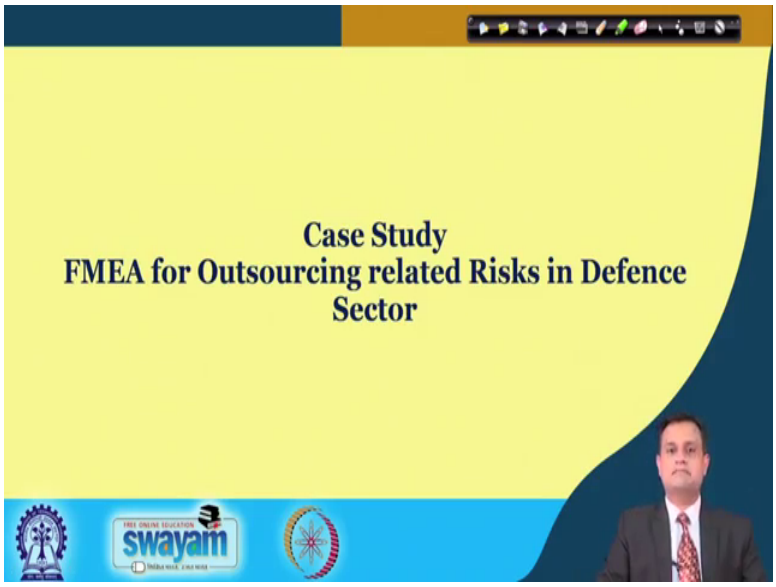
Absolute uncertain as I mention somebody will have an heart attack. And before 5 hours 3 hours there was absolutely no problem suddenly this fellow gets collapsed. You may think about a machine you may think about any other system. Then absolutely uncertain then it is 10 very remote 9 remote 8 and if it is almost certain that it is 1.

(Refer Slide Time: 22:03)



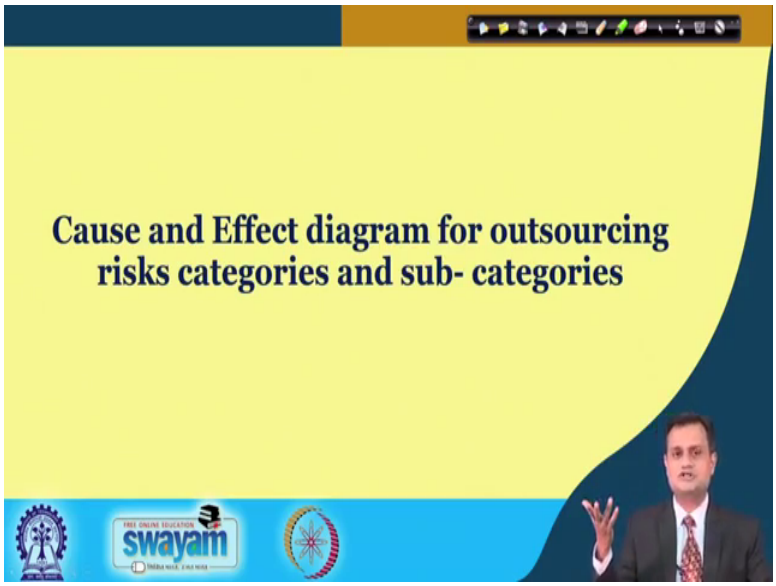
So, typically my RPN is basically severity into occurrence into detection is equal to RPN. And this is how I compute the RPN. Let us see a case study to give you better confidence in executing FMEA.

(Refer Slide Time: 22:16)



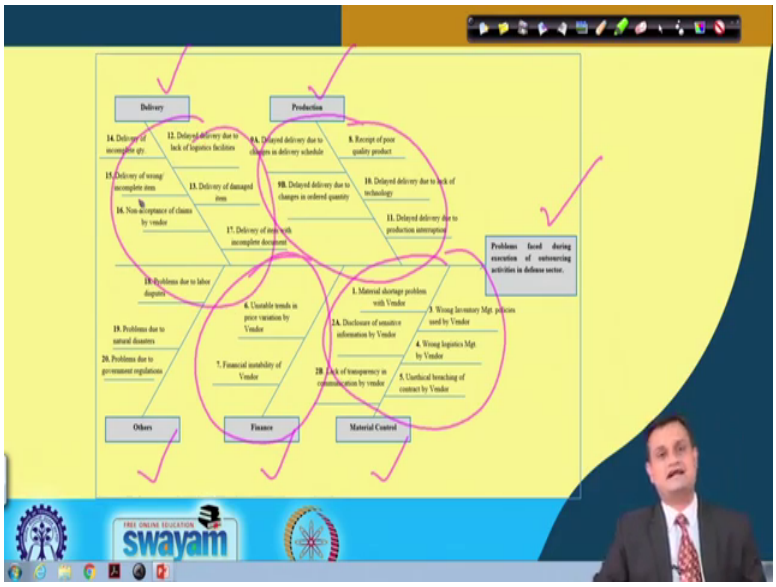
So, here we did some research and FMEA for outsourcing related risk in defence sector. basically this application of FMEA was conducted.

(Refer Slide Time: 22:32)



So, first thing as you understand I need to do cause and effect brainstorming analysis.

(Refer Slide Time: 22:40)



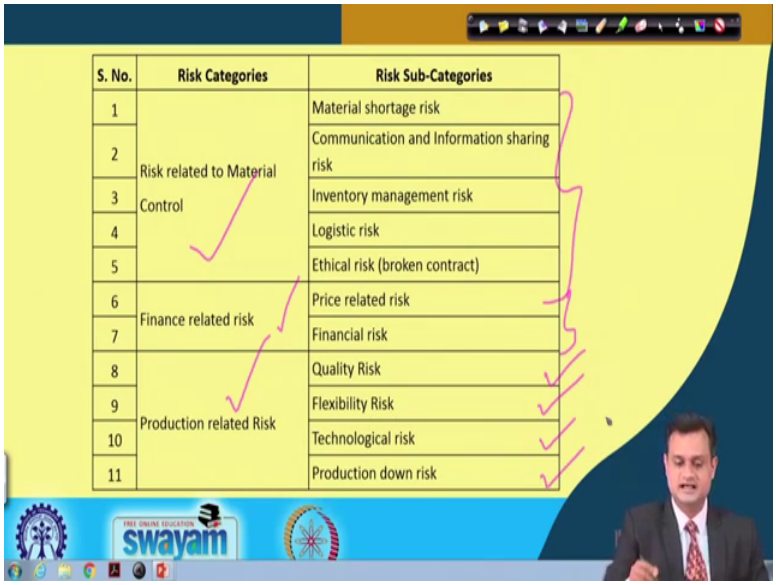
And this is a done for risk pertaining to outsourcing process in defence sector. So, here I have consider the effect problems faced during execution of outsourcing activities in defence sector. Delivery, production, others, finance, material I have identified material control. Let us say there could be a shortage problem disclosure of sensitivity information by vendor.

It is a defence sector, lack of transparency in communication, wrong logistics management. If you look at let us say finance then unstable trains in price variation by vendor, financial inability of the vendor. And similar way you can see the production and delivery related factors.

(Refer Slide Time: 23:36)

So, once I did this I could list the risk categories and subcategories.

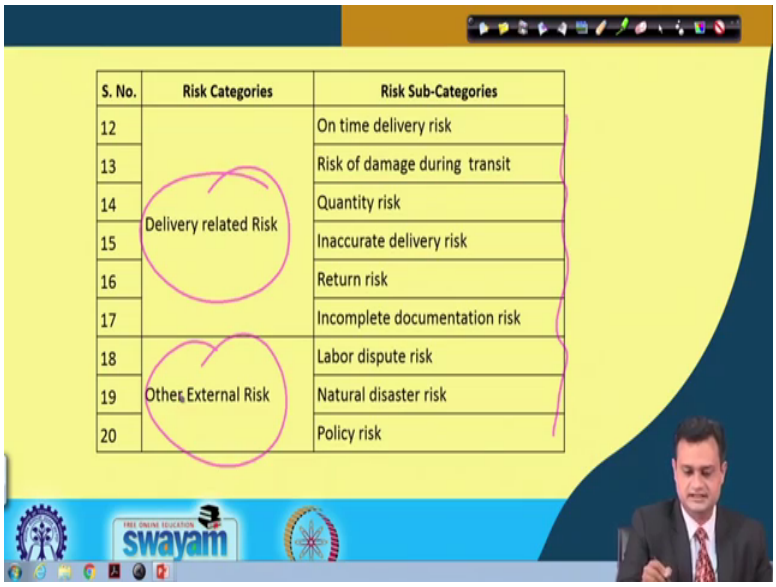
(Refer Slide Time: 23:39)



And it is like this. So, risk related to material control are basically this material shortage risk, communication problem, inventory management, logistic risk, finance related. Then

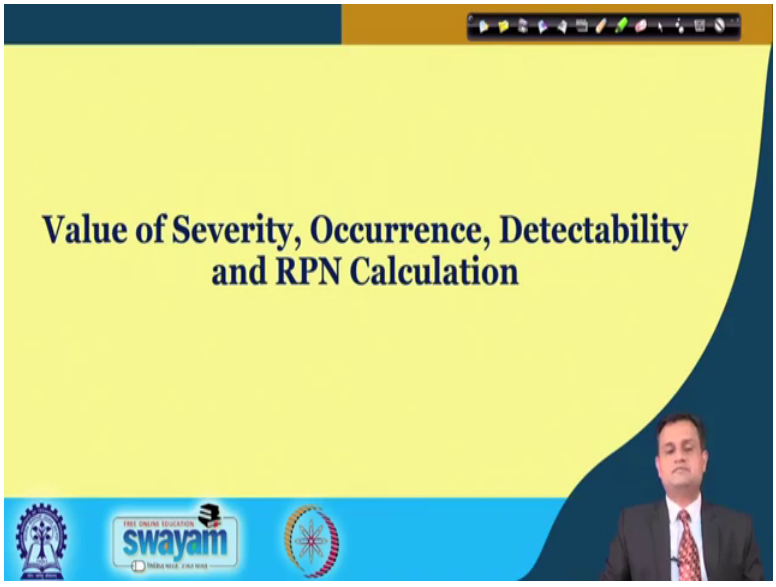
it is price related finance related. Then production related quality risk, flexibility risk, technological risk, production down risk, and so on. So, basically I have identified through cause and effect.

(Refer Slide Time: 24:07)



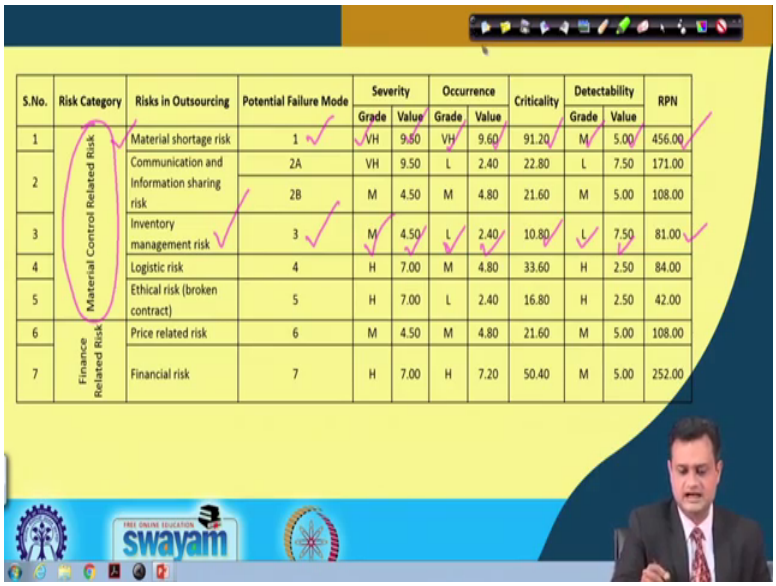
Some 20 risk pertaining to different risk categories. So, I have 20 risk. All these are my risk and they are pertaining to all these are my risk pertaining to different risk categories.

(Refer Slide Time: 24:29)



So, with this I can find now the value of severity occurrence and detectability for RPN calculation.

(Refer Slide Time: 24:34)

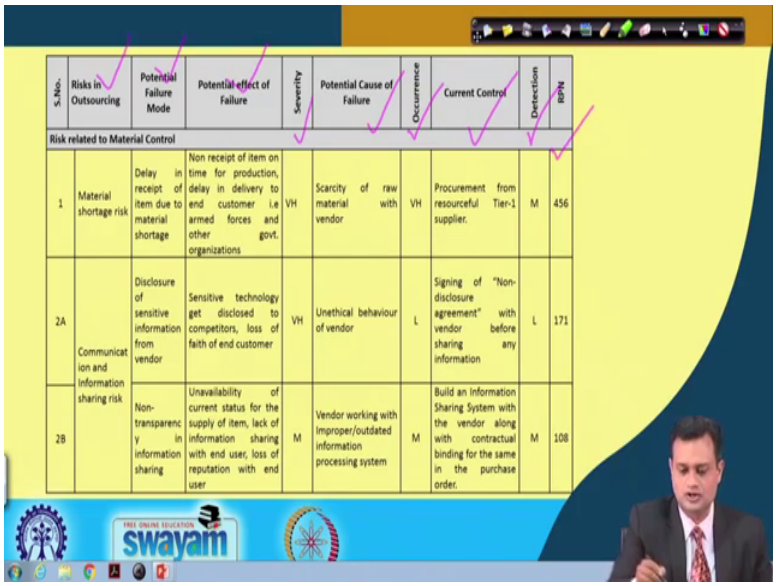


So, what I have done here for each particular risk like material storage risk which is part of the risk category material control related risk. This is failure mode 1. This is the number I will given to a particular failure mode. And let us say the grade is very high and I assign some value 9.5 if you are not comfortable with decimal value you can just put 9 8 or 10 whatever you like.

Similar way occurrence of this particular material shortage is very high 9.6 criticality 191.20. Detectability is medium it is 5 and my RPN value is 456. Similar way you can just see inventory management risk this is the number I have given to this particular risk. The grade is medium value is 4.5 occurrence it is low 2.4 criticality 10.8 detectability low 7.5 and the RPN is 81.

So, with this kind of simple analysis you can calculate the RPN for all the 20. And here it is calculated for all the sub risk pertaining to different risk category and 20 RPN values are computed. Now when I have computed the RPN value I will definitely get an idea.

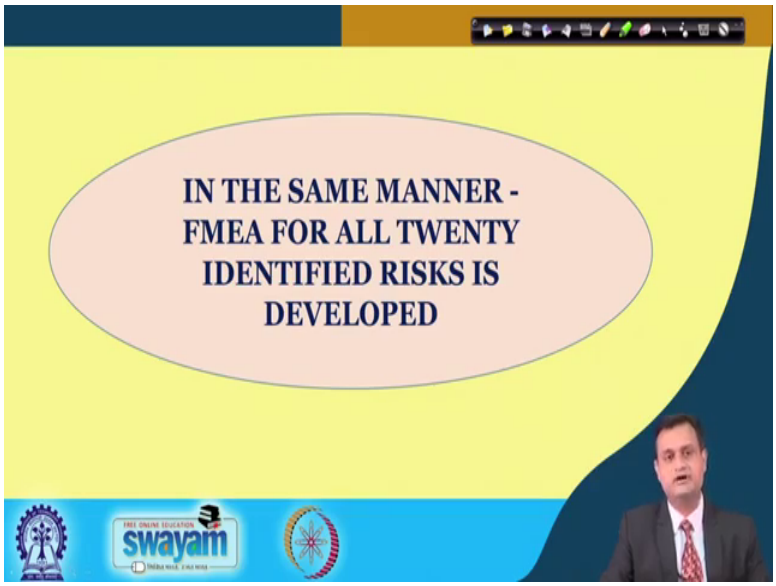
(Refer Slide Time: 26:01)



That which particular risk is having the maximum RPN and then the second one. So, before I go for any other analysis I can have some kind of risk management plan. And this particular risk management plan will help me basically to figure out that this is the risk in outsourcing this is the potential failure mode potential effect of failure I am elaborating.

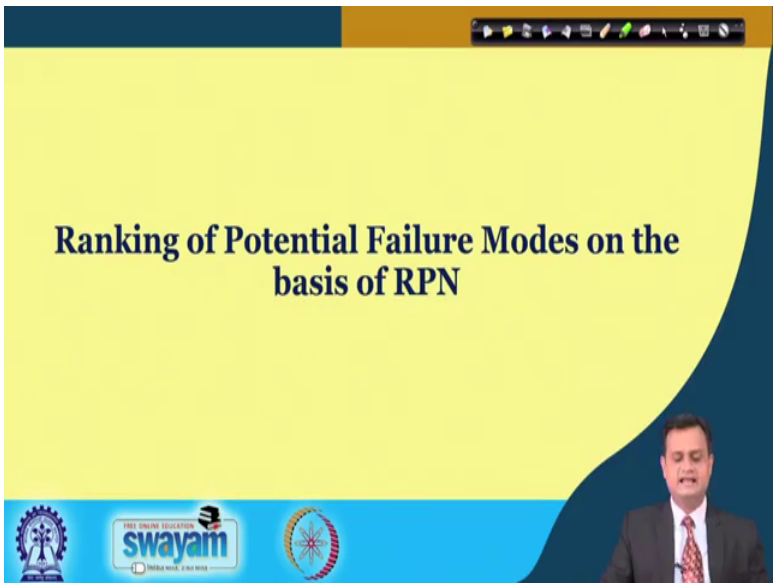
This is the severity potential cause of failure occurrence current control detection and RPN. So, I can make a very good descriptive say analysis. So, that people they feel confident comfortable in excepting the RPN value as well as go deeper into the cause. As well as the reasons behind a particular severity occurrence detectability of a given risk. So, with this I can develop this for all the 20.

(Refer Slide Time: 27:08)



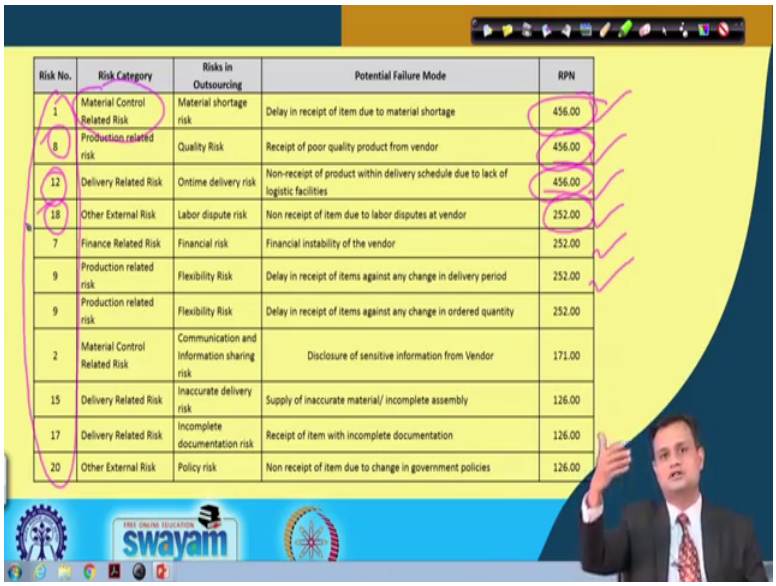
And same way I have not put the entire table for all the 20 this kind of risk management plan is develop.

(Refer Slide Time: 27:14)



Now, you run the potential failure mode based on the RPN and what you can see here that. Now I have put the risk these are the risk numbers not the priorities, but I have put the risk as per their RPN value.

(Refer Slide Time: 27:21)

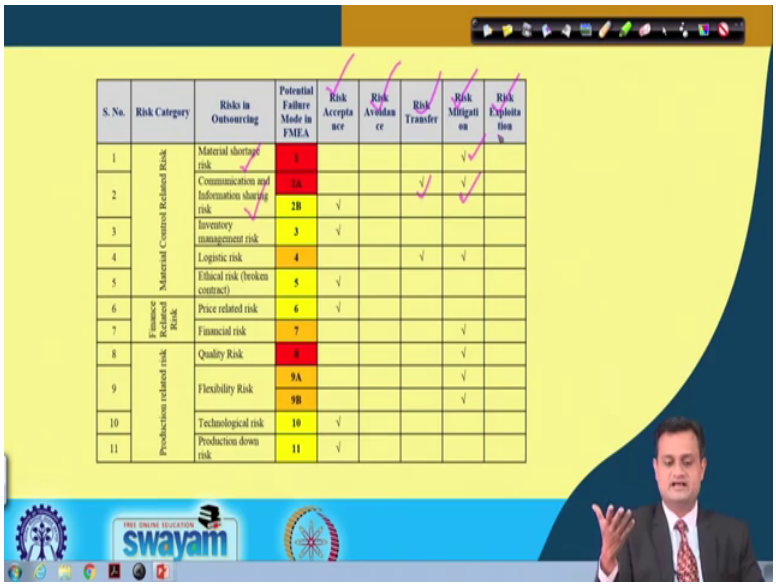


Risk No.	Risk Category	Risks in Outsourcing	Potential Failure Mode	RPN
1	Material Control Related Risk	Material shortage risk	Delay in receipt of item due to material shortage	456.00
8	Production related risk	Quality Risk	Receipt of poor quality product from vendor	456.00
12	Delivery Related Risk	Ontime delivery risk	Non-receipt of product within delivery schedule due to lack of logistic facilities	456.00
18	Other External Risk	Labor dispute risk	Non receipt of item due to labor disputes at vendor	252.00
7	Finance Related Risk	Financial risk	Financial instability of the vendor	252.00
9	Production related risk	Flexibility Risk	Delay in receipt of items against any change in delivery period	252.00
9	Production related risk	Flexibility Risk	Delay in receipt of items against any change in ordered quantity	252.00
2	Material Control Related Risk	Communication and Information sharing risk	Disclosure of sensitive information from Vendor	171.00
15	Delivery Related Risk	Inaccurate delivery risk	Supply of inaccurate material/ incomplete assembly	126.00
17	Delivery Related Risk	Incomplete documentation risk	Receipt of item with incomplete documentation	126.00
20	Other External Risk	Policy risk	Non receipt of item due to change in government policies	126.00

So, the highest [rpm] RPN value is 456 and this is for risk number 1. Then again second is 456 this is for risk number 8. Then 456 again risk number 12 then 252 risk number 18.

And this is how I have put my risk in the descending order means the highest RPN number first and then lower lower lower and the lowest. And I just put it to get the idea that what are the risk which receives the highest RPN same way I did it for all twenty and then I just proposed.

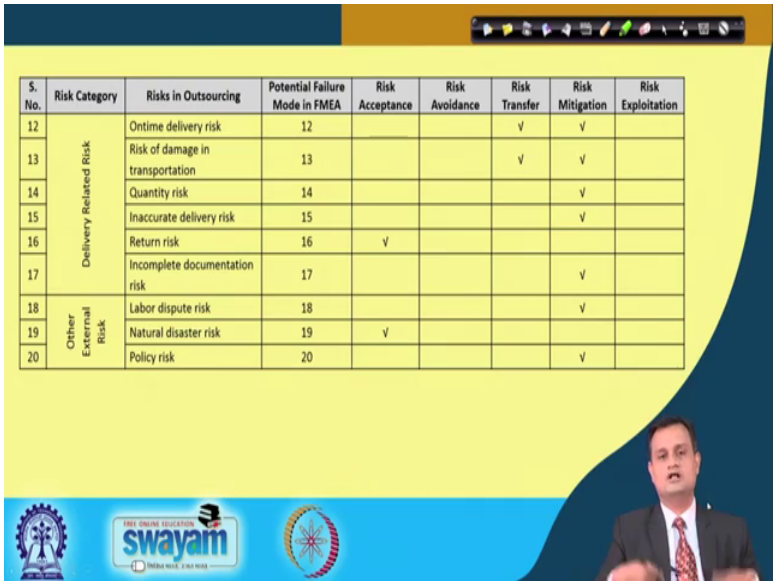
(Refer Slide Time: 28:09)



S. No.	Risk Category	Risks in Outsourcing	Potential Failure Mode in FMEA	Risk Acceptance	Risk Avoidance	Risk Transfer	Risk Mitigation	Risk Exploitation
1	Material Control Related Risk	Material shortage risk	1				√	
2		Communication and Information sharing risk	2A			√	√	
			2B	√				
3		Inventory management risk	3	√				
4		Logistic risk	4			√	√	
5		Ethical risk (broken contract)	5	√				
6	Finance Related Risk	Price related risk	6	√				
7		Financial risk	7				√	
8	Production related risk	Quality Risk	8				√	
9		Flexibility Risk	9A				√	
			9B				√	
10		Technological risk	10	√				
11		Production down risk	11	√				

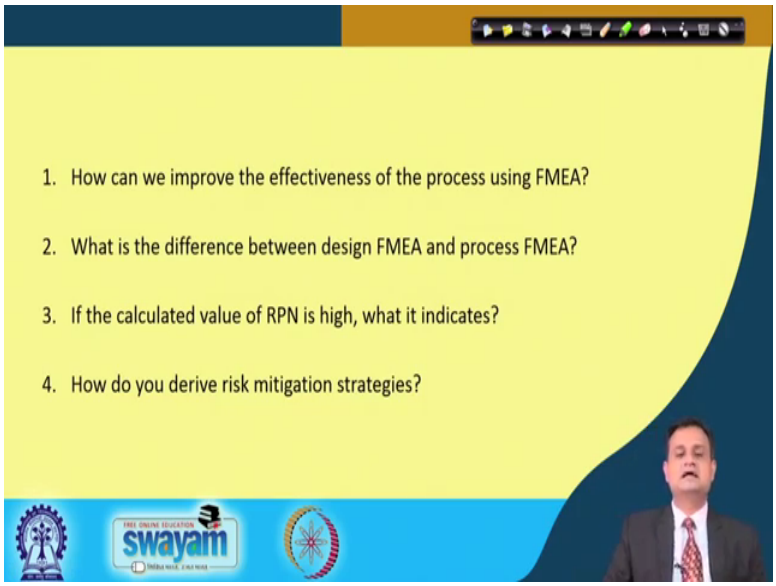
The risk mitigation plan how can I mitigate the risk. So, there are well known strategies that either you accept the risk you avoid the risk transfer the risk mitigate the risk and exploit the risk. So, for each particular risk let us say material shortage you try to go for risk mitigations plan. That means you take the action by which this risk can be mitigated. But if you see communication and information sharing risk you transfer the risk as well as mitigate the risk. I can just give you the example how you can transfer the risk. So, you can out source maybe your information system maintenance and the coordination to some third party. And you can have very well coordination through a sound information system. So, communication problem can be addressed. So, likewise you can have various strategies to mitigate your risk and this is exactly I have decided.

(Refer Slide Time: 29:12)



For all the 20 you also need to validated through expert opinion.

(Refer Slide Time: 29:21)

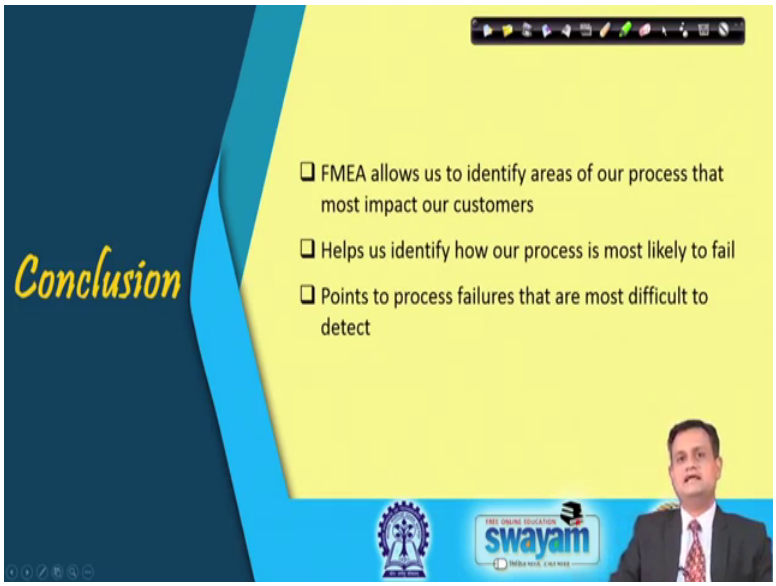


So, as a usual practice before I end let me try to float couple of think it. How can we improve the effectiveness of the process using FMEA? What is the difference between design FMEA and process FMEA? If the calculated value of RPN risk priority number is high what it indicates? And how do you derive risk mitigation strategies? So, please try to go through the lecture and see that are you in a position to answer these questions or not. If yes, then the purpose of this lecture is solved.

(Refer Slide Time: 29:56)

So, you can refer this references for better understanding.

(Refer Slide Time: 30:01)



So, finally, as a conclusion FMEA allows us to identify areas of work process that most impact our customers. Their sentiments, their satisfaction, their loyalty, helps us identify how our process is most likely to fail. What could be the probable reason that my process will fail. Put a points to process failure that are most difficult to detect that also we can figure out.

So, with this let me close this session on failure mode effect analysis. And I hope you have appreciated this concept and it has a very wide scale applicability from very small system to the large system whether manufacturing or service. So, please keep revising and refer the suggested textbooks for better understanding. And interest pack through some real life application of the concepts. So, be with me enjoy.