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

**Lecture – 05**
**Six Sigma Principle and Focus Areas (Part 2)**

Hello friends I am Dr. Jitesh Thakkar, I once again welcome you to our journey of Six Sigma and we are in this lecture 5 discussing Six Sigma Principles and Focus Areas part 2. Already we have seen some of the important concepts in the last lecture as part 1 and this time we will try to go deeper into some Six Sigma principles and the focus areas.

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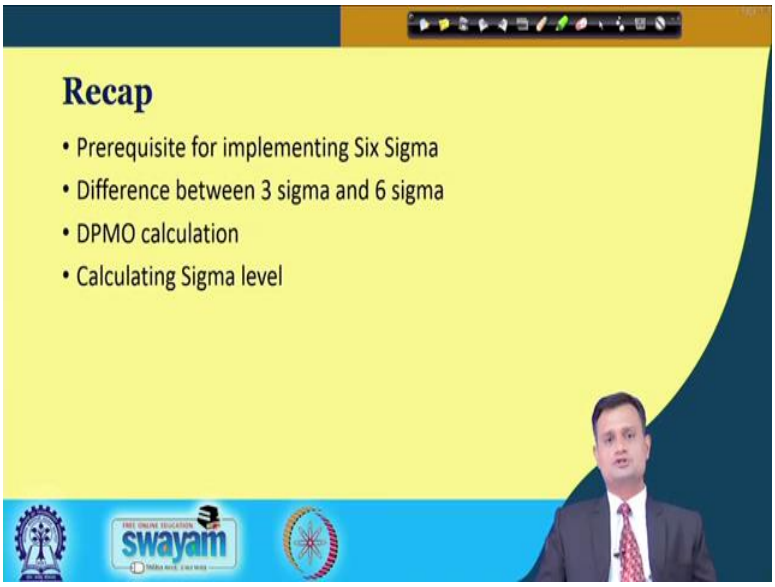


So, before we proceed further let us just see that what we have discussed last time, we have talked about some of the prerequisites that an organization must satisfy to implement Six Sigma as a process improvement strategy. There is a difference between Three Sigma and Six Sigma and Six Sigma means reduced variability of the processes and hence my processes are more centric towards mean. DPMO calculation we have seen defects for defects for million opportunities and then we have also seen that how we can use DPMO to find the sigma level for a process. And once we know the sigma level we can set the benchmark for the necessary improvement.

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Now this particular lecture is very very important and I would like you to appreciate the concepts like Rolled Throughput Yield RTY, classic yield, First Pass Yield FPY. What is hidden factory is a very very important thing and many organizations they take pride that they are producing good products their final rejection rate is very low, but there are certain serious concerns.

So, that we will see and you cannot implement Six Sigma unless you have the organized systematic effort and for that we need to appreciate that what are the different roles responsibilities in Six Sigma.

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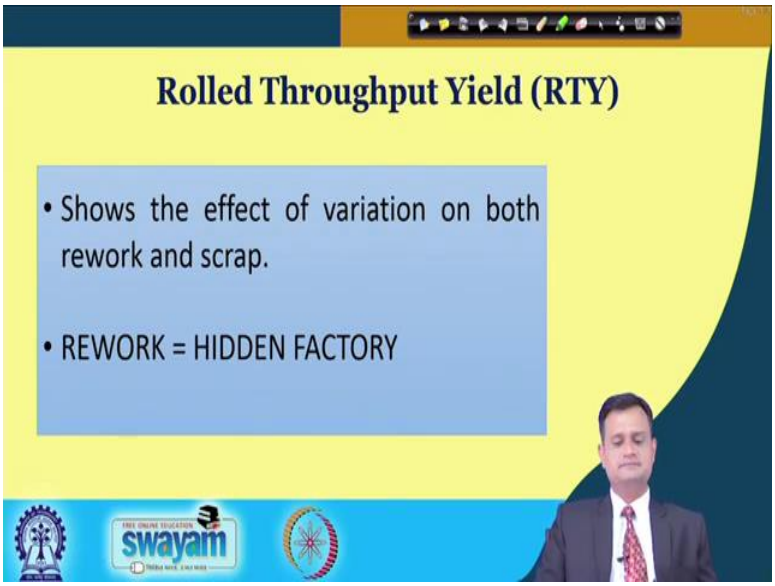


Now, let us see what is RTY typically called rolled throughput yield. So, this shows the effect of variation on both rework and scrap, now you see you have produced a product and this product is checked by the quality inspector has either hold or reject.

Now, if it is reject then; obviously, it will lose its entire processing value and even the material cost because it is scraped. Suppose let us say this is put under hold and you are permitted to apply the correction through rework then again you have to put additional processes, human resource, electricity, power, machines everything to correct your defect. So, both the way it is a loss to the company and typically rework is called as the hidden factory. So, unless you appreciate the concept of hidden factory you will never realize the importance of implementing Six Sigma.

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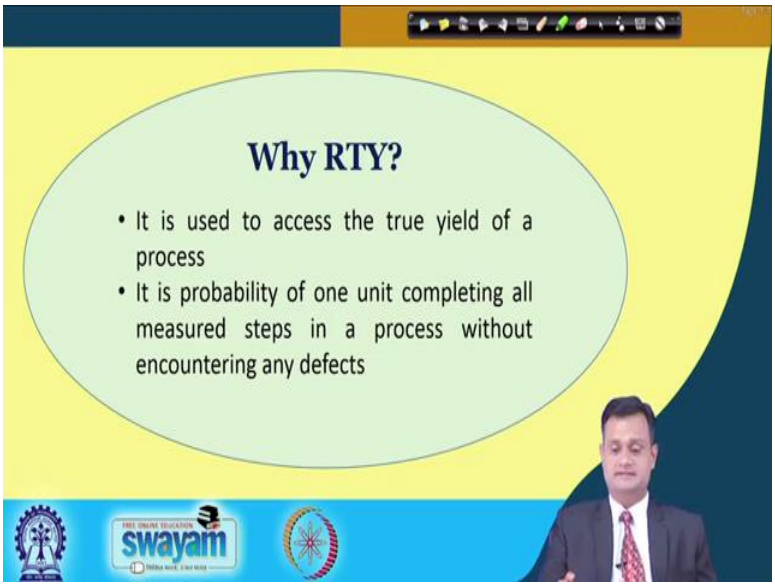


So, why RTY? So, typically it is used to assess the true yield of a process, there is something which is true yield and there is something which is a pseudo yield. So, many a times in between you may correct the products your WIP final yield may be very good, but your RTY rolled throughput yield is very poor.

So, it is the probability of one unit completing all major steps in a process without encountering any defects. So, if my product is produced after having gone through various steps and processes where no defect is produced, then I will say my rolled throughput yield is 100 percent and nowhere there is rework scrap rejection anything.

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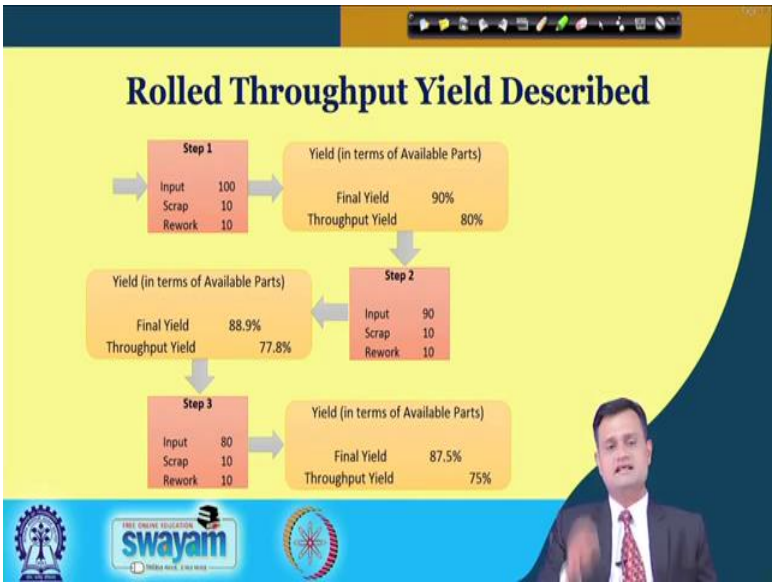


Let us see a very simple example to appreciate the concept. So, step 1 let us say I have input 100, scrap 10 and rework 10. So, at the end of this process if I compute the yield my final yield is 90 percent and throughput yield 80 percent. So, 90 percent because I am producing 10 as a scrap and this 10 will not at all be there so, 90 percent because I have initially input 100. So, 90 percent is a final yield at the end of the process 1 or step 1, if I see throughput yield it is 80 percent because 10 is scrap and 10 is rework. Now if I go to step 2, 10 components are already discarded scrap.

So, now I am left with 90 again let us say there is scrap of 10, rework of 10 I am ending with final yield at the end of the step 2 88.9 and throughput yield which is much lesser 77.8 percent. Once again I go to step 3 with 80 as input scrap is 10 rework is 10 and keeping the constant then final yield is 87.5 percent and throughput yield is 75. So, please see that every time because of my scrap and rework my RTY rolled throughput yield is significantly going down.

And what does it mean? We will see it, but in general you can understand it means I would be spending more resources in satisfying the customer requirement. So, typically this is a hidden factory which is not visible, but this consumes lot of resources adds to the final cost of the product and hence makes my product less competitive in the market.

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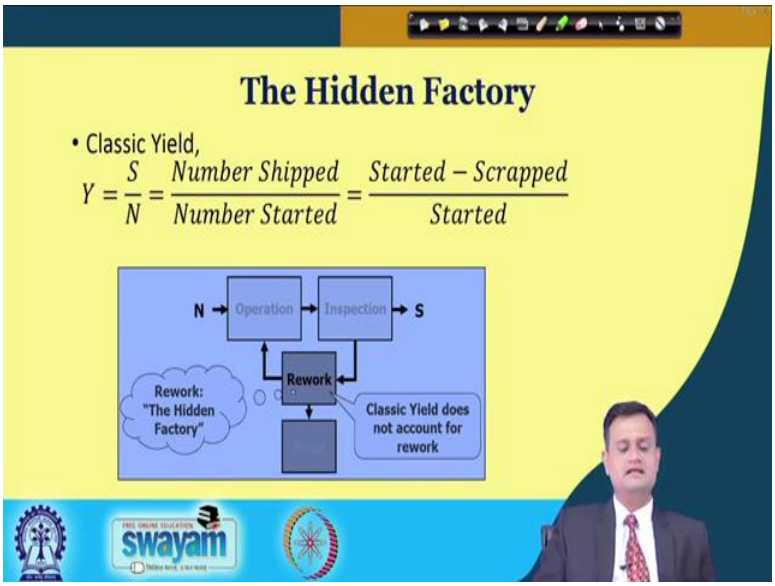


So, typically this hidden factory I just put it that rework is the hidden factory and classic yield does not account for rework ok. So, this is something where we are making the mistake when we count the classic yield we just say fine I produce this much of the good products. But this does not make sense because ultimately you have input of more resources in terms of manpower machine everything to produce those many products. So, a classic yield is S by N very simple, number shipped number started in between whatever is there, whatever leakages are there that has not been counted. So, started minus scrap divided by started there is no concern for rework which consumes huge amount of resources.

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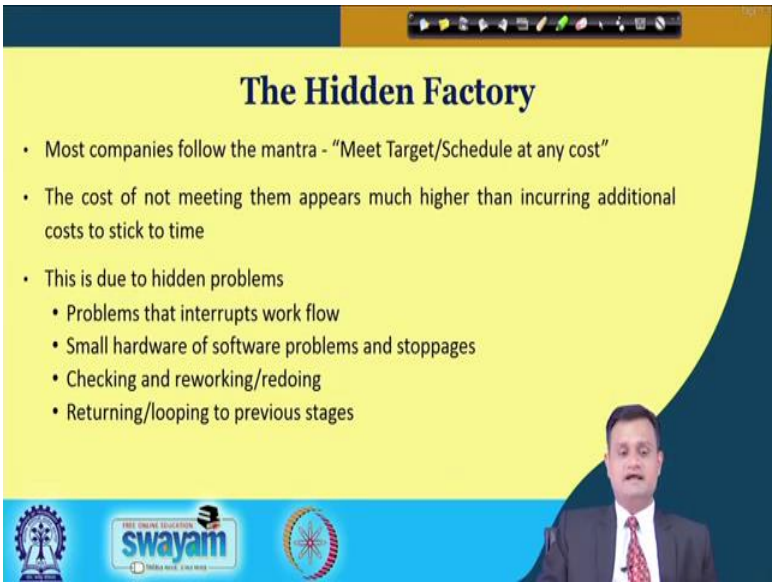


So, hidden factory is the concept basically the most companies they follow the mantra need target schedule at any cost. So, my customer should receive the consignment, but you cannot just keep doing these at the cost of enormous amount of rework you are producing within the factory. So, the cost of not meeting them appears much higher, then increasing additional cost to stick to time and this is mainly due to hidden problems.

So, when you really look at the tip of the iceberg things are not visible, there are many things which are within the water level and that basically interrupts the workflow smaller small hardware of software problems and stoppages then checking and reworking, redoing, rerunning, looping to previous stages and likewise there is a and lot of loss.

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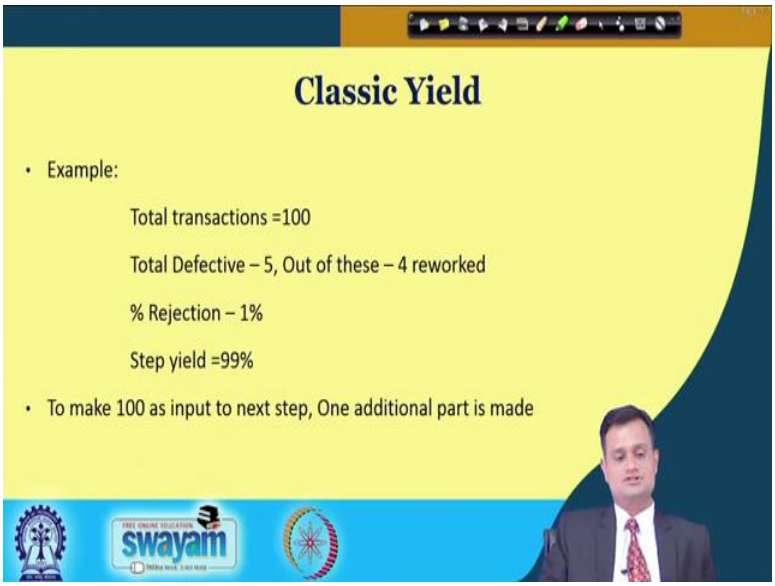


Classic yield basically total inspection is 100, total defective 5 out of these 4 are reworked. Percentage rejection; obviously, because I rework 4, 1 percent and it is 99 percent that is the classic yield, but as I mentioned classic yield ignores the amount of resources invested in rework and hence classic yield gives me the false satisfaction about the productivity of my manufacturing or service system and I am ignoring one of the very important element which is the hidden factory.

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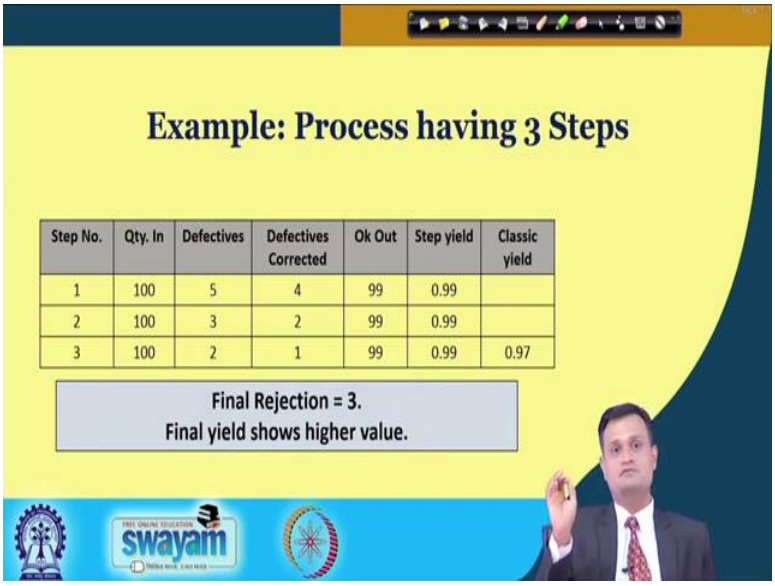

So, let us say I have process which typically includes 1, 2 and 3 steps and quantity in is 100 every time for each step let us say in first step there are 5 defectives, second step 3, third step 2, defectives have corrected in step 1 are 4, step to 2, 2 step 3, 1. So, finally, the column says that outcome all cases 99, 99, 99; my step yield is 0.99, 0.99, 0.99 and my classic yield is just the multiplication of these 0.97.

So, I would be happy that my final reject is only 3 my classic yield is 99 percent, but this is not the real story because there is huge amount of resources invested in correcting the error.

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So, although final yield measures the process performance it does not expose the hidden factory which is within the factory itself and we are not able to appreciate it.

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So, typically classic yield percent defective is only 3 percent since the output is checked and reworked and let us say there are 3 critical to quality characteristics for this product, customer requirement, maybe total length of OD Outer Diameter, bore ID Inner Diameter. And the sigma value for this product we can calculate has final yield 97 percent because there is 3 percent defective. Defective rate 0.03; obviously, DPMO it is 10000, opportunity is 3 defective rate per opportunities is 0.01 and from that table we discuss last time you can computed the sigma level this is 3.79. But if you really count RTY rolled throughput yield you realize that this sigma level is just a false indicator based on classic yield it is giving me the wrong picture of my efficiency, quality in the company.

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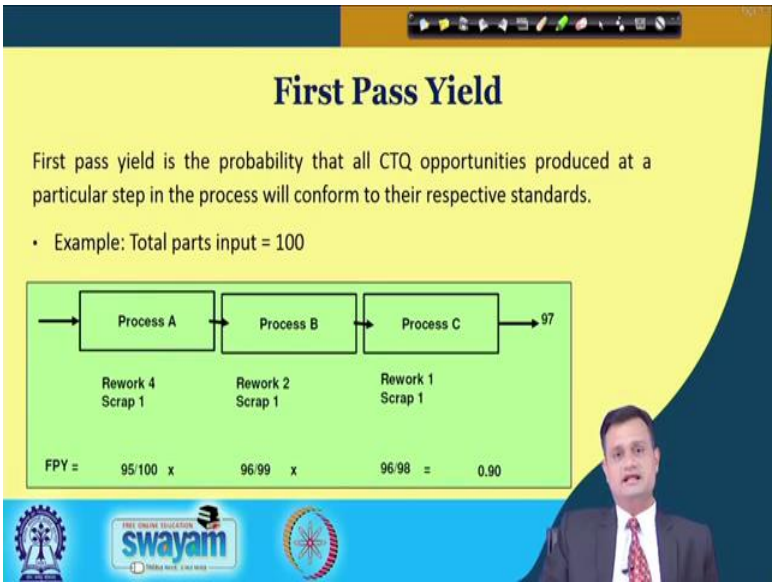


Now, let us see there is first past yield FPY. Now here I have considered three processes process A, process B, process C and there is a rework of 4 scrap of 1, rework of 2 scrap of 1 and process C rework of 1's scrap of 1. I am considering total input as 100 everywhere you can see that 95 divided by 100 because 4 rework and 1 scrap. So, I am counting now not only 1, I am counting 4 plus 1 and deducting this 5 from 100. So, 95 by 100 multiplied by second stage because 1 is scraped I am getting 99 as the input in process B. Out of these 99, three fall into rework and scrap category. So, 96 by 99 in similar way process C 96 by 98.

So, multiplication of these three leads to 0.9. So, you can now see that first pass yield is much lesser than your classic yield.

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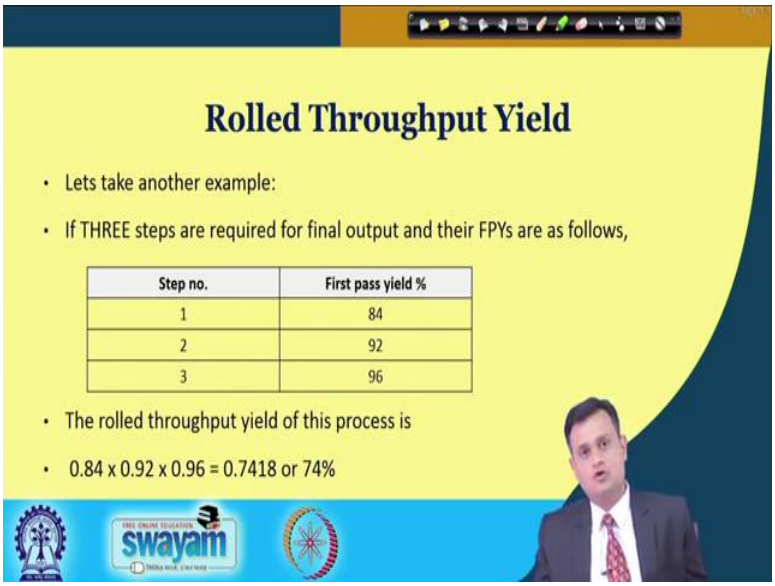


Now, if we go to another concept which is very much promising that is rolled throughput yield then step 1, my first pass yield let us say is 84 percent, step 2, my first pass yield is let us say 92 percent and in step 3 it is 96 percent. If I just multiply this then it results in 74 percent rolled throughput yield.

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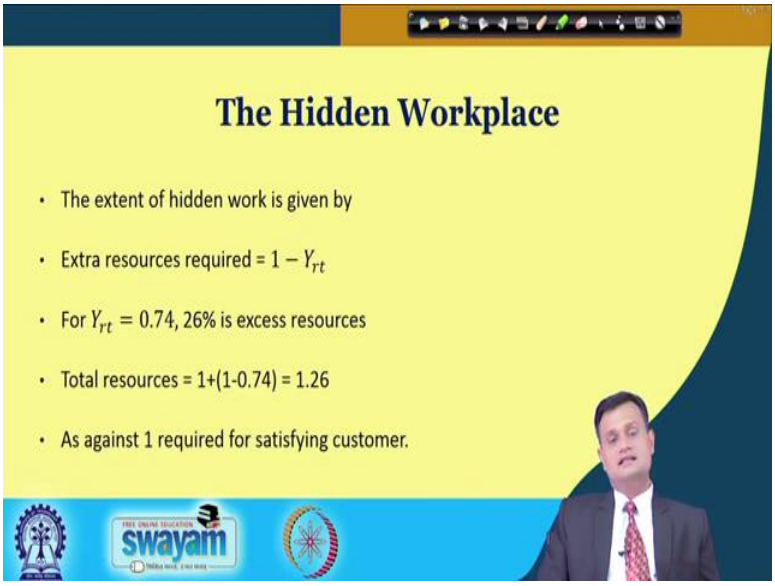


So, here there is a catch and the catch is like this, my role throughput yield is 74 percent it means 0.74, if I just abstract this from 1 I will get 0.26 that is 26 percent basically this is

the excess resource I will be consuming to correct my products and to improve upon my classic yield.

So, you can say more technically that 1.26 times I am utilizing more resources in order to satisfy my customer. So, customer satisfaction is there, but I am utilizing more resources which is typically a hidden factory can get exposed through your RTY role throughput yield.

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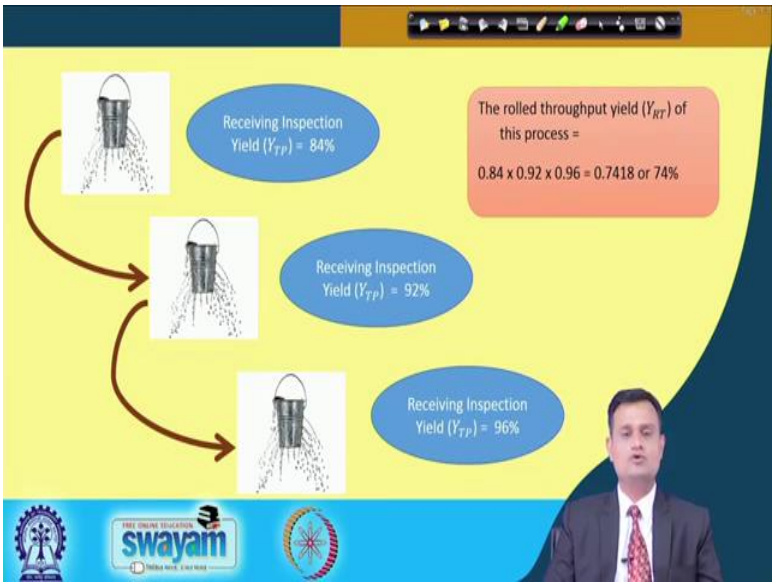


So, to better make you appreciate the concept I will just put here the picture of leaking bucket, everywhere there is a leakage means scrap, rework, and let us say receiving inspection yield YTP at bucket 1 is 84 percent; bucket 2, 92 percent bucket 3, it is 96 percent. When I multiply these three that is my YRT rolled throughput yield it comes out to be only 74 percent.

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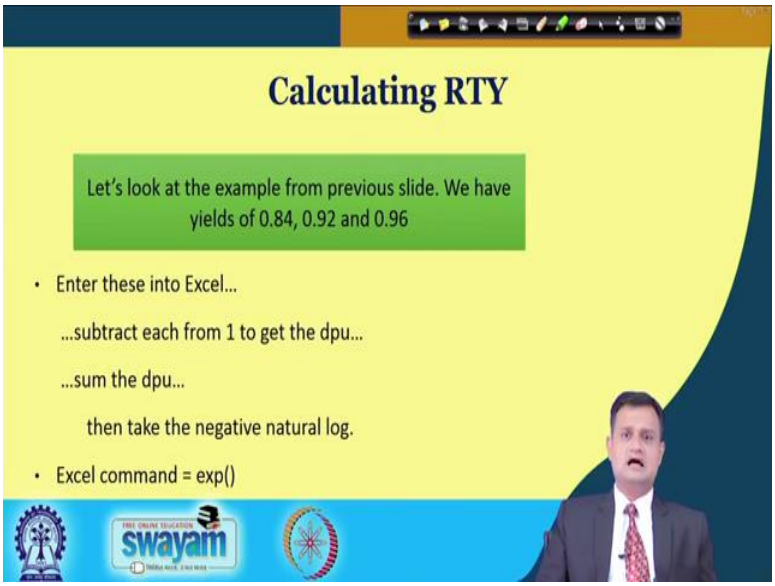


So, a there is another way to even calculate RTY which is much simplify simplified version and if we continue with the same example 0.84, 0.99 and 0.96 as the yields then you can use the excel function command exponential and you can just find the $e^{-0.28}$.

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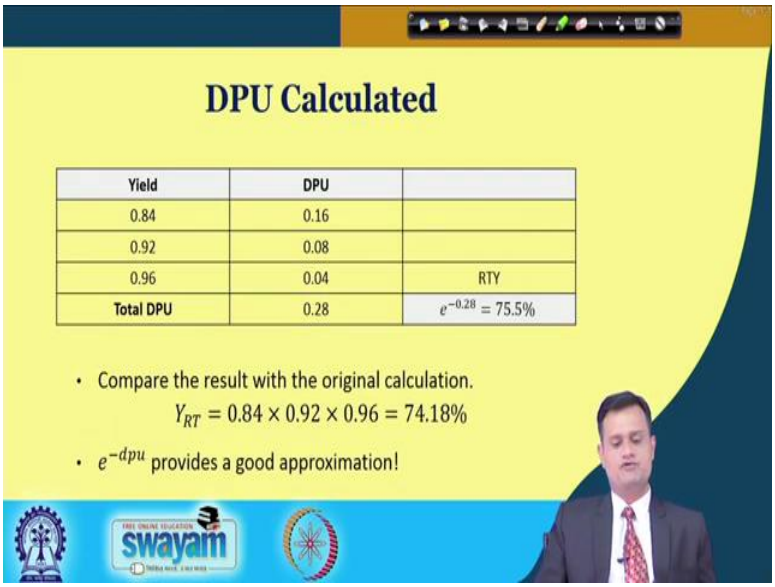


So, here yield is 0.84, same example I am continuing 0.92, 0.96 just 1 minus 0.84 is point DPU, Defects Per Unit. So, I got 0.16, 0.08, 0.04 and total DPU is 0.28. If you take the negative power of e then you will get 75.5 percent and if I just multiply this as per my regular procedure of finding YRT then this comes out to be 74.18 percent. So, typically

we can say that $e^{-dpu}$ it provides a good approximation and more or less you will get the same calculated value of TRY rolled throughput yield.

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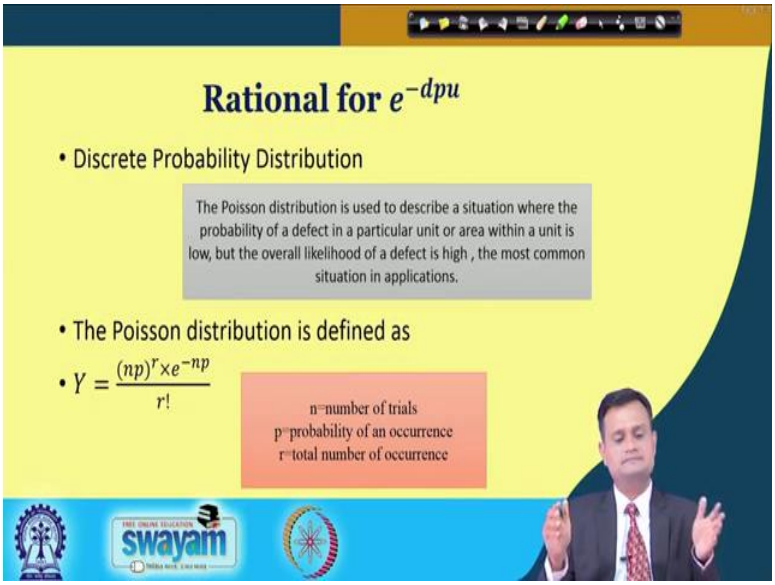


So, here there is a rational behind $e^{-dpu}$ we have not yet discuss the statistical concepts in detail, but here just I would like to say give you some glimpses that why $e^{-dpu}$ gives me more or less same rolled throughput yield. So, here there is a probability distribution, discrete distribution and typically Poisson distribution is used to describe the situation where the probability of a defect in a particular unit or area within a unit is low, but the overall likelihood of a defect is high.

So, the most common situation in application, and I can compute using the expression typically probability distribution function of Poisson distribution $Y = \frac{(np)^r \times e^{-np}}{r!}$ , n is the number of trial p is the probability of occurrence and r is the total number of occurrence.

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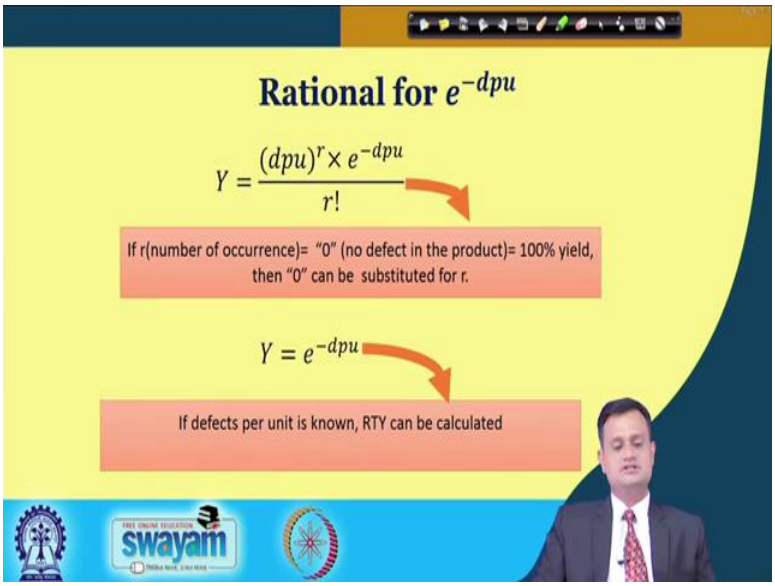


So, I can just little bit say do substitution and $Y = \frac{(dpu)^r \times e^{-dpu}}{r!}$ So, suppose if r is number of occurrence that is 0 it means no defects in the products isn't it, then my yield is 100 percent. So, then 0 can be substituted for r and you will. So, 0 factorial would be 1 and if you if you put this r then your first term will also become 1.

So, you will get $e^{-dpu}$ . So, defect per for unit is known RTY rolled throughput yield can be calculated.

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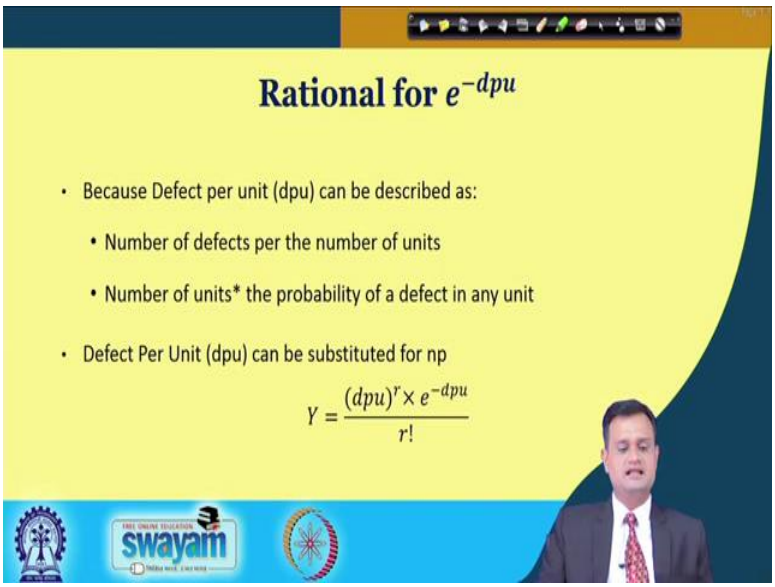

So, this is typically the rational behind $e^{-dpu}$ and that will help you to compute more or less say very close a number of our rolled throughput yield which you can calculate otherwise.

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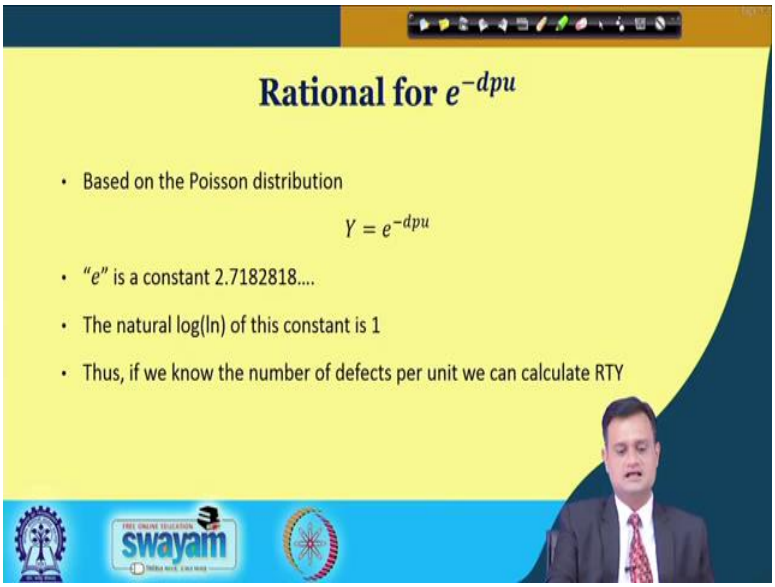


So, this is something that just try elaborated.

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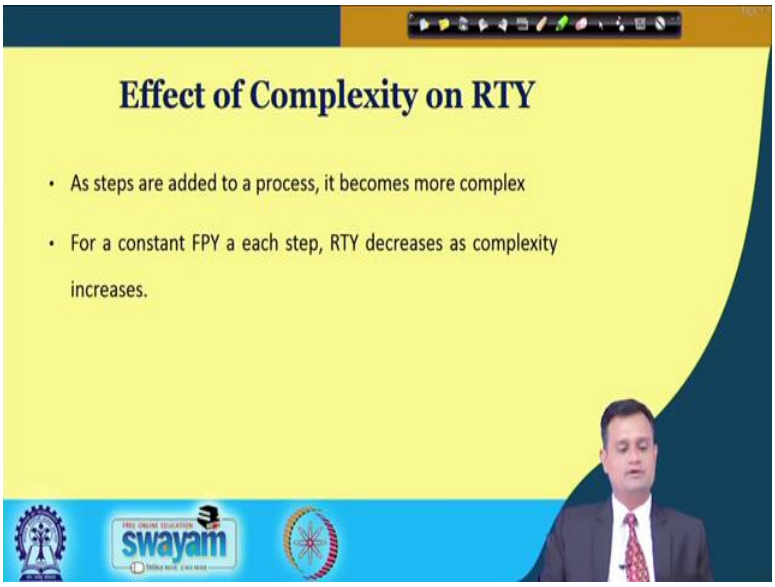


So, effect of complexity on RTY, now just think that my particular process may include n number of steps whatever we have seen so far we just considered three steps and then also

we have seen that there is a significant effect on my rolled throughput yield and my hidden factory.

So, if you just try to relate the number of steps and rolled throughput yield, you would really be surprised to see that my first pass yield in this table.

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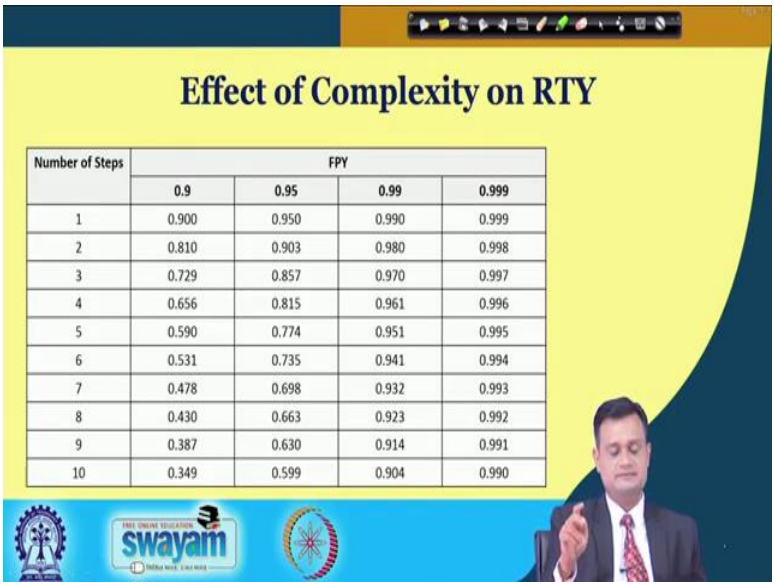


Let us say I am considering 4 different FPY first pass yield 0.9, 0.95, 0.99 and 0.999. I am keeping first pass yield 0.9 or 0.95 same for all let us say steps. So, you will see that here 0.9 into 0.9 will bring 0.810, further you multiply it by 0.9 0.729 and so on. So, every time when I multiply say because of number of steps my say rolled throughput yield RTY is going down.

So, let us see how it looks like when I put it in the graphical form.

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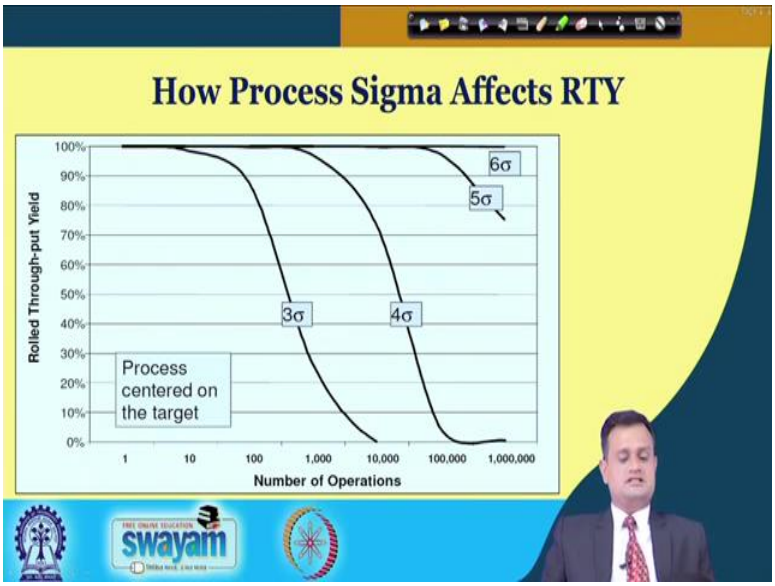


Ah just see that number of operations I am demonstrating on x axis and rolled throughput yield on y axis. So, process is centered on the target let us say, now if I have number of operations just see on the x axis 1000, 10000 and I have some amount of RTY.

Then typically I would be following Three Sigma or other way round you can say that if my process is Three Sigma then I would be able to cater the complexity of maybe around 1000 to 10000 operations with set of RTY and my rolled throughput yield would be very low if I am increasing the number of operations when the process is maintained at Three Sigma level. If I just shift to higher sigma, 4 sigma you can say that my ability to accommodate number of operation increases or for the same number of operations my RTY is higher you can see five sigma and Six Sigma. Six Sigma can accommodate more than 10 lakh number of operations and despite of these my RTY is almost 100 percent.

So, you can see that what enormous amount of benefits it gives me in terms of efficient processes producing less rework if I can achieve higher sigma level 5 sigma or Six Sigma and my rolled throughout yield will improve like anything it means my hidden factory cost will drastically come down.

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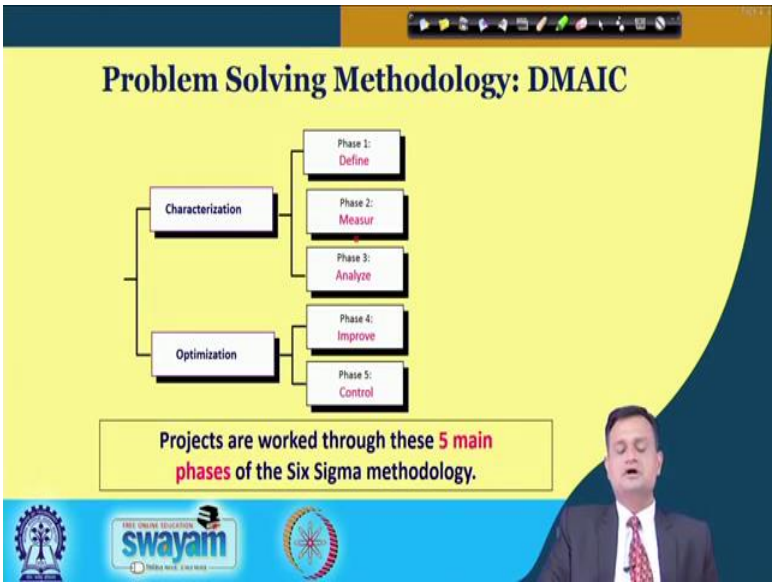


So, this is possible through a systematic approach of DMAIC, Define Measure Analyze Improve and Control and typically the first three step, they call the process Characterization and the last two steps they call improve and control they call they are called Optimization.

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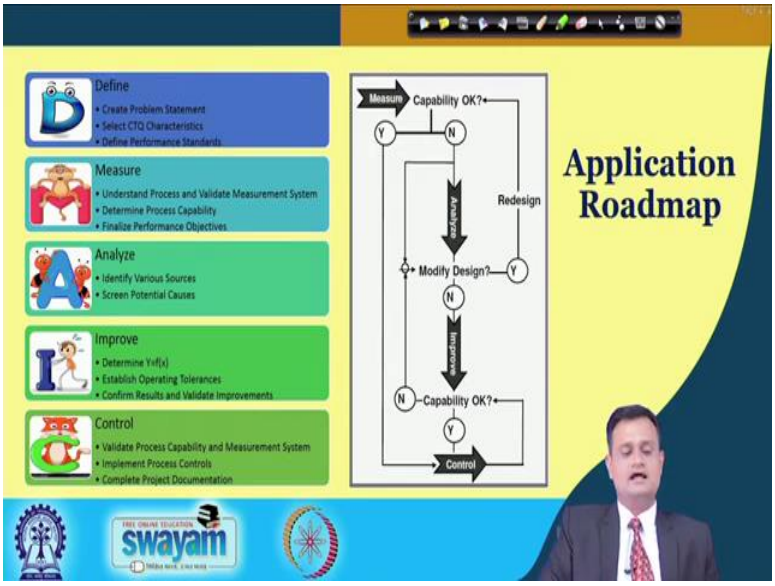


So, we always try to appreciate this DMAIC cycle you can see here the roadmap it is a continuous journey and I have to keep checking modifying at the design stage, at the

verification stage and then see that once again I can operate the DMAIC cycle for the process which achieved the better sigma level and further sigma level can be improved.

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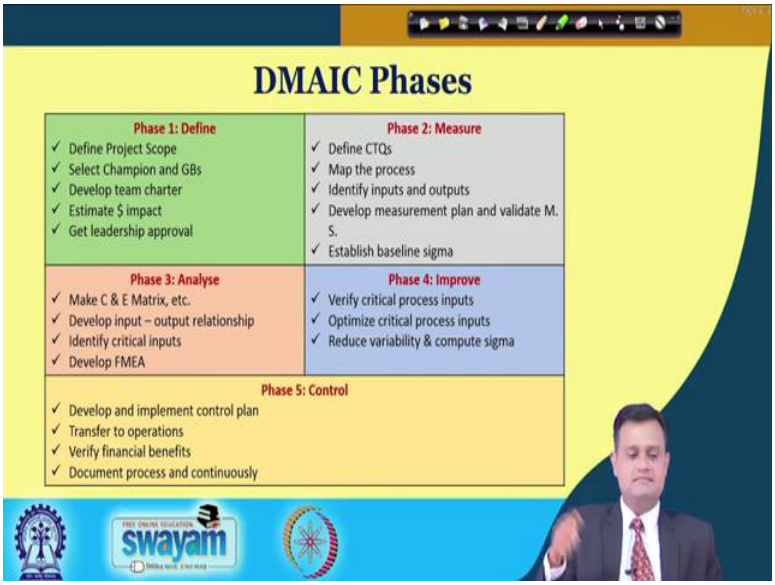


So, typically my DMAIC phases define, measure, analyze, improve, and control and as I mentioned define means you believe clear about your project scope, champions, greenbelts, estimated, dollar impact, leadership, top management support. Measure; define CTQs, map the process, establish baseline sigma. Analyze, make C and E matrix and other as say tools to analyze the process, develop FMEA. Improve and finally, has a part of control develop and implement the control plan transfer to operations, verify financial benefit and sustain the process.

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You can also see the same cycle, I am just trying to expose you right at the beginning to DMAIC steps and what are the issues we are trying to address. So, define what is the problem? What is the scope? Measure; what data is available? Is the data accurate? Analyze, what are the root causes? Have the root causes been verified? And so on. Improve; do we have right solutions? How will we verify the solutions? And finally, control; how do we recommend? Is their support for suggestion? What is our plan to improve and so on?

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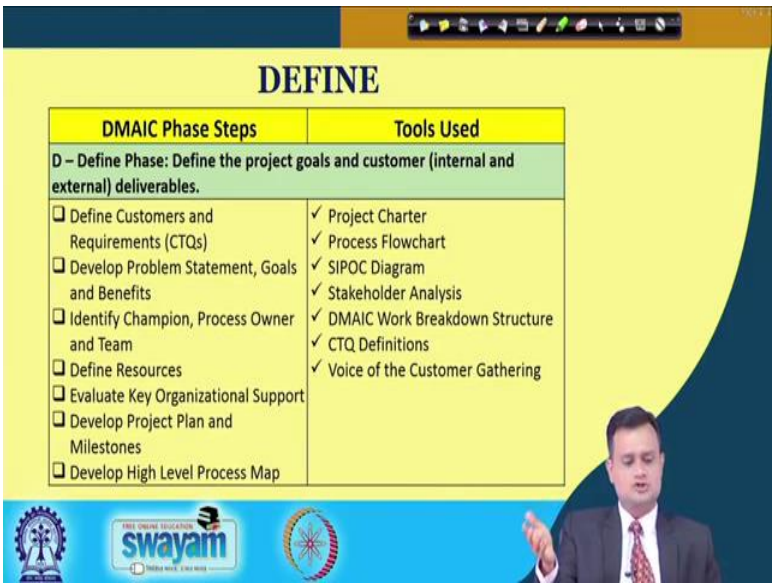

So, I also put it another way each phase, its objectives and the various tools that we use. So, define phase we try to define the project goals and customer requirements and deliverables. So, project charter process, flow charts, SIPOC, than stakeholder analysis, DMAIC, CTQ voice of customer, measure phase.

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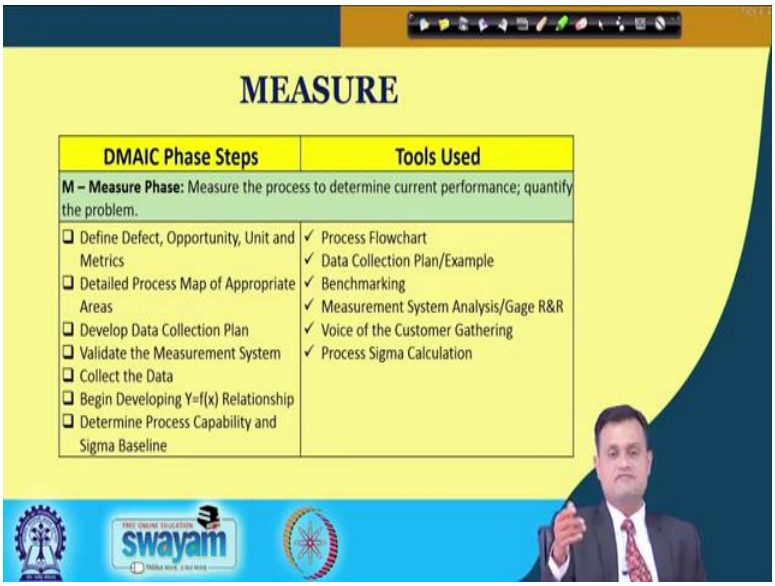


You can say use process flow chart data collection, benchmarking, voice of customer.

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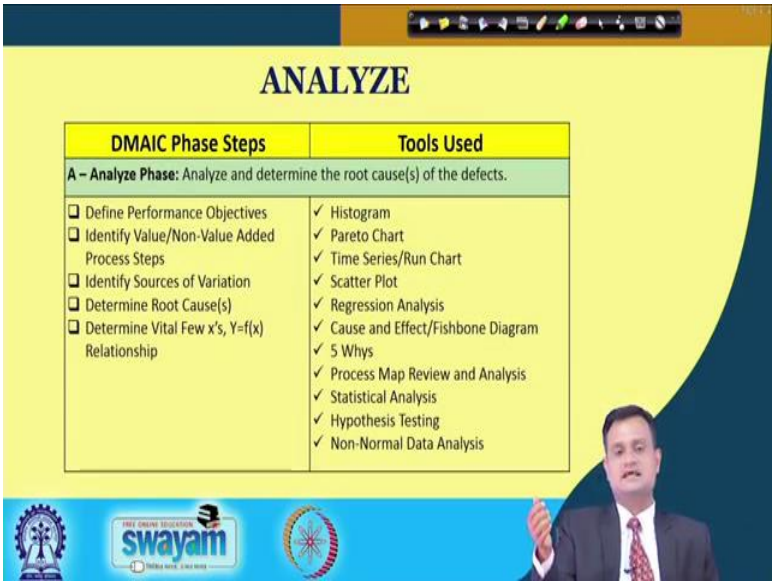


Analyze histogram, Pareto chart, Cause and Effect, hypothesis testing, non normal data analysis.

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Improve; brainstorming, mistake proofing, QFD, FMEA and so on and finally, control.

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Process sigma calculation, control chart, control savings calculation, and control plan.

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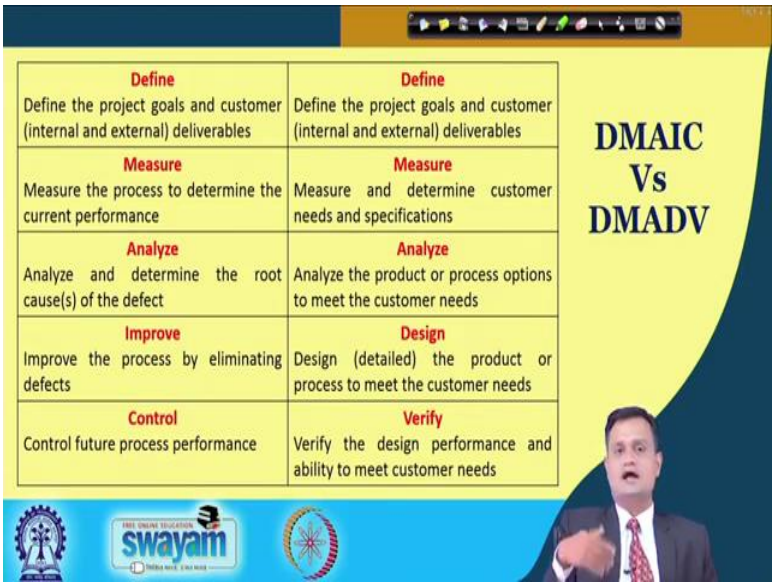


So, this is how I operate there is a small distinction I would like to bring to your notice that like DMAIC there is DMADV and typically when there is a need for design and verify my DMAIC cycle would more like operate as DMADV and this cycle can help me to have new product development or new process development.

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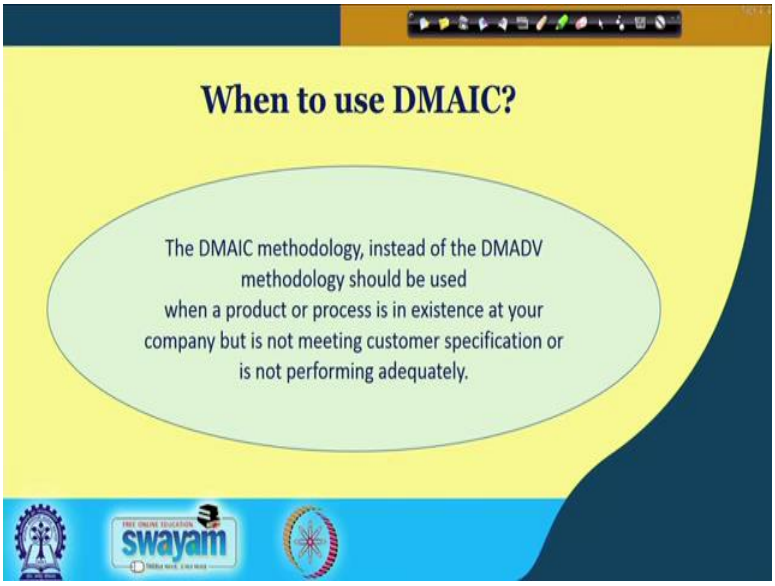


So, when to use DMAIC? So, typically you will use DMAIC instead of DMADV when a product or process is in existence and your company is struggling with the customer specifications.

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You will use DMADV typically a product or process is not in existence and you are trying to develop a new product. So, existing product or process whatever you have and has been optimize using either DMAIC or not and still does not meet the level of customer specification or the sigma level.

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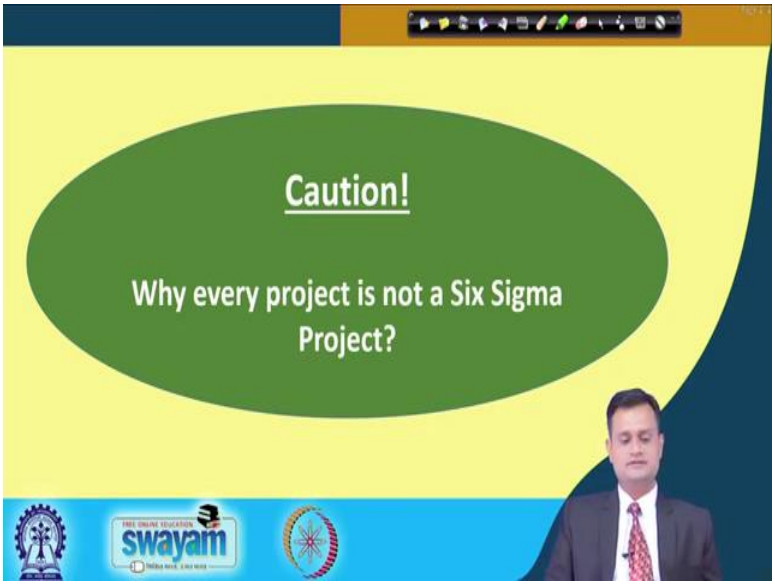


So, there is a caution every project is not a Six Sigma project please remember, after going through this journey please do not try to boost that whenever there is a problem I should consider it as a sigma project it is not like that..

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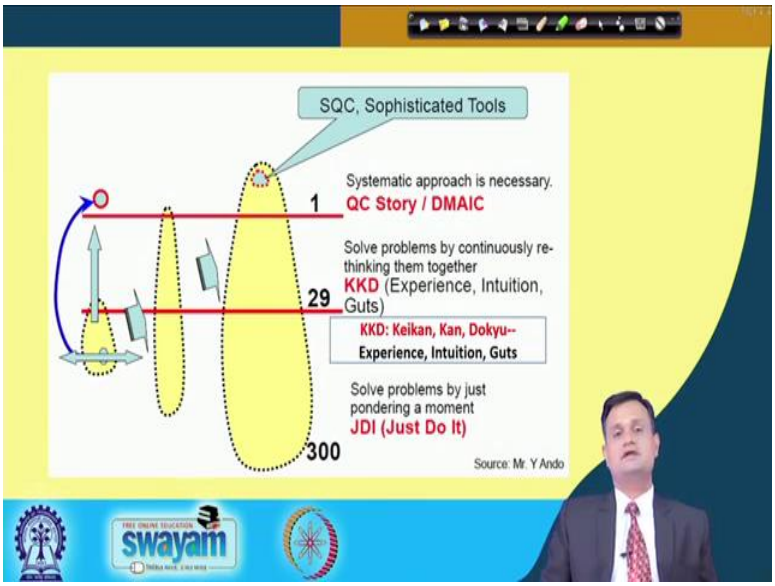


Because sigma project demands investment, long term commitment, money, resources and we cannot make a mistake in accepting all the projects as the sigma projects. So, just to sensitize you suppose you look at a particular organization you may have the problems maybe let us say 300 problems this large number of problems can just be solved by a very very simple approach Just Do It, that is it that is called JDI. So, solve problem just by pondering a moment, you think and try to get the solution. Second is let us say some 29 problems still higher in number you apply KKD, KKD is stands for in Japanese term Keikan Kan and Dokyu.

So, it means experience, intuition, and guts you use your experience and guts to solve the problem you do not consider them as DMAIC Six Sigma project. Finally, you will see that when you really know the scrutiny you will end up with only few problems which demands a systematic approach DMAIC and a rigorous analysis through Six Sigma and hence the investment of resources.

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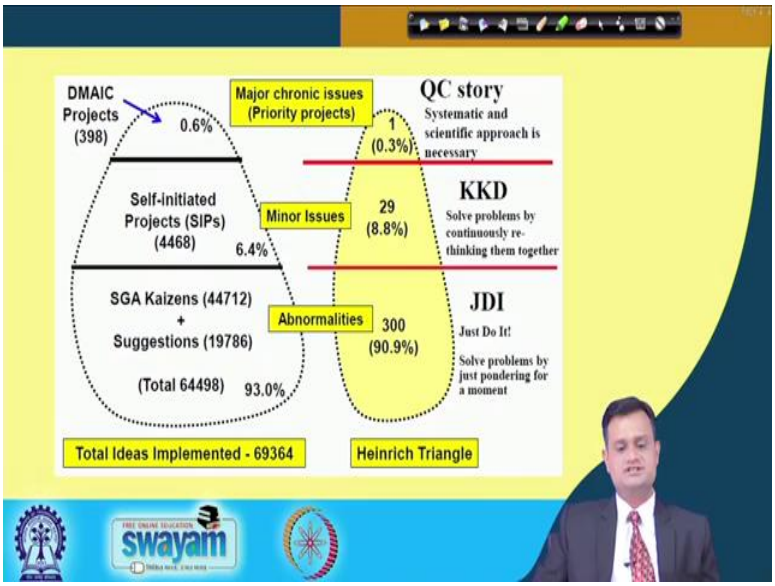


So, same thing you can see here that chronic issues priority projects needs to be identified and you cannot make a mistake in accepting all the projects as the Six Sigma projects.

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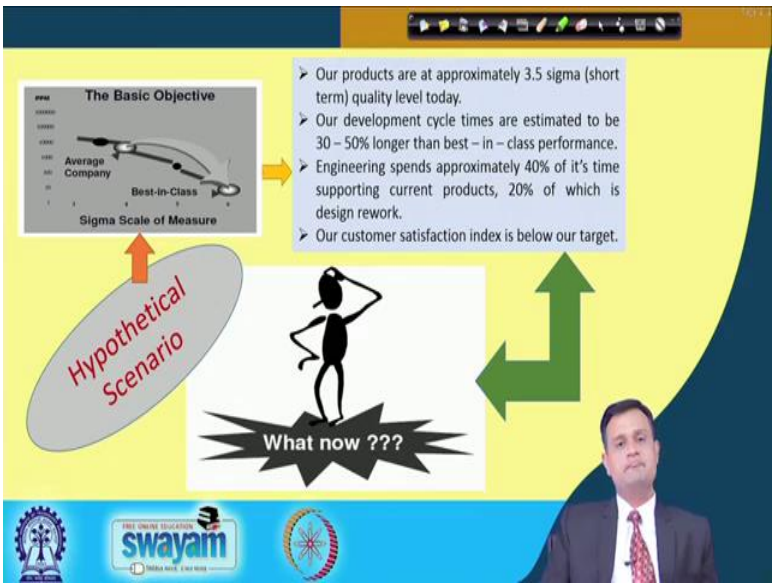


So, just see organizations have various complaints when they are in this zone of average company our products are at approximately 3.5 sigma; quality level today our development cycle times are estimated to be 30 to 50 percent longer than best in class performance. Engineering spans approximately forty percent of its time, supporting current products our customer satisfaction it is in index is below our target.

So, the answer lies in systematically adopting and implementing Six Sigma and getting rid of the hidden factory and gradually, continuously, improving the quality level.

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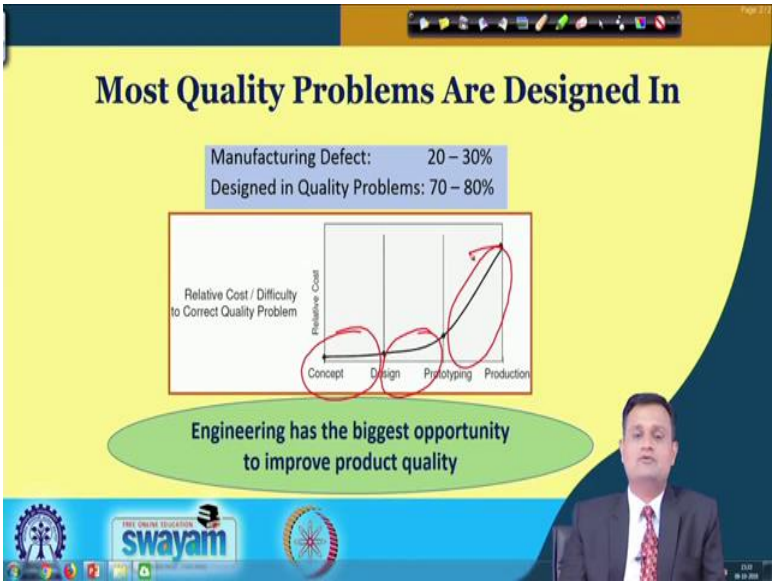


So, many quality problems are designed in and you can see very well through this graph that if you can address them at the concept stage your relative cost is least if you go to little bit higher the cost increases and finally, if it goes from prototyping to production you have to have enormous cost waste or money wasted and that may not be recovered.

So, this is the main concern that we try to apply Six Sigma right at the engineering stage which can bring maximum advantage for the companying finally, I would like to emphasize on Six Sigma roles, you cannot implement is Six Sigma without having a Six Sigma structure or organization.

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And typically you can see that a when you need all employee to understand vision and apply the concepts there is the structure of people who basically try to see that Six Sigma project become successful. So, you can see there are project team members, they are part time, there is green belt. Part time and they basically help the black belts, their preliminary knowledge green belt, black belt is a high responsibility devote 50 percent to 100 percent of time to black belt activities facilitate and practice problem solving, train and coach builds and project teams master back belt they are full time, train and coach black and green belts and statistical problem solving experts in depth knowledge and there are champions who are basically the project owner implement solutions and there is executive support basically they look for the overall vision, direction, integration and lead the change.

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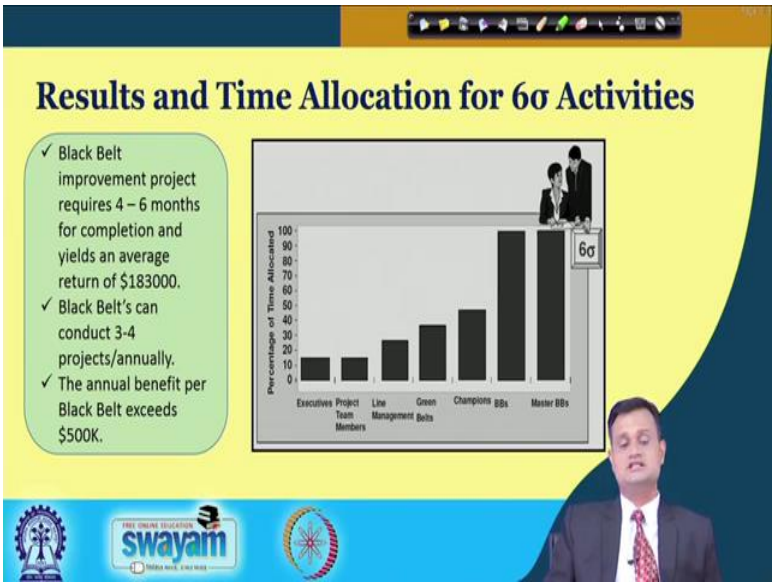


So, if we also analyze the various roles in terms of percentage of time allocated then just see that executive maybe 12 to 13 percent project team leader more or less 12 to 13 percent. Line management little bit higher 25 percent, greenbelt 30 percent, champions 35 percent black belts they have to spend almost 95 and same is the master black belt. So, black belts can conduct 3 to 4 projects annually as a rule of thumb an annual benefits for black belt are expected to exceed 500000 dollar.

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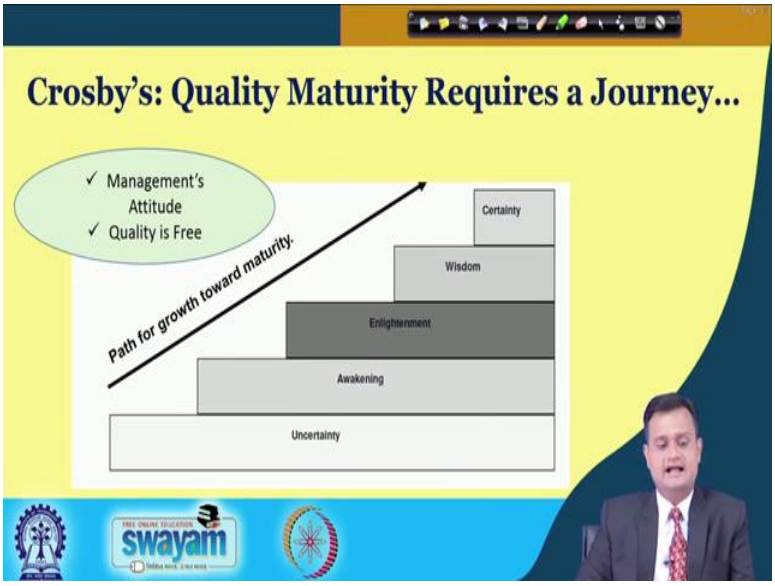


Just see that Crosby a well known quality say that quality maturity requires the journey.

So, that is why repeatedly I am saying Six Sigma is a journey and you are trying to move from the stage of uncertainty, to awakening, to enlightenment wisdom uncertainty. So, you cannot achieve this in one day, but Six Sigma assures you that if you work on the right project through DMAIC or DMADV cycle then gradually your level of awareness will improve and you will advance on the path of your journey for quality and Six Sigma. So, just before I end I want to post couple of questions for thinking.

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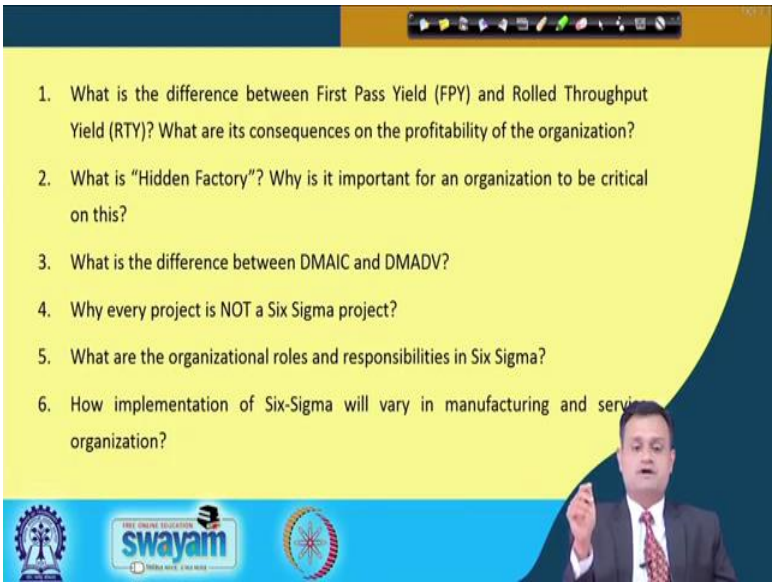


What is the difference between first pass yield and rolled throughput yield? And what are its consequences on the profitability of the organization? Think it critically use another data set recalculate it or gather some practical data or real life data and just try to see that how really it conveys the concept of hidden factory.

So, the second question is "what is hidden factory"? Why is it important for an organization to be critical on this? What is the difference between DMAIC and DMADV? Why every project is not a Six Sigma project? What are the organization roles and responsibilities? And finally, just give a thought that how implementation of Six Sigma will vary in manufacturing and service organizations? Where the distinction would really lie and what are the precautions you would like to follow.

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These are the references you can use Evans, introduction to Six Sigma; Mitra, fundamentals of quality control and Roderick Munro and Govindarajan,\ certified Six Sigma green belt to appreciate this concepts. So, with this we can conclude that organization must improve awareness on hidden factory and critically measure the utilization of resources in meeting the customer requirement. And DMAIC is the key for reducing variability and successively improving the sigma level of your processes.

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So, with this thank you very much I hope you enjoyed this discussion and you are able to relate the discussion of each particular lecture and this will really help you even to move from the state of unawareness to awareness and wisdom and maturity in the cycle in the journey of Six Sigma. So, wish you all the best be with me we will discuss another topic in the next lecture and continue our journey.