Production and Operation Management
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Lecture 54
Maintenance Management

Welcome friends. We are discussing different important issues which operation manager may face and now we have completed about more than 50 sessions in this particular course. And you must have fair idea that the scope of activities for a operation manager is too wide, right from planning to execution and then quality control, the forecasting, the inventory management, the production planning and then different other activities in case of TQM, where you also need to have an eye on the customer's requirement.

So, the scope is really very vast for operation manager. And as in the beginning, we discussed that there are lot of issues which are overlapping with industrial engineers and operation managers. And one such overlapping issue we are going to discuss in one of the coming sessions that is about the work measurement, that is about the productivity analysis of the employees. And in this session also, we are going to discuss a similar kind of discussion, which is partly related to our reliability analysis and partly related to operation management.

And the topic of that discussion is Maintenance Management. Maintenance management is one of the most ancient issue related to operation management. When scientific management started, the basic idea of scientific management was twofold. One is to identify the best way of doing a particular task and according to that give training to all your employees, so that they work according to that best way.

And the second idea was to have the up to date maintenance of your plant, so that there is maximum output, maximum productivity from your organizations. So, these were the initial 2 thoughts that if my plant is running 24 into 7, I will have maximum output and for doing that, I need to train my employees, so that they can work with the best way of that particular product.

We know that some drivers are there who drive very casually and very often either they will do accidents or they will create lot of maintenance issue for your vehicle. And there are few drivers who are very mindful, they drive very carefully and most of the time they will not involve into any accidents and their vehicle also does not require much maintenance.

So, depending upon their training, depending upon the skills you have, you will use your vehicle, you will use your equipments, you will use your machinery, so that it can perform the best output. For that purpose, we are going to discuss in this session, the concepts of maintenance management. Maintenance management as we have discussed with respect to most of the other topics of operations management is a complete subject in itself.

But we will like to summarize the important concepts of maintenance management in two sessions. We can have a full-fledged NPTEL course only on maintenance management, it is such a vast area. And again, as we discussed about TQM, that is the guiding philosophy for most of the organizations these days. Similarly, in the maintenance management there is a concept coming, that is TPM, Total Productive Maintenance.

So, how maintenance can provide competitive advantages to your organization, that has become a modern day issue, a modern day philosophy for the organization. So, it is not simply the cost or it is not simply a reactive function it can be highly strategic function for the organization. How can you take the strategic advantage of the maintenance, that is a very important thing. And therefore, it is worthwhile to discuss the concept of maintenance management almost in the last of this particular session, so that you remember that why maintenance management is important issue.

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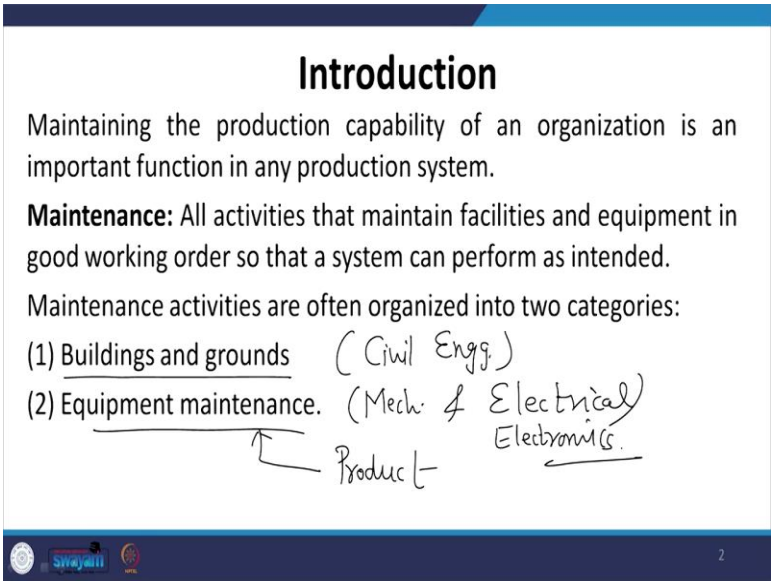

Now when we are discussing maintenance, generally maintenance is related to issues like buildings, grounds, etc., that some leakage is there so you have to do some kind of repair work, some other kinds of issues are there. So, lot of issues related to civil engineering are associated with respect to maintenance management. And then the other kind of maintenance that is the equipment maintenance, this is related to mechanical and electrical.

These are the two important, you can say branch of engineering, which are associated with equipment maintenance. So, with respect to maintenance, normally we consider building grounds, equipment maintenance. The product maintenance is also the part of your equipment maintenance, the finished product which is coming to the market and if there is a issue with respect to quality, with respect to performance of that equipment this product, that is part of your equipment maintenance. Now because most of the equipments are having a lot of electronics component. So, even electronics is also the part of this maintenance activity.

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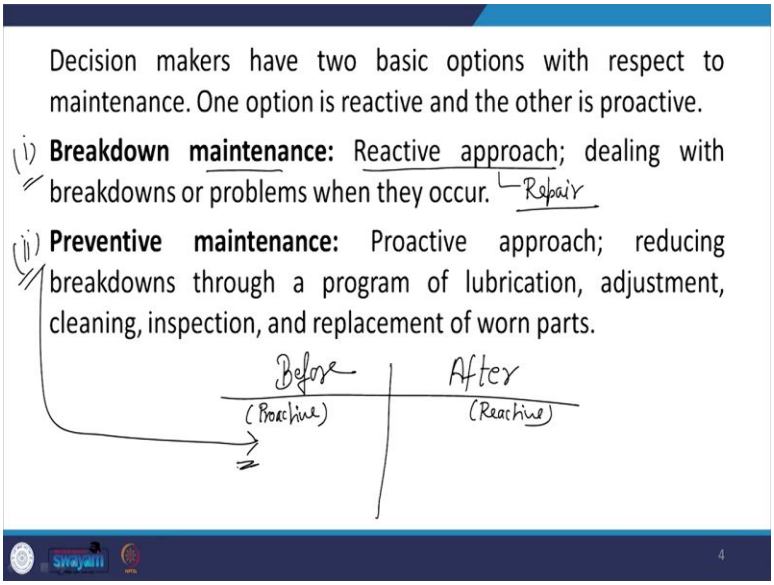

Now when we are talking of maintenance, there are two important concepts which immediately come to our mind and these are two names. One is breakdown maintenance and another is preventive maintenance. Breakdown maintenance is a reactive approach, that some loss has taken place. Like in case of building there is some seepage which is happening, only when seepage is happening then you will go for maintenance of that seepage. When something has

happened, so how to repair that? So, this breakdown maintenance is more with respect to repair, repair of some kind of malfunctioning.

When your equipment is not functioning properly then you go for breakdown maintenance. Another very common example, you are driving your vehicle and all of a sudden there is a puncture in the tire, so you will only go for breakdown maintenance. So, to repair that punctured tire, you go to a shop, you go to a repair shop, and then you get it repaired. So, that is the kind of breakdown maintenance.

So, whenever some issue has happened, whenever some problem has happened. Then the maintenance activity you undertake, that is breakdown maintenance. The breakdown maintenance, which is done that is always reactive in nature, it is after the incidents. So, you can divide the issue of maintenance in two categories; after and before. So, before the issue has emerged, before something has happened that is known as proactive. This is reactive.

Well dengue has happened to you then you are taking medicine, so that dengue does how to cure dengue. But you know that in my city dengue is happening all around, so what type of preventive actions I can take that is proactive maintenance. So, this preventive maintenance is part of proactive maintenance. And now, most of the time organizations are shifting to this preventive maintenance because this preventive maintenance is a system where you will not have any kind of undesirable interruption in your production schedule.

Whenever breakdown maintenance is done, it disturbs your production cycle. You will not be able to achieve the required lead time; you will not be able to deliver products on the promised dates to your customers. So, this breakdown maintenance is a dangerous thing. Breakdown maintenance should be avoided. And to avoid breakdown maintenance, we need to have a very proper robust planning of preventive maintenance that you can foresee that what is the maintenance requirement of this particular equipment accordingly you decide a schedule of maintenance.

And if a schedule of maintenance is coming in between of your delivery dates then accordingly you can make sufficient scope in your delivery date, so that right from the beginning you promise a delivery date to your customer, which is realistic. But if you have promised, now your equipment has failed, your machine has failed, and then you will not be able to deliver products

on the due date, so it is going to result into customer dissatisfaction. So therefore, preventive maintenance is a very useful thing and we need to see how do we plan preventive maintenance properly.

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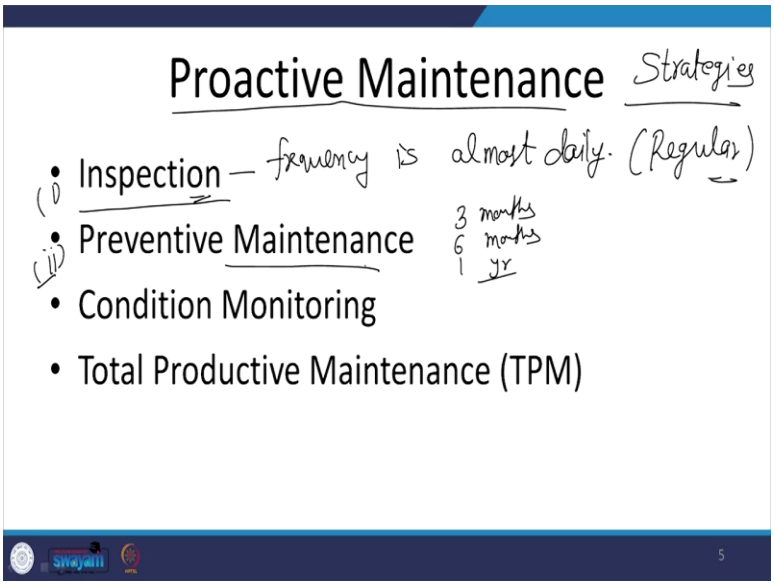

Now this proactive maintenance which is done in anticipation that there may be some failures, there may be some issues with respect to my machine. So, we have different types of strategies, these are, you can say productive, proactive maintenance strategies. And what are these proactive maintenance strategies, the one is inspection.

Whenever you start your machine in the morning, whenever you are taking your car out of the garage in the morning, you do some preliminary checks, whether the oil level is appropriate, whether the tires have enough pressure, whether the coolant is appropriate. So, 2, 3 important things you check and if you feel that all these things are okay, then only you start your vehicle.

When you are starting your machine in the morning, you check whether the all fuses are appropriately tighted, whether the tools is appropriately bound on the machine, whether the jobs are appropriately available or not. So, these are 3, 4 indicators, which you check in the morning when you are starting the machine, so that we do, without calling it a kind of a maintenance strategy.

But for most of us, it is part of our habit that we do some kind of initial checking before starting the work. So that is a inspection activity, that is one of the kind of our proactive maintenance strategy. And the frequency is, is almost daily. Daily means, whenever you are using this equipment, you are initially doing the inspection and then only you are starting the work. So, it is a very regular kind of activity, you can say it is a regular kind of activity.

So lot of break down issues can be avoided if you are doing a routine inspection, so that you understand how the condition is deteriorating, how the condition is, may create more failures, so you can accordingly take a decision about the products, about the machine's maintenance. But many a time we become so careless that we even do not go for this kind of inspection and we immediately start the machine without checking the oil, without taking the pressure, we take the vehicle out and go for a long ride and that is going to damage the vehicle very severely.

So, that is to be a permanent habit that wherever we are starting anything, we need to check our equipments, that is a simple thing. The second is preventive maintenance. You develop a schedule of maintenance that frequency may be in 3 months, for somebody it maybe in 6 months, for somebody it may be in 1 year, so you may have a particular frequency of preventive maintenance.

Again, we take the example of car. In case of car, we have a schedule of preventive maintenance that after every 6 months we will take our car to a garage and we will do some necessary check in the car. And the idea of this preventive maintenance is to again avoid the breakdown maintenances. If you are not taking car to your garage then anytime any major loss may happen. So, to avoid those major losses, those breakdowns we follow a schedule of preventive maintenance.

For many of you, you must have noticed that whenever you purchase a new car, whenever you purchase a new 2 wheeler with that you get a small booklet. And in that booklet a schedule of maintenance activities is printed. And that schedule is nothing but the schedule of this preventive maintenance that after 20000 kilometers, you need to go for oil change. After these many kilometers you need to go for gear wire change, after these many kilometers you need to go for alignment check, after these many kilometers you need to go for your tire change.

So, all those things are the part of your preventive maintenance and that is nowadays available for almost all the machines. Whenever you go for purchase of a machine for your factory in that also there is a proper maintenance schedule and that is preventive maintenance. The idea is, again to reduce the breakdown maintenance when we have the preventive maintenance. And for that purpose, because preventive maintenance and breakdown maintenance are very closely associated. More preventive maintenance you follow, more preventive maintenance you follow you have less chances of breakdown maintenance.

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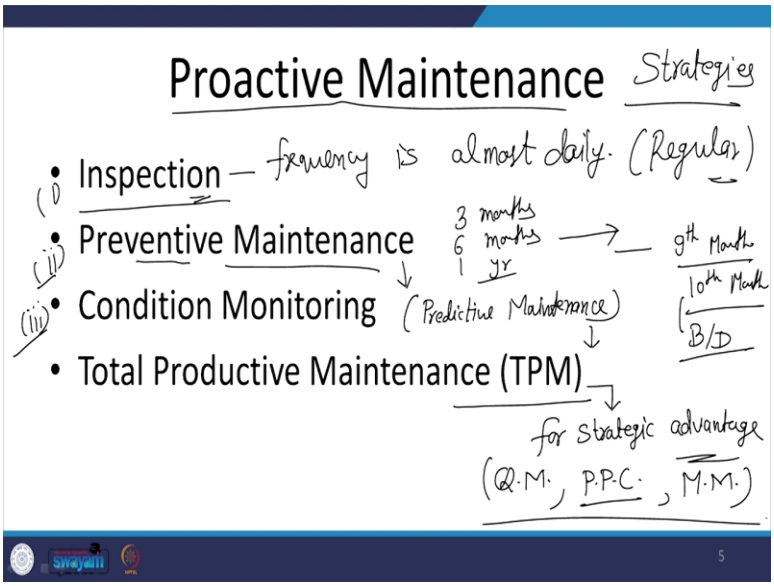

And, but there is a cost of everything, there is a cost of everything and based on that relationship there is a relationship between preventive and breakdown maintenance. Now what is this, that on this x axis we have the efforts or the level of maintenance, whether it is preventive maintenance or the breakdown maintenance and on the y axis we have cost of maintenance.

Now you see, as our efforts of maintenance with respect to preventive is increasing, when this preventive maintenance efforts are increasing, I am doing more and more preventive maintenance, the efforts are increasing, it means that I am doing more and more preventive maintenance. So, what is happening, in that case continuously my breakdown maintenance is decreasing, my breakdown maintenance cost is decreasing when I am putting more efforts in the preventive maintenance.

When my cost of more efforts means, every time I am doing a preventive maintenance, I incur some costs, so I am measuring my efforts in terms of cost. So, as my preventive maintenance cost is increasing, my breakdown maintenance cost is decreasing. Though even at this level, even at this level when we are having very high level of preventive maintenance cost there is some breakdown maintenance cost. So, you can see that at this level when you have very high level of preventive maintenance cost but at this level also it has some breakdown maintenance cost, it is not 0.

Because we know that when you are bringing your new car, when you are bringing your new car from the garage, it is quite possible that as soon as you come out of the showroom, there are chances that your tier may get punctured, within 5 kilometers it is possible that your tire may get puncture. So, even with full preventive maintenance, you are using a new product even at that time there may be chances of breakdown maintenance.

So, though it will be very rare, but you cannot eliminate that probability. So therefore, with very high level of preventive maintenance cost, there will be some breakdown maintenance cost also. So, we find the total of these 2 cost, the preventive maintenance cost and the breakdown maintenance cost A.

And this dotted line, this dotted curve is representing the total cost curve, which is actually the sum of preventive maintenance cost plus breakdown maintenance cost. This total cost curve is some of preventive maintenance cost and breakdown maintenance cost. And here, you have the lowest total maintenance cost or you can say this is the optimal level, this is the optimal level of cost curve where you have a, because breakdown maintenance is not in your hand, breakdown maintenance is not in your hand that how many breakdown maintenances you want to have. But preventive maintenance is in your hand.

So, this gives you a particular level of expenditure, particular level of frequency of preventive maintenance, that you should spend this much amount of money on the preventive maintenance or this will be translated in terms of frequency of preventive maintenance, that if you have this level of frequency of preventive maintenance, it will keep your overall cost of maintenance at the lowest possible level.

So, this is a very important relationship between preventive maintenance and breakdown maintenance. The relationship is inverse as your preventive maintenance cost increases, breakdown maintenance cost decreases and therefore we get the point of lowest total maintenance cost. Then another important type of proactive maintenance strategy is condition monitoring, that is another important thing and that is also known as predictive maintenance.

This predictive maintenance is a new area, which is based on symptoms because you have done a preventive maintenance on the basis of 6 month frequency, that after every 6 month you are taking your machine, you are doing a preventive maintenance. But it is quite possible that in the nineth month some problem started coming and in the tenth month this resulted into breakdown. Now, you are following a good schedule of preventive maintenance of doing the maintenance after every 6 months, but all of a sudden in the nineth month, some problems started coming.

You did not recognize; you did not pay attention because you thought that I will do maintenance at the end of the sixth month now. And 3 more months are here to come but in the tenth month it resulted in to the breakdown. So, your entire efforts of preventive maintenance become useless. So therefore, nowadays people go with condition monitoring predictive maintenance, where they continuously monitor the health of the machine, they continuously monitor the health of the machine with the help of various sensors and these sensors are put at the important places, important places from where the data is taken.

For an example, nowadays we have these smart watches and these smart watches kind of a sensor. It is regularly tracking your pulse rate. And if pulse rate is going beyond a particular limit or it goes down beyond a particular limit, it will immediately send you a signal that you need to visit to a hospital, you need to go to a doctor. So that you can do your checkup, you can do the proper maintenance activity.

So, same thing we do with respect to machine also that we are now installing various sensors into the machine, so that you can get the regular data about the health of the machine. And once you get the regular data on of the health of the machine, then you can say that whether the machine is going to perform okay for next 1 month, 2 month, 3 month. Otherwise you need to plan that we need to have immediately some kind of maintenance activity.

So nowadays we are moving from preventive maintenance to predictive maintenance, that you have to maintain your machine with respect to the health of the machine, you need not to have a rigid schedule of preventive maintenance, rather you should be aware about the current health of your machine, current health of your equipment. And whether it is buildings, dams, or bigger installations everywhere now the sensor technologies are coming and with the help of the sensors we are able to monitor the health of the equipment on a real time basis.

So, that is the predictive maintenance, so that is you can say one level advance with respect to maintenance strategy, this is one level further the movement to proactive maintenance. Further to that, we go to total productive maintenance that Total Productive Maintenance, TPM is a concept which is available to most of the organization these days organizations which want to use maintenance for strategic advantage, these organizations use maintenance for the strategic advantage.

And in this particular case, we design our maintenance program as a holistic activity where we are also involving people from quality management, we are also involving people from production planning and control, and obviously the maintenance management is core of these. So, we are involving people from other functional areas also in performing the maintenance activities so that maintenance is not only a cost center, maintenance is not only a supportive center, but it can also be considered as a strategic function for the organization.

And therefore, TPM has become a very popular concept nowadays, like TQM is a popular concept, so TPM has also become a very important area for many organizations. And it is a very satisfactory thing that many organizations from India also are now continuously going into TPM related excellence awards. So, every year TPM excellence awards are given. And in our next session we will discuss some of the important criteria about TPM excellence awards. So, you will see that of how the number is growing for TPM excellence awards, in India.

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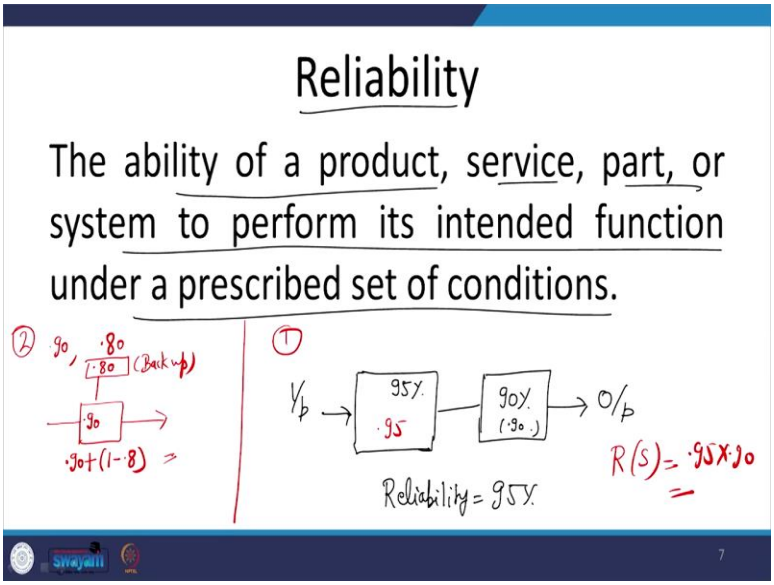

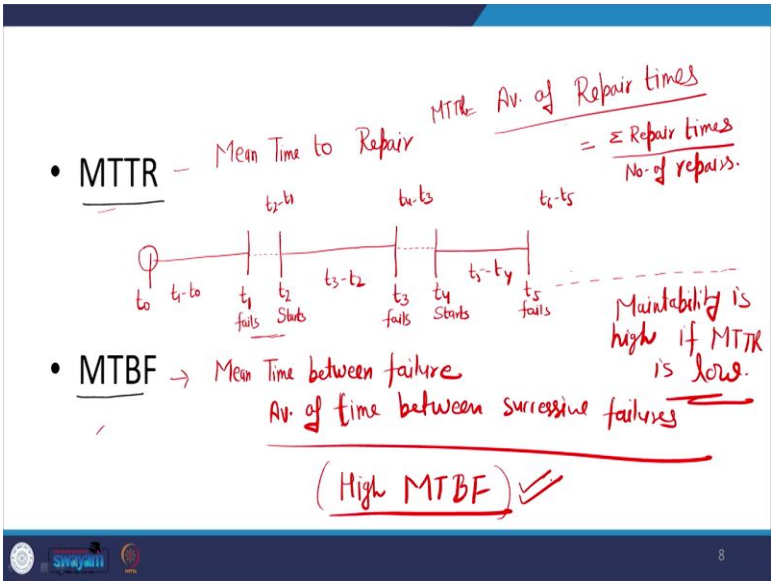

Now, when we are talking of all these things with respect to maintenance, there are few important terms we must know. One important term which is worth knowing is reliability. Reliability is the ability of a product, service, part or system to perform its intended function under a prescribed set of conditions.

So, you have some specified condition and within those specified condition if equipment is working properly, you say that it is a reliable equipment. But if the equipment is not working properly then you say that it is not a reliable equipment. So, with the maintenance function, with

the maintenance function we want to improve the reliability of our equipments that in all the conditions which are prescribed for that particular equipment, it should work most of the time.

So, we want to have very high reliability. So, one of the you can say quantification of your maintenance function is with the help of reliability. Traditionally reliability used to be the measure of our maintenance activity, how good my maintenance is there.

And for that purpose, you have different types of measures MTTR and MTBF. These are the two important measures for measuring the reliability of the system. Now, first we understand what do we mean by quantification of reliability. You see this is an equipment, now out of 100 times, out of 100 times whenever I want to operate this equipment, this is readily available. I can use this equipment 95 percent of the time or you can say 95 times this equipment is working properly under the given condition, so the reliability of this particular equipment 95 percent. Now, there are cases where 2 equipments are there.

And first, this equipment will work and then the second equipment will work, then only my output will be available. So, the reliability of this equipment is 90 percent or 0.90 and reliability of the first equipment is 0.95. So, the reliability of this system is 0.95 into 0.9, so that will be the reliability of this system. Sometime you have some other cases also. For an example, there maybe this is case 1, case 2 simply, like there is a room and in room there are 2 bulbs, in a room there are two bulbs.

Now the reliability of the bulb is 0.90 and reliability of other bulb is 0.80, the meaning is that whenever you want to switch on the bulb A, 90 percent of the time, it is working. When you want to switch on the bulb B, 80 percent of the time bulb B is working. Now to illuminate the room only one bulb is sufficient the other bulb is acting as a backup, the other bulb is acting as a backup. Out of 2, 1 bulb is sufficient and anyone out of 2 because 2 switches are there. So, you can switch on any of these bulb.

If the first bulb is not working, then you will switch on the second bulb. So, now this is not a sequential process, it is like this way, first bulb and the second bulb, this is a backup. So, in the first case, you have switched on the bulb of 0.9 reliability and the backup is of 0.8 reliability, so the reliability of the entire system is 0.90 plus 1 minus 0.80. So, that is going to have the reliability of the entire system, as the reliability when the backup plans are available.

Based on these reliability concepts we have the issues of MTTR and MTBF. MTTR, stands for Mean Time To Repair and MTBF stands for, Mean Time Between Failures. Now what happens, you have started using a product and this product is working properly. At a particular time, t1 you started the product at t naught, at t1 it fails, then it takes some time to repair and at t2 it again starts, then it is working with you up to t3, then it again fail.

It takes some time to repair, at t4 it again starts, then it is working and at t5 again it fails. So, this type of thing keep happens, that sometimes it is working, sometimes it fails, then you go for maintenance and so on. Now whenever it is failing, whenever it is failing it is taking some time to repair. So, at first time it is taking t2 minus t1 time to repair, then it is taking t4 minus t3 time to repair, then it is taking t6 minus t5 time to repair.

So, the average of these times, average of repair time divided by, so this is the average of repair time that is MTTR and that is calculated as the sigma of repair times divided by number of repairs. So, that gives you MTTR and we want that our product should have good maintainability, our product should have main ability and the measure of good maintainability is low MTTR. Maintainability is high means; you have a good maintainability if MTTR is low.

The second thing is MTBF. Now product is working from t naught to t1, t2 to t3, t4 to t5, so from t1 minus t naught, t3 minus t2, t5 minus t4, these are the time periods when the product is working properly. So, you can take the average of, average of time between successive failures. And that is going to give you mean time between failure and that is going to be another indicator of our product's performance. So, we want high MTBF, it means the product is available to us, product is available to us for longer duration of time.

It takes long time between two failures, that is high MTBF, if MTBF is low it means product is failing at a very regular speed and that is again, not desirable. Now, we can also combine MTBF and MTTR let us see how.

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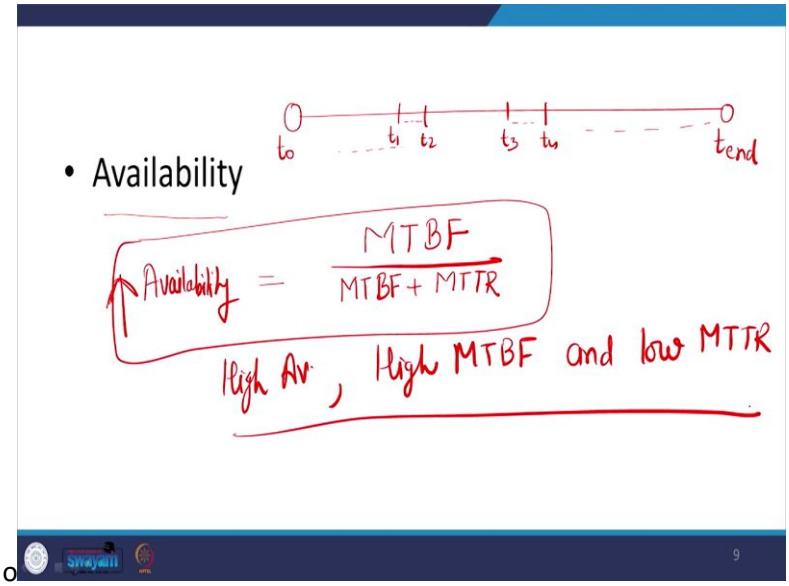

And that combination is possible with availability, by developing this relationship of availability that out of this entire life t naught to t end, many times it is it is working, it is failing, it is working, it is failing, and so on it is happening. So, the product is available to you out of this entire cycle, product is available to you only when it is working and that is determined by mean time between failure. When it is not failed, only during that time product is available to you and the total time from t naught to t end, can be represented by time which is, in which the product is available to you and the time when the product is under maintenance.

So, MTBF upon MTBF plus MTTR can be a good relationship which can be used for determining the availability. So obviously, you can understand that we want high availability, high availability, high MTBF, and low MTTR. So, this is what we want, that high availability, high MTBF, and low MTTR. If we are, if our maintenance system is able to help us regularly on getting the higher availability, higher MTBF and lower MTTR, it means we have a good maintenance strategy.

But this is the traditional way of knowing the performance of your maintenance system. Now, we will see in our next session, the modern concepts of maintenance management that how we have used new indices for understanding the performance of our maintenance system. And that will help us in strategic use of maintenance function. So with this, we come to end of this session. Thank you very much.