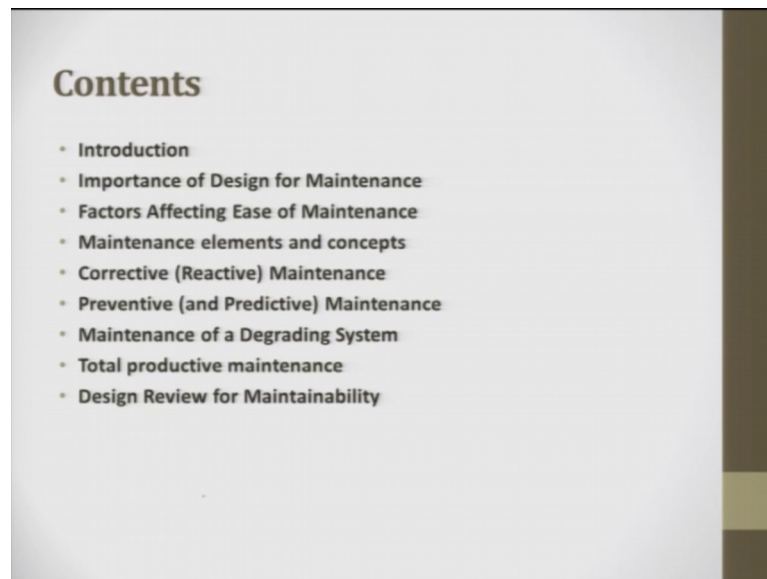


Product Design and Manufacturing
Prof. J. Ramkumar
Department of Mechanical & Design program
Dr. Amandeep Singh Oberoi
Department of Industrial and Production Engineering
Indian Institute of Technology, Kanpur
National Institute of Technology, Jalandhar

Lecture – 20b
Design for Maintenance

The next topic of discussion we are getting into Design for Maintenance; this is very new concept. People initially started with design for manufacturing and in manufacturing you have part making assembly. Then, people started making design for assembly and disassembly, now people have started talking about a new concept called design for maintenance.

(Refer to Slide Time: 00:49)



So, in this topic we will go through an introduction, then importance of design for maintenance, factors affecting ease of maintenance, then maintenance element and concepts, corrective maintenance, then we will have preventive maintenance, maintenance of a degrading system, total productivity maintenance, design review for maintainability. So, these are the topics we will cover through this.

(Refer to Slide Time: 01:11)

Design for Maintenance

Introduction:

- When a system fails to perform as required it is said to be repairable or maintainable, it can be maintained by a suitable methodology, be it repair, overhaul, or replacement either manually or by an automated action.
- It is important, therefore, that every effort be to reduce maintenance requirements for newly introduced systems and equipment.

FMEA →

Source: http://www.dotcomcreations.biz/website_re-Design_and_maintenance.php

So, introduction, when a system fails to perform as required it is said to be repairable or maintainable. Car you buy and the car count of after 10,000 kilometers or a scooter you buy count of at 10,000 kilometers, then the system would have been promised for 1 lakh kilometer, but now it has got count of after 10,000 kilometers. Suppose if it is a manufacturing defect the company pulls back and then gives replaces a new product to you, if it is your problem; that means, to say a customer when because of his driving performance the performance has fallen down or the machine has count of then it is then there is an option for maintenance. So, it is said to be repairable or maintainable.

It can be maintained by a suitable methodology and maintenance also cannot be done haphazardly. So, today what is happening is we have preventive maintenance, predictive maintenance and even the maintenance today what they are saying is it has to be given a schedule and you have to follow that schedule, and in that schedule also it is not necessary that you should do 100 percent maintenance of all the parts.

They try to divide, suppose if there are 100 spots where you have to look for maintenance and in that also they try to rank them which is more frequently to fail which fails very rarely. So, then the checking cycle also reduces for doing those parts with rarely fail, on top of it there is a schedule which is given what all schedule and a suitable protocol is given what all and how should it be checked. So, it can be maintained by a

suitable methodology be at repair over oiling are replacing the either manual or by automatic action.

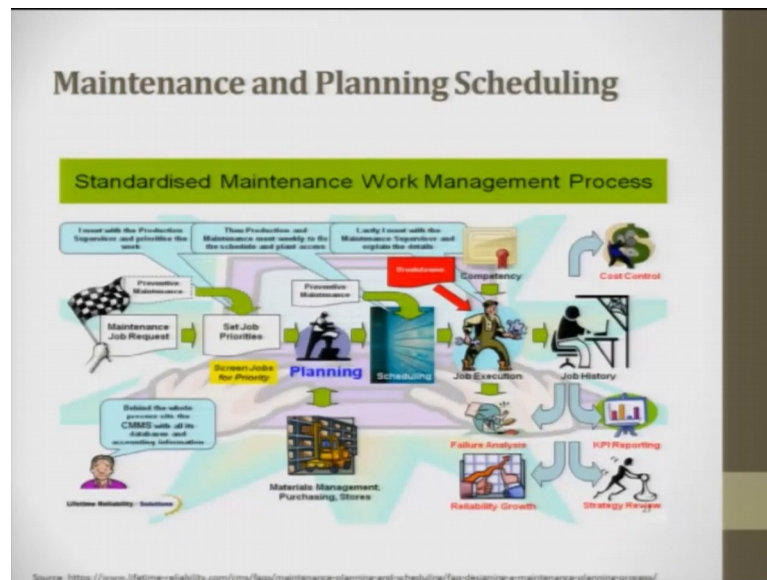
So, today what happens is many of the automotive sectors what they do is after selling the scooter or car or even a truck the agent keeps calling you at regular intervals of time and he says that sir your vehicle is prone for is a schedule now for going a maintenance check. So, the maintenance check generally they try to do oil maintenance, they used to check the engine performance, spark plug performance and all those things, that is scheduled. And in scheduled also there is a protocol what has to be checked and how. And while checking if they find out any untoward incident then they say sir please replace this, ok. So, that is what maintenance, repairable or maintainable.

It is important therefore, that preferred be to reduce maintenance requirements for newly introduced system and equipment. So, we would love to have 0 maintenance, but many a times it might not be possible. So, as far as possible try to extend the maintenance time; that means, to say frequency of maintenance should be reduced drastically, ok; this is what we are trying to say.

Here if you look back, we have done this FMEA analysis, right. In that FMEA analysis also what we try to do is we try to see which are the parts going to fail and how do you improvise their design and after getting the points we rehydrate and re-rerun the entire FMEA and then get to see the points we compare it and then do it. So, this design for maintenance also is an offshoot, it moves off from FMEA and we look for this design for maintenance.

So, these two are completely different, but I am just giving you an analogy FMEA here also you do failure mode effect analysis, and here what you do is you have design for maintenance, ok. A very similar one, but it is not the same.

(Refer to Slide Time: 05:19)



So, standardized maintenance work management process; so, if it looks like this I met with the production supervisor and priorities the work. So, this is the maintenance job request, set job priority; so this is what it is. So, it is for a preventive maintenance. Then what he does is he plans all the activities and then he schedules the activities, and then he job executes either he or through another one he does.

And after job executions he keys in what are all the components has, he keys in the status of different parts of the of the machine and that is used to hold the record and if you go back and see design for assembly disassembly, we said acquiring data from history this is the place where they record the history, ok. And then what all has to be charge they charge and what all has to be free they give it free and this is given to the customer.

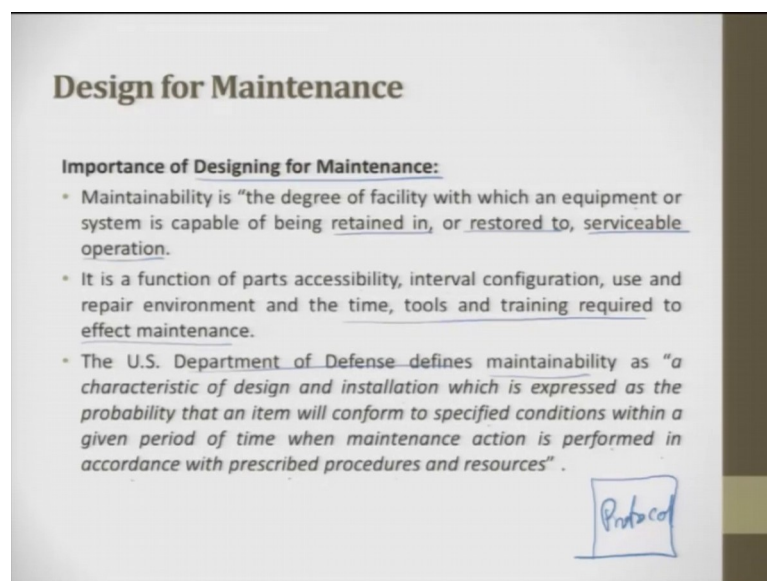
So, here if you see the production and the maintenance meet week to fix the schedule and the plant access. So, here what do I mean the scooter agent calling you is based on the scheduling, ok?

Lastly, I met the maintenance supervisor and explain him the details. So, this is what is breakdown and then he does. He also tries to give the complementary and this fellow is very smart to analyze it, ok. At that here if you see the planning action, so according to this planning action. So, it also tries to plan the stores and others other purchases which is to be done. So, then failure analysis ,I have already talked about you, reliability growth and then what we do is we try to have strategic reviews and try to figure out why this is

frequently failing and if need based we try to introduce a better material property there or we try to heat treat or we try to do some modification in the geometry such that we meet out the requirements.

So, this is maintenance and planning scheduling which is generally followed in a product. So, this a standardized maintenance work management process. So, you have maintenance job request, then set job priorities, then your plan, then you schedule then you execute and then you start reporting it this is KPI reporting.

(Refer to Slide Time: 07:41)



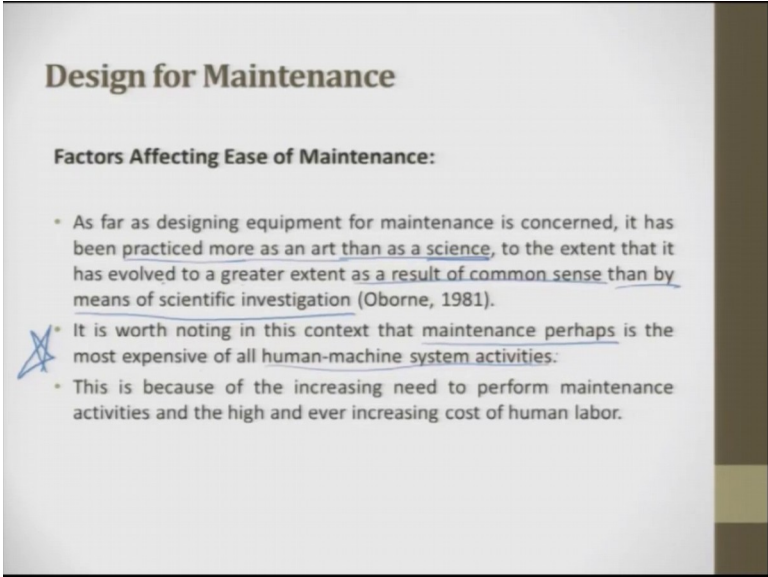
So, the importance of designing for maintenance is maintainability is the degree of facility with which an equipment or system is capable of being retained in or restored to serviceable operations. So, after doing this maintenance we are trying to pull back the equipment to 100 percent efficiency, if not 100 we go stop at 90 percent efficiency. So, once you do maintenance we are trying to pull back or improvise the system and try to achieve 100 percent.

It is a function of part accessibility, interval configuration, use and repair environment, and the time tool and training required to do an effective maintenance. See earlier days when you are on travel we always used to say please check the radiator coolant whether it is full or not, then they say please check the oil level whether it is full or not, then they say please check the pressure in that tire is to the required specification or not; today all those things are replaced by sensors, ok.

And now the and the sensors are also nowadays trying to tell us if a particular part has got worn and torn; that means, to say a particular part is very rapidly wearing it out, so they are sensors today which measure and directly tell us that please look into these particular points where there is there needs your attention. So, the maintenance and when they say maintenance today you also see it is software based. So, you also it also displays what is the protocol to be followed to access that point and what all the points to be checked before we try to do any more big maintenance, ok.

The US department of defense defines maintainability as a characteristic of design and installation which is expressed as the probability that an event will conform to specified conditions within a given period of time when maintenance action is performed in accordance with the prescribed procedures and resources. So, maintenance should always be followed with the protocol. This protocol will try to, you do not follow a protocol then that is not called as maintainable maintenance or design for maintenance. The protocol has to be displayed and then you have to follow this protocol and then try to get your machine repaired.

(Refer to Slide Time: 10:37)



Design for Maintenance

Factors Affecting Ease of Maintenance:

- As far as designing equipment for maintenance is concerned, it has been practiced more as an art than as a science, to the extent that it has evolved to a greater extent as a result of common sense than by means of scientific investigation (Osborne, 1981).
- It is worth noting in this context that maintenance perhaps is the most expensive of all human-machine system activities:
- This is because of the increasing need to perform maintenance activities and the high and ever increasing cost of human labor.

The factors affecting is for maintenance as far as design equipment for maintenance is concerned, it has been practiced more as an art than as a science. So, art means you do not have to have a set procedure, science means you have a set procedure. For every action there is a question raised under standard procedure or an explanation is given in

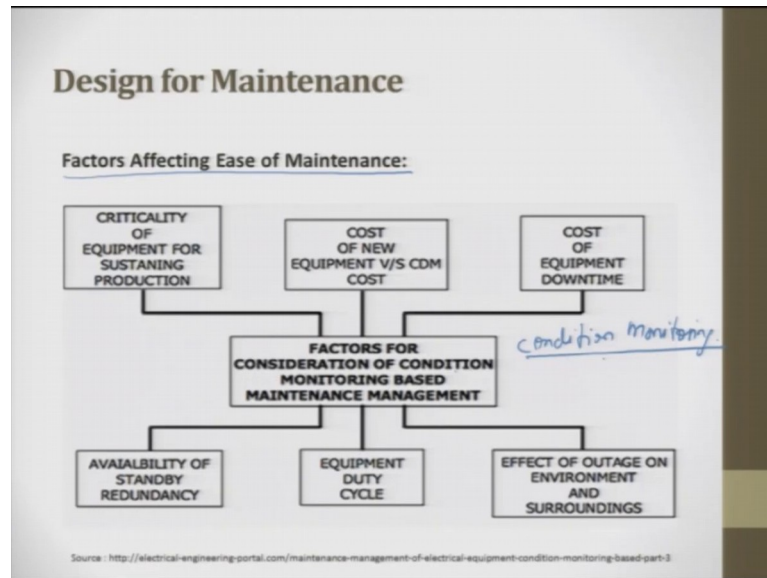
science, in arts it need not be; so that is what it is told. So, as far as that designing equipment of for maintenance is concerned it has been practiced as an art. Now, today this art has to change into a science.

So, what do I do? How do I do? When do I do? And is these the best practice? All these things has to be spelt out, to the extent that it can it has evolved to a greater extent as a result of common sense than by means of scientific investigation. This science also has to be predominantly around common sense. It is worth noting in this context that maintenance perhaps is most expensive of all human machine system activities, very important.

Today finding a person for repairing is next to impossible, it has become pretty expensive. For example, in your own house or in my own house when there is a plumbing failure happened. So, we have to wait for a plumber for 3 days and the plumber who comes does half an hour job and gets the entire day salary from us. So, that makes it very clear that maintenance, whoever does it is more expensive that is why today world has more to the concept of use and throw. When you follow this use and throw concept, we are now concerned about sustainable manufacturing.

So, when we throw, we have to make sure that we throw certain things which are not going to make any hazardous damage to the mother earth. This is because of the increasing need to perform maintenance activities and high and ever-increasing cost of human labor; so, this is what it is.

(Refer to Slide Time: 13:11)



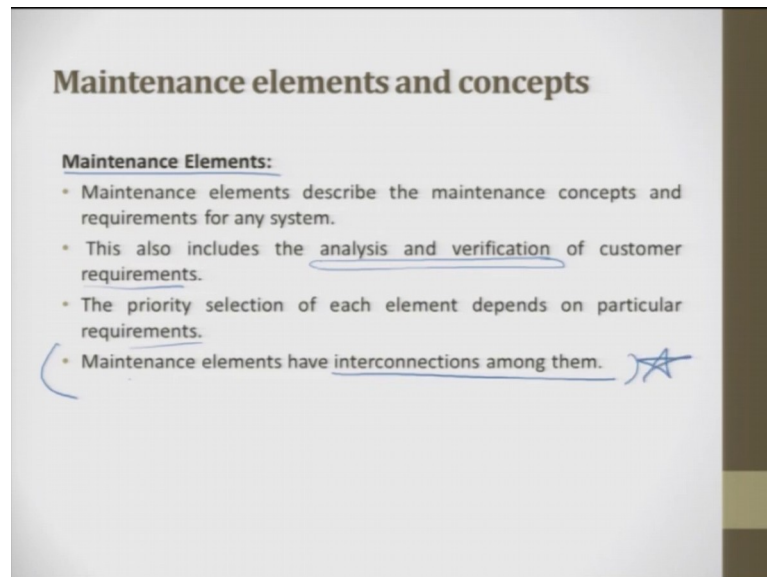
So, the factors affecting for the ease of maintenance continuing criticality of equipment for sustainable production, cost of new equipment versus CDM cost, cost of equipment downtime. So, all put together goes to factors for consideration of condition monitoring based maintenance management. So, then availability, then availability of standby redundancy, equipment duty cycle, and then it effect of outage on environmental and surrounding. So, these are the 6 factors which affect the ease for maintenance. So, factors for consideration of condition monitoring ,based maintenance management.

So, now, what people are talking about condition monitoring. What is the condition monitoring? Condition monitoring of the part where there is go, where there is a wear and tear effect going to be there. So, you are trying to measure a part where there is going to be wear and tear and at regular intervals you are going to tell me the status how is the status going and what was it before 10 minutes and how was it now.

And today the software's are become so powerful it also gives you a speculation saying that it can behave like this be very careful, condition monitoring, ok; so, that is condition monitoring. Condition monitoring can be for a compressor, condition monitoring can be for a car, condition monitoring for a cutting process, condition monitoring for refrigerator with air condition, everywhere today there is condition monitoring because the sensor technology has become more energy efficient and reliable.

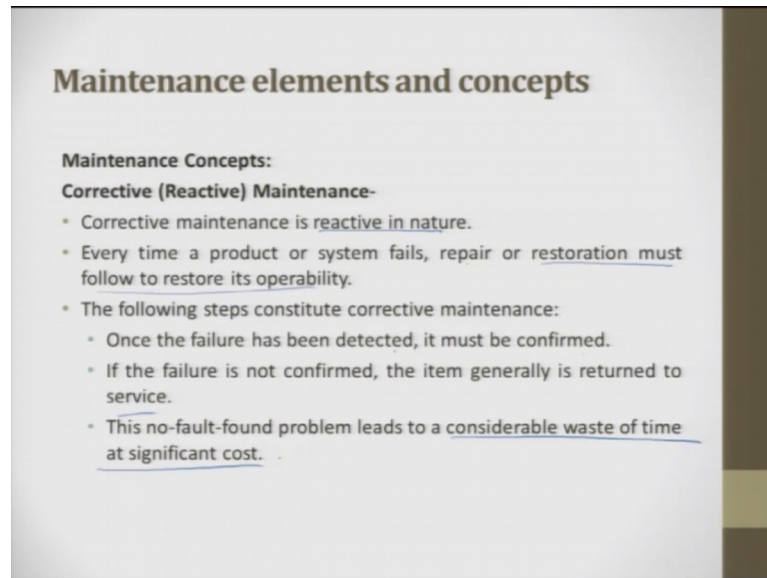
So, the criticality of the equipment cost of new equipment, cost of equipment downtime, availability, equipment duty cycle and effect of outage on environmental and surrounding place. These are the 6 factors which are to be considered for condition monitoring.

(Refer to Slide Time: 15:27)



So, the maintenance elements, the maintenance element describe the maintenance concept and requirement of any system. It includes the analysis and verification of customer requirement. Look at it. Maintenance includes analysis and verification of customer requirement. The priority selection of each element depends on the particular requirement. Maintenance elements have interconnection among them self, ok. So, this is very important maintenance elements have interconnection.

(Refer to Slide Time: 16:01)



Maintenance elements and concepts

Maintenance Concepts:

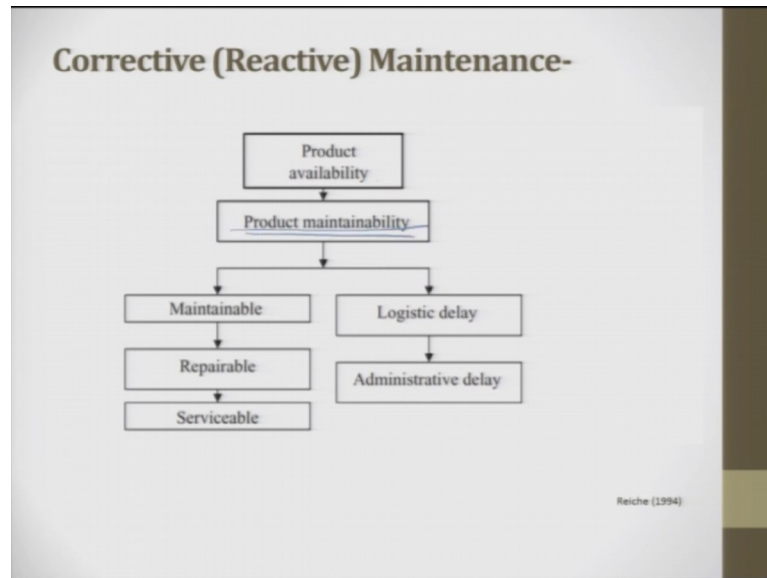
Corrective (Reactive) Maintenance-

- Corrective maintenance is reactive in nature.
- Every time a product or system fails, repair or restoration must follow to restore its operability.
- The following steps constitute corrective maintenance:
 - Once the failure has been detected, it must be confirmed.
 - If the failure is not confirmed, the item generally is returned to service.
 - This no-fault-found problem leads to a considerable waste of time at significant cost.

What are the corrective maintenance? Corrective maintenance is a reactive in nature. Every time a product or a system fails repair or restoration must be followed to restore its operation. And wearing footwear the footwear gives off I take it to a cobbler get it fixed that is corrective maintenance, ok. I have a pipe which is leaking, I have a computer which is which is not opening, call an expert, he comes repairs the system, makes it functional, go. That is corrective maintenance, which is reactive in nature.

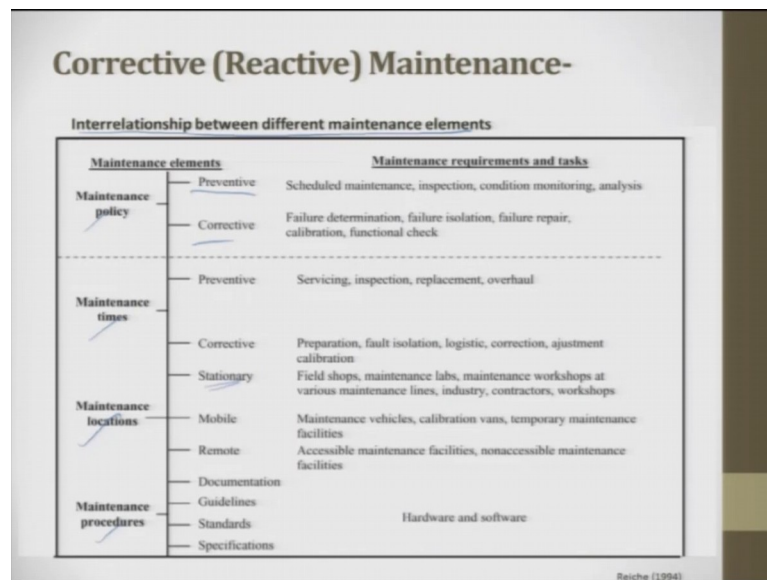
The following steps constitute corrective maintenance; once the failure has been detected it must be confirmed, ok. If somebody says the tap is broken and without even seeing it people try to communicate the message that is not correct. You have to confirm yes there is a tap breakage happening. If the failure is not confirmed the item generally is returned back to service. This no fault found problem leads to considerable wastage of time at significant cost. So, once you call a plumber and then he comes and say oh that is not a problem at all and then still you have to pay 500 rupees what he has done and he has also wasted his time.

(Refer to Slide Time: 17:17)



So, the product availability, product maintainability, and logistics delay. So, you have maintenance ability, reparability, serviceability, this is logistics delay and administrative delay. So, these are all factors of product for maintainability.

(Refer to Slide Time: 17:35)



So, this is the maintain, the interrelationship between the maintenance elements which I dealt 3 slides back, so the maintenance element is preventive, corrective. Preventive means it is scheduled maintenance, inspection, condition monitoring and analysis preventive. You just check at every half an hour or when you go by train, and once the

train comes to a halt at a big station immediately you will see a railway employee going around checking the temperature profile or the temperature at the wheels or at the suspension system. What is he doing? He is trying to see is there any very is there any temperature rise drastically and then if it is drastic, he goes reports this and then immediately necessary actions will be taken. So, scheduled maintenance, inspection, condition monitoring and analysis is preventive.

Corrective is moment the failure has happened, so the failure determination, failure isolation, failure repair, calibration and functional check are part of the tasks which is to be done. So, in a car also you try to figure out the motor of a car whatever the wiper motor concept. So, you just strip of the wiper motor alone, take it to the shop, replace the motor and start going that is corrective; you are isolating the system from rest, ok.

Next is maintenance items; so, maintain it, the maintenance elements can be policy, can be a times, location and procedure. So, maintenance time is preventive, servicing, inspection, replacement and overhauling ,these are the maintenance time. Corrective it can be preparation failure isolation logistics correction adjustment and calibration. It can be stationary that means, to say field shops, maintenance labs; they all can be part of it, ok. Then maintenance location it can be mobile, it can be remote; mobile is maintenance vehicle.

Say for example, if you nowadays you see that you have tow vehicles which go around on the highways. So, the tow vehicle you just give them a call number they just give them a call, they come to the spot with all the kits with all whatever it is required for that particular car and then quickly they start working on it set it, right give the bill on the spot take it and then take the cash or take the money and then leave.

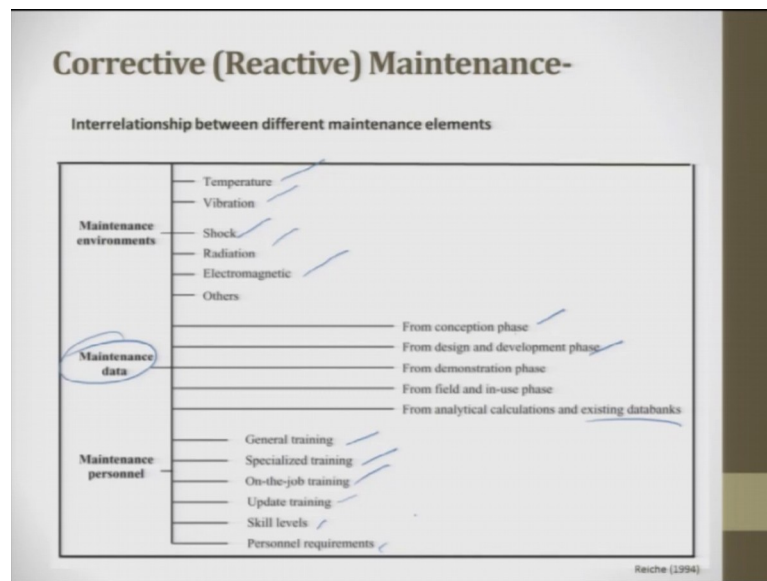
Or the other way around is they tow you from the spot bring it to the service station, work on it and put it put you back to the main road. So, you can have maintenance location mobile, you can have maintenance location remote. Remote is today when you have all this big cars big luxurious cars which are sold. So, all the cars have their service stations only at metros.

For example, Chennai, Bombay, you might have in Delhi and then maybe in Haryana. But suppose if somebody own owns a luxurious car, at a very eastern corner for a somewhere in (Refer to Time: 20:26) he holds. So, he does not have a maintenance

person to come all the way from Delhi to go to his place that is what is called as remote locations.

Then procedures, it can be documented, guidelines, standards and specifications, this can be in hardware, this can be in software, which can be shared or which can be transferred to the people. So, the maintenance environment can be the maintenance procedure.

(Refer to Slide Time: 20:53)



The maintenance environment it can it should have temperature proof, vibration proof, shockproof, radiation proof, electromagnetic. When you are talking about when you talking about sensors or when you are talking about electronic gadgets EMI plays a very important role.

The maintenance data is going to be from the conception stage you take it, design and development stage you trying to take the maintenance; that means, to say when you are trying to build a cars, when you are trying to build a car or trying to build a machine when you have screws; you can always put the screws on top of the surface where you can access your screw, access those screws with the screwdriver to remove a lid.

You can also put it right at the bottom where in which you do not show the screws at all. When you put, right at the bottom the accessibility difficulty comes. When you put exactly on the spot or on his eyesight when it is visible then that is going to hamper or

that is going to make the entire product look little uglier. So, you have to have a trade off in the design stage itself where to have the screws and bolts such that they can be fasten.

The other way around is the design stage itself you say I hate this screws and bolts let us have press fit, sitting fit, done. So, it is in the design concept itself you should bring in form the maintenance data has to go. From demonstration phase from field in use phase you take the maintenance data and then analytical calculations in the existing data bank. So, this is for trying to figure out what is the performance.

Then maintain maintenance personal can be general training, specialized training, on the job training, updating training, and then skilled level and personal requirement. General trainers are people who can do any job jack of all trades. Specialized trainers are turner fitter welder they know only all about turning. On the job I do not know anything even in turning I can do only this job that is on the job training.

Updated training, till now I was a drafts man now I realized the computers have come. So, I will I would take a training of computer and I updated myself and then I start doing it. Skill levels is also very important and the personal requirements.

(Refer to Slide Time: 22:57)

Corrective (Reactive) Maintenance-

- The item is prepared for maintenance if the failure is confirmed and then the failure report is completed.
- Localization and isolation of a failed part in the assembly is the natural next step in corrective maintenance.
- The failed part is removed for disposal or repair.
- The item may be reassembled, realigned, and adjusted after repair. It is checked before being put back to use.

S/No	defect	Remark	Res

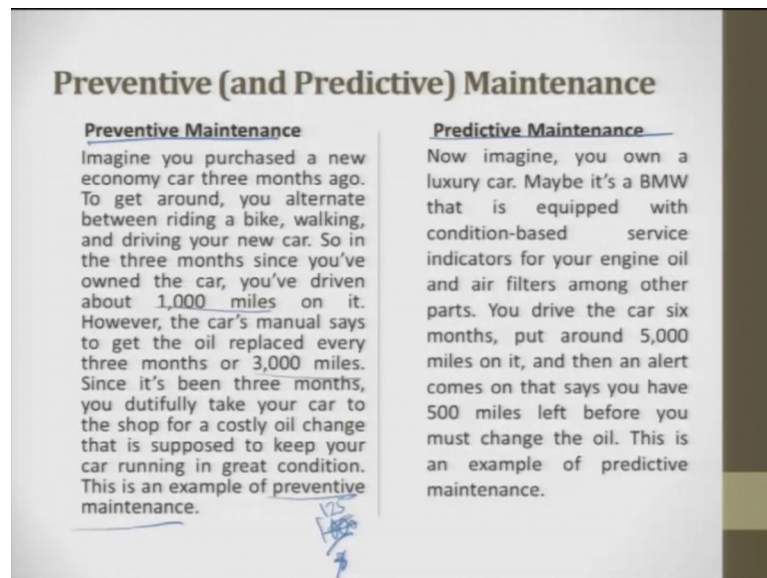
But you look at corrective maintenance, the item is prepared for maintenance if the failure is confirmed and then the failure report is complete. So, in US or in even developed countries or in costlier automotive things they always make a sheet which

says serial number, it says defect and then they say remarks and then they will have one more column they say who is responsible. So, then he starts not looking at the product and then he starts writing on the defects.

And in fact, in certain cases they also give a space where in which you can draw the part and then try to mark which all locations the defective has happened and then try to write your remarks and then say who takes the responsibility in fixing it. And then if you still want you can also have you can give them what is a time that they have to fix them and then give back.

So, localization and isolation of the failure parts in the assembly is the natural next step or corrective. The failed part is removed for disposal and the item may be reassembled, so that it can put back into working conditions.

(Refer to Slide Time: 24:03)



Preventive maintenance, predictive maintenance; I have just put the full example. So, imagine you have purchased, imagine you purchased a new economic car 3 months ago. To get around you alternate between riding a bike, walking and driving your car. So, in 3 months since you have owned the car you have driven about 1000 miles on it. However, the car manual says to get the oil replaced every 3 months or 3000 miles.

So, now, the company has already prescheduled assuming that in 3 months time you will go 3000 miles, 3000 miles in 3 months divided by 100, it is a day you will go 30 miles. I

am staying in a campus where my house and my office is hardly a kilometer away. So, if I have a car and if I have to use the car I go morning, come back for lunch, go to the office and then come back for dinner.

So, I go 4 time's maybe this 4 can become 6 times or 8 times a day. So, 8 kilometers a day I go. So, if I want to even touch 1000 kilometers. So, 8 divided by 8 its naturally takes me almost, so 100 divided by 8, I said 1000 divided by 8, so it is 16 times, so 12, 96 40; so 125. So, it takes me 125 days and it is all 125 days I do not go. So, it is all Saturday, Sunday coming in between, so it becomes almost.

So, now the company by taking a data from so many people and knowing their performance of the engine and all they say please replace the oil within the first 3 months time or this. Since it has been 3 months you dutifully take your car to the shop for a costly oil change that is supposed to keep your car running in a great condition this is an example for preventive maintenance. Understood?

So, a schedule is given do or die you go to the shop or to you go to the repair shop throw your vehicle, dump your vehicle there, get everything replaced, pay that money and then come back; so that is preventive maintenance. If you logically say I have only travelled 100 kilometers as again 1000 or 3 months time. So, should I still do it? So, now the company says, if you do not want, we will we were our schedule thing is to do 4 times free service, I remove one of the free service you come for the next time I will do whatever I can do, that is what is it; so, this is preventive maintenance.

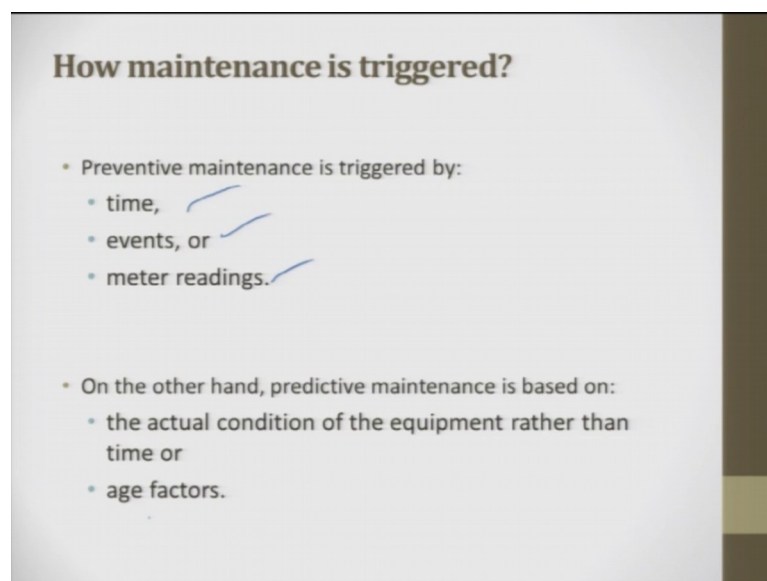
But suppose if your vehicle is running for a long time maybe 10 years is over, now this 3 months time plays a very important role. Every 3 months you go to the you go to the mechanic shop and show it to him, get yourself assisted because your vehicle has crossed the your vehicle is moving towards old age. So, it is 10 years passed by; so, that is preventive. So, preventive for a new vehicle is a different impact, preventive for a 10 year old vehicle has a different impact. Let us now move to predictive maintenance.

Now, imagine you own a luxury car, maybe a BMW that is equipped with condition based service indicator, for your engine oil and air filter among the parts. You drive the car 6 months put around 5000 miles on it and then an alert comes on that say you have 500 miles left before you must change the oil. This is an example for predictive maintenance. So, what happens here is you have put sensors, these sensors maybe base

or it has a vision based sensor, it sees once the color changes when it is becoming dark in color.

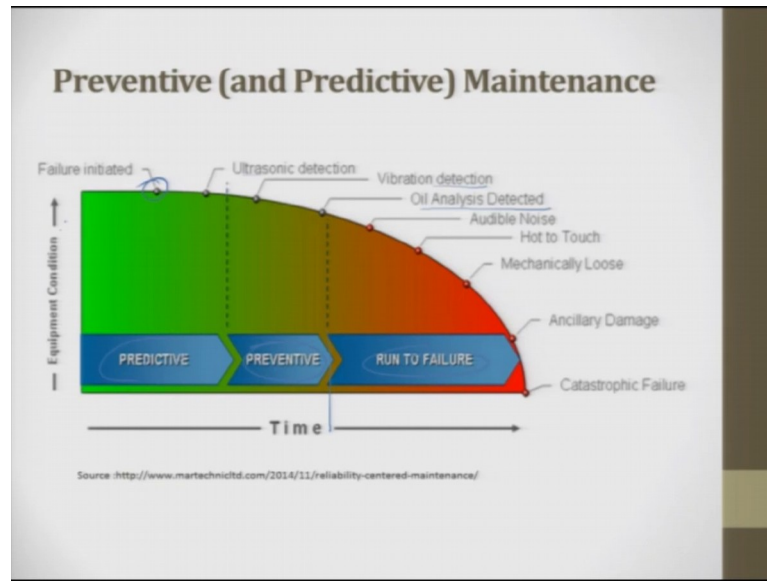
So, it quickly comes and tells you boss now it has become very dark or very black in color. So, now, you have to go for replacement or do some corrections and it is not right now you go we will give you some more time; we will give you another one more month or 15 more days by the time please make sure it goes; so it is called as predictive maintenance.

(Refer to Slide Time: 28:47)



So, preventive maintenance is triggered by time, event, and meter reading; on the other hand predictive maintenance is based on actual condition of the equipment rather than time and age factor.

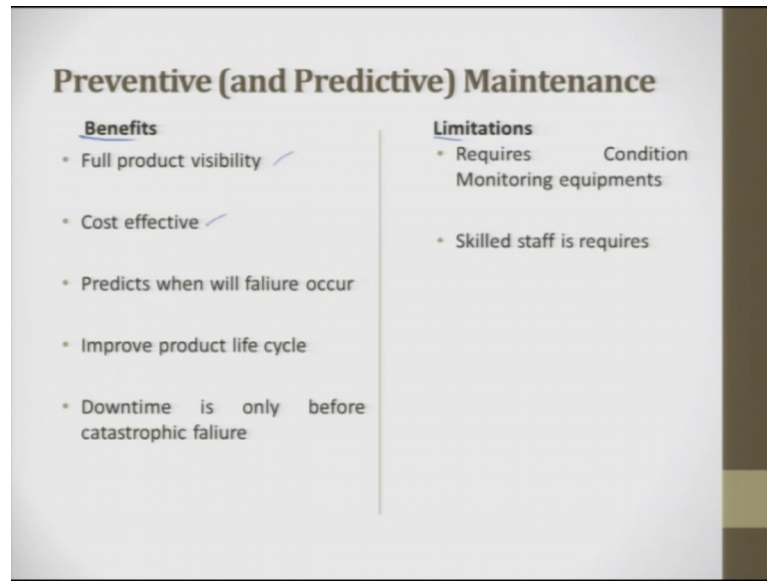
(Refer to Slide Time: 26:57)



So, equipments condition; so failure indicates, so if you say predictive, preventive, predictive, preventive, run to failure this is the time period, ok. So, this is called as predictive, in predictive you have failure indicates and here is a technique ultrasonic technique which is used which is used for detecting the failure, then in preventive we always try the vibration detection, oil analysis detection we do it. And once it crosses this time limit then what we do is we use aquatics, we use temperature we use mechanical loss, we use auxiliary damage and then finally, we look at the catastrophic failure; so, these are the things which happens.

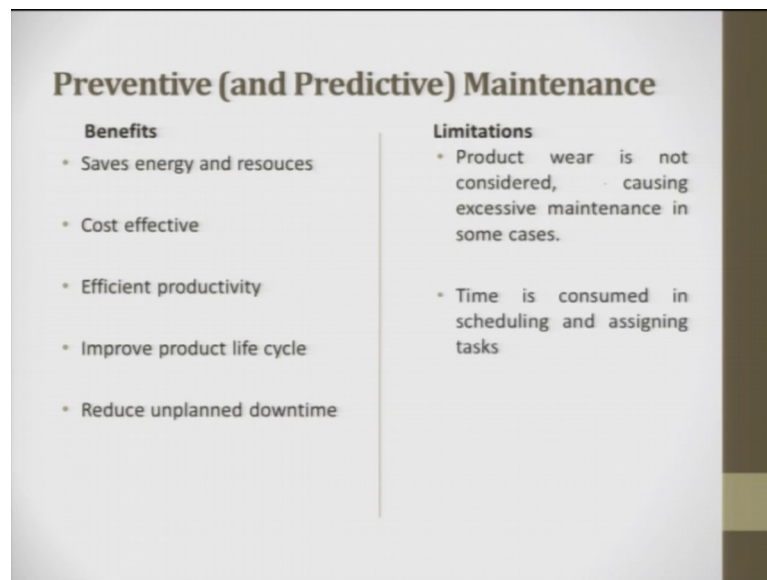
So, here the failure is indicative, so that is predictive. Preventive is ultrasonic detection and vibration it is preventive and run to failure is you will have audio. So, suppose you keep running a car an hour or over a period of time you say all of a sudden all of a sudden there is a sound which comes out. So, you say something is wrong I hear a new sound. So, then you go to the mechanic and say this is what a sound I hear is. So based upon your interpretation then he starts working on it to give to us also solution; so what are the benefits and what are the limitations?

(Refer to Slide Time: 30:17)



Full product visibility, cost effective, preventive, predictive with when will failure occur, improve product life cycle and downtime is reduced. Limitation requires condition monitoring and skilled based of staffs.

(Refer to Slide Time: 30:31)

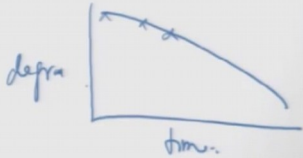


Saves energy, predictive sales energy and the resource cost effective, it is effective efficient productivity, redundancy of unplanned downtime. So, all these things are part of benefits and these are the limitations.

(Refer to Slide Time: 30:49)

Maintenance of a Degrading System

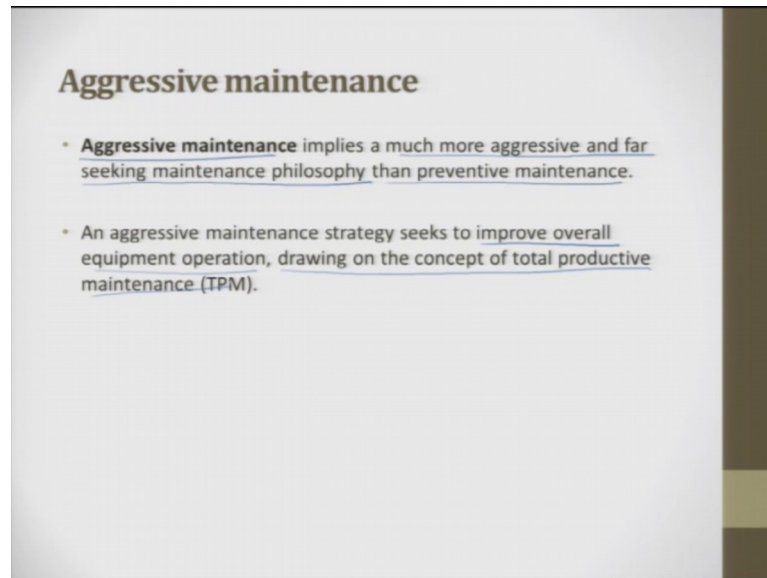
- Most systems operate with some sort of degradation occurring throughout their useful lives.
- A review has to be done periodically to determine what actions need to be taken to enable the maintenance of such systems.
- To optimize the maintenance schedule, it has been suggested that the level of degradation be monitored instead of time.
- This approach enables the addition of factors such as maintenance costs and distribution of degradation.



So, maintenance of degrading system, degrading system is a human body is also degrading. For example, when you are born you have been given the best flexibility, but over a period of time this flexibility is killed and you become more and more and more rigid. Let it be even your spinal cord the sitting posture, the fitness what we have it is all like degrading of a system. So, most system operates with some sort of degradation occurring throughout their useful lives.

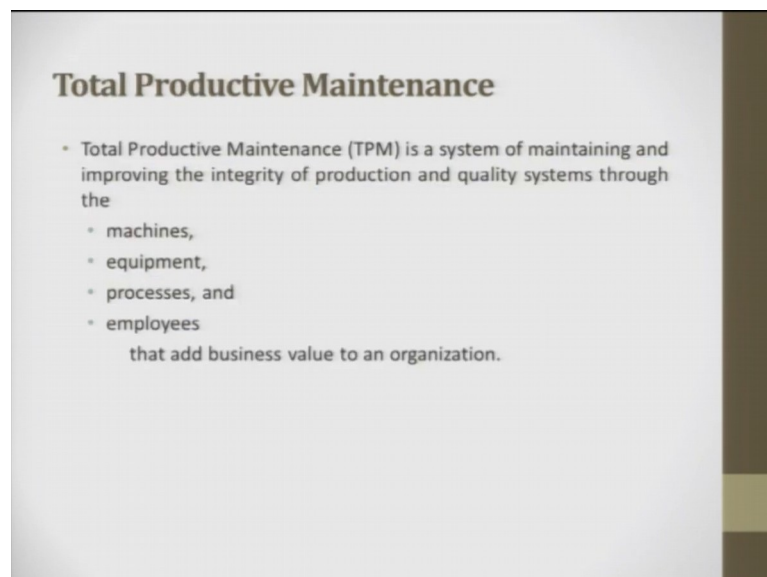
Review has been, has been done periodically to determine what action need to be taken to enable the maintenance of such system. To optimize the maintenance schedule, it has been suggested that the level of degradation be monitor instead of time; so this is degradation this is the time. So, degradation happens like this they say please do not look at that time. But look at the life sacrifice or the damage which is getting induced to the peace more than this time. This approach enables the addition of factors such as maintenance cost and distribution of degradation.

(Refer to Slide Time: 31:55)



Aggressive maintenance; aggressive maintenance implies a much more aggressive and far seeking maintenance philosophy than preventive maintenance. In aggressive maintenance strategy seeks to improve overall equipment operation, drawing on the concept of total productivity maintenance, ok. So, this is little bit more than preventive maintenance.

(Refer to Slide Time: 32:21)

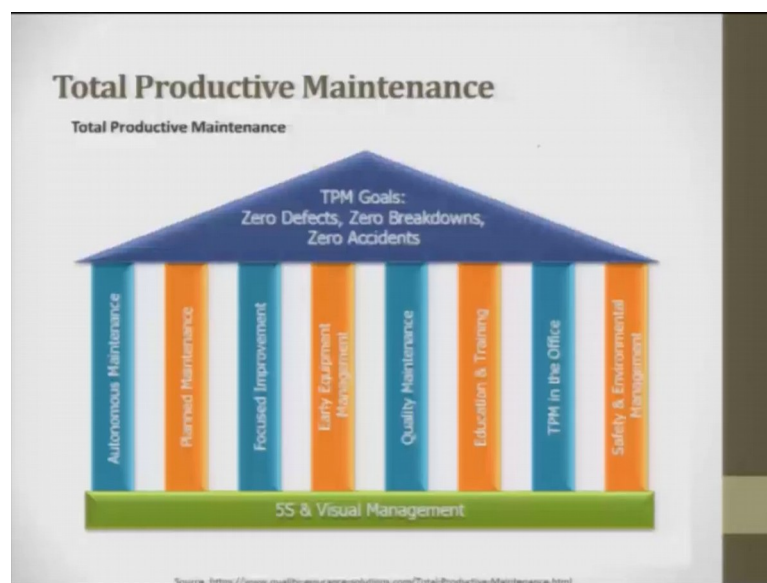


So, what is Total Productive Maintenance? Total product TPM total productive, pt management is also the total productivity maintenance. So, here we talk about total

productivity maintenance is a system of maintaining and improving the inter integrity of the production and the quality system through machines, equipment process and employment that adds business value to the organization.

So, is a system of maintaining and improving the integrity of the production and quality system, maintaining and improving the integrity. Integrity means it is a holistic approach, ok. So, it can be through machines equipments process and employment employees it can be done.

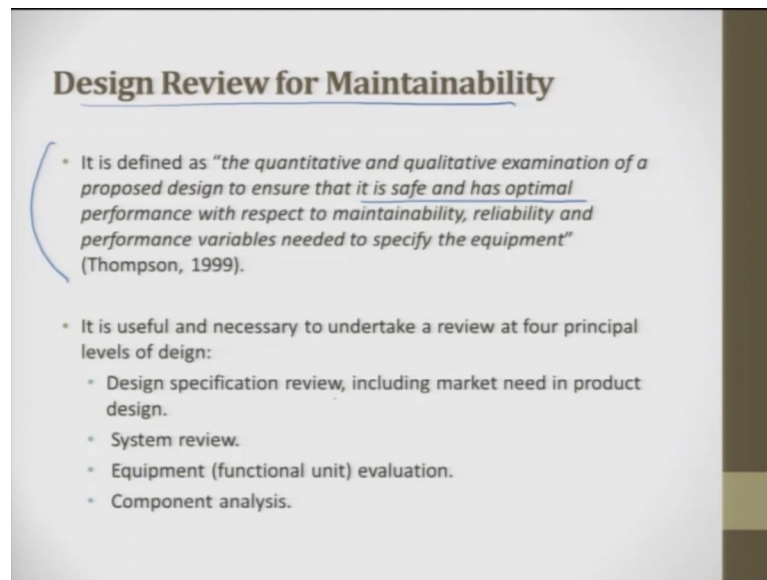
(Refer to Slide Time: 33:09)



So, the TPM goal is 0 defect, 0 breakdown, 0 accident, so it is all in 0 is going to be TPM goal.

So, you have autonomous maintenance should be there, planned maintenance should be there, you should have focused improvement should be there, early equipment management should be there, quality maintenance should be there, then education and training system should be there, TPM in the offline platform should be there, safety and environmental management also should be there. Basically, they try to say 5 s and visual management system has to be there. So, these are all the building blocks or pillars for achieving the TPM goal of 0 defects, 0 breakdown and 0 accidents.

(Refer to Slide Time: 33:59)



Design Review for Maintainability

- It is defined as *“the quantitative and qualitative examination of a proposed design to ensure that it is safe and has optimal performance with respect to maintainability, reliability and performance variables needed to specify the equipment”* (Thompson, 1999).
- It is useful and necessary to undertake a review at four principal levels of design:
 - Design specification review, including market need in product design.
 - System review.
 - Equipment (functional unit) evaluation.
 - Component analysis.

So, design review for maintainability. The quantitative and qualitative examination of the proposed design to ensure that it is safe and has optimal performance with respect to maintainability, reliability and performance variables need to specify the equipment.

So, this is a definition which is given by Thomson. It is usual and necessary to undertake a review about the 4 principle levels of design; design specification review includes market need in the product design, system review, equipment evaluation and the component analysis. These are the 4 principle levels of design, ok; these all are for review.

(Refer to Slide Time: 34:47)

Review of Design Specifications

- The objective of the design specifications review is to make certain that all parts and specifications are understood at the outset and the importance of different statements is appreciated.

Structured Design Review Procedure

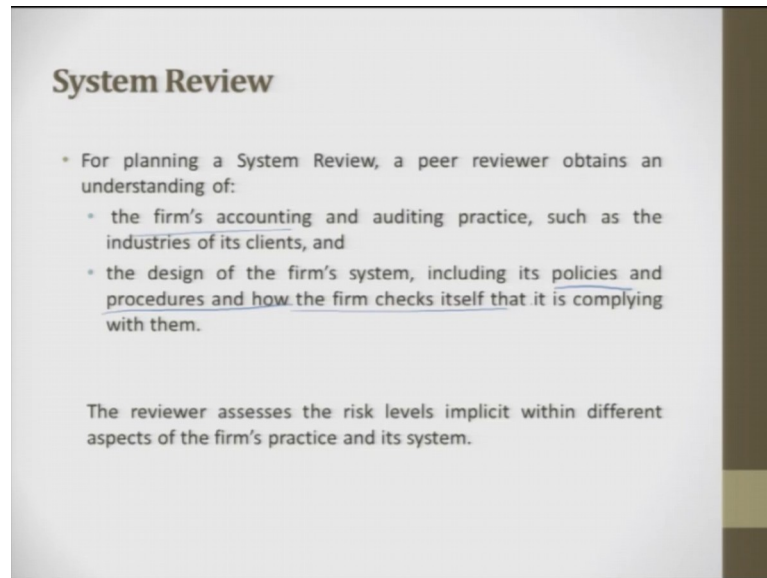
Stage and Activity	Purpose	Timing
1. Review of design specifications	To ensure that the significance of all points contained within the design specifications are understood	Prior to the commencement of any design activity
2. Activity systems level review	To identify critical areas of the design that may affect plant availability and communicate to the detail design teams the necessity to pay particular attention to these areas To comment on the advisability of pursuing projects with a high risk content To examine equipment groups to maximize uniformity and stability To maximize the reliability systems formed by manufacturing and process considerations	Prior to the start of equipment design After the completion of the first equipment design
3. Equipment (functional unit) evaluations	To evaluate quantitatively critical items of equipment To undertake qualitative reviews of equipment	After the completion of the first detailed design
4. Component analysis	To check that certain important sets of components will not give rise to maintainability or reliability problems in service	After the completion of the first detailed design

Thompson, 1999

So, the objective of the design specification review is to make certain that all parts and specifications are understood at the outset and importance of different statements is appreciated. Review of the design specification, specification to ensure that the specification of all the point containing within the design specification are understood, prior to the commencement of any design activity, activity system level review.

So, these are all the different reviews we done. Equipment to evaluate quantitatively critical items of equipments; so these are the equipments and these are the component level design review techniques. System review is also part of that. So, here it was defined design review, design specification for design for maintenance.

(Refer to Slide Time: 35:37)



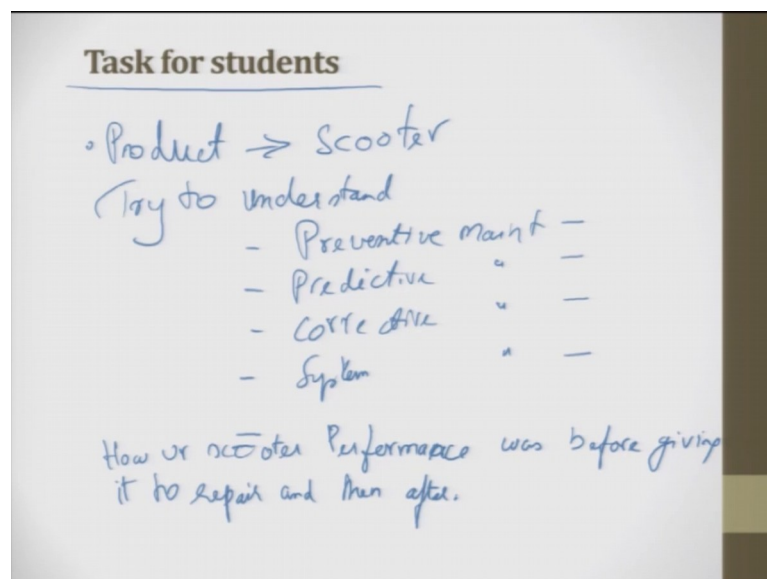
System Review

- For planning a System Review, a peer reviewer obtains an understanding of:
 - the firm's accounting and auditing practice, such as the industries of its clients, and
 - the design of the firm's system, including its policies and procedures and how the firm checks itself that it is complying with them.

The reviewer assesses the risk levels implicit within different aspects of the firm's practice and its system.

Then system review for planning, a system review, a peer reviewer obtains an understanding of the firms accounting auditing practice such that the industry the as the industries of its clients are. The design of the firm system includes its policies and procedures how the form checks itself that it is complying with them. So, the system is supposed to make a car, so the car has to have certain specification how good is your manufacturing and how did you meet the specification. The reviewer assesses the risk levels implicit within different aspects of aspects of the firms practice and its system.

(Refer to Slide Time: 36:27)



Task for students

- Product → Scooter

Try to understand

- Preventive maint -
- Predictive " -
- corrective " -
- System " -

How is scooter Performance was before giving it to repair and then after.

So, with this we come to an end to this lecture. So, task for students. So, what you will do is you try to look at a product, let us try to take your scooter. Try to understand preventive maintenance, predictive maintenance, corrective maintenance, system maintenance, ok.

You try to figure out what type of preventive maintenance, what type of predictive maintenance, what type of corrective maintenance are going on in your scooter and finally, your system maintenance also. Then you will also try to appreciate how your scooter performance, performance was before giving it to repair and then after, ok. So, you will see how, because of this maintenance how is the performance getting enhanced, ok.

Thank you very much.