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# Re-Scheduling Of Maintenance Tasks for Diesel Locomotive (ZDM) Maintenance Work Using FMEA Technique- An Industrial Engineering Approach for Saving the Resources

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**ABSTRACT:** *Maintenance is the keyword in today's corporate strategy for survival in the global market. With a scheduled and cost-effective maintenance of the facility an organization can ensure its competitive edge in the market. Keeping this in mind a study is performed at the Diesel Loco Shed situated at Motibagh, Nagpur, Maharashtra, of the Indian Railway. This shed is responsible for the maintenance of the Diesel Locomotive for the ZDM line. Presently there are 46 locos are maintained. From the field survey ongoing maintenance schedule is obtained. The maintenance schedule is six parts program comprising of Trip, Fortnightly, Monthly, Quarterly, Half-Yearly and Yearly. After a detailed analysis of the schedule, wastage of process was found in the form of misplaced steps in various schedules. The failure data for 3 years starting from 2006 till 2009 was obtained. From the analysis, the most common causes of failure in four major area of maintenance were detected. These failures were due to the misplaced steps in the present schedule i.e. steps which should have been performed in the earlier part of the schedule were delayed to the latter parts. The critical components are identified and the causes for their failure are also discussed.*

**Keywords:** *Scheduled maintenance, causes of failure, wastage, FMEA (Failure Mode Effect Analysis)*

## I. INTRODUCTION

Since the beginning of time, humans have always felt the need for the maintenance of their equipment, machine, even the most rudimentary tools. Most of the failures experienced have been a result of abuse, as it sometimes still happens. First, they would do maintenance only when it was no longer possible to run it. That was called "Breakdown or Reactive Maintenance". It was until 1950's that some groups of Japanese engineers started a new concept in maintenance that consisted on following the manufacturers' recommendations about the care that should be taken in the operation and maintenance of the machines and devices. That is called "Preventive Maintenance". To make it more effective proper scheduling can be done on the basis of history sheet of the system and past experience.

## II. PROBLEM DISCUSSION

Indian Railway is one of the organization in which schedule maintenance is mostly preferred along with the condition based maintenance for maintaining their diesel locomotives at various diesel maintenance workshops. They have the various schedules on the basis of running hours (days) such as Trip schedule – every after seven days, Fortnight schedule – every after fifteen days, monthly schedule – every after 30 days, Quarterly schedule – every after 90 days, Half yearly & yearly schedule. They also follow the major schedule such as three yearly and six yearly schedules called as periodic overhauling. It is observed that they are following conventionally framed scheduled maintenance system. As maintenance is the key word in today's corporate strategy for survival in the global market. With a schedule and cost-effective maintenance of the facility an organization can ensure its competitive edge in the market. Keeping this in mind a study is performed, to identify the wastage of process in the form of misplaced steps in their schedules to avoid the repetitive failure of loco on track, at diesel maintenance workshop called Diesel Loco Shed, Motibagh, Nagpur.
This shed is run under the south- central zone of Indian Railway, which is one of the diesel loco shed out of number of loco sheds spread across the country. This shed is responsible for the maintenance of Diesel Locomotive for the ZDM line. Presently they are handling 46 locos. The locomotive should have high rate of availability and reliability, as it means of very sensitive mode of transportation, related to public and goods and that too for long distances. It shows that a single on line failure of loco leads towards the huge financial losses for Indian Railway.

## III. OBJECTIVES

This work aims at detail study of present maintenance schedule for maintaining the ZDM loco. This can be achieved by identifying the most critical components in the various systems of the locomotive. Present practices of maintenance schedule, past failure data and their experiences can be taken into consideration for identifying the critical components.

The criteria of Risk Priority Number (RPN) can be applied to those components to make a decision of differ in the present schedule of maintenance of it. N. Cotaina(2000), explained the 'Failure Mode & Effects analysis' and stated that it evaluates, documents and rank the potential impact of each functional and hardware failure. It improves the personnel safety, system performance and availability. Rodrigo D.Q.S.(2008), discussed that FMEA have great importance for evaluation of potential failures in a system. It is a technique that complements the maintenance system & recommended that can be used for a more complete reliability study. Ribrant J. (2006) concluded that FMEA is beneficial when it comes to reduce the amount of failures of the wind mill power plant by scheduling the preventive maintenance.

The objectives of the work are:-
Identifying the problems regarding schedule of maintenance.
To find the cause of failure rates in the systems of locomotive.

### Need of Maintenance

The need of maintenance in organization is not being questioned by today's top industrial organization & management, but the due importance & the rightful places which are to occupy in the organization are yet to be recognized by most of them. With the growing complexity of equipment and process & the magnitude of losses suffered in production due to breakdowns today's management can no longer look upon maintenance as only a subsidiary function to production, but as one of the main tools to planned maintenance, which must be effectively used to obtain highest availability of equipment commensurate with maintenance cost.

Maintenance is required for almost all types of machinery and applies also to the mechanical & automobile system. The type of maintenance that is performed can be defined as either preventive or corrective maintenance. Preventive maintenance is carried out at predetermined intervals or according to prescribed criteria and is intended to reduce the probability of a failure. Corrective maintenance is carried out after a failure and is intended to repair the system. In other words, preventive maintenance is performed before a failure and the corrective is preformed after the failure occurs. Consequently the challenge in planning the maintenance is to decide on when to perform preventive maintenance.

Here two different types of system maintenance are exposed. One is corrective maintenance and another is preventive maintenance. Further it can be classified as scheduled maintenance and condition based maintenance.

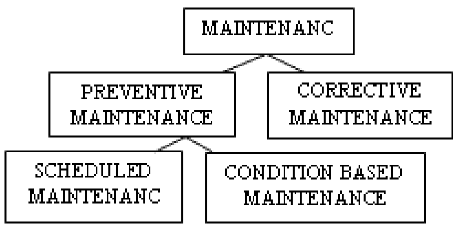


Figure1Classification of Maintenance

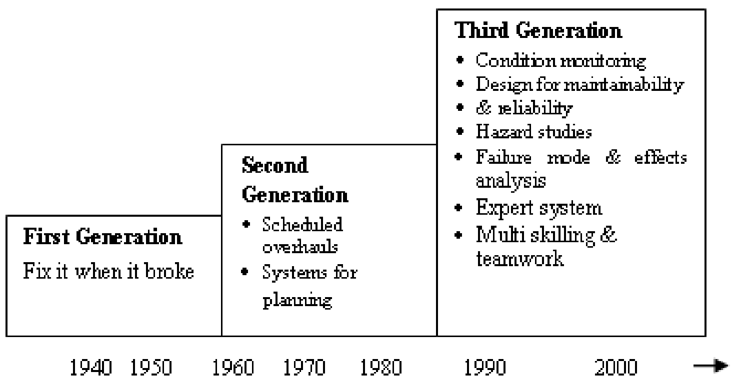


Figure 2 Maintenance Generation Development Process

### Generation of maintenance

In the past of maintenance, researchers have seen that maintenance has increased rapidly in complexity, over the last 70 years. With that, in consideration, new maintenance methods & maintenance ways have been developed through three different phases generating from 1930's.

The generations of maintenance are;
First generation (1940-1950)
Second generation (1960-1970)
Third generation (1980- until )

## Industrial profile, systems & maintenance schedules

The project work is carried out at Diesel locomotive shed, Motibagh, Nagpur. The various systems of locomotive which are taken into consideration for the study to find out the critical components are studied at this shed. Also the structure of present schedules is also studied on the basis of which the deferment of that maintenance schedule is to be carried out. In this workshop shed, only the maintenance work of ZDM system has been carried out since last 30 years, Table 1 shows the various schedule carried out at the shed.

## Systems under the consideration for study

The above systems are studied which are the main parts (components) of the diesel Locomotive engine.
Fuel Oil System
Oil Lubricating System
Water Cooling System Compressed Air System
Super Charged Air System
Vacuum Brake
Bogie
Voith Transmission System
The schedules followed at Motibagh shed has been described in the Table 1 below which shows the time & staff required to complete the schedules.

| 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 |
|---|---|---|---|---|---|---|---|
| Name of SCHEDULE | TRIP | FORT-NIGHT | MONTHLY | QUARTERLY | HALF YEARLY | YEARLY | TWO YEARLY |
| Carried Within Days | 07 days | 15 days | 30 days | 60 days | 120days | 365 days | 365 days |
| Time Required | 02 hrs | 04 hrs | 08 hrs | 12 hrs | 24 hrs | 15 days | 30 Days |
| Staff Required | 04 staff | 04 staff | 08 staff | 08 staff | 08 staff | 12 staff | 12 staff |

Table 1 Details of Maintenance Schedule for Diesel Locomotive followed at shed

COLLECTION OF FAILURE DATA FOR THE ANALYSIS OF STUDY

The field failure data for current three consecutive years (i.e. from 2006 to 2009) has been collected from Loco shed, Motibagh, Nagpur. It is arranged in tabular form in which the date of failure of loco along with loco number is given. The system and its sub-system which is failed are also mentioned. The cause of failure of that system/sub-system is stated.

Table2. Failure Analysis of Ng Locos with Responsibilities for the Year 2006-07

| | | Responsibilities | | | | |
|---|---|---|---|---|---|---|
| Sr. No | System | Material failure | Failure Detected At shed | Crew Account failure | Others | % |
| 1 | Behr Pump | 0 | 0 | 0 | 0 | 0 |
| 2 | Bogie | 2 | 1 | 0 | 0 | 10 |
| 3 | Water Cooling Sys. | 0 | 1 | 0 | 0 | 3 |
| 4 | Electrical System | 2 | 1 | 0 | 0 | 10 |
| 5 | Engine | 1 | 3 | 0 | 0 | 14 |
| 6 | Fuel Oil System | 2 | 4 | 0 | 0 | 21 |
| 7 | Lube Oil System | 1 | 0 | 0 | 0 | 3 |
| 8 | Trans. | 1 | 0 | 0 | 0 | 3 |
| 9 | Air Brake | 2 | 2 | 0 | 0 | 16 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | System | | | | | |
| 10 | Compressor | 1 | 0 | 0 | 0 | 3 |
| 11 | Governor | 0 | 2 | 0 | 0 | 7 |
| 12 | Vacuum Ext. | 0 | 0 | 0 | 0 | 0 |
| 13 | TSC | 1 | 0 | 0 | 0 | 3 |
| 14 | Periflex | 0 | 0 | 0 | 0 | 0 |
| 15 | Misc. | 2 | 0 | 0 | 0 | 7 |
| 16 | Total | 15 | 14 | 0 | 0 | 100 |

Table 3. Failure Analysis of Ng Locos with Responsibilities for the Year 2007-08

| | | Responsibilities | | | | |
|---|---|---|---|---|---|---|
| Sr. No. | System | Material failure | Failure detected at shed | Crew Account failure | Others | % |
| 1 | Behr Pump | 2 | 1 | 0 | 0 | 5 |
| 2 | Bogie | 2 | 0 | 0 | 0 | 3 |
| 3 | Water Cooling Sys. | 3 | 5 | 0 | 0 | 14 |
| 4 | Electrical System | 3 | 1 | 0 | 0 | 7 |
| 5 | Engine | 2 | 2 | 0 | 0 | 7 |
| 6 | Fuel Oil System | 0 | 6 | 0 | 0 | 10 |
| 7 | Lube Oil System | 4 | 0 | 0 | 0 | 7 |
| 8 | Trans. | 2 | 0 | 0 | 0 | 3 |
| 9 | Air Brake System | 1 | 3 | 0 | 0 | 7 |
| 10 | Compressor | 1 | 0 | 0 | 0 | 2 |
| 11 | Governor | 2 | 2 | 0 | 0 | 7 |
| 12 | Vacuum Ext. | 3 | 2 | 0 | 0 | 9 |
| 13 | TSC | 5 | 5 | 0 | 0 | 17 |
| 14 | Periflex | 0 | 0 | 0 | 0 | 0 |
| 15 | Misc. | 1 | 0 | 0 | 0 | 2 |
| 16 | Total | 31 | 27 | 0 | 0 | 100 |

Table4. Failure Analysis of Ng Locos with Responsibilities for the Year 2008-09

| | | Responsibilities | | | | |
|---|---|---|---|---|---|---|
| Sr. No | System | Material failure | Failure detected at shed | Crew Account failure | Others | % |
| 1 | Behr Pump | 1 | 0 | 0 | 0 | 3 |
| 2 | Bogie | 1 | 0 | 0 | 0 | 3 |
| 3 | Water Cooling Sys. | 3 | 2 | 0 | 0 | 15 |
| 4 | Electrical System | 0 | 1 | 0 | 0 | 3 |
| 5 | Engine | 2 | 3 | 0 | 0 | 15 |
| 6 | Fuel Oil System | 3 | 6 | 0 | 0 | 28 |
| 7 | Lube Oil | 0 | 0 | 0 | 0 | 0 |

| | | Responsibilities | | | | |
|---|---|---|---|---|---|---|
| | System | | | | | |
| 8 | Trans. | 0 | 0 | 0 | 0 | 0 |
| 9 | Air Brake System | 0 | 1 | 1 | 0 | 6 |
| 10 | Compressor | 0 | 0 | 0 | 0 | 0 |
| 11 | Governor | 0 | 3 | 0 | 0 | 9 |
| 12 | Vacuum Ext. | 0 | 2 | 0 | 0 | 6 |
| 13 | TSC | 0 | 1 | 0 | 0 | 3 |
| 14 | Periflex | 1 | 2 | 0 | 0 | 9 |
| 15 | Misc. | 0 | 0 | 0 | 0 | 0 |
| 16 | Total | 11 | 21 | 1 | 0 | 100 |

STATISTICAL REPRESENTATION OF FAILURE DATA ON THE BASIS OF RESPONSIBILITIES

Figure 3, 4 and 5 shows the statistical representation of the data from the year 2006 to 2009, the horizontal axis shows the systems & vertical axis shows the number of failure occurred in the respective system. It can be seen that the failure occurred due to responsibility 'Bad workmanship' which indentify the critical systems showing high number of failures.

The statistical representation clears the critical systems, with the help of that the maintenance tasks carried to repair the particular system can identify the schedule in which the maintenance work is to be done.

This representation is important by which risks identification in the system can be identified.

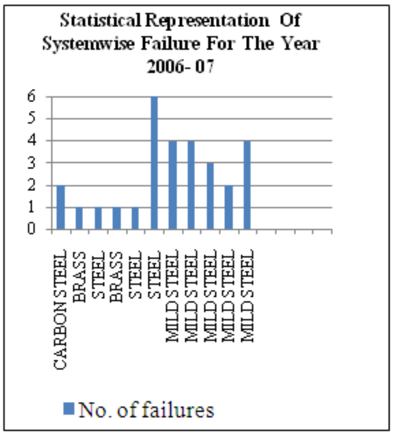


Figure 3 Statistical Representations for 2006-07

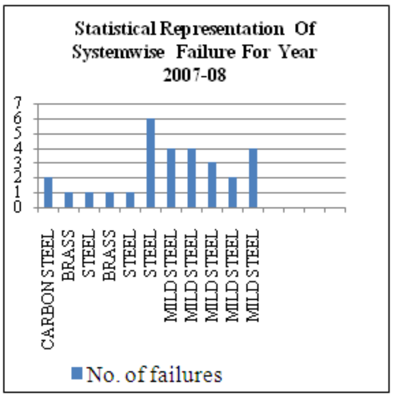


Figure 4 Statistical Representations for 2007-08

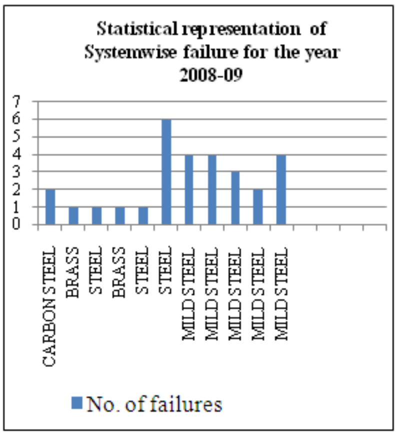


Figure 5 Statistical Representations for 2008-09

**Identification of critical system**

On the basis of above statistical failures representation, critical systems in which failure occurred repetitively & high percentage can be identified. Due to bad workmanship in the shed, these failures are occurred by following present maintenance schedule at shed. So, the systems which are badly affected due to improper maintenance tasks are as follows;

Fuel oil system
Engine
Water cooling system
Governor

The schedules which are performed in the present maintenance work also show that the tasks of repair for such systems are less; if we increase the repairs for these systems may less the probability of chance of failure in the above system. But, firstly we have to analyze exactly the specific reasons due to which the systems are failed repetitively. In next paragraph discussion of the specific reasons of failure should be carried out.

**Identifying specific reasons of failures**

With the help of failure data analysis, following are the reasons due to which system get failed repetitively. Specific reasons of failure can be discussing system wise;

Fuel oil system

Loco failed due to air lock in fuel oil system.
Loco failed due to Fuel feed pump not working properly.
Loco failed due to shut down & could not restart.
(Shut down occurs due to- Lube Oil pressure should not be taken 1.5 $Kg/cm^2$. Water Temperature should not rise above $95^0$ C. Over feeding of engine should not be over 1000 RPM.)
Loco failed due to fuel oil return pipe broken.
Loco failed due to low hauling. (Low hauling means- Less turbo run. Wrong fuel pumps timing, feeding and less dry run.)
Loco failed due to fuel oil leakage from cylinder inlet pipe joint broken.
Loco failed due to not hauling the load & RPM not rose.
Engine
a. Loco failed due to heavy oil leakage from the joint near TSC.
b. Loco failed due fuel feed pump not working
Engine failed due to heavy oil leakage from lube oil system.
c. Loco failed due to low hauling.
d. Unusual sound coming from car body filter & demanded to relief the engine.
e. Loco failed due to cylinder exhaust valve seat defect.
f. Loco failed due to vacuum not building.
g. Loco failed due to heavy black smoke coming h. from exhaust valve.
i. Loco failed due to heavy air lock in fuel oil System.
j. Train detained (suddenly fail, can't run) in the section due to hot engine.
3) Water cooling system.
a. Loco failed due to water spouting in the system.
b. Loco failed due to heavy water leakage from radiator core.
c. Loco shut down due hot engine.
d. Loco failed due to Water inlet pipe clamp broken, causes heavy water leakage.
e. Loco failed due to Lube oil heat exchanger water pipe uncoupled, causes heavy water leakage.
4) Governor
a. Loco failed due to suddenly engine RPM raised & engine shut down.
b. Loco failed because of RPM not increase due to air lock in fuel oil system occurs.
c. Loco failed due to governor linkage uncoupled.
Suddenly engine RPM Dropped & power shut down.
d. Loco failed due to RPM not increased.

## Implementation of FMEA

As it is said that, Failure modes & Effects Analysis (FMEA), is a systematic proactive method for evaluating a process to identify where & how it might fail & to access the relative impact in different failures, in order to identify the parts of the process that are most in need of change.

## Identification of severity, ccurrences & detection

The process for conducting an FMEA is straightforward. It is developed in three main phases, in which appropriate actions need to be defined.

**Step 1: Severity**

Determine all failure modes based on the functional requirements and their effects. Examples of failure modes are: Electrical short-circuiting, corrosion or deformation. A failure mode in one component can lead to a failure mode in another component; therefore each failure mode should be listed in technical terms and for function. Hereafter the ultimate effect of each failure mode needs to be considered. A failure effect is defined as the result of a failure mode on the function of the system as perceived by the user. In this way it is convenient to write these effects down in terms of what the user might see or experience. Examples of failure effects are: degraded performance, noise or even injury to a user. Each effect is given a *severity number (S)* from 1 (no danger) to 10 (critical). These numbers help an engineer to prioritize the failure modes and their effects. If the severity of an effect has a number 9 or 10, actions are considered to change the design by eliminating the failure mode, if possible, or protecting the user from the effect. A severity rating of 9 or 10 is generally reserved for those effects which would cause injury to a user or otherwise result in litigation.

**Step 2: Occurrence**

In this step it is necessary to look at the cause of a failure mode and how many times it occurs. This can be done by looking at similar products or processes and the failure modes that have been documented for them. A failure cause is looked upon as a design weakness. All the potential causes for a failure mode should be identified and documented. Again this should be in technical terms. Examples of causes are: erroneous algorithms, excessive voltage or improper operating conditions. A failure mode is given an *occurrence ranking (O)*, again 1–10. Actions need to be determined if the occurrence is high (meaning > 4 for non-safety failure modes and > 1 when the severity-number from step 1 is 9 or 10). This step is called the detailed development section of the FMEA process. Occurrence also can be defined as %. If a non-safety issue happened less than 1%, we can give 1 to it. It is based on your product and customer specification.

**Step 3: Detection**

When appropriate actions are determined, it is necessary to test their efficiency. In addition, design verification is needed. The proper inspection methods need to be chosen. First, an engineer should look at the current controls of the system, that prevent failure modes from occurring or which detect the failure before it reaches the customer. Hereafter one should identify testing, analysis, monitoring and other techniques that can be or have been used on similar systems to detect failures. From these controls an engineer can learn how likely it is for a failure to be identified or detected. Each combination from the previous 2 steps receives a *detection number (D)*. This ranks the ability of planned tests and inspections to remove defects or detect failure modes in time. The assigned detection number measures the risk that the failure will *escape detection*. A high detection number indicates that the chances are high that the failure will escape detection, or in other words, that the chances of detection are low.

After these three basic steps, risk priority numbers (RPN) are calculated

RISK PRIORITY NUMBERS

RPN do not play an important part in the choice of an action against failure modes. They are more threshold values in the evaluation of these actions.

After ranking the severity, occurrence and detect ability the RPN can be easily calculated by multiplying these three numbers: RPN = S × O × D

Where, S = Severity,

O = Occurrences

D = Detection.

This has to be done for the entire process and/or design. Once this is done it is easy to determine the areas of greatest concern. The failure modes that have the highest RPN should be given the highest priority for corrective action. This means it is not always the failure modes with the highest severity numbers that should be treated first. There could be less severe failures, but which occur more often and are less detectable.

RANKING OF SEVERITY, OCCURRENCES & DETECTION

1. Ranking of severity of failure

| Effect | SEVERITY of Effect | Ranking |
|---|---|---|
| Catastrophic | Sudden highly affected | 10 |
| Extreme | Farthest possibly affected | 9 |
| Very High | Very high possibly affected | 8 |
| High | High possibility affected | 7 |
| Moderate | Not extremely affected | 6 |
| Low | Low possibly affected | 5 |
| Very Low | Very Low possibly affected | 4 |
| Minor | Small amount affected | 3 |
| Very Minor | Very Small amount affected | 2 |
| None | No effect | 1 |

Ranking of OCCURRENCES of failure

| | | |
|---|---|---|
| Moderate | Moderate chance the control will prevent | 5 |
| Moderately High | Moderately High chance the control will prevent | 4 |

| | | |
|---|---|---|
| High | High chance the control will prevent | 3 |
| Very High | Very high chance the control will prevent | 2 |
| Almost Certain | Control will prevent | 1 |

3. Ranking of Detection of failure

| Detection | Likelihood of DETECTION | Ranking |
|---|---|---|
| Absolute Uncertainty | Control cannot prevent | 10 |
| Very Remote | Very remote chance the control will prevent | 9 |
| Remote | Remote chance the control will prevent | 8 |
| Very Low | Very low chance the control will prevent | 7 |
| Low | Low chance the control will prevent | 6 |
| Moderate | Moderate chance the control will prevent | 5 |
| Moderately High | Moderately High chance the control will prevent | 4 |
| High | High chance the control will prevent | 3 |
| Very High | Very high chance the control will prevent | 2 |
| Almost Certain | Control will prevent | 1 |

## IV. CONCLUSION

It is observed that there is scope in deferment of the schedule in maintenance work of diesel locomotive. The schedules which are performed in the present maintenance work shows that the tasks of repair for such systems are less. If there has been increase in the repairs for these systems than it may less the probability of chance of failure in the above system. Specific reasons of failure have been found out and it can be analyzed using fmea method and by finding rpn number. And therefore rescheduling can be done.

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