SSRG International Journal of Mechanical Engineering
ISSN: 2348 – 8360 /doi:10.14445/23488360/IJME-V7I6P106
Volume 7 Issue 6, 33-40, June 2020

Decreasing Machine Down Time by Enhancing Existing Preventive Maintenance System

Temesgen Hailegiorgis Abebe[#1]

[# 1]*Department of Mechanical Engineering, Wolaita Sodo Univerity, Sodo City, Ethiopia*

Abstract — *This article aims to allow Minota Metalworks and Manufacturing share company in Sodo city. Ethiopia to achieve preventive Maintenance scheduling involves functional checks, repairing or replacing necessary devices, machinery, and supporting utilities in industrial and governmental installations. Maintenance is keeping something in good condition and the process of continuing something or keep it in existence. However, the company has faced high machine downtime caused by poor maintenance practice and leads the company to low productivity. Preventive maintenance is maintenance performed to avoid failures, safety violations, and unnecessary tasks to keep something such as a building, machine, or piece of equipment required and in production costs and losses. This article is conducted on Minota Metalworks and Manufacturing company to improve preventive maintenance (PM) scheduling and develop accidental budget planning for the maintenance department to enhance productivity. To address such a problem, this article mainly includes calculation and explanation. It also presents the company's existing problem and finally provides a solution by preparing an improved maintenance schedule to enhance the company loss due to poor preventive schedule practice.*

Keywords — *ECU, Mean downtime, preventive maintenance, PM schedules, MTBF*

I. INTRODUCTION

Maintenance involves functional checks, repairing or replacing necessary devices, machinery, and supporting utilities in industrial and governmental installations. Maintenance is keeping something in good condition. Performance measurement for maintenance systems can be based on various factors, and effective maintenance can reduce the consequences of failure and extend the life of a system. Implementation of maintenance refers to maintenance policies, which can be defined as the plans of action used to provide direction and guidelines to carry out further maintenance actions required by a system [1]. In general, maintenance is defined as combining all technical and administrative actions, including supervision, which ensure that a system is in its required functioning state [2]. Ab-Samat carried out a case study on planning for PM with the aid of tree diagrams. The authors outlined the company's problems in their case study, which included the insufficiency in numbers of maintenance staff available to perform PM and the systems breakdowns that led to inefficient PM planning [3]. Based on the data of prior failures and system breakdowns, a root cause analysis of the issues involved in the ineffective PM was presented as an affinity diagram. Then, a PM planning model was developed, and the analysis was presented in the form of a tree diagram that enabled possible solutions to be generated. The proposed solution validated at the company studied provided for the maintenance staff to perform PM by focusing on the critical systems instead of the non-critical systems, which improved their PM processes.

In another study, Ahmad conducted a case study on a single-unit system with a single processing industry component. The authors developed a PM model consisting of three general steps: problem identification, evaluation of the current system condition, and maintenance decision [4]. FMECA was used in the model developed to identify possible external factors that contributed to the component failure. Ahmed and Cicek also proposed a failure analysis methodology for PM planning. The evaluation was conducted using a reliability model, which permitted flexible intervals between maintenance interventions. The authors focused on the failures and accidents to achieve the best possible safety levels at the lowest possible cost [4]. Dekker developed a framework for integrating optimization, prioritizing, planning, and combining PM tasks [5]. Dekker and Wilderman grouped PM actions using a dynamic program with a rolling horizon approach to preparing for a properly scheduled job, thus minimizing costs [5]. The rolling-horizon approach for grouping PM actions was based on component usage. Another basic analysis for deriving the best PM planning, failure-based planning, involves analysis that takes into account information about system or component deterioration. The literature on failure-based PM planning has been reviewed and involved in a detailed definition of failures that occur with systems or components before further analysis is carried out. Several failure-based planning methods would affect the PM's overall effectiveness.

Maintaining a system is usually related to maintenance actions such as repairing, replacing, overhauling, inspecting, servicing, adjusting, testing, measuring, and detecting faults to avoid any failure that would lead to interruptions in production operations [6]. Khan and Haddara presented a new, critical-based maintenance methodology for decision-making in PM planning by integrating the issue of reliability with safety and environmental issues [7]. Normally, PM is planned and performed after a specified period of time, or when a specified system has been used, to reduce the probability of its failure [14]. Maintenance systems are maintained while a significant amount of their useful life remains whenever PM practices in a good manner. In this paper, a review has been carried out based on the challenges faced during PM planning processes to secure better organization rates. The three categories of PM planning cost, time, and failure based have been reviewed thoroughly.

Nowadays, the efficiencies and effectiveness of a manufacturing operation depend on systems or equipment's sustainable performance, leading to valuable improvements in quality, cost, and time [9]. To produce better product quality at a minimal cost, the production line's availability and reliability, widely known as "the system," plays a central role in sustaining a competitive edge over other manufacturing organizations. Cost-based planning analyzes the capital cost and benefits to PM organizations and the revenue it helps to generate. It is important to have cost-based planning as a fundamental assessment. It compares the costs of solutions with the economic benefits gained if the solution was put into effect. Maintenance costs are formulated depending on the cost of downtime, reliability characteristics, and assets' redundancy. The methods are conducted based on the maintenance factors that affect PM planning's effectiveness. Kobbacy has performed cost-based planning to determine the relationship between the PM interval and the operating cost per unit of time and the component availability of a single-unit system [10].

The methodology is comprised of three main modules; estimation, evaluation, and planning. In the estimation module, the consequences, as well as the probability of failure, were identified. The evaluation module consisted of a version and acceptance analyses that reduced failure among components before designing the PM planning [11]. This was done to reduce the level of risk resulting from system failure in the final module of PM planning. Based on the results obtained from the analyses, the PM interval time for the system was determined.

II. STATEMENT OF THE PROBLEM

The machine downtime is high in the company caused by poor maintenance practice and leads the company to low productivity. The company's main problems are high downtime due to lack of improved preventive maintenance activities such as periodical lubrication of machine parts, inspection and checking tightening and cleaning of parts, replacement of warn items or components, and other maintenance servicing activities. As a result, company productivity decreases from time to time and is exposed to unnecessary maintenance-related costs such as subcontracting technology and maintenance resources.

III. OBJECTIVES OF THE STUDY

General Objective

The main objective of this research is to minimize the downtime of machines and also to maintain the lifetime and reliability of the machines by improving the existing preventive maintenance schedule

Specific objective

The specific objectives are:

- To determine the inspection of machine components or items periodically to determine their serviceability.
- To find out the causes of machine downtime.
- To determine the failure rate and repair rate of machines
- To propose a new preventive maintenance schedule
- To develop accidental budget planning for the maintenance department

IV. METHODOLOGY OF THE STUDY

To study this article, we use the following data collection methods. Different department managers and respective employees of the company were interviewed regarding the impact of maintenance on the machine downtime, nature of work, maintaining their machines, how much maintenance workers exist, the techniques of maintenance they practice, and other working conditions. Depending on the company's data, the total downtime and frequency of failure would be calculated. Moreover, based on this data given, I have evaluated the maintenance performance of the company. Having analyzed the existing system, I have proposed a new preventive maintenance schedule to overcome those problems. Moreover, accidental budget planning analysis was conducted by taking real data from the company supervisors and employees.

V. RESULTS AND DISCUSSIONS

A. Existing preventive maintenance schedule of the company

No.	Machines to be lubricated	Type of lubricant(oil scale)	Lubrication time(oil change time)
1	Lathe machine	Oil 62, grease	Five months
2	CNC lathe machine	Oil 10, grease	When finished
3	Milling machine	Oil 32, grease	Four months
4	CNC milling machine	Oil 10, grease	When finished
5	Drilling machine	Oil 32,grease	15 days
6	Grinding machine	Oil 32 and oil 10, grease	10 days
7	Rolling machine(circular work pies)	Oil 10, grease	One month
8	Rolling machine(plate work pies)	Oil 32 and oil 10,grease	One month
9	Heat treatment machine	No oil used for machine, grease	
10	Hand pumping machine	Oil 32, grease	When finished
11	Power axon or metal cutting machine	Oil 32, grease	One month
12	Hydraulic ironwork(cutter) machine	Oil 32, grease	One month
13	Automatic tubular bender machine	Oil 10, grease	When finished
14	Sheet metal rolling machine	Oil 32, grease	One month
15	Shearing machine(sheet metal cutting)	Oil 10,grease	One month
16	Hydraulic press break(sheet metal bender) machine	Oil 10,grease	15 days

Table 1: Existing preventive maintenance schedule of the company

Figure 1: HRC machine

Figure 2: Hydraulic press bending machine

Figure 3: Bending Machine

Figure 1: CNC milling machine

Figure 5: CNC lathe machine

But this preventive maintenance schedule is not enough to become productive and competitive within the market. The main problem of the Minota Metalworks Manufacturing Company is machine downtime. The cause of this problem is poor maintenance activities. Therefore, the company should improve its maintenance schedules. After calculating the company's current performance, the company problem would be identified, and I propose a new maintenance schedule. Based on the company's data, I have analysed the down time of machines caused by poor preventive maintenance practice for three months [December, January, and February], as depicted in the following table.

B. Machine downtime and frequency of failure of December, January, and February

Months	**Total machine downtime per month (minute)**	**The total frequency of failure per month**
December	6,303	121
January	5,801	128
February	5,408	110

Table 2. Total down time and frequency of failure per month

Now let us calculate the effectiveness of maintenance planning of the company:
EMP = Effective maintenance planning
DSM = scheduled down time maintenance
DTM= Mean down time
EMP=DSM/DTM

DTM= (6303+5801+5408)/3 =17512/3 (1)
=5837.33

DSM=610+600+580+500+610+700 (2)
=3600

EMP=3600/5837.33 (3)
=0.62
=62%

This shows that the effectiveness of maintenance planning of the company is poor.
Depending on the data given above, evaluate the maintenance performance of the company [11]:

1. Equipment capacity utilization (ECU)

Capacity utilization is a metric used to compute the rate at which probable output levels are met or used.

ECU = (EOT/AET)*100 (4)
EOT = Equipment operating time
AET = Available Equipment time

The company works by two 2 shifts per day. Each shift has 4 working hours and it works 6 days per week.
Average repair rate within the three months:
Average Repair rate π = (0.019+0.022+0.021)/3
= 0.062/3 =0.021/ min

AET=24*8*3=624hours/month = 37440 min/month.
EOT=37440 min/month – (6303+5801+5408)/3
=37440-5837.33=31602.667min/month
ECU=31602.667/37440=0.844
ECU=84.4 %
This shows that the company can utilize 84.4 percent.

2. Frequency of breakdown (FBD)

FBD=number of breakdown/available machine hours (5)
Number of break down per month=
(121+128+110)/3=119.6 breakdowns per month
Therefore, FBD =119.6/37440= 0.0032 breakdown/ min = 0.1916 breakdowns per hour

3. Mean down time (MDT)

MDT =1/ $N_f \sum_{j=1}^{j=Nf}$ TDj (6)

TD=down time
N_f=number of failure

MDT December =MDT=1 /$N_f \sum_{j=1}^{j=Nf} TD$j
=1/121(6303) =52.09 min/failure
=0.868 hours/failure

MDT January =1/$N_f \sum_{j=1}^{j=Nf}$ TDj
=1/128(5801)
=45.32min/failure = 0.755 hours/failure

MDT February =1/ $N_f \sum_{j=1}^{j=Nf}$ TDj
=1/110(5408) =49.16 min/failure
=0.819 hours/failure

4. Repair rate (π): rate of occurrence of failure incidences for a repairable system; these rates are called repair rates.

π = 1/MDT (7)

Repair rate **π** December = 1/$MDT_{December}$=1/ 52.09min/failure
=0.019/min
=1.14/hour

Repair rate **π** January = 1/ $MDT_{january}$
=1/45.32min/failure
=0.022/min
=1.32/hour

Repair rate **π** February = 1/$MDT_{february}$
=1/49.16min/failure
=0.021/min
=1.26/hour

= 1.24/hour

The following table shows the total downtime, mean downtime, repair rate, and failure rate

Months	Total downtime	Mean down time(min/failure)	Repair rate(/min)	Failure rate
December	6303	52.09	0.019	121
January	5801	45.32	0.022	128
February	5408	49.16	0.021	110

Table 3. Total downtime, mean downtime, repair rate, and failure rate

5. Mean time between failure (MTBF)

Meantime between failures (MTBF) is the predicted elapsed time between a mechanical or electronic system's inherent failures during normal system operation. MTBF can be calculated as the arithmetic mean (average) time between failures of a system. Calculation of MTBF to the reciprocal of the failure rate of the system

MTBF=1/λ or (8)

MTBF = Equipment operating time / average number of failure

EOT=31602.667min/month

Average no of failure=119.67

MBF=31602.667/119.67 = 264.08min/failure

=4.4 hours/failure

6. Machine failure rate (λ)

The failure rate is the frequency with which an engineered system or component fails, expressed in failures per unit of time. It is often denoted by the Greek letter λ (lambda):

λ = 1/MTBF or number of failure/operating equipment time (9)

=1/ 264.08 = 0.00378failure/min

=0.2268 failure per hour

7. Average mean down time (MDT_{aveg})

MDT_{aveg} =(52.09+45.32+49.16)/3 = 48.856 min/failure (10)

=0.814 hour/failure

8. Availability

Availability is the percentage of time during which a process (or equipment) is available to run. This can sometimes be called uptime. To calculate operational availability, divide the machine's operating time during the process by the net available time.

Availability = MTBF / (MTBF +MDT_{aveg}) (11)

=264.08 / (264.08 + 48.856) =0.84 =84%

Or Availability =EOT/AET

=31602.667/37440

=0.84

This means 84% of the machine is available and 16 % unavailable.

C. *Proposed Solution*

Preventive maintenance is the prevention of equipment breakdowns before the occurrence. It is performed while the equipment is still working so that it does not break down unexpectedly. Typical preventive activities include periodic inspections, adjustments, regular service, item replacements, cleaning, and lubricating moving parts. Preventive maintenance prevents breakdowns and ensures that equipment is operational and safe to prevent the facility [12]. It can reduce downtime, reduce failure rate and breakdowns, increase equipment reliability, reduce overall maintenance, lower cost, etc.

Schedules need to be developed separately for both users and maintainers. Users can perform checks daily, and whereas maintenance team can set a specific day of the week or month to carry out regular maintenance tasks. Therefore daily inspection and lubrication will be held at the end of the morning shift and the end of the afternoon shift gives one hour for both inspection and lubrication. The company works six-day per week:

Therefore, one hour * 6 days = 6 hours per week for lubrication and inspection.

= it gives 24 hours per month.

The company does not work on Sunday, so it's better to do the maintenance activities because the other six days are the company's working day. Every Sunday, there is full machine maintenance activates, and every six months, all parts of each machinery in the company should be given maintenance.

The solution to prevent machine downtime in the company is the following points;

1. Keep machinery clean.
2. Lube the machines up.
3. Skim oil off the machines.
4. Monitor machine cutting fluid.
5. Check the machines.
6. Prepare the machine checklist.

Depending on the standard of machine lubrication time and frequency of down time, the company's improved maintenance schedule is depicted below in the following table.

a) Rotating parts of the machines which need grease and oil after each week.

No	Machines	Type of lubricant (oil scale)	Lubrication time (oil change time)
1	Lathe machine	Oil 62, grease for rotating parts.	Oil change in two months and for rotating parts grease is added daily. Check the machine weekly.
2	CNC lathe machine	Oil 10 and grease	Oil change after One month and grease added after daily work, and also parts check.
3	Milling machine	Oil 32 and grease	Two months for an oil change, grease added daily
4	CNC milling machine	Oil 10 and grease	One month for an oil change and the whole machine check every week. Grease added daily.
5	Drilling machine	Oil 32, grease	10 days for an oil change and grease
6	Grinding machine	Oil 32 and oil 10 and grease for rotating parts	Oil change in 10 days and grease added.
7	Rolling machine(circular work pies)	Oil 10 and grease	After 15 days, oil has changed, and grease is added.
8	Rolling machine(plate work pies)	Oil 32 and oil 10 Grease for rotating parts	15 days to change oil and for rotating parts grease.
9	Heat treatment machine	Grease	One week and after one week, the machine should be checked.
10	Hand pumping machine	Oil 32 Grease	One month for an oil change and grease in one week shift and check.
11	Power axon or metal cutting machine	Oil 32 Grease	15 days for an oil change and grease.
12	Hydraulic ironwork(cutter) machine	Oil 32	15 days for an oil change and grease for the rotating parts.
13	Automatic tubular bender machine	Oil 10 Grease	After One-month oil change and weekly grease and checked.
14	Sheet metal rolling machine	Oil 32 Grease	15 days to change the oil and weekly check and grease.
15	Shearing machine(sheet metal cutting)	Oil 10 Grease	15 days to change oil and grease
16	Hydraulic press break(sheet metal bender) machine	Oil 10 Grease	10 days to change, and daily grease is added and machine check.

Table 4. Rotating parts of the machines that need oil and grease after each week.

B. Accidental budget planning and analysis

The maintenance department of the company doesn't have an allocated accidental budget in case of failure occurrence. So, to overcome unforeseen machine failure, an accidental maintenance budget should be allocated. Therefore, to formulate an accidental budget, I have computed the two inputs of accidental budget a follows [13]:

I.Labor cost estimation
II. Spare part cost estimation

I. Maintenance Labor cost estimation

The cost per employee is expressed by:

$$Cemp = LR(1+BR)*TAH \qquad (12)$$

Where, Cemp = cost per employee
LR= hourly labor rate
TLC = total labor cost
BR = benefit ratio
TAH = total number of annual hours

Total labor cost is also expressed by:

TLC ═ N* Cemp (13)

Where N ═ number of employee/workers

Mechanical Maintenance manpower

Labor force	Salary/Month in Ethiopian Birr (ETB)	Number of employees
Supervisor	2,880	2
Senior Mechanic	1,900	3
Mechanic	1,440	7
Junior Mechanic	1,200	6

Table 5. Maintenance manpower.

Therefore, TLC can be calculated as total working days per month multiplied by total working hours per day. i.e:

TLC ═ 2 days/month * 8 hours

═208 hours/month (14)

Then I have to compute also for LR for each employee a follows:

A. LR for Supervisor ═ Salary per Month / TLC (15)

═ 2,880 / 208

═ 13.85

B. LR for Senior Mechanic ═ Salary per Month / TLC

═ 1,900 / 208

═ 9.13

C. LR for Mechanic ═ Salary per Month / TLC

═ 1,400 / 208

═ 6.92

D. LR for Junior Mechanic ═ Salary per Month / TLC

═ 1,200 / 208

═ 5.77

The benefit ratio can be calculated by utilizing the following formula:

BR ═ actual working hour / standard working hour

═ 7 / 8 (16)

═ 0.875

the standard working hour in Ethiopia is 8 hours. However, one hour is wasted due to: tea and coffee break time during the morning and afternoon shift, due to set up time and being late.

Then, the total number of annual hours can be computed a follows:

TAH ═ 26 days * 8 hours * 12 months (17)

═ 2,496 hrs/year

Having calculated the above hourly labor rate, finally cost per employee is computed by utilizing the formula from equation (12).

I. Cost per employee for Supervisor:

Cemp ═ LR*(1+BR)*TAH

═ 13.85*(1+0.875)*2496

═ 64,818

II. Cost per employee for Senior Mechanic:

Cemp ═ LR*(1+BR)*TAH

═ 9.13*(1+0.875)*2496

═ 42,728.4

III. Cost per employee for Mechanic:

Cemp ═ LR*(1+BR)*TAH

═ 6.92*(1+0.875)*2496

═ 32,385.6

IV. Cost per employee for Junior Mechanic:

Cemp ═ LR*(1+BR)*TAH

═ 5.77*(1+0.875)*2496

═ 27,003.6

Hence, Total labor cost can be calculated by using the formula from equation (13).

TLC ═ N*C_{emp}

═ (2*64,818) + (3*42,728.4) + (7*32,385.6) + (6*27,003.6)

═646,542 ETB/year

So, the company should allocate ***646,542 ETB/year*** for TLC to maintain the machine failure soon.

I. Spare part cost estimation

The total spare part cost (SPC) estimation of the company involves spare parts for the utility/ supply section, which is about 22,770.0 ETB, and for the motor rewinding purpose is 39,654.00 ETB. Thus, the total spare part cost is ***64,424.6 ETB***. Hence, the total annual accidental budget cost (TA_{bc}) is the summation of labor cost and spare part cost.

by ═ TLC +SPC (18)

═ 646,542 ETB + 62,424.6ETB

═708,966.6ETB

Therefore, the company must allocate 708,966.6ETB for an accidental budget per year to avoid financial problems pertaining to purchase the spare part at the time of failure occurrence so that the maintenance technicians maintain the machine quickly.

VI. Conclusions

Product loss exists in the company because of poor preventive maintenance, mainly caused by machine downtime. As depicted in the analysis part, the company loses much of its products due to poor preventive maintenance schedule. Therefore, to overcome such problems, this article set possible directions of solution. Thus, an improved preventive maintenance schedule is necessary to decrease the machine's downtime and enhance the company's product loss. Moreover, an accidental budget plan for labor co**s**t and the **s**pare part co**s**t i**s** developed. For thi**s** rea**s**on, the company should fully apply the propo**s**ed preventive maintenance scheduled to reduce the existing high machine downtime.

Acknowledgment

I would like to thank Taye for his valuable and special support to improve this article's quality.

REFERENCES

[1] Preventive Maintenance (PM) planning: a review, Journal of quality in maintenance engineering, 23(2) .

[2] The reason, J., Cognitive Engineering in Aviation Domain, Lawrence Erlbaum Associates, Mahwah, NJ, (2000).

[3] Ab-Samat, H., Jeikumar, L.N., Basri, EI, Harun, NA, and Kamaruddin., Effective preventive maintenance scheduling: a case study, Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management, July 3-6, Istanbul, Turkey, (2012) 1249 – 1257.

[4] Ahmed. S, Hassan, M. and Taha, Z, TPM Can Go Beyond Maintenance – Excerpt From A Case Implementation, Journal of Quality in Maintenance Engineering, 11(1) , (2005) 19-42.

[5] Dekker, R,Integrating optimization, priority setting, planning, and combining of maintenance activities. European Journal of Operational Research, 82 (2), (1995) 225 – 240.

[6] Duffuaa, S. O, Raouf, A. and Campbell, J., Planning, and Control of Maintenance Systems: Modelling and Analysis. John Wiley & Sons, Inc, New York. Fitouhi, C. M. and Nourelfath, M. (2014) Integrating noncyclical preventive maintenance scheduling and production planning for multi-state systems, Reliability Engineering and System Safety, 121 (1999) 175–186,.

[7] Khan, F. I., and Haddara, M.M., Risk-based maintenance (RBM): a quantitative approach for maintenance/inspection scheduling and planning. Journal of Loss Prevention in the Process Industries, 16 (6) (2003) 561 – 573.

[8] Muath Al-Falahi, Tang Sai Hong and Monaaf D.A. Al-Falahi, Reliability-based Maintenance Planning Methods in Power Industry: A Review, SSRG International Journal of Industrial Engineering 3(2) (2016) 8-12.

[9] Nakajima, S, TPM – challenge to the improvement of productivity by small group activities. Maintenance Management International, .6 (1986) 73 – 83.

[10] Kobbacy, K.A.H., Percy, D.F. and Fawzi, B.B., Small data sets, and preventive maintenance modeling. Journal of Quality in Maintenance Engineering, 3(2), (1997) 136 – 142,

[11] Doc palmer., Maintenance planning, and scheduling Hand Book: MC Graw-hill, New York, (1999).

[12] Lindley, R.H, Maintenance Engineering Hand Book: 5th Ed, MC Graw-hill, New York, (1995).

[13] Dhillo, B. S, Engineering Maintenance, a Modern Approach: CRC pre, Ney York, (2002).

[14] Kimura, Y., Maintenance Tribology: its significance and activity in Japan. Wear, 207 No.1-2, 63-66, 1997.