Journal of Critical Reviews

ISSN- 2394-5125 Vol 7, Issue 1, 2020

Research Article

INVESTIGATING A COST REDUCTION-BASED MICRO HIERARCHICAL MODEL APPROPRIATE FOR NET SYSTEM (MAINTENANCE AND REPAIRS)

IMAN YAZDANPANAH SAFARI KOCHI

Master of Industrial Engineering, Productivity Management Orientation, Payame Noor University, Asaluyeh International.

Received: 10 Oct 2020 Revised and Accepted: 14 Dec 2020

ABSTRACT

One of the most important measures in connection with the efficiency of maintenance and repair and perhaps the most important of which is maintenance and repair costs. Maintenance costs are used as a significant measure for the efficiency of the maintenance process in different manufacturers. In this research, the maintenance and repair unit of Behbahan Cement Factory was investigated in a case study and attempts were made to present a hierarchical model, using mathematical models, GAMS software, AHP method and genetic algorithm as a scheduling model for the factory's net system. It is worth noting that in order to obtain the coefficients of the objective function of the models in the research, involving two micro and macro models, data should be collected from senior managers and senior consultants of the factory and the views of middle managers be applied. To calculate the coefficients of the objective function of each of these two models, the AHP method was used to meet the man-hours limit of manpower in the factory net unit, the required machine time limits for the net unit, cost restrictions in the project risk limitations, the mathematical models in the research were addressed. As a result, attempts were made to provide for the costs of the net system, including the costs of manpower, equipment and parts, by specifying all the net activities of this factory in three different time formats and improved delivery and interest expectation to have a higher production line.

Keywords: maintenance and repair, hierarchical model, cost, genetic algorithm, GAMS, AHP

DOI: http://dx.doi.org/10.22159/jcr.07.01.01

INTRODUCTION

The issue of maintenance and repairs is a requisite in every factory and manufacturing company, and implementing so-called PM systems incurs costs. This low initial cost prevents from a higher cost caused by large failures and production shutdowns. Now, considering t1he limitations, one can gain more profitability in production, if the costs from implementing and establishing PM systems are reduced.

The main objective of the maintenance and repairs system is to create a systematic method to control the condition of existing equipment and machinery and to optimize their capabilities to reach the maximum level of efficiency and to reduce their failure rate and shutdown. In the meantime, increasing the strategic quality and preventing problems caused by machinery failure as well as reducing energy costs such as electricity, fuel, etc. and costs from repetitive and consecutive repairs, and also using spare parts better, etc. in addition to meeting the above main goal, are desired.

Here, we speak of Maintenance and Repair or so-called Preventive Maintenance (PM) which refers to a set of measures that aimed at retaining equipment at an acceptable level from an operation point of view (maintenance) or to restore defective equipment to the cycle of use (repair) and operation. An expected result from these measures will be the readiness, preservation of operational capability, and operational continuity of the equipment for some defined circumstances. In general, the objectives of the PM system in a unit are: efficient, effective and rapid accountability when there is a need for preventive and corrective activities, in order to protect that unit at a standard and acceptable level.

Running PM systems requires planning, scheduling, and expenditure. In the planning section, attention is more focused on repairs and maintaining parts as well as machinery before the system fails. The costs incurred from a maintenance system is such that it generally includes about 10 to 12% of production related costs. These expenditure will be calculated and spent in different sections, some of which will be cited below:

The costs from the paying for the staff of the PM department, the costs from spare parts, of repairing the needed parts, and of the opportunity lost because of failed production, etc. are among the costs considered as maintenance-incurred costs.

To reduce the costs from the PM, some activities can be performed such as reducing the number of employees in the PM department, increasing the accuracy of preventive repairs and more appropriate maintenance of the system, etc.

In the meantime, the issue of warehousing the PM's system is an effective factor in lowering the costs from the PM system and lowering production costs in general. In many cases, system failures and repairs require spare parts and accessories that must be immediately made available to minimize the production shutdown and to prevent higher costs of supplying parts in an emergency condition. To solve this problem, companies supply and maintain these parts and accessories in their own warehouse to the level they require.

The important point is that it will be irrational and very expensive to supply all the required spare parts for an emergency condition. As well, in many factories, it is not possible to protect some sensitive parts while the damage caused by their failure will be high.

In sum, the costs from the PM can be stated as follows:

a) Costs from wages, which is related to the internal employees at the organization and also to secondary contracts.
b) Costs from spare parts which rises as PM rises.
c) Costs from machinery shutdown.

It is possible to estimate the cost of preventive maintenance and repairs as it is planned, but it is not feasible to estimate the cost of haphazard repairs. This is because one cannot estimate how long

ISSN- 2394-5125 Vol 7, Issue 1, 2020

the repair will take or what parts and accessories be applied. The following data must be available to estimate repair related costs.

- Number of failures systems encounter (failure frequency)
- Status of failure and breakdown in each period.
- Duration of failure each time.
- Secondary costs from malfunctioning systems.

For this purpose, it is necessary to refer to the history of the machine and to estimate it by accessing an appropriate information system and collecting statistical information. But it is also important to note that statistical data cannot be relied on throughout the machinery's life cycle. This is because the machinery actually disintegrates over time and the resulting statistical data will be inaccurate.

There are various approaches to machinery service and maintenance, the most important of which are:

Emergency maintenance and repairs (EM): In this technique, the equipment is repaired after the first failure of the equipment.

Corrective maintenance and repairs (CM): In this method, after signs of a defect appear leading to the non-cessation of the equipment, some special planning is made to eliminate the defect at an appropriate time and to restore the situation as it was before.

Preventive maintenance and repairs (PM): In this method, equipment is maintained and retained at definite time periods and in line with a specific scheduled program.

Wider goals of the maintenance system are:

- Reducing energy costs, e.g., electricity, fuel, etc.
- Reducing the cost from repetitive and consecutive repairs followed by a better use of spare parts, etc.
- Increasing the strategic quality and preventing problems caused by equipment and system failing.
- Establishing order and standardizing repair related work.
- Optimizing maintenance and repair incurred costs.
- Appraising the way existing equipment and systems operate in order to modify their future purchasing policies.

Therefore, the issue of warehousing and the optimizing the inventory is considered one of the criteria for evaluating PM related costs. Preventing capital stagnation in the warehouse, creating flexibility in using goods, warehousing related to essential needs and preventing the purchase of non-essential goods are all measures which reduce costs. Therefore, by concentrating on this aspect of system maintenance, the production secondary costs can be greatly reduced.

Also, reliability is one of the most important qualitative features of large and complicated components, products and systems, which assumes a significant role in meeting the objectives and examining their status quo. Today, this issue has been widely accepted in all practical aspects as a certain principle, such that inclusive programs have been developed to achieve it. Military systems have overtaken all other sectors in this regard and have met a high level of reliability as one of their main objectives. The most important role of reliability may be in the area of cost reduction. When reconstructing defective elements incurs unprofitable overhead costs on the organization, and that maintenance related costs not only include parts and labor, but also such items as transportation and warehousing, it is here that reliability requirements can be regarded as the main goal.

Many researches have been performed in the field of maintenance and repairs, only a few cases were observed which are as follows:

Honarmand et al. (2011) introduced a method for prioritizing the implementation of repairs in power distribution systems and transformers service and maintenance. In this method, according to the available information, the likelihood of failure and prioritization of each transformer to perform the service and repair process was determined.

Yasad et al. (2014) presented a paper on reliable PM's optimization in power distribution systems. This article had two main goals based on reliability PM, i.e., guaranteeing safety and reliability through preventive maintenance activities and preventive repairs and when safety precautions are not focused attention, cost-effective actions are needed.

Zhang and Wang (2014) provided maintenance cost modeling for infrastructure assets with data constraints. Their model makes use of the knowledge of experts. A Bayesian linear approach was used to estimate the unknown parameters and the proposed model was tested by data from the railway industry. Berichi et al. (2010) provided a two-purpose model for production and maintenance scheduling as they solved it using an ant algorithm approach. This article aimed to find an appropriate production and maintenance schedule for periodic preventive repairs. The findings suggested that the answers from the ant colony optimization approach were superior to the multi-purpose genetic algorithms.

As said, we seek to answer the question: "How is the integrated hierarchical modeling of production planning and maintenance? and What are the optimal outputs of this modeling?

MATERIALS AND METHODS

Research method, data collection tool and analysis method

In this study, first, by considering warehousing criteria and controlling the inventory to optimize the costs incurred by warehousing spare parts, the model's limitations were determined, and in the macro stage, by considering the outputs of the previous section, the maintenance and repairs system costs were minimized.

In this research, first, using library sources, the required materials are collected and research background is discussed, and in the next stage, the required data are collected by field observation and note-taking to present an appropriate model.

In order to analyze the data and compare the model, the output of optimization problem-solving software such as GAMS was used as it was possible to increase the variables in the function and that the problem-solving software did not meet the demands. In the final section, the results are compared with the system's pre-implementation stage.

Also, no specific statistical population is considered in this study with the Behbahan Cement Factory being regarded as a case study.

Investigation of answers to the problem using genetic algorithm:

Problem parameters

I=27 equals to number of variables

C= Objective function coefficients

A1= Constraint coefficients in type2

A2=Constraint coefficients in type5

B1 =The numbers on the right in type2

B2 =The numbers on the right in type5

```
%% Algorithm parameters
npop=50;
maxit=1500;
pc=0.7;
nc=2*round(pc*npop/2);

mu=0.3;
nmu=round(mu*npop);

individual.X=zeros(2,I);
individual.Cost=[];

pop=repmat(individual,npop,1);
bestpop=repmat(individual,maxit,1);
```

bestcosts=zeros(maxit,1);

Algorithm parameters
Npop = 50 is the initial population considered equal to 50 (this value is considered completely experimental). This initial population id the same as chromosomes.
Maxit = 1500 is the maximum number of iterations equal to 1500 (it can be any number, depending on the fact how many iterations would produce a fixed final answer) as it is a condition for stopping the algorithm
Pc = Probability of intersection/crossover; this probability is considered to be 0.7. The intersection operator runs with probability p (it is recommended to be considered 0.45 <p <0.85).
Nc = The number of crossovers obtained from the formula 2*round (pc*npop / 2)
0.3= mu= The mutation is usually considered with a small probability. A mutation is usually run for each gene with a probability of p.
Nmu = The number of mutations obtained from the formula round (mu*npop)
Individual = The selection of chromosomes; here we combine the population of children and parents together and as a result creating a population twice the size of the original population. The combination is aimed not to remove superior answers from the parent and child population.

Crossover operator
The most important operator in the genetic algorithm is the Crossover Operator. Crossover is the process in which an older generation of chromosomes is combined to create a new generation of chromosomes. The pairs considered parents in the selection section get their genes exchanged with each other in this section, creating new members. Crossover in the genetic algorithm causes a loss of dispersal or genetic diversity of the population. This is because it allows good genes to find each other. This type of crossover operator allows for the children produced to be always law-abiding (i.e., it is never possible to have chromosomes not corresponding to any member of the response space).
Common methods include single-point, two-point, multi-point, and uniform displacement. The simplest mode of displacement is single-point displacement. In single-point displacement, first a pair chromosome of the parent (binary strand) is cut at a certain point along the strand, with then parts of the cut point being substituted. Thus, two new chromosomes appear, each of which inherits genes from the parent chromosomes. The following figure illustrates an example of a single point crossover in the crossover operator.

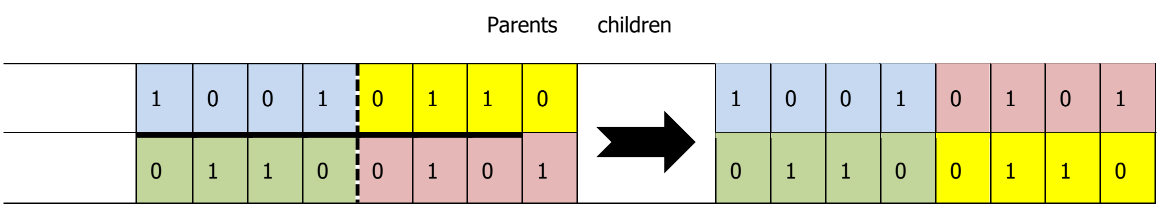

Figure 1- Crossover operator

Mutation operator
Mutation is another operator that yields other possible answers. In the genetic algorithm, after a new member is born in a new population, each of its genes mutates with the possibility of mutation. In mutation, a gene may be removed from a population of genes or be added to it never before present in that population. Gene mutation means a change in that gene, and depending on the type of coding, different mutation methods are used.
Finding answers closer to various optimal answers in a population and maintaining them in different generations are two distinct issues. Although it is possible to discover multiple answers during the initial generations, it is not possible to automatically keep them in a genetic algorithm. It is necessary to use a variable maintaining operator to maintain multiple optimal answers. A mutation operator is often used as an operator maintaining diversity in an evolutionary algorithm. Although selection and crossover operators help find different optimal answers, these operators will not be able to maintain such useful answers after many generations elapsed. The mutation operator has both a constructive and a destructive effect. Moreover, this operator can eliminate a good answer as it is able to produce a better answer by disrupting an answer. Since we only tend to accept the constructive effect of a mutation, and on the other hand, a study of the vibration of any possible mutation output may require too many calculations, the mutation is usually used with a low probability in a genetic algorithm (mu = 0.3).

RESULTS

Solving the model
As said, the proposed model needs to be validated. To test the model, the data from the Behbahan Cement Company was collected to provide a final improved model by considering the intended parameters. Table 1 illustrates all the activities related to maintaining the cement production line. These values were obtained by collecting data from maintenance and repair experts working on the production line as they are theoretical in nature.

Table 1: List of activities

Replacing RM board	FC1
Replacing shaft encoders	FC2
Replacing the tart encoder	FC3
Replacing coal	FC4
Replacing the magnetic switch	FC5
Replacing tacos	FC6
Replacing the brushes	FC7
Replacing the fuse screw	FC8
Replacing keyboards	FC9
Replacing tart brake	FC10
Replacing the monitor	FC11
Replacing I/O board	FC12
Replacing CRU board	FC13
Replacing shaft micro-switch	FC14
Replacing cooling system	FC15
Replacing contactor	FC16

ISSN- 2394-5125 Vol 7, Issue 1, 2020

Replacing PS board	FC17
Replacing Spindle fuse pins	FC18
Replacing hydraulic jaws	FC19
Replacing hydraulic pressure breaker	FC20
Replacing soap water pump	FC21
Replacing tool drive	FC22
Replacing transformer diode bridge	FC23
Replacing spindle ball-bearing	FC24
Replacing TacoMotor	FC25
Replacing the Guide PIN	FC26
Replacing spindle radial shaft seal	FC27

Problem model
(Micro level model)

$$\text{Max } f_2 = .009x_{1\,1} + .018x_{1\,2} + .0225x_{1\,3} + .0541x_{1\,4} + \text{[illegible]}$$
$$+ .0631x_{1\,8} + .0541x_{1\,9} + .0541x_{1\,10} + .027x \text{ [illegible]} + .027x \text{ [illegible]} + .0315x \text{ [illegible]}$$
$$+ .036x_{1\,14} + .045x_{1\,15} + .0541x_{1\,16} + .036x_{1\,17} + .063x_{1\,18} + .054x_{1\,19}$$
$$+ .036x_{1\,20} + .045x_{1\,21} + .018x_{1\,22} + .027 \text{ [illegible]} \; 26$$
$$+ .018x_{1\,27}$$

$$\text{Max } f_3 = .0106x_{2\,1} + .0159x_{2\,2} + .0177x_{2\,3} + .0566x_{2\,4} + .0372x_{2\,5} + .0451x_{2\,6} + .0602x_{2\,7} + .0628x_{2\,8} + .0584x_{2\,9} + .0549x_{2\,10} + .0239x_{2\,11} + .0274x_{2\,12} + .031x_{2\,13} + .0354x_{2\,14} + .0442x_{2\,15} + .0531x_{2\,16} + .0336x_{2\,17} + .0631x_{2\,18} + .0531x_{2\,19} + .0345x_{2\,20} + .0451x_{2\,21} + .0195x_{2\,22} + .0265x_{2\,23} + .0088x_{2\,24} + .0265x_{2\,25} + .0221x_{2\,26} + .0354x_{2\,27}$$

Optimal answers obtained using GAMS software; micro model

Table 2: Optimal answers of the micro level model

Activity	Cement type 5
FC3	1
FC6	1
FC10	1
FC11	1
FC12	1
FC13	1
FC14	1
FC18	1
FC19	1
FC22	1
FC23	1
FC25	1
FC27	1

Activity	Cement type 2
FC1	1
FC2	1
FC3	1
FC5	1
FC11	1
FC12	1
FC13	1
FC20	1
FC22	1
FC23	1
FC27	1

Optimal answers obtained using genetic algorithm; micro level model

Table 3: Optimal answers of micro level model

Activity	Cement type 5
FC1	1
FC3	1
FC5	1
FC20	1
FC22	1
FC23	1
FC25	1
FC26	1

Activity	Cement type 2
FC1	1
FC3	1
FC5	1
FC10	1
FC11	1
FC18	1
FC22	1
FC25	1
FC26	1

ISSN- 2394-5125 Vol 7, Issue 1, 2020

CONCLUSION

In this research, a scheduling model for Behbahan Cement Factory's PM system was provided, which was more effective than previous models. The proposed model provided a scheduling plan for the factory's PM unit and a schedule for the equipment related PM separately. In this way, a zero and one model was presented for the PM system and this very zero and one model was considered in the general model for scheduling the equipment PM; since, we assumed the model was a unique PM system, so it cannot simultaneously deal with both processes, hence we resorted to a zero and one model, presented in the form of a constraint in the main model.
The cost of using the PM system is viewed one of the most significant factors in cement factories. Therefore, we had a report on the improvement of the cost situation and the reduction of costs by launching the PM system. In reality, PM system costs include the costs related to manpower, equipment and parts, etc.
As noted, scheduling maintenance activities can lead to more productivity if performed correctly. Applying mathematical models can be a very suitable solution for scheduling maintenance activities of category items to yield the best results. The innovative aspect of this research is related to the fact that the model was hierarchical in nature, which at the primary level concerns the warehousing structure and controlling an inventory of spare parts, while in the secondary level, it focuses on the costs from the maintenance system.

REFERENCES

1. Mohammad Esmaebel Honarmand - Mahmoud Reza Haghi Fam - Hadi Doost Bar Haghi, (2011). Presenting a new method of prioritizing the implementation of repairs based on importance, International Conference on Electricity
2. Yssaad, B., M. Khiat, and A. Chaker, Reliability centered maintenance optimization for power distribution systems. International Journal of Electrical Power & Energy Systems, 2014. 55(0): p. 108-115.
3. Zhang, W. and W. Wang, Cost modelling in maintenance strategy optimisation for infrastructure assets with limited data. Reliability Engineering & System Safety, 2014. 130(0): p. 33-41.
4. Berrichi, A., et al., Bi-Objective Ant Colony Optimization approach to optimize production and maintenance scheduling. Computers & Operations Research, 2010. 37(9): p. 1584-1596..