JEAS
Journal of Economics and Administrative Sciences
E-ISSN: 2148-1792 P- ISSN: 1302-2024
Volume 3, Supplement Issue 3
www.jeasweb.org

Providing a cost-reduction hierarchical model appropriate for the net system (maintenance and repair)

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ABSTRACT

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 inthe 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

Introduction

Today, maintenance has been the focus of attention as a determining factor in leading industries and companies. Leading companies have always sought to optimize their maintenance by proper planning and scheduling while reducing repair and maintenance-incurred costs. Of course, their programs have always aimed at balancing between production line costs and maintenance-related costs. In today's highly competitive market, wasting time as a result of machinery failure imposes heavy costs.

In most factories and industrial companies, the issue of machinery failure has become a challenge for managers. These failures have sometimes temporarily been repaired with the machinery continuing to function as before. However, in some cases, the failure may be substantial and stop production for a longer period of time. This causes too many losses such as cessation and non-production-related costs and also repair costs and most importantly the time wasted during the repair period which is irreversible.

To this end, managers and engineers in manufacturing companies have thought of implementing maintenance systems for their industrial machines so that they could take the necessary precautions before they sustain losses due to defective machinery.

One of the most important issues in industrial production organizations in general is how to maintain and repair equipment and machinery, i.e., how to technically protect physical assets.

Failure to pay attention to this causes the cost of maintaining machinery to spike, resulting in undue depreciation, sudden shutdown, inability to provide services and huge financial losses. Here, we speak of maintenance and repairs, as the acronym PM denotes Preventive Maintenance. Of course, over time, several corrections have been made to the terminology, including the replacement of "Preventive" with "Predictive". This is while PM stands the opposite of EM, meaning sudden shutdown and abrupt cessation.

When machines operate, they inevitably need maintenance as they may break down and fail. PM seeks to minimize the shutdown and failure, and more importantly, make it as planned and predictable.

In cases where it is not possible to estimate repair costs (as a production unit fails to launch, or when no statistics on the practical operation of the machinery is available), the fee cost invoice (manpower) is set as the criterion for prediction and estimation. The more manpower is set for maintenance and repairs, the higher the cost of PM's fees. This is made proportion to the time of machine failure, and as a result, the cost of machine shutdown decreases.

Maintenance and repair or Preventive Maintenance (PM) manpower includes:

• PM's programmers and experts
• Technical inspectors and experts
• Service staff, repair teams and support units

Maintenance and repairs planning and scheduling concerns organizing and prioritizing work for the maintenance and repair activities to be performed with high efficiency.

This planning sets the right human workforce in the right place at the right time with the right tools. The benefits of appropriate planning and scheduling include the following:

• Savings in costs for an efficient use of work force
• Increasing production efficiency as a result of performing activities faster
• Reducing stress and injuries as a result of a better workflow

Maintenance and repairs planning and scheduling are two activities that optimally guarantee the required resource allocation and resource allocation sequence, thus any activity can be performed in a shorter time and at a lower cost. Although planning and scheduling are often used interchangeably, they are two distinct operations. Planning is the answer to the "What, where, how" questions, while scheduling answers the "who, when" questions.

Also, a factory's production system is closely related to a maintenance system and is greatly dependent on it. Maintenance and repairs system scheduling and production planning make it possible to simultaneously reduce production and opportunity costs resulting from shutdown production line. Here, one can better understand the importance of integrated modeling.

In this research, an attempt was made to develop a maintenance planning model using a hierarchical modeling approach.

Reliability-based PM or reliability PM is a process which determines which activities are required to keep physical assets at a certain level of efficiency (according to their users) to maintain their functioning.

In fact, RCM is an engineering method to determine PM's applications at the organization level, which considers reliability as a critical concept. Another main feature of this method is its function-based approach. In other words, the analysis process begins by defining and specifying the functions of each of the systems and equipment included in the program, after the scope of work is determined.

Too many researches have been done in this area. In a study entitled Using AHP and Fuzzy TOPSIS techniques to determine the condition of the machine in developing an optimal maintenance plan and in line with preventive repairs, Weiss et al. (2012) have investigated the conversion of descriptive data into quantitative data and also the use of MCDM techniques to optimize the PM's program.

Behmardi (2011) also surveyed a mathematical programming model to improve the efficiency of TPM and provided his model according to the PM's time and cost in each system. The main goal was to determine an optimal volume of material flow between different operational levels based on the technical specifications of the machines.

Abirami et al. (2014) sought to optimize maintaining and repairing power and transmission line transmission lines using learning models. In this study, they stated that power systems maintenance and repairs were crucial to extend the life of equipment. The most important components of these systems are generators and transmission lines. In this research, optimization is performed on the integrated scheduling problem. The optimization used in this research was trainer and learner optimization.

Guo et al. (2013) provided a maintenance optimization model for mission-based systems. Their model is founded on mission-based systems in which gradual failure takes place. Their modeling process is a random process.

Panagiotiodou (2014) presents a model to optimize spare parts ordering and maintenance and repairs strategies. In this paper, two types of general and partial failure are considered with inventory policies on continuous and discrete reviews being taken into account. Sensitivity analysis done in this model indicated that the model had been reliable against incorrect estimation of parameters and did not change much.

In this study, the main objective was to reduce the costs of maintenance system, which seeks to reduce the costs relating to the PM's system by taking into account the costs incurred by controlling the spare parts inventory and optimizing its costs in several stages. Based on this, the goals are stated as follows.

- Reducing maintenance system-incurred costs with the help of a hierarchical model
- Optimizing spare parts warehousing system
- Controlling spare parts costs by controlling the inventory

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.

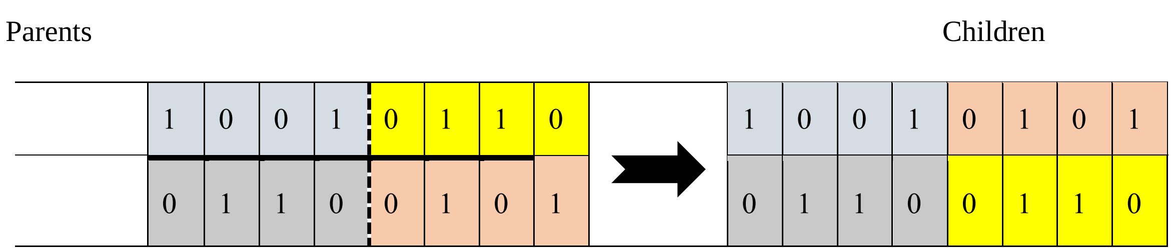

Figure 1- Crossover operator

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
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 (Macro level model)

$\text{Max } f_1 = .0045x_{1\,1} + .00893x_{1\,2} + .01116x_{1\,3} + .02679x_{1\,4} + .01786x_{1\,5} + .02232x_{1\,6} + .03125x_{1\,7} + .03125x_{1\,8} + .02679x_{1\,9} + .02679x_{1\,10} + .01339x_{1\,11} + .01339x_{1\,12} + .01563x_{1\,13} + .01786x_{1\,14} + .02232x_{1\,15} + .02679x_{1\,16} + .01786x_{1\,17} + .03125x_{1\,18} + .02679x_{1\,19} + .01786x_{1\,20} + .02232x_{1\,21} + .00893x_{1\,22} + .01339x_{1\,23} + .00446x_{1\,24} + .01339x_{1\,25} + .01339x_{1\,26} + .00893x_{1\,27} + +.00536x_{2\,1} + .00804x_{2\,2} + .00893x_{2\,3} + .02857x_{2\,4} + .01875x_{2\,5} + .02277x_{2\,6} + .030306x_{2\,7} + .0317x_{2\,8} + .02946x_{2\,9} + .02768x_{2\,10} + .01205x_{2\,11} + .01384x_{2\,12} + .01563x_{2\,13} + .01786x_{2\,14} + .02232x_{2\,15} + .02679x_{2\,16} + .01696x_{2\,17} + .03036x_{2\,18} + .02679x_{2\,19} + .01741x_{2\,20} + .02277x_{2\,21} + .00982x_{2\,22} + .01339x_{2\,23} + .00446x_{2\,24} + .01339x_{2\,25} + .01116x_{2\,26} + .01786x_{2\,27}$

Subject to:

$1800000x_{1\,1} + 3000000x_{1\,2} + 2900000x_{1\,3} + 4900000x_{1\,4} + 24000000x_{1\,5} + 17900000x_{1\,6} + 5000000x_{1\,7} + \cdots + 260000x_{1\,27} \leq 25000000$ (1)

$12x_{2\,1} + 18x_{2\,2} + 20x_{2\,3} + 64x_{2\,4} + 42x_{2\,5} + 51x_{2\,6} + 68x_{2\,7} + \cdots + 40x_{2\,27} \leq 35000000$ (2)

$5x_{1\,1} + 15x_{1\,2} + 10x_{1\,3} + 5x_{1\,4} + 10x_{1\,5} + 10x_{1\,6} + 10x_{1\,7} + \cdots + 10x_{1\,27} \leq 100$ (3)

$4x_{2\,1} + 13x_{2\,2} + 8x_{2\,3} + 6x_{2\,4} + 9x_{2\,5} + 18x_{2\,6} + 13x_{2\,7} + \cdots + 9x_{2\,27} \leq 130$ (4)

$8x_{1\,1} + 3x_{1\,2} + 10x_{1\,3} + 8x_{1\,4} + 10x_{1\,5} + 9x_{1\,6} + 8x_{1\,7} + \cdots + 7x_{1\,27} \leq 120$ (5)

$6x_{2\,1} + 4x_{2\,2} + 6x_{2\,3} + 4x_{2\,4} + 2x_{2\,5} + 6x_{2\,6} + 10x_{2\,7} + \cdots + 9x_{2\,27} \leq 110$ (6)

$9x_{1\,1} + 8x_{1\,2} + 7x_{1\,3} + 8x_{1\,4} + 9x_{1\,5} + 5x_{1\,6} + 7x_{1\,7} + \cdots + 11x_{1\,27} \leq 200$ (7)

$11x_{2\,1} + 5x_{2\,2} + 9x_{2\,3} + 5x_{2\,4} + 7x_{2\,5} + 11x_{2\,6} + 9x_{2\,7} + \cdots + 10x_{2\,27} \leq 190$ (8)

$x_i = (0,1) \ \ (i = 1,2,3, \ldots ,27)$ (9)

In this section, Constraints 1 and 2 investigate the maximum budget level available for each of the two types of cement in access. Constraints 3 and 4 concern the limited number of man-hours. Constraints 5 and 6 deal with the maximum hour machine required for each of the two types of cement available. Constraints 7 and 8 concern the risk of each project.

GAMS software outputs

Optimal answers obtained using GAMS software; macro model

Table 2 Optimal answers provided by the macro level model

	Cement type 2	Cement type 5
FC4	1	1
FC6	1	
FC7	1	1
FC8	1	1
FC9	1	1
FC14	1	
FC15	1	1
FC16	1	1
FC17	1	1
FC19	1	
FC20		1
FC21	1	1
FC25	1	

Optimal answers obtained using genetic algorithm; macro model

Table 3: Optimal answers provided by the macro level model

	Cement type 2	Cement type 5
FC4	1	1
FC6	1	1
FC7	1	1
FC8	1	1
FC9	1	1
FC12	1	1
FC13	1	1
FC14	1	1
FC15	1	1
FC16	1	1
FC17	1	1
FC18		1
FC19	1	1
FC20	1	
FC21	1	1
FC23	1	

Conclusion

Considering the extreme economic competition in the national and global arenas, markets need better quality and lower costs. Under such a highly competitive market, an organization will survive and remain stable which equips itself with the latest technological and managerial achievements. In the age of constant transformations, fast reactions and using modern managerial attitudes are deemed necessary issue for survival. Planned and scientific maintenance processes along with modern global techniques directly influence productivity, quality, direct production costs, finished costs, reliability, usability and profitability. By maintenance and repair, it is a set of systematic activities, operations and techniques to preserve and control the condition of equipment, installations and machinery (physical assets) under optimal conditions or to change them into optimal conditions in accordance with acceptable standards. These processes include planning for a modified PM, prevention, prediction, the way spare parts are supplied, planning for manpower, etc. Maintenance and repairs systems consist of methods, forms and instructions that meet the above objectives and help the PM management to better plan and monitor over maintenance and repairs affairs of industrial units, with which, the existing facilities can be maximally applied. Considering that the plan to improve and manage systems, consisting of humans, facilities, machinery, equipment and materials to yield better utilization and to increase the useful life of equipment and efficiency of the system, and given the optimal use of resources such as budget, personnel, etc. require an appropriate system for planning, analyzing, controlling and benefiting from correct management techniques, thus developing an effective and dynamic maintenance system is very crucial in this connection. According to the research findings, one can state that as we reported the result from GAMS software and genetic algorithm, if the scheduling process is done properly and the PM activities are run at the specified times, the goals set in the proposal will be met. Another major result of this research is that mathematical programming is viewed a solution to reduce costs, increase productivity and efficiency of the PM system in each industrial unit.

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