Formation of Model for Diligences founded on benchmark jobs

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Abstract— **Manufacturing products have many facet of cost and incidentals spend to maintain the plant and equipment are treated as overheads without perturbing much. Subsequently, only the breakdown maintenance cost has a great impact over product cost and overall economy of the diligences. Three process diligences under study has one common equipment, the Boiler of overriding prominence as its fractional or complete fiasco halt the intact production system. That's why, need felt to form a model to estimate the cost experienced by any breakdown based upon some benchmark jobs as none knows the expenses incurred following a breakdown in terms of many associated expenditures. So, a preemptive goal programming model is formulated by considering benchmark jobs and other influencing factors. Conversely, these factors have been sub-leveled further for an awfully precise assessment of the most advantageous maintenance times.**

Index Terms— **Model formation, Benchmark Jobs, Breakdown Maintenance, Cost, Diligences**

I. Introduction

Because breakdown maintenance has a great impact over the cost of the final product and performance of the maintenance system is conquered by numerousinfluences like manpower/equipment planning and management of needed spares. Accordingly, the search for an amended system to overcome the constraints prevailing at the diligences has been a major cause and to frame such a model so that estimation of maintenance jobs can be attained easily.

a. Goal Programming

It is an approach to provide the multiple solutions for practical problems. It resolves complexity in decision making process. That's why is one tatteredmanner to resolve practical difficulties [10].

II. Literature Review

An et al. [2]developed two computer-aided tools as part of the Smart Plant Process Safety (SPPS) system. One is to help with the task of identifying hazards related to maintenance work and the other is to carry out cause and effect analysis automatically. This paper highlights the main functions of these two tools and describes how they are developed. It also illustrates how the cause effect analysis tool can be used to support hazard identification before carrying out the maintenance work.

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Arora and Arora [4] observed that most of the problems on facility location are in reality multicriteria problems. In practice, facilities may have constraining capacities on the amount of demand they can serve. To bridge the gap between theory and practical, they have considered the multiobjective capacitated plant location problem. The multiobjective plant location problem is decomposed into two sub-problems. The allocation of plants to the clients when the capacities are restricted has been discussed in detail. Two algorithms are presented to solve the allocation problem.

Artana and Ishida [5] delivered a method for determining the optimum maintenance schedule for components in wear out phase. The interval between maintenance for the components is optimized by minimizing the total cost. Desai and Mital [8] have presented the basic concepts and an outline of current research in the field of designing products/systems to enable ease of maintenance and understood that most of the researches are reactive in nature and is not useful as far as design is concerned. A methodology that enables product design for maintenance is conspicuous by its absence. So, focuses on research efforts that can be directly helpful in the evolution of such a methodology.

Huang [11] focused on this study to optimally coordinate the maintenance schedule of machines to save the maintenance cost incurred, which is named as the maintenance scheduling problem for a family of machines (MSPFM). Jeong et al. [12] described an integrated decision support system to diagnose faults and generate efficient maintenance and production schedules of electronics manufacturing system. The proposed integrated system was composed of three modules, namely, the Diagnosis Module, the Maintenance Planning Module, and the Scheduling Module.

Lee et al. [16] addressed that how maintenance can be transformed from pure 'strategies' into 'a service function'. A state-of-the-art review on maintenance design is conducted and then a methodology and tools for effect predictive maintenance service design are presented. Nikolaos et al.[20] projected a maintenance system design framework and presents a successful implementation of the suggested design framework in a Greek manufacturing company. Oke et al. [21] have dealt with facility maintenance scheduling model which incorporates opportunity and inflationary costs.

Panayiotou et al. [22] highlighted the significance of plant maintenance as profit generator for the corporation and developed a suitable maintenance concept. That concept had enabled the decision of specific maintenance strategies based on the existing situational factors to affect the functioning of the organization. Waeyenbergh andPintelon[26] described the CIBOCOF framework to develop a customized maintenance concept in a specific company. Specific and new to this framework is that the optimization problem of maintenance is also taken into account. As such, Models described in literature finally find a way to practice, and the gap between theory and practice is closed a little bit in this paper; the framework is presented and illustrated by means of a case study.

Wenzhu et al. [27] proposed a sequential Condition-Based Maintenance (CBM) policy for intelligent monitored system based on cost and reliability prioritization. This maintenance policy differs from other policies in taking into consideration of influences from the frequency of maintenance activities and operating time on system's failure rate function subject to a deterioration process.

Kareem and Aderoba[13] developed a model for estimating the cost of maintenance gang(s) in maintenance systems utilizing salient factors such as interest and inflation, with the heuristics and real life functions. The cost of operating the gang is estimated using Activity-Based Costing (ABC) and it includes the cost of crew, tools/equipment, inventory, building, utilities among others. Ananda andMaiti [3] adopted the risk-based maintenance (RBM) approach to design an alternative strategy to minimize the loss resulting from these breakdowns or failures. The methodology consists of four modules: system definition, risk assessment, risk acceptance criterion and maintenance planning. In this study, the RBM approach was adopted for a gas expansion turbine of a steel plant.

Tsakatikas et al. [8] evolved a methodology and Decision Support System (DSS) for the establishment of spare parts criticality with a focus on industrial unplanned maintenance needs. The obtained criticality is used to rationalize the efficiency of the plant spare parts inventory. Chang [6] has proposed a new concept of level achieving in the utility functions to replace the aspiration level with scalar value in classical Goal programming (GP) and Multi-choice goal programming (MCGP) for multiple objective problems. According to this idea, it is possible to use the skill of MCGP with utility functions to solve multi-objective problems. Choi [7] described a new mathematical model of line balancing for processing time and physical workload at the same time by goal programming approach and designed an appropriate algorithm process for the operation managers to make decisions on their job scheduling efforts, whereas various computational test runs are performed on the processing time only model. Kharrat et al. [14] proposed an interactive optimization method for imprecise multiple-objective decision-making situations. The aim of the proposed approach is to integrate explicitly the decision-maker's (DMs) preferences within the interactive imprecise goal programming model. The DMs preferences will be expressed through the satisfaction functions concept. Kharrat et al. [15] adapted a record-to-record travel (RRT) algorithm with an adaptive memory named taboo central memory (TCM) to solve the lexicographic goal programming problem. The proposed method can be applied to non-linear, linear, integer and combinatorial goal programming. Because that the RRT has no memory, the adaptive memory TCM is inserted to diversify research.

Mezghani et al. [19] addressed an effective method to elaborate an aggregate plan which takes into account the manager's preferences by a Goal Programming (GP) approach, with satisfaction functions. Patia et al. [23] have formulated a mixed integer goal programming (MIGP) model to assist in proper management of the paper recycling logistics system. The model studies the inter-relationship between multiple objectives (with changing priorities) of a recycled paper distribution network.

III. Problem Formulation

Numerous problems are encountered by Diligences and Breakdown Maintenance is selected for study work where existing maintenance system of boiler has been carried out. After in depth study in three different process industries, it is observed that varieties of problems are arises in the boiler maintenance system and absence of estimation of maintenance cost of any particular breakdown under different prevailing conditions is peculiar one.

a. Objective

- To develop the model for cost estimation of breakdown maintenance of Boilers under different prevailing situations with the application of Goal programming
- To estimate the cost of breakdown maintenance of boilers under different types of failure

IV. Methodology Of The Study

Censoriously the intactmaintenance system of the boilers and their accessories/mountings is examined, in accordance with the importance of maintenance, their types, down time, etc. The study integrates following:

- Standing Maintenance Practice
- Model Formulation
- Estimationof Maintenance Cost

a. Model Formulation

After studying the existing maintenance practice; major influencing factors and their complexity levels are discussed with Chief of the maintenance sections and other persons related to the maintenance system for boilers. Then model is developed based upon some assumptions, benchmark jobs and constraints.

b. Assumptions

Assumptions taken into consideration are:

- Breakdown maintenance is included in the study.
- Above eight man hours of failure is considered as breakdown time.
- Conserving time of boilers is ignored.

c. Influencing Factors

Six factors are considered, those influence the maintenance time, which are given under the heads (J_i) as:

a) Job Quality (J_1)
b) Skill of the Worker/Workers (J_2)
c) Resource Items (J_3)
d) Supervision Quality (J_4)
e) Working Environment (J_5)

f) Teamwork Relationship (J_6)

For more critical analysis, each factor Ji (i = 1, 2... 6) is categorised under five different levels (j = 1, 2... 5) with respect to the complexity of maintenance job.

However, influence of these factors on the maintenance system may differ from breakdown to breakdown. In order to achieve the overall maintenance requirements, a model has been developed by grouping each of these factors to correspond to different complexity.

As presented in Table: 1, the ascending order of the levels in this table signifies the increasing complexity in maintenance jobs:

Table 1: Influencing Factors

Factor J_i	**Job Complexity Level 'j'**				
	1	**2**	**3**	**4**	**5**
Job Quality	J_{11}	J_1	J_1	J_1	J_1
Skill of Worker	J_{21}	J_2	J_2	J_2	J_2
Resource Items	J_{31}	J_3	J_3	J_3	J_3
Supervision Quality	J_{41}	J_4	J_4	J_4	J_4
Environment	J_{51}	J_5	J_5	J_5	J_5
Teamwork	J_{61}	J_6	J_6	J_6	J_6

d. Benchmark Jobs

To formulate the model, number of maintenance jobs is estimated by considering different levels of job complexity and limit constraints, which are termed as benchmark jobs.

The most composite benchmark job ought to consist of factors having the highest involvedness levels. The minutestdispensedscore to the utmostsubstance benchmark job is:

$$J_{15} + J_{25} + J_{35} + J_{45} + J_{55} + J_{65} \leq 100 \quad \text{... (1)}$$

Similarly, other benchmark jobs are identified and given as:

$$J_{14} + J_{25} + J_{35} + J_{44} + J_{54} + J_{65} \leq 90 \quad \text{... (2)}$$

$$J_{15} + J_{25} + J_{32} + J_{42} + J_{54} + J_{64} \leq 75 \quad \text{... (3)}$$

$$J_{14} + J_{23} + J_{31} + J_{41} + J_{54} + J_{62} \leq 55 \quad \text{... (4)}$$

$$J_{14} + J_{21} + J_{31} + J_{42} + J_{51} + J_{61} \leq 40 \quad \text{... (5)}$$

Despite the setting of goals for each of the benchmark jobs, some deviations would always exist in real life. However, any deviation from the goal should be allowed only within the permissible limit for a better functioning of the maintenance system. The other constraints are as such:

$$J_{i1} \geq (9 - i) \quad \text{... (6)}$$

$$J_{i5} \leq 20 \quad \text{... (7)}$$

$$J_{i(j+1)} - J_{ij} \geq 3 \quad \text{... (8)}$$

For developing the model, equations (1) to (8) can now be written as below for developing the goal programming model:

$$J_{15} + J_{25} + J_{35} + J_{45} + J_{55} + J_{65} - p_1 = 100 \text{...}$$

$$J_{14} + J_{25} + J_{35} + J_{44} + J_{54} + J_{65} - p_2 = 90 \text{ ...}$$

$$J_{15} + J_{25} + J_{32} + J_{42} + J_{54} + J_{64} - p_3 = 75 \quad \text{... (A)}$$

$$J_{14} + J_{23} + J_{31} + J_{41} + J_{54} + J_{62} - p_4 = 55 \text{ ...}$$

$$J_{14} + J_{21} + J_{31} + J_{42} + J_{51} + J_{61} - p_5 = 40 \text{ ...}$$

$$J_{i1} + n_{i+5} = (9 - i) \quad \text{... (B)}$$

$$J_{i5} - p_{i+11} = 20 \quad \text{... (C)}$$

$$J_{i(j+1)} - J_{ij} + n_{\{5(i-1)+j+17\}} = 3 \quad \text{... (D)}$$

For i = 1, 2... 6 and j varies from 1 to 5 for each i.

Where, p_i (i = 1, 2... 5) and **ni** (i = 1, 2... 5) are the positive and negative deviational variables.

Objective function of base rate estimation model is given by equation (E):

5 11 17 41

Minimize, Z = { $P_1 (\Sigma p_i)$, $P_2 (\Sigma n_i)$, $P_3 (\Sigma p_i)$, $P_4 (\Sigma n_i)$} ... (E)

i = 1 i = 6 i = 12 i = 18

subject to the equation sets (A), (B), (C) and (D).

Where, P_i **(i = 1, 2, 3, 4)**specify the priorities assigned.

a) In equation (E), top priority P1 is assigned to minimize the deviations from the goals in equations set (A); next priority P2 is assigned to equation set (B) and so on.

b) Assuming that **P1 = 1** and **P2 = P3 = P4 = 0.**

c) Once the solution is arrived at the attainment for the highest priority goal P1, then problem is solved by assuming P2 = 1 by taking all other priority goal values are zero and so on to obtain the solution.

d) The optimal values for the decision variables J_{ij} are obtained using the software for Goal Programming.

Table 2 depicts the optimal score_of Estimation Model, obtained by using the Goal Programming Software.

Table 2: Optimal Score for Maintenance Time Influencing Factors

Fact	Complexity Levels ($_j$)				
J_i	1	2	3	4	5
J_1	8	11	14	17	20
J_2	3	6	9	12	15
J_3	7	10	13	16	19
J_4	2	5	8	11	14
J_5	6	9	12	15	18
J_6	1	4	7	10	13

From the above Model, optimal maintenance cost under different prevailing situations can be estimated depending upon the complexity levels of applicable job factors on that particular breakdown of the boilers. Method of estimationof breakdown cost is well explained in preceding article 6.2.4

e) Worth for benchmark jobs reflecting the deviations in respective cases are shown in Table 3 and it is evident that worth for benchmark jobs 1, 4 and 5 are below one point to the assigned worth.

f) The worth for benchmark jobs 2 and 3 have been attained exactly the same as assigned. So, it varies maximum 3%.

Table 3: Worth for Benchmark Jobs

Benchmark Jobs	Allotted	Goal Achieved	Under Achievement
1	100	99	1
2	90	90	0
3	75	75	0
4	55	54	1
5	40	39	1

e. Estimation of Maintenance Cost

If the first benchmark job with the score of 100 has to acquire a cost of W rupees per maintenance manhour, then one can evaluate any maintenance job comprising of different job factors. Where 'W' is the cost factor, which varies from time to time and influenced by high class technical skill cost, high class supervision cost, high class environmental control cost and high class tools and tackles cost for supporting the work progress in one hour.

For Example: A job comprising of different job factors like J_{13}, J_{23}, J_{34}, J_{44}, J_{51}, J_{63}. The total score of this maintenance job using the optimal scores of various job factors from Table 2 would be:

$$\mathbf{J_{13} + J_{23} + J_{34} + J_{44} + J_{51} + J_{63} = 63}$$

How Many Persons are there for work: 3

Enter the Job Quality Grade of the first person: 3

Enter the Skill of Worker Grade of the first person: 3

Enter Resource Items Grade of the first person: 4

Enter Supervision Quality Grade of the first person: 4

Enter Environment Grade of the first person: 1

Enter Teamwork Grade of the first person: 3

Total points generated is: 63.0

Cost of job is Rs. 63.0W

Enter the Time for working: 8.5

Cost of 1 person is Rs. 535.5W

Is the next person is same as previous?: 'Y/N' n

Enter Job Quality Grade of the second person: 3

Enter Skill of Worker Grade of the second person: 1

Enter Resource Items Grade of the second person: 3

Enter Supervision Grade of the second person: 2

Enter Environment Grade of the second person: 0

Enter the Teamwork Grade of the second person: 0

Total points generated is: 35.00

Cost of job is Rs. 35.00W

Enter the Time for working: 7.5

Cost of two persons is Rs. 262.50W

Is the next person is same as previous? 'Y/N' n

Enter the Job Quality Grade of the third person: 3

Enter the Skill of Worker Grade of the third person: 2

Enter the Resource Items Grade of the third person: 1

Enter the Supervision Quality Grade of the third person: 1

Enter the Working Environment Grade of the third person: 0

Enter Teamwork Grade of the third person: 1

Total points generated is: 30.00

Cost of job is Rs. 30.00W

Enter the Time for working: 5

Cost of three persons is Rs. 150.00W

Total Cost is Rs.948.00W

V. Results And Discussion

Model is formed for the estimation of the cost for different breakdowns of the boilers, whereas study is demeanour at nearby three processing diligences where boilers are the soul of the process. Desired data has been collected from the concerned authorities of the plants under study.

To estimate the cost, a goal programming model is formulated by considering some priority based benchmark jobs, constraints, assumptions and other foremost factors.

By amending any one of the persuaded factors, the maintenance time would also get altered. Conversely, these factors have been sub-leveled further for an awfully precise assessment of the most advantageous maintenance times with due regard to the complexity level of the maintenance jobs to be completed. From Table 3, it is also palpable that:

- Virtue of the benchmark jobs 1, 4 and 5 are below one point to the assigned score.
- Worth of the benchmark jobs 2 and 3 have been conquered exactly the assigned score.

- Deviation in the score of the benchmark jobs is 3% from the total dispensed score.

VI. Conclusion

It is found that the formulated model has the optimal solution within the negligible variation and is highly satisfied result for these diligences.

VII. Scope for Future Work

1. The present investigation has been focused only on boilers whereas the concept may be applied to other machines and equipment namely deployed at such plants.

2. The study is executed in three diligences and can be extended to others sectors too.

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