GLOBAL JOURNAL OF ENGINEERING, DESIGN & TECHNOLOGY
(Published By: Global Institute for Research & Education)
www.gifre.org

ARCHETYPAL ARTICULATED BY CONSIDERING SWAYING ASPECTS IN AN INDUSTRY

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Abstract

In any manufacturing unit, maintenance executes a vigorous role owed to disposition of costly paraphernalia and any botch may suffer the organisation heavily. Present exertion is taken at an industrial set-up where boilers are chosen for study out of many other mechanisms. Purpose is to estimate the outlays of any maintenance activity per man-hour under different predominant circumstances based upon the poised data and other related information. For the estimation, goal programming archetypal is articulated by considering swaying aspects. Any alteration in these aspects immediately affects the expenditures invariably. For the precise estimation of these disbursements, micro dissection of these aspects is conversely executed. Cconclusively the sensitivity analysis is conceded out to validate the archetypal yield and found that final archetypal is quiet a satisfaction.

Key words: Archetypal, Maintenance, Swaying Aspects, Industry, India.

Introduction

In any medium and large manufacturing unit; Production, Materials, Marketing and Sales, Quality Control, Stores and PPC (Production Planning and Control) are equally essential departments [Mishra and Gupta, 2010]. Whereas, Maintenance has an edge due to deployment of costly equipment/machines and any failure in such equipment/machines, may suffer the organisation in the form of loss of production, loss of labour time, loss of profits, loss of potential customers, loss of business, loss of goodwill and market reputation. Thus, a proper way for the deployment of maintenance manpower, resources, working environment, supervision and management have been considered to be the essential requirement for the success of the maintenance system[Gupta,2010].

Consequently, the search for an improved system performance to overcome the constraints prevailing at the industries has been a major issue. Inevitably, the responsibility lies with the maintenance system for their efficient functioning so that the availability of the machines and equipment can be improved to achieve the ultimate goal of the production [Gupta et al., 2011]. Hence, it is felt necessary to carry out an in-depth study on the functioning of the maintenance system [Kumar et al., 2007]. After the study, major problems are encountered in the maintenance system are: absence of vital knowledge in performing the job, absence of knowledge sharing culture, absence of data base of staff competencies, dominating attitude of individuals due to their experience and position, absence of cost estimation of any breakdown per manhour under different prevailing conditions etc.

Moreover, for the betterment of the organisations' performance, management should restrict maintenance time and its cost. Present exertion is taken at a nearby industrial set-up where boilers are chosen for study out of many other mechanisms. Purpose is to estimate the outlays of any maintenance activity per man-hour under different prevailing conditions which requires working out the expenses incurred on any kind of breakdown for the boilers.

Goal Programming

1) Goal programming is a multi objective optimization technique/approach, which helps to formulate the software to provide the multiple solutions under different constraints and situations. As managerial decisions involve more or less conflicting goals; the goal programming approach is one way through which these difficulties are alleviated [Gupta and Hira, 2005].

Sensitivity Analysis

Once the optimal solution to a problem has been attained, it may be desirable to study how the current solution changes when the parameters of the problem get changed. The study of the effect of discrete changes in the values of the parameters on the optimal solution is called sensitivity analysis or post optimality analysis. The objective is to determine sensitiveness of the optimal solution with the changes in the values of input parameters [Gupta and Hira, 2010].

Literature Review

Extensive review of related literature is partially supporting the present study in the light of understanding the method and process of working. Some of them are as:

1) Goal programming archetypal has been designed, developed and applied in different organizations to achieve different objectives where optimal solutions are achieved out of various conflicting goals:.

Chang [2011] 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. The major contribution of using the utility functions of MCGP is that they can be used as measuring instruments to help decision makers make the best/appropriate policy corresponding to their goals with the highest level of utility achieved. In addition, the above properties can improve the practical utility of MCGP in solving more real-world decision/management problems. Choi [2009] 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, the physical workload only model, and the integrated model. Comparing the pay-offs between the two overloads, tests were conducted and obtained the result that well balanced job allocation is able to be obtained through the proposed model which may be very useful for the operation managers to make decisions on their job scheduling efforts.

Kharrat et al. [2010] 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. The new interactive imprecise goal programming approach is solved by the taboo central memory-simulated annealing algorithm. The use of this meta-heuristic allows the proposed approach to deal with large scale decision-making situations. Kharrat et al. [2010] 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. Computational experiments in several types of problems with different variable types (integer, continuous, zero-one and discrete) collected from the literature demonstrate that the proposed metaheuristic reaches high-quality solutions in short computational times. Furthermore, it requires very few user-defined parameters.

Mavrotas et al. [2009] applied an integrated approach in order to find the mixture of Best Available Techniques (BAT) for the entire industrial sector that satisfies as much as possible the economic and the environmental criteria. The former represent the industry owner's point of view expressed by the Net Present Value of the projects and the latter represent the society's point of view quantified by the emission reduction in some major pollutants. The developed multi-objective optimization model is addressed using two methods: (1) goal programming and (2) generation of the Pareto optimal solutions using an augmented version of the ϵ-constraint method followed by an interactive filtering process in order to select the most preferred Pareto optimal solution. The generation of the Pareto optimal solutions is performed using an improved version of the widely used ϵ-constraint method that overcomes some of its known drawbacks. The COMBAT tool (combinatorial optimization with multiple criteria for BAT selection) that is developed for implementing these methods is also described and the results from its application in the industrial sector of the greater Athens area are presented.

Mezghani et al. [2009] 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. Applied to a real case problem, weighted GP has initially been used; the results were not satisfactory for the manager. The proposed GP with satisfaction function given very satisfactory results for the manager. Patia et al. [2008] 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. The objectives considered are reduction in reverse logistics cost; product quality improvement through increased segregation at the source; and environmental through increased wastepaper recovery. The proposed model also assists in determining the facility location, route and flow of different varieties of recyclable wastepaper in the multi-item, multi-echelon and multi-facility decision making framework. Romero and Carlo [2001] elucidated an optimization structure called Extended Lexicographic Goal Programming (ELGP) which is then demonstrated that there are a significant number of Multiple Criteria Decision Making (MCDM) approaches that, from a logical point of view, can be reduced to the ELGP structure by assessing the theoretical and practical advantages of the proposed unified approach.

2) Sensitivity Analysis

Dominguez-Caballero et al. [2010] used an iterative algorithm for the design and optimization of a binary phase computer generated hologram for high-resolution lithography in on-axis and off-axis geometries is presented. A sensitivity analysis is performed to estimate the effect of CGH manufacture errors using electron-beam writing. Khorramshahgol and Tamiz [2007] used Taguchi's loss function to assess the loss associated with a solution provided by a particular Multi-Criteria Decision Making (MCDM) method. Although the idea proposed in this paper, derived from Taguchi's philosophy and his idea of social loss, can be invariably applied to any MCDM method, the paper utilizes Goal Programming (GP) to illustrate the applicability of the proposed method.

Oke et al. [2008] established a new approach to evaluate the sensitivity of a preventive maintenance scheduling model that is based on an integrated operations-maintenance activity schedule in a resource constrained environment. The paper deals with sensitivity analysis of Total Preventive Maintenance (TPM) scheduling cost in a shipping company where work is motivated by the need to improve on the quality of maintenance scheduling models through the development and application of robust models in practice. Reddy and Mohanty [2007] explained that in decision making under risk, sensitivity analysis is often resorted to understand the selection of an optimal alternative. Also, explained that if problem deals with only two states of nature and a limited number of alternatives, the graphical method can be used and when many alternatives are to be considered, the graphical method is of no help in doing sensitivity analysis. So, a Linear Programming (LP) approach is used to do sensitivity analysis in problems involving many alternatives and two or three states of nature. It is rather a unique and interesting application of the LP methodology in the sense that it makes use of all the extreme points of the feasible region.

Sowlati et al. [2010] elaborated that sensitivity analysis is an important step in multi-criteria decision making that provides useful information and insights on the decision problem. The solution of a decision problem is not complete if only the ranks of alternatives are determined, since any change in the input parameters may change the ranking and the final decision. This article presents a mathematical programming model for sensitivity analysis in the analytic hierarchy process method to assess the minimum required changes in the weights of criteria to alter the alternatives ranking. The proposed model is applied to a real case of evaluating and selecting design and manufacturing software packages in a kitchen cabinet manufacturing company in Canada. The results of sensitivity analysis are used to assess the robustness of the final decision. Zavadskas et al. [2007] depicted the optimal criterion linked to sensitivity analysis. The aim is however to show case to multi-attribute utility analysis. Therefore, the authors go out from Simple Additive Method (SAW), but come to normalization by the use of ratios where test matrices are formed. It is concluded that only significant attributes relative to the other attributes have an impact on the results. The proposed model for determining method sensitivity to changes of separate parameters enables us to increase the reliability of the applied methods.

3) Optimal production by preventive/corrective maintenance planning, scheduling & control systems and computerized maintenance management systems(CMMS)

Saranga [2002] nvented the relevant condition predictor (RCP) based maintenance approach for optimum preventive maintenance strategy coupled with the fast-developing condition-monitoring techniques, so that, failures due to gradual deterioration of mechanical items in order to improve system reliability and availability can be prevented and required reliability level of the system can be maintained. Labib [2004] described the need of computerized maintenance management systems (CMMSs) in industry and identify their current deficiencies by a proposed model, to provide a decision analysis capability that is often missing in existing CMMSs, followed by the provision of reasons for current deficiencies in existing off-the-shelf CMMSs.

Cassady and Kutanoglu [2005] proposed an integrated model to coordinate preventive maintenance planning decisions with single-machine scheduling decisions to minimize the total expected weighted completion time of jobs and by integrating the two decision-making processes, an average improvement of approximately 2% and occasional improvements of 20% is resulted. Dreyer [2006] suggested the Advance Maintenance Planning and Scheduling (AMPS) perform in reducing the maintenance turnaround time and increasing system availability by significantly increasing maintenance productivity). Karuppuswamy et al. [2007] described the importance of Computerised Maintenance Management System (CMMS) functions in manufacturing organisations which directly contributes for value addition in product development and marketing. They described the performance of a fin rolling machine, software development, and implementation of Computerized Maintenance Management System (CMMS) and effects of implementation in an automotive radiator-manufacturing organization to reduce machine failures, inconsistent product quality and unsafe operations.

Kenne and Nkeungoue [2008] addressed a computational algorithm, based on numerical methods for solving the optimal control problem to minimize a discounted overall cost consisting of maintenance cost, inventory holding and backlog cost if the production planning was well done and Wenzhu et al. [2009] proposed a sequential Condition-Based Maintenance (CBM) policy for intelligent monitored system based on cost and reliability prioritisation by assuming that system's reliability should be continuously monitored to construct more practical maintenance model and a numerical problem is tested to its efficiency.

Problem Formulation

Nearby industry is selected for the study and encountered the various problems in the maintenance system like: improper allocation of maintenance manpower, absence of vital knowledge in performing the job, absence of knowledge sharing culture, absence of data base for staff competencies, dominating attitude of individuals due to their experience and position, absence of estimation of maintenance cost of any particular breakdown per manhour under different prevailing conditions etc.

This study is focused only on the cost of any breakdown per manhour under different prevailing conditions because no body in the organisation is aware about the expenses incurred on any breakdown per manhour. So necessity is felt to evaluate and future action to be taken to reduce the breakdown cost per manhour.

Objective of the Study

To articulate breakdown estimation archetypal for the boilers

To estimate the breakdown cost per men-power for boilers under different prevailing situations

Methodology

An attempt is made to examine critically the entire system of the boilers and their accessories/mountings according to the importance of maintenance, types of breakdown, their down time, etc. The study incorporates the following areas:

- **Existing Maintenance Practice**
- **Archetypal Articulation**

Existing Maintenance Practice

The study is based on the existing system analysis prevailing in the Industry. The maintenance operations follow in general the logic and are broadly categorized as below:
a) Daily check-up and maintenance
b) Preventive maintenance
c) Breakdown maintenance
d) Rehabilitation

Archetypal Articulation

After studying the existing maintenance practice, swaying aspects and their complexity levels are discussed related to the maintenance system for boilers. Then archetypal is articulated based upon some assumptions, benchmark jobs and constraints.

Assumptions

- Only breakdown maintenance problems are included in the study.
- Cooling time of boilers is not considered as breakdown time.
- Spare parts procurement time is excluded.
- Above seven man-hours of breakdown time is considered only.

Swaying Aspects for Maintenance Time

Six aspects are considered, those influence the maintenance time, which are given under the heads (**Ji)** as:

a) Grade of the Job (J_1)
b) Degree of Skill of the Worker/Workers (J_2)
c) Grade of Resource Items (J_3)
d) Degree of Supervision (J_4)
e) Grade of Working Environment (J_5)
f) Degree of Teamwork Relationship (J_6)

For more critical analysis, each aspect, Ji (i = 1, 2... 6) is categorised under five different levels (j = 1, 2... 5) with respect to the complexity of maintenance job:
As presented in Table: 1, the ascending order of the levels in this table signifies the increasing complexity in maintenance jobs:

Table: 1: Aspects influencing the Maintenance Time

Aspect J_i	Job Complexity Level j				
	1	2	3	4	5
Job quality	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}
Skill of worker	J_{21}	J_{22}	J_{23}	J_{24}	J_{25}
Resource items	J_{31}	J_{32}	J_{33}	J_{34}	J_{35}
Supervision quality	J_{41}	J_{42}	J_{43}	J_{44}	J_{45}
Working environment	J_{51}	J_{52}	J_{53}	J_{54}	J_{55}
Teamwork relationship	J_{61}	J_{62}	J_{63}	J_{64}	J_{65}

Benchmark Jobs

Before the application of the goal programming archetypal, a number of maintenance jobs are estimated by considering different levels of job complexity and limit constraints, which are termed as benchmark jobs.

The most complex benchmark job should consist of aspects having the highest complexity levels. The minimum score assigned to the highest worth benchmark job may be represented as:

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

Similarly, other benchmark jobs are identified and given as:

$$J_{15} + J_{25} + J_{34} + J_{44} + J_{55} + J_{64} \leq 90 \quad \text{... (2)}$$
$$J_{14} + J_{24} + J_{33} + J_{43} + J_{54} + J_{64} \leq 75 \quad \text{... (3)}$$
$$J_{13} + J_{23} + J_{32} + J_{42} + J_{53} + J_{62} \leq 55 \quad \text{... (4)}$$
$$J_{12} + J_{22} + J_{31} + J_{41} + J_{52} + J_{62} \leq 40 \quad \text{... (5)}$$

To elaborate further, the second benchmark job represented by equation (2) consists of 5th level of factor group **J_1**, 5th level of factor group **J_2**, 4th level of factor group **J_3**, 4th level of factor group **J_4**, 5th level of factor group **J_5** and

4th level of factor group J_6. The total score for the second benchmark job is 90% of the first. Similarly, the other benchmark jobs are also identified alongwith the respective score values with respect to first benchmark job given above.

Other Constraints Assumed

a) Lowest level of first factor (J_{11}) has score of point 7 and second factor (J_{21}) has 6 i.e. one point below the previous factor and so on and is given by equation no. 6.
b) Highest level (J_{i5}) of each of the factors should be less than score point 20 and is given by equation no. 7.
c) Score at a particular level should be at least 3 points higher than the immediate preceding level as given by equation no. 8.

$$J_{i1} \geq (8 - i) \quad ... \quad (6)$$
$$J_{i5} \leq 20 \quad ... \quad (7)$$
$$J_{i(j+1)} - J_{ij} \geq 3 \quad ... \quad (8)$$

Now, equations (1) to (8) can now be written as below for articulating the goal program archetypal:

$$\left.\begin{aligned} J_{15} + J_{25} + J_{35} + J_{45} + J_{55} + J_{65} - p_1 &= 100 \quad ... \\ J_{15} + J_{25} + J_{34} + J_{44} + J_{55} + J_{64} - p_2 &= 90 \quad ... \\ J_{14} + J_{24} + J_{33} + J_{43} + J_{54} + J_{64} - p_3 &= 75 \quad ... \\ J_{13} + J_{23} + J_{32} + J_{42} + J_{53} + J_{62} - p_4 &= 55 \quad ... \\ J_{12} + J_{22} + J_{31} + J_{41} + J_{52} + J_{62} - p_5 &= 40 \quad ... \end{aligned}\right\} \quad (A)$$

$$J_{i1} + n_{i+5} = (8 - i) \quad ... \quad (B)$$
$$J_{i5} - p_{i+11} = 20 \quad ... \quad (C)$$
$$J_{i(j+1)} - J_{ij} + n_{\{5(i-1)+j+17\}} = 3 \quad ... \quad (D)$$

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 deviational variables.

Objective function of Cost Estimation Archetypal is given by equation (E):

$$\text{Minimize, } Z = \left\{ P_1\left(\sum_{i=1}^{5} p_i\right), P_2\left(\sum_{i=6}^{11} n_i\right), P_3\left(\sum_{i=12}^{17} p_i\right), P_4\left(\sum_{i=18}^{41} n_i\right)\right\} \quad ... \quad (E)$$

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

Where, P_i **(i = 1, 2, 3, 4)** indicate the priorities assigned to the different goals.
a) In equation (E), top priority P**1** is assigned to minimize the deviations from the goals in equations set (A); likewise the next priority P**2** is assigned to equation set (B) and so on.
b) Assuming that P**1** = 1 and P**2** = P**3** = P**4** = 0.
c) Once the solution is arrived at the attainment for the highest priority goal P**1**, then problem is solved by assuming P**2** = 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 Goal Program.
e) Table 2 depicts the optimal score of Cost Estimation Archetypal, obtained by using the Goal Program.
f) Worth for benchmark jobs reflecting the deviations in respective cases are shown in Table 3.

Table 2: Optimal Score for Maintenance Time Influencing Aspects

Aspect	**Levels (j)**				
J_i	**1**	**2**	**3**	**4**	**5**
J_1	7	10	13	16	19
J_2	6	9	12	15	18
J_3	5	8	11	14	17
J_4	4	7	10	13	16
J_5	3	6	9	12	15
J_6	2	5	8	11	14

Table 3: Worth for Benchmark Jobs

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

Result and Discussions

- It is evident from the table 3, that the worth for each of the benchmark jobs 1, 4 and 5 are below one point to the assigned worth.
- The worth for the benchmark jobs 2 and 3 have been attained exactly the same as assigned.

- The maintenance time influenced by the working environment, supporting facilities, teamwork relationship, kind of supervision, etc. Still, an in-depth study on the manpower planning in maintenance is really lacking.
- Still, it is quite satisfactory result with negligible variation.

Sensitivity Analysis

The Table 2 shows the output results of the goal programming archetypal to enable sensitivity analysis. To validate the articulated archetypal, sensitivity analysis is conducted. This analysis is grouped under three different cases as detailed below:

Case 1:

- In this case, first benchmark job score is kept constant i.e. with 100 points.
- Scores for rest of the benchmark jobs are varied by 5 points on the lower or higher side of the scores.
- From the Table 4, it is observed that the deviation in scores varies from 3% to 8% and in few cases, it is higher upto 23%.
- Hence, the selection is based on 3% deviation.

Table 4: Sensitivity Analysis of Results with Score Variation in Benchmark Jobs

SL. No.	Allotted score for Benchmark Jobs					Deviations in score for Benchmark Jobs				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1	100	85	75	55	40	6	0	5	6	6
2	100	90	75	55	40	1	0	0	1	1
3	100	95	75	55	40	1	5	0	1	1
4	100	90	70	55	40	6	5	0	6	6
5	100	90	75	55	40	1	0	0	1	1
6	100	90	80	55	40	1	0	5	1	1
7	100	90	75	50	40	5	4	4	0	5
8	100	90	75	55	40	1	0	0	1	1
9	100	90	75	60	40	1	0	0	6	1
10	100	90	75	55	35	5	4	4	5	0
11	100	90	75	55	40	1	0	0	1	1
12	100	90	75	55	45	1	0	0	1	6

Case 2:

- Now, the number of benchmark jobs are increased successively to observe the deviations in the scores and tabulated in Table 5.
- Additional benchmark jobs are introduced by variation of the score points 5.
- It is observed that total minimum deviation is 3% with five basic benchmark jobs, which varies from 3% to 13% with further increase in benchmark jobs.
- Since, deviations with the five basic benchmark jobs appear as the minimum, hence same becomes acceptable.

Table 5: Sensitivity Analysis of results with the Variation in number of Benchmark Jobs

SL.No.	Allotted score for Benchmark Jobs									Deviations in score for Benchmark Jobs								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	100	90	75	55	40	-	-	-	-	1	0	0	1	1	-	-	-	-
2	100	95	90	75	55	40	-	-	-	1	2	0	0	1	1	-	-	-
3	100	95	90	80	75	55	40	-	-	1	2	0	2	0	1	1	-	-
4	100	95	90	80	75	65	55	40	-	1	2	0	2	0	3	1	1	-
5	100	95	90	80	75	65	55	45	40	1	2	0	2	0	3	1	3	1

Case 3:

- Here, the values of the lower limit, higher limit and those for the difference in the consecutive sublevels of the system are varied.
- The lower limit and the difference in sublevel values are varied by 1 point on lower or higher sides.
- For the higher limit the variations are by 5 points on lower or higher sides.
- From the Table 6, it is observed that the deviation in scores varies from 3% to 13% and in few cases; it is higher upto 23%.
- Most of the observations are showing that total deviations are atleast 3% and not lesser than 3%.

Table 6: Sensitivity Analysis of Results with Score Variation for Lowest Level (LV), Highest Level (HV) and Difference in Corresponding Sublevels (DV)

		RH. side value			Deviations in Score for Benchmark Jobs				
SL. No.	Job No.	LV	HV	DV	1	2	3	4	5
1	1	6	20	3	2	1	1	2	2
2	1	7	20	3	1	0	0	1	1
3	1	8	20	3	1	0	0	1	1
4	1	7	15	3	5	4	4	5	5
5	1	7	20	3	1	0	0	1	1
6	1	7	25	3	1	0	0	1	1
7	1	7	20	2	5	4	3	3	2
8	1	7	20	3	1	0	0	1	1
9	1	7	20	4	1	0	1	3	4
10	2	5	20	3	2	1	1	2	2
11	2	6	20	3	1	0	0	1	1
12	2	7	20	3	1	0	0	1	1
13	2	6	15	3	4	3	3	3	4
14	2	6	20	3	1	0	0	1	1
15	2	6	25	3	1	0	0	1	1
16	2	6	20	2	5	4	3	3	2
17	2	6	20	3	1	0	0	1	1
18	2	6	20	4	1	0	1	3	4
19	3	4	20	3	2	1	1	2	2
20	3	5	20	3	1	0	0	1	1
21	3	6	20	3	1	0	0	1	1
22	3	5	15	3	3	2	2	3	1
23	3	5	20	3	1	0	0	1	1
24	3	5	25	3	1	0	0	1	1
25	3	5	20	2	5	3	2	2	1
26	3	5	20	3	1	0	0	1	1
27	3	5	20	4	0	0	1	3	3
28	4	3	20	3	2	1	1	2	2
29	4	4	20	3	1	0	0	1	1
30	4	5	20	3	1	0	0	1	1
31	4	4	15	3	2	1	1	2	2
32	4	4	20	3	1	0	0	1	1
33	4	4	25	3	1	0	0	1	1
34	4	4	20	2	5	3	2	2	1
35	4	4	20	3	1	0	0	1	1
36	4	4	20	4	0	0	1	3	4
37	5	2	20	3	2	1	1	2	2
38	5	3	20	3	1	0	0	1	1
39	5	4	20	3	1	0	0	1	1
40	5	3	15	3	1	0	0	1	1
41	5	3	20	3	1	0	0	1	1
42	5	3	25	3	1	0	0	1	1
43	5	3	20	2	5	4	3	3	2
44	5	3	20	3	1	0	0	1	1
45	5	3	20	4	1	0	1	3	4
46	6	1	20	3	2	1	1	2	2
47	6	2	20	3	1	0	0	1	1
48	6	3	20	3	1	0	0	1	1
49	6	2	15	3	1	0	0	1	1
50	6	2	20	3	1	0	0	1	1
51	6	2	25	3	1	0	0	1	1
52	6	2	20	2	5	3	3	2	2
53	6	2	20	3	1	0	0	1	1
54	6	2	20	4	0	0	0	3	3

Conclusion

1. Present research work is the cost estimation for different breakdowns of the boilers based upon the collected data.
2. For the objective, goal programming archetypal is articulated by considering major swaying aspects, constraints, assumptions and some priority based benchmark jobs.
3. Final archetypal is articulated, within the variation of 3% from the selected benchmark jobs.
4. Sensitivity analysis is carried out to understand the accuracy of the results specified by articulated archetypal:
   - By varied some points on the lower side or higher side of the scores of benchmark jobs and it is observed that the deviation in scores varies from 3% to 8% and in few cases, it is higher upto 23% .
   - By increasing the number of benchmark jobs and the output results have deviations varying from 3% to 13%.
   - By changing the values of lower limit, higher limit and the difference in the consecutive sublevels; then the output results have deviations varying from 3% to 13%, exceptionally upto 23%.
5. The articulated archetypal has the optimal solution with variations of 3% minimum, which is quite satisfactory.

Scope for Future Work

1. The present investigation has been carried out with regard to cost estimation of breakdown of boilers' operating in an industry. However, the concept may be applied to other mechanisms and paraphernalia.

2. However, this study is for maintenance job evaluation under different prevailing conditions and can be extended for possible application in other industrial sectors.

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