Maintenance Job Analysis in Mechanical Industries-A Goal Programming Approach

Vineet Gupta, Associate Professor, MMU, Mullana (Distt. Ambala) (Haryana)
E-mail: vineetgupta108@yahoo.co.in

Abstract
Recession, render down economy and fold up of giant corporate houses are very frequent phenomenon now, having affect on society directly. These effects change the society badly in the form of sociological, economical and physiological changes. For the welfare of common people and self, industrialists have to espouse the newer and effectual technologies to minimise the risk of loosing the business. In industries, every equipment plays an imperative function and its malfunction leads to heavy cost, fearing of loosing the business forever. The present study to resolute the expenditure inference conjures up of maintenance of boilers at Sugar Plant. For this, a preemptive Goal Programming conjures up by considering foremost influencing factors. Any alteration in these factors, maintenance time also gets ostentatious. However, these factors are sublevelled more for an accurate conjecture of optimal maintenance time. Finally, the conjure up is worked out within 3% variation from the benchmark jobs involved.

Key words: Goal Programming; Expenditure Inference Conjure up; Societal changes; Social welfare; Base-Rate Estimation; Break-down Maintenance; Boilers; Sugar Plant.

1. Introduction
Production target of every industry depends largely on the performance of its machines and equipment (Panayiotou et al., 2009). As this number is quite large and increases with time due to modernisation, so maintenance policy plays a decisive role (Oke et al., 2008). However, performance of the maintenance system is dominated by various factors like manpower planning and its allocation, selection of supporting machines and management of spare parts etc. (Tsakatikas, 2008). To maximize the utilisation of maintenance resources, working discipline is a must for optimal utilisation of maintenance resources (Kumar et al., 2007). These may involve maintenance manpower, resources, working environment, supervision and management (Gupta, 2010).
Consequently, the search for an improved system that overcomes the constraints prevailing at the industries has been a major issue from a very long time (Singh and Khamba, 2009; Ghosh and Roy, 2010). Major constraints in maintenance system involve absence of vital knowledge, insufficient data base of staff competencies, lack of knowledge sharing culture, egoistic attitude of individuals and absence of base rate of maintenance apart from some conventional reasons as faulty operation, repeated repairs without any replacement of parts, improper maintenance, lack of proper job distribution, excessive backlog, improper job planning, absent of post-mortems analysis, general tendency to complete the short time consumption jobs to shorten the pending list, etc. (Fong and Wong, 2009; Mishra and Gupta, 2010; Gupta, 2010).

Whereas, Base Rate is the cost of maintenance per man-hour of an equipment or set up under different prevailing situations, which depends on complexity level of the jobs, skilled manpower deployed for the job, cost of the parts and their procurement cost, supporting machines for the maintenance, proper working environment at the working place and kinds of supervision provided for the various jobs, etc. (Gupta, 2010). Consequently, base rate may be different under unusual prevailing situations for particular maintenance jobs.

1.1 Goal Programming

Goal Programming is a technique/approach to formulate the software to provide the multiple solutions for base rate estimation of maintenance jobs under different constraints, situations and parameters, which is different from the usual linear programming technique. The facet of latter is the consistency in establishing of an objective function and can cater to only one objective e.g., maximizes profit or minimizes cost or some other objective criterion. But under normal circumstances, many managerial decisions may involve dichotomy and myriad goals. It introduces complexity in decision making process. Thus, the goal programming is one unraveled way to deal and resolve such difficulties (Gupta and Hira, 2010).

The proceedings of the paper reveal in such fashion, where, Section 2 specifies the related literature and Section 3 entrenches the problem undertaken in research work. Section 4 illuminates the research methodology in details with objectives of the research. In Section 5, an outcome of the paper is explicated. Finally, the Section 6 expounds the conclusion and managerial implication including inadequacy of the study and prospect of the research work.

The purpose of this paper is to elucidate the formulated base rate expenditure inference conjure up for the maintenance of the boilers at a sugar plant reason being maintenance expenditure of boilers and their
sub systems can be estimated and further witted down by enumerating and selecting the alternative influencing factors.

2. Literature review

Extensive literature is reviewed pertaining to the present research work and only a few of them are reported below:

Gupta and Ahmed (1988) have described that jobs are often evaluated based upon subjective judgment. By considering each job to consisting of certain levels, develops a goal programming model to evaluate various levels of job factors. Further, jobs are categorized according to their complexities by providing infrastructure and facilities in different conditions. Illogical pay structures may lead to inequalities to determine salaries paid for performing various jobs.

Ulusoy et al. (1992) presented a preventive maintenance (PM) planning and control system design implemented to a large foundry to increase the scope and effectiveness of PM activities within the production facility. The degree of planning in maintenance and the setting up of tasks in order of priority as well as the amount of PM work have come out to be the essential decision issues for increasing the performance of the foundry in plants.

Alkhamis and Yellen (1995) proposed an integer programming approach in a unit for maintenance. Maintenance scheduling problem was highlighted to determine the schedule for preventive maintenance units over a specialized operational planning horizon so that the unit utilization level is maximized and maintenance constraints are satisfied. This model is also linked to the master and production planning model in refineries to optimize production as well as maintenance scheduling.

Ramo and Munoz- Moro (1999) have presented a goal programming methodology incorporating multi-criterion approach for solving maintenance scheduling at thermal generating units under economic and reliability criteria. The advantages of this approach are demonstrated by comparing the effects of costs and reliability affecting have on each other in power plants maintenance scheduling.

Romero (2001) has explained an optimization structure called Extended Lexicographic Goal Programming (ELGP) which demonstrated a significant number of Multiple Criteria Decision Making (MCDM) approaches. From a logical point of view, it may be reduced to the ELGP structure by assessing the theoretical and practical advantages of the proposed unified approach.

Cassady and Kutanoglu (2005) proposed an integrated model that coordinates preventive maintenance planning decisions with single-machine scheduling to minimize total expected weighted completion time of
the jobs. The problems were studied, integrating the two decision-making processes, which resulted in an average improvement of approximately 2% and occasional improvements of as much as 20%.

Karuppuswamy et al. (2007) have described the importance of Computerized Maintenance Management System (CMMS) functions in manufacturing organisations which directly contribute for value addition in product development and marketing. Also, described the performance of a fin rolling machine, software development, and implementation of CMMS and its effect of implementation in an automotive radiator-manufacturing organization to reduce machine failures, inconsistent product quality and unsafe operations.

Kumar et al. (2007) analyzed the failure data of automatic internal grinding machine used in bearing manufacturing along with various replacement and change in design options such as introduction of pneumatic system in place of electromagnetic solenoids for improvement of reliability of the plunger movement mechanism.

Barabady and Kumar (2008) conducted reliability analysis of mining equipment and stated that the reliability should be an integral part of mine engineering management for the effective utilization of production. Finally concluded that the conveyor subsystem and secondary screen subsystem are more critical from reliability point of view, however, secondary crusher subsystem and conveyor subsystem are also critical from an availability point of view.

Oke et al. (2008) have 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.

Choi (2009) has described a new mathematical model of line balancing for processing time and physical workload at the same time by goal programming approach. Also suggested and designed an appropriate algorithm process for the operation managers to make decisions on their job scheduling efforts by various computational test runs performed on processing time only model, physical workload only model and integrated model.

Mavrotas et al. (2009) have developed the multi-objective optimization model using two methods: (1) Goal Programming and (2) generation of the Pareto Optimal Solutions; using an augmented version for
optimal solution. An integrated approach is applied in order to satisfy as much as possible the economic and the environmental criteria where both point of views are considered, that is, the industry owner's point of view expressed by the Net Present Value of the projects and the society's point of view quantified by the emission reduction in some major pollutants.

Panayiotou et al. (2009) 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.

Wenzhu et al. (2009) have proposed a sequential Condition-Based Maintenance 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.

Arora and Arora (2010) have discussed the need of explicitly considering several criteria simultaneously. To bridge the gap between theory and practice, considered the multiobjective capacitated plant location problem and 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.

Ghosh and Roy (2010) presented an improved Multiple-Criteria Decision Making methodology for selecting the optimal mix of maintenance approaches for different equipment in a typical process plant where criticality of individual equipment is achieved by risk ranking them. Where a fuzzy adaptation of the Analytic Hierarchy Process technique is applied to individual equipment embedded into a Goal Programming (GP) model to optimise multiple objectives such as risk reduction and cost minimisation.

Kaiser et al. (2010) have described that use of weblogs for knowledge sharing and creation is a novel social and organisational phenomenon. It is assumed that successful knowledge management requires the motivation of people to engage in knowledge-related communication. However, several studies indicate that Information and Communication Technologies (ICTs) do not always improve organisational knowledge sharing and creation as a result of a missing motivation to use ICTs. Thus, discussed two partially opposite cases, in order to identify and explain contingency factors that directly influence the motivation towards making a contribution in knowledge sharing and creation.

Lupo (2010) developed a model for an effective maintenance policy with refer to a global service
contract between a services provider company and a company for the waste management. The tackled problem concerned the determination of an effective opportunistic maintenance policy in order to assure the required service performance levels at the minimum global maintenance cost. The problem was mathematically formulated by a constrained partition model that has become very difficult to solve by mathematical approach for large practical systems.

3. Problem Formulation
Although goal programming, linear programming, availability, reliability, condition based maintenance, production scheduling, etc. had attracted plenty of scholarly attention, there is a paucity of research about the base rate estimation for the maintenance system. A nearby Sugar Plant is selected for study and analysis carried out for their existing maintenance system of plant and equipment. After in depth study, observed the varieties of problems in the maintenance system like: improper allocation of maintenance manpower, absence of vital and essential knowledge in performing the job, absence of knowledge sharing culture, insufficient data base for staff competencies, dominating attitude of individuals by virtue of their experience and position and absence of base rate of breakdown under different prevailing conditions etc.

The present study is focused only on the base rate of breakdown of equipment under different prevailing conditions, as hardly any in the organisation is aware about the expenses incurred on a breakdown. For this reason, necessity to ascertain the base rate of maintenance is essential for their evaluation and for future action to reduce the breakdown cost.

Some of the assisting equipment namely turbines, cane chopper, boilers, crystallizer, elevators, centrifugal machines, hopper etc. are deployed to manufacture the sugar. Whereas, the boilers are considered to be of the prime importance, because steam generated by these boilers is extensively used:

• To operate the prime movers to generate electricity, this further used to run other equipment and machines of the plant.
• For processing of sugar manufacturing.

4. Research Design
After collecting the failure data from the plant, come to understand that availability of boilers is much below the expected level. Also understand that recurring cost of maintenance under various conditions plays vital role as it affects the total cost of maintenance system and overall production cost as well. So, in order to achieve the Base Rate Estimation of Boilers and their subsystems, constraints are set by the chief engineer of the plant according to the plant situations which get changed frequently.
Given below are the objectives set before designing the research work:

**4.1 Study Objectives**

1. To achieve the base rate expenditure inference conjure up for the maintenance of boilers
2. To guesstimate the optimal maintenance cost under diverse prevailing situations
3. To establish cost effective business for social welfare.

**4.2 Methodology**

The study incorporates the following areas:
1. Existing maintenance practice
2. Conjured -up formulation
3. Estimation of maintenance cost

**Figure 1** Activities flow chart

Incorporated areas are described in the subsequent sections as under:

**4.3 Existing maintenance practice**

An attempt is made to examine critically the entire system for the boilers and their accessories according to the importance of the maintenance, types of breakdowns and their down time etc. In order to achieve the base rate estimation of boilers and their subsystems, constraints are set by the Plant Chief as per the plant
situations because constraints and prevailing situations differ from plant to plant and time to time.

4.4 Conjured up Formulation

After studying and analysing the existing maintenance practice of the boilers at sugar plant, an attempt has been made to study the major influencing factors related to the maintenance system and to estimate the base rate of maintenance jobs for the boilers. The constraints in such a formulation are obtained by providing some priority based benchmark jobs. The conjure up is developed by the application of pre-emptive goal programming technique. It is based upon some assumptions mentioned below:

4.5 Assumptions

Assumptions taken into consideration under the research work are as under:

1. Only breakdown maintenance problems are included in the study.
2. Cooling time of boilers is not considered as breakdown time, which is affected by climatic conditions and may vary from 60 to 72 hours.
3. Spare parts cost and their procurement cost is not included in the maintenance cost as it is assumed that the spares are available at maintenance stores.
4. Below seven man-hours of breakdown time are treated as running maintenance.

4.6 Factors Influencing the Maintenance Time

The boilers maintenance planning for the proper man and machine utilization is primarily depend on six factors, which are denoted under the heads ($J_i$) as:

a) Grade of Job ($J_1$)
b) Degree of skill of worker ($J_2$)
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 ($J_6$)

However, the degree of influence of these factors on the maintenance system may differ from each organisation. The Chief Engineer/ Deputy Chief Engineer may adopt the degree of influence of these factors in respective cases of breakdowns in their own manner to meet the requirements. 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 per the constraints of the prevailing system.

For a more critical analysis, each such factor $J_i$ ($i = 1, 2... 6$) 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: Factors Influencing the Maintenance Time**

<table>
<thead>
<tr>
<th>Job Complexity Level j</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Job quality</strong></td>
<td>J₁₁</td>
<td>J₁₂</td>
<td>J₁₃</td>
<td>J₁₄</td>
<td>J₁₅</td>
</tr>
<tr>
<td><strong>Skill of worker</strong></td>
<td>J₂₁</td>
<td>J₂₂</td>
<td>J₂₃</td>
<td>J₂₄</td>
<td>J₂₅</td>
</tr>
<tr>
<td><strong>Resource items</strong></td>
<td>J₃₁</td>
<td>J₃₂</td>
<td>J₃₃</td>
<td>J₃₄</td>
<td>J₃₅</td>
</tr>
<tr>
<td><strong>Supervision quality</strong></td>
<td>J₄₁</td>
<td>J₄₂</td>
<td>J₄₃</td>
<td>J₄₄</td>
<td>J₄₅</td>
</tr>
<tr>
<td><strong>Working environment</strong></td>
<td>J₅₁</td>
<td>J₅₂</td>
<td>J₅₃</td>
<td>J₅₄</td>
<td>J₅₅</td>
</tr>
<tr>
<td><strong>Teamwork relationship</strong></td>
<td>J₆₁</td>
<td>J₆₂</td>
<td>J₆₃</td>
<td>J₆₄</td>
<td>J₆₅</td>
</tr>
</tbody>
</table>

The quality of maintenance work and the nature of its complexity should be duly considered in planning. In many situations, adequate skilled heads are not available, commensurate with the total workload of the section. The poor quality spares or assisting equipment increases the maintenance time. Proper maintenance supervision would generally need comparatively lesser maintenance time, while a high degree of skill of the maintenance workforce may reduce the maintenance job completion time even when the supervision is inferior. Moreover, the working attitude of the maintenance team members influences the maintenance time considerably. It is needless to mention that a poor teamwork relationship would lead to an increased maintenance job time. Further, the working atmosphere for the maintenance group also plays a vital role in carrying out the task. Undoubtedly, a favourable working environment would increase the output of the workmen.

**4.7 Benchmark Jobs**

Before the application of the goal programming model, a number of maintenance jobs are determined and used as a basis for the evaluation of maintenance strategy. Based on the gathered information, these maintenance jobs are estimated with due consideration to the different levels of job complexity. Such jobs are termed as the benchmark jobs. The most complex benchmark job should consist of factors having the highest complexity levels. The minimum score assigned to the highest worth benchmark job may be represented as:

\[ J_{15} + J_{25} + J_{35} + J_{45} + J_{55} + J_{65} \leq 100 \]  ... (1)
Similarly, other benchmark jobs are identified and given as:

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

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 along with the respective score values with respect to first benchmark job given above. Although, these are the goals for each of the jobs, some deviations would invariably exist in practice. The deviation from the goals should be allowed only within the permissible limits for the maintenance system to function smoothly. The other constraints to restrict the lower limit, higher limit and the difference of the consecutive values of each factor are as follows:

\begin{align*}
J_{ii} & \geq (8 - i) \quad \ldots \ (6) \\
J_{i5} & \leq 20 \quad \ldots \ (7) \\
J_{i(i+1)} - J_{ij} & \geq 3 \quad \ldots \ (8)
\end{align*}

The constraints (1) to (5) can now be written as below for developing the goal programming model:

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

Where, \( p_i (i = 1, 2... 5) \) are the positive deviational variables.

It is indicated that the total job scores as evident from the constraints (1) to (5) are the acceptable scores. The score structure for any maintenance system may satisfy absolutely by the above equations. In the set of equations (A), the presence of deviational variables indicate that the factors should be carefully evaluated in a quantitative manner so that each equation must satisfy with some values of deviation considering the following limit constraints as given in equation (B), (C) and (D) i.e. the scores for each of the five benchmark jobs will satisfy as close as possible to their respective minimal goals.
Apart from the deviations from the scores of the benchmark jobs, it is likely that there may be some deviations in the predetermined individual score of each level factor wise. It may be assumed that the lowest level of first factor ($J_{11}$) at least a score of point 7 and second factor ($J_{21}$) a score of point 6 i.e. one point below the next factor and so on. These differences are due to the importance and priority of the maintenance time influencing factors. The highest level ($J_{i5}$) of each of the factors should not be more than a given limit of score point 20. Further, the score of a factor at a particular level should be at least 3 points higher than that of the immediate preceding level. By introducing negative and positive deviational variables, the constraints (6) to (8) may be written as:

$$J_{i1} + n_{i+5} = (8 - i) \quad \ldots \quad (B)$$
$$J_{i5} - p_{i+1} = 20 \quad \ldots \quad (C)$$
$$J_{i(j+1)} - J_{ij} + n \left(5(i-1)+j+1 \right) = 3 \quad \ldots \quad (D)$$

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

Where, $p_i$ and $n_i$ represent the positive and negative deviational variables.

The significance of various goals for the equation sets (A) to (D) may be different in respective cases. It is more important to meet the goals of the benchmark jobs as close as possible to their assigned values. The goal programming model for the problem may be framed as below to minimize the deviations and to obtain the score value:

$$\text{Minimize } Z = \{ P_1 \left( \sum p_i \right), P_2 \left( \sum n_i \right), P_3 \left( \sum p_i \right), P_4 \left( \sum n_i \right) \} \quad \ldots \quad (E)$$

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

Where, $P_1 (i = 1, 2, 3, 4)$ indicate the priorities assigned to the different goals.

In the achievement function (E), the top priority $P_1$ is assigned to minimize the deviations from the goals in equation set (A) for the benchmark jobs; likewise the next priority $P_2$ is assigned to equation set (B) and so on. In fact, the pre-emptive goal programming approach caters for successively solving the model under the assumption that the optimality has been arrived for the highest priority goal. Based on this approach the present model may be solved first assuming that $P_1 = 1$ and $P_2 = P_3 = P_4 = 0$. Once the solution for the corresponding problem is arrived at the attainment for the highest priority goal $P_1$, is stated as a constraint to be satisfied at its optimal level. Then the objective function is modified to exclude the highest priority goal and the problem may now be solved by assuming $P_2 = 1$ with all the other priority goal values to be
zero. The process is continued till a solution is obtained that would satisfy all the goals as close as possible in the hierarchy of the goal priorities.

The optimal values for the decision variables $J_{ij}$ are obtained using the software for Goal Programming. Table 2 depicts the optimal score of the factors at different levels. The goal attainment in benchmark jobs reflecting the deviations in respective cases are shown in Table 3.

Table 2: Optimal Score for Maintenance Time Influencing Factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Levels ($j$)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$J_1$</td>
<td>7</td>
<td>10</td>
<td>13</td>
<td>16</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>$J_2$</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>15</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>$J_3$</td>
<td>5</td>
<td>8</td>
<td>11</td>
<td>14</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>$J_4$</td>
<td>4</td>
<td>7</td>
<td>10</td>
<td>13</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>$J_5$</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>$J_6$</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>11</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Worth for Benchmark Jobs

<table>
<thead>
<tr>
<th>Benchmark Jobs</th>
<th>Allotted Score</th>
<th>Goal Achieved</th>
<th>Under Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>99</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
<td>75</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>55</td>
<td>54</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>39</td>
<td>1</td>
</tr>
</tbody>
</table>

4.8 Estimation of maintenance cost

If the first key job with the score of 100 has to incur a manpower cost of Rupees (Rs.) $W$ per maintenance manhour, the management can evaluate another maintenance job comprising of different job factors like $J_{12}$, $J_{24}$, $J_{34}$, $J_{44}$, $J_{53}$, $J_{63}$. The total score of this maintenance job using the optimal scores of various job factors (Table 2) would be:

$$J_{12} + J_{24} + J_{34} + J_{44} + J_{53} + J_{63} = 69$$
Hence, the human resource cost for this job would be Rs. 0.69 W i.e. (Rs.69 x W/100) per maintenance manhour. Thus, having determined the optimal score for the different factors level wise with regard to any particular maintenance operation, the manpower cost for other such jobs can be arrived at by comparing the levels of factors involved in that job to those of the key job. Indeed, the cost per maintenance manhour will increase when the complexity level of the job elements goes higher. When all the influencing factors correspond to the lowest level of job complexity (e.g. Level 1) for any maintenance task, the cost per maintenance man-hour would be the minimum i.e. Rs 0.27 W (Rs. 27xW/100) per man-hour. In a similar manner, the cost per maintenance man-hour would be the maximum when all the influencing factors correspond to the highest complexity level (e.g. Level 5) i.e. Rs 0.99W (Rs 99 x W / 100) or Rs. W (approximately) per man-hour where ‘W’ is the wage rate, which varies from organisation to organisation and time to time. ‘W’ influenced by high class technical skill, high class supervision, high class environmental control cost and high class tools and tackles for supporting the work progress in one hour. Apart from all these, maintenance time and manpower costs would depend on the kind of job and its complexity.

5. Results and Discussion

The developed Base Rate Expenditure Inference Conjure Up, as depicted in Table 2, is based upon certain pre-determined parameters, benchmark jobs, constraints and the influencing factors over maintenance time; where ascending order of the sub-levels signifies the increasing complexity of various influencing factors. Whereas, the developed Base Rate Expenditure Inference Conjure Up has incorporated the various constraints:

1. Lowest level of first factor has score point seven and lowest level of second factor has one point below the previous factor and so on.
2. Highest levels of each of the factors have score point less than twenty.
3. Score at a particular level is three points higher than the immediate preceding level.

From Table 3, it is concluded that:

1. Worth for each of the benchmark jobs 1, 4 and 5 are below one point to the assigned score.
2. Worth of the rest two benchmark jobs 2 and 3 have been attained exactly the same as assigned and hence a satisfied condition.
3. Variation in the score of benchmark jobs is within 3% from the total assigned score.
The attained result is quite satisfactory as selected benchmark jobs are within 3% variation of the achieved conjure up which is belittle in such complex conjure up. Involvement of such a huge parameters and to reduce the maintenance cost up to the expectation level of the management and society, is quiet a satisfaction.

6. Conclusion and Managerial Implications

Present research work is the Estimation of Base Rate for maintenance of boilers and to reduce the maintenance cost in nearby Sugar Plant. It is for the survival and long life of industry for social and economic benefit for common men, industrialist itself and for entire nation. It is observed that developed conjure up is within the variation of 3% from the selected benchmark jobs, which is quite satisfactory because it supports in exercising the best alternative influencing factors to reduce the maintenance time and subsequently the maintenance cost to give the plant a competitive edge.

As the research work is carried out with regard to estimation of base rate of boilers only, it may be applied to other equipment of the plant; namely turbines, cane chopper, extracting mills, crystallizer, elevators etc. Even may be extended for possible application in other industrial sectors like automobiles, power plants, railways, paper mills, rolling mills, foundries, service sector, etc. Also, only six influencing factors are included in the study, so to make the study more elaborative, other unreckoned factors may be worked out. Apart from the five sublevels of different influencing factors considered under study, sublevels may be extended for more effective and in profundity study.

References


