An Integrated DEMATEL and AHP Approach for Personnel Estimation

Bijoyeta Roy*
Assistant Professor, CSE Department
Sikkim Manipal Institute of Technology
East Sikkim, India
Email: roybijoyeta@yahoo.com

Santanu Kr. Misra
Associate Professor, CSE Department
Sikkim Manipal Institute of Technology
East Sikkim, India
Email: misra_santanu@rediffmail.com

Preeti Gupta, Neha, Akanksha Goswami
UG Students, CSE Department
Sikkim Manipal Institute of Technology
East Sikkim, India

Abstract — Key to success of an organization is selection of qualified human resource as the quality of software product totally depends on its development team. Earlier, eligible candidates were interviewed and most qualified were selected. It would be beneficial to have computing models which could take various candidate competencies into consideration and show the most qualified person with high degree of accuracy as an output. The selection process for the members of a team takes into consideration many criteria which might be conflicting among themselves. Hence, the requirement of a software model for prioritizing the various criteria and selection of human resource in an organization is important. This paper supports adequately the decision making process with the help of Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Hierarchical Process (AHP). The DEMATEL method is used to prioritize the importance of various criteria and AHP utilizes multi criteria decision making (MCDM) approach to support project decisions and rank the alternatives in a preferred order to select the best personnel from a number of alternatives.

Key Words - AHP, DEMATEL, MCDM, Personnel Selection.

I. INTRODUCTION
Personnel management is an overall responsibility of all the line managers, staff managers and a function that needs to be performed all throughout the organization. Personnel selection is a process that attempts to fit the right people with the positions that are best suited for them. This is beneficial to individuals and to companies. Individuals are benefited because it is generally held that people are happier and find more enjoyment in jobs that suit them. Companies are benefited because qualified and well-suited employees tend to be more productive. Personnel selection can therefore involve a variety of things including assessments of personality, physical ability, and work history. In other words, it means all the programs, functions and the various activities which are performed and certain changes which are adopted in order to maximize the possibilities of achieving the goals. It also includes the strategies that are implemented in order to attract and hire talented, skilled employees, nurturing workplaces properly and maintaining healthy and sound environment at the workplaces. The selection process of human resource varies with the project requirements. Different projects may require different criteria. If the responsibility for selection is given to a single person (expert), his choices will be biased. However, if we opt for a software model that considers the opinions of several such experts and follows some pre-defined algorithm for the selection of criteria among the various conflicting criteria, then the results will be more precise and it will avoid conflict of ideas and biasness. Lack of human resource management possesses certain challenges: managing human resources in globally distributed team, shortage of software professionals having sufficient knowledge and competencies, low-skilled nature of the work, lack of well-developed Human Resource systems and processes, high employee turnover, lack of work-life balance, and the problems associated with the use of contract employees.

The organization of this paper is as follows: The next section highlights the various techniques used for project selection in the past literature and reveals the drawbacks of the existing methodologies. Then the subsequent sections discuss the procedures of the proposed model and the validation of the proposed
model giving a numerical application of the proposed model. Finally it highlights the outcomes and benefits of the proposed model under the heading of conclusion.

II. LITERATURE REVIEW
In the past literature on personnel estimation, Alecos Kelemenis, Dimitrios Askounis [1] in 2010 has considered the steps of fuzzy Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) which incorporates a new concept for the ranking of the alternatives. Chun-Chin Wei, Chen-Fu Chien, Mao-Jian, Wang in 2004 presented a framework for selecting a suitable ERP system based on AHP decision analysis in their paper [2] and the frame work offered the advantage of consistent structure of objectives, decomposing complex ERP selection problem into smaller ones and the flexibility to incorporate new attributes. A team formation model based on knowledge and collaboration by Hyeongon Wi, Seungjin Oh, Jungtae Mun and Mooyoung Junghas in 2009[3] evaluated the knowledge possessed by the candidates in quantitative ways using fuzzy model on publications issued by candidates for projects, by excluding conventional qualitative evaluations. A fuzzy-genetic decision support system for project team formation by D. Strnad and N. Guid in 2010 has presented a new fuzzy-genetic analytical model for the problem of project team formation. It builds on previous quantitative approaches, but adds several modeling enhancements like derivation of personnel attributes from dynamic quantitative data, complex attribute modeling, and handling of necessary over competency [4]. Santanu Kr. Misra and Amitava Ray has given stress to develop a selection model combining analytical hierarchy process (AHP) and Bayesian network for choosing the efficient developers in [5]. A generic method for software selection and hybrid knowledge base system (HKBS) was discussed by Anil Jadhav and Rajendra M. Sonar in [6]. This paper also compared HKBS with AHP and WSM technique and finds HKBS is better with regard to computational efficiency, flexibility and consistency. A fuzzy multiple criteria decision making (MCDM) methodology based on the TOPSIS for selecting employee presented in [7]. Thomas L. Saaty, Kirti Peniwati, Jen S. Shang 2007 [8] showed that the combined AHP and Linear Programming (LP) model is capable of solving hiring problems involving synergy, such as when two persons with different complementary skills work as a team. Ceyda Gungor Sen. proposed a hierarchical objective structure in 2009[10] that contains both qualitative and quantitative objectives are used to evaluate software products systematically. This approach uses a heuristic algorithm, a fuzzy multi-criteria decision making procedure and a multi objective programming model to make final selection decision. Wei-Wen Wu in 2008 proposed an effective solution for software selection using a hybrid approach by combining three MCDM methods-DEMATEL, ANP and ZOGP [11]. A simple approach of selecting best set of project based on integrated approach of AHP and ARAS using new additive ratio assessment method was proposed by Tuli Bakshi and Bijan Sarkar in 2011 [12].

Therefore, extensive literature review reveals the following drawbacks of the existing methodologies:

- The existing methodologies do not consider the subjective and objective measures.
- Robustness of the system has not been discussed in the existing models.
- In most of the cases, researchers focus on the flexibility rather optimality and the model does not give the optimal ranking.

The proposed model for personnel selection encounters some of the above limitations and extends in several ways. The objective of the proposed integrated model using the concepts of AHP and DEMATEL is to select qualified and talented human resource that can fulfill the requirements of an organization as well as provide customer satisfaction.

III. DECISION MAKING TRIAL AND EVALUATION LABORATORY (DEMATEL):
DEMATEL method is used to visualize the structure of complicated causal relationships between criteria of a system and obtain the influence level of these criteria. The results suggested by DEMATEL method might provide insight for outreach personnel to improve performance.

DEMATEL method could improve understanding of the specific problem, the cluster of intertwined problems, and contribute to identification of workable solutions by a hierarchical structure [7]. It can identify the interdependence among the elements of a system through a causal diagram. The causal diagram uses digraphs rather than directionless graphs to portray the basic concept of contextual relationships and the strengths of influence among the elements.

The procedure of DEMATEL method is summarized as follows [7]:

**Step 1:** Compute the average matrix. Each respondent was asked to evaluate the direct influence between
any two factors by an integer score ranging from 0, 1, 2, and 3, representing “no influence”, “low influence”, “medium influence”, and “high influence”, respectively. The notation \( x_{ij} \) indicates the degree to which the respondent believes factor i affects factor j. For \( i=j \), the diagonal elements are set to zero. For each respondent, a \( n \times n \) non-negative matrix can be established as \( X^k = [x_{ij}^k] \), where \( k \) is the number of respondents with \( 1 \leq k \leq H \), and \( n \) is the number of factors. Thus, \( X^1, X^2, X^3, \ldots, X^H \) are the matrices from \( H \) respondents. To incorporate all opinions from \( H \) respondents, the average matrix \( A = \frac{1}{H} \sum_{k=1}^{H} x_{ij}^k \) can be constructed as follows:

\[
a_{ij} = \frac{1}{H} \sum_{k=1}^{H} x_{ij}^k
\]

**Step 2:** Calculate the normalized initial direct-relation matrix. Normalize initial direct-relation matrix \( D \) by \( D = A \times S \), where \( S = \frac{1}{\max_{1 \leq i \leq n} \sum_{j=1}^{n} a_{ij}} \).

Each element in matrix \( D \) falls between zero and one.

**Step 3:** Calculate the total relation matrix. The total relation matrix \( T \) is defined as \( T = D(I - D)^{-1} \), where \( I \) is the identity matrix. Define \( r \) and \( c \) be \( n \times 1 \) and \( 1 \times n \) vectors representing the sum of rows and sum of columns of the total relation matrix \( T \), respectively. Suppose \( r_i \) be the sum of \( i^{th} \) row in matrix \( T \), then \( r_i \) summarizes both direct and indirect effects given by factor \( i \) to the other factors. If \( c_j \) denotes the sum of \( j^{th} \) column in matrix \( T \), then \( c_j \) shows both direct and indirect effects by factor \( j \) from the other factors. When \( j=i \), the sum \( (r_i + c_i) \) shows the total effects given and received by factor \( i \). That is, \( (r_i + c_i) \) indicates the degree of importance that factor \( i \) plays in the entire system.

**Step 4:** Set up a threshold value to obtain the digraph. Since matrix \( T \) provides information on how one factor affects another, it is necessary for a decision maker to set up a threshold value to filter out some negligible effects. In doing so only the effects greater than the threshold value would be chosen and shown in digraph. In this study, the threshold value is set up by computing the average of the elements in matrix \( T \). The digraph can be acquired by mapping the dataset of \((\text{Criteria, } r_i + c_i)\).

**IV. ANALYTICAL HIERARCHY PROCESS**

The Analytic Hierarchy Process (AHP), is a procedure designed to quantify managerial judgments of the relative importance of each of several conflicting criteria used in the decision making process. AHP uses a hierarchical structure and enables decision makers to measure the relative importance of projects, including their benefits, costs, risks and opportunities. AHP can be applied in any organization with any level of maturity.

In AHP, the primary problem or goal is broken down into several components/elements. Ratio of scales is then used to compare their relative importance and identify the most important factor. It is therefore quite useful for identifying the critical factors needed for solving problems containing uncertainty or multi-attribute decision making.

The following steps are followed in AHP model:

**Step 1:** List the Overall Goal, Criteria, and Decision Alternatives.

**Step 2:** Develop a Pair wise Comparison Matrix: Rate the relative importance between each pair of decision alternatives and this rate is based on Saaty’s nine point scale (Table 2). The matrix lists the alternatives horizontally and vertically and has the numerical ratings comparing the horizontal (first) alternative with the vertical (second) alternative. For each criterion, perform steps 2 through 5.

**Step 3:** Develop a Normalized Matrix: Divide each number in a column of the pair wise comparison matrix by its column sum.

**Step 4:** Develop the Priority Vector Average: Average each row of the normalized matrix. These row averages form the priority vector of alternative preferences with respect to the particular criterion. The values in this vector sum to 1.

**Step 5:** Calculate the Consistency Ratio [CI, RI, and CR]: Calculate the eigenvector or the relative weights and for each matrix of order \( n \). Compute consistency index using \( CI = \frac{\beta_{\text{max}} - n(n-1)}{n} \). RI = Random Inconsistency \( = 1.987(n-2)/n \) and CR = CI/RI. The acceptable CR range varies according to the size of matrix. That is 0.05 for the 3 by 3 matrix, 0.08 for a 4 by 4 matrix and 0.1 for all larger matrices, \( n>=5 \).
Step 6: Develop a Priority matrix and a criteria development priority matrix.

Step 7: Develop a Priority Matrix: Develop the overall priority vector by multiplying normalized matrix of criteria with the priority matrix of decision alternatives which is formed with priority vectors of different criteria [5].

V. PROPOSED METHODOLOGY

Step 2: Calculate the normalized initial direct-relation matrix $D$ by the following formula:

$$D = A \times \frac{1}{\max_{i,j} a_{ij}}$$

Step 3: Calculate matrix $T$ by the following formula:

$$T = D(I - D)^{-1}$$

Step 4: Calculate the sum of rows ($r_i$) and the sum of columns ($c_j$) from matrix $T$ and then calculate $r_i + c_j$.

The $r_i + c_j$ values calculated from matrix $T$ are shown in Table 1.

<table>
<thead>
<tr>
<th>DIMENSIONS</th>
<th>$r_i + c_j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Contacts</td>
<td>9.6096</td>
</tr>
<tr>
<td>(B) Communication Skills</td>
<td>10.3151</td>
</tr>
<tr>
<td>(C) Technical Skills</td>
<td>11.8046</td>
</tr>
<tr>
<td>(D) Creativity</td>
<td>10.2440</td>
</tr>
<tr>
<td>(E) Experience</td>
<td>10.9057</td>
</tr>
</tbody>
</table>

VI. NUMERICAL APPLICATION OF PROPOSED MODEL.

Seven major criteria were identified including (A) contacts, (B) communication skills, (C) technical skills, (D) creativity, (E) experience, (F) dependability, and (G) efficiency. To follow the procedure of DEMATEL method, the following steps are considered.

Step 1: A questionnaire was developed based on these seven criteria to 10 managerial personnel and ten $7 \times 7$ non-negative matrices based on the opinion of the 10 experts. The average matrix $A$ of the ten $7 \times 7$ matrices are calculated as shown below:
The importance of each criterion in selection of the best personnel is represented by a pie chart as shown in fig.2 above.

Four criteria with the highest value of $r_i + c_j$ are selected as the most appropriate criteria for the particular project. Then taking these as input, we calculate the personnel best suited for the job with the help of AHP.

The detailed calculation of AHP is as follows:

**Step1:** Calculate the normalized matrix from the pair wise comparison matrix. Four pair wise comparison matrices for the personnel are taken based on Saaty’s nine point scale given in table 2 [9].

### TABLE 2

<table>
<thead>
<tr>
<th>Level of satisfaction</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely preferred</td>
<td>9</td>
</tr>
<tr>
<td>Very strongly preferred</td>
<td>7</td>
</tr>
<tr>
<td>Strongly preferred</td>
<td>5</td>
</tr>
<tr>
<td>Moderately preferred</td>
<td>3</td>
</tr>
<tr>
<td>Equally preferred</td>
<td>1</td>
</tr>
<tr>
<td>Intermediate judgment between two adjacent judgment</td>
<td>2,6,4,8</td>
</tr>
</tbody>
</table>

Personnel 1:

$$A = \begin{bmatrix}
1 & 5 & 6 & 8 \\
0.2 & 1 & 4 & 7 \\
0.126 & 0.1426 & 0.333 & 1 \\
0.128 & 0.1426 & 0.333 & 1 \\
\end{bmatrix}$$

A is the pair wise comparison matrix for personnel 1.

The normalized matrix ($N_1$) obtained for Personnel 1 is given by

$$N_1 = \begin{bmatrix}
0.77417 & 0.782130 & 0.829427 & 0.421038 \\
0.00000 & 0.156426 & 0.332952 & 0.36821 \\
0.120935 & 0.039106 & 0.088238 & 0.18789 \\
0.096772 & 0.022385 & 0.029383 & 0.032632 \\
\end{bmatrix}$$

The priority vector is:

$$p_1 = \begin{bmatrix}
0.262686 \\
0.219450 \\
0.103875 \\
0.050281 \\
\end{bmatrix}$$

The average is 4.184493. The Consistency Index is 0.061498 and the Consistency Ratio is 0.061900.

Similarly the priority vector is calculated for Personnel 2, 3 and 4 and the Consistency Index and Consistency ratio obtained is shown in the table 3.

### TABLE 3

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Consistency Index</th>
<th>Consistency ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel 1</td>
<td>0.061498</td>
<td>0.061900</td>
</tr>
<tr>
<td>Personnel 2</td>
<td>0.096244</td>
<td>0.096874</td>
</tr>
<tr>
<td>Personnel 3</td>
<td>0.081167</td>
<td>0.081698</td>
</tr>
<tr>
<td>Personnel 4</td>
<td>0.096623</td>
<td>0.097155</td>
</tr>
</tbody>
</table>

**Step 2:** Calculate the normalized matrix ($N_c$) from the pair wise comparison matrix ($E$) for the four criteria’s.

$$E = \begin{bmatrix}
1 & 7 & 9 & 6 \\
0.1428 & 1 & 4 & 3.333 \\
0.111 & 0.23 & 1 & 0.1667 \\
0.1667 & 3 & 6 & 1 \\
\end{bmatrix}$$

The normalized matrix $N_c$ is:

$$N_c = \begin{bmatrix}
0.703978 & 0.622222 & 0.250000 & 0.800000 \\
0.105245 & 0.088889 & 0.200000 & 0.044444 \\
0.078142 & 0.022222 & 0.200000 & 0.022222 \\
0.117859 & 0.266667 & 0.200000 & 0.133333 \\
\end{bmatrix}$$
The priority vector $P_c$ is:

\[
P_c = \begin{bmatrix} 0.644038 \\ 0.108385 \\ 0.043148 \\ 0.204340 \end{bmatrix}
\]

The total priority vector $R$ is:

\[
R = \begin{bmatrix} 0.609747 \\ 0.232968 \\ 0.099248 \\ 0.049037 \end{bmatrix}
\]

The final matrix $F$ is

\[
F = \begin{bmatrix} 0.388894 \\ 0.237434 \\ 0.141699 \\ 0.081973 \end{bmatrix}
\]

The score of each personnel is reflected in the final matrix $F$ and it is clear that the ranking of the personnel are like $P_1 > P_2 > P_3 > P_4$. The final score for each personnel is represented by the graph shown below in fig. 3.

From the final matrix $F$ and from the graph in fig. 3 above it is clear that Personnel 1 having score 54 % is best suited for the job.

VII. CONCLUSION

The research vehicle proposed in this paper is a combined model for personnel selection. It is integration of two models: decision making trial and evaluation laboratory (DEMATEL) and analytic hierarchy process (AHP). First, it is considers several criteria(e.g. experience, technical skills, contacts, etc.) that may be needed in different projects in an organization and then selects the best criteria by calculations based on experts judgments. Then these criteria are used as inputs in AHP model which helps us to select the personnel best suited for the project. We can use any number of criteria and personnel in a project as input and choose the one’s with the highest priority values. The proposed methodology is simple and straight forward and is well suited for appropriate ranking of deserving personnel’s based on technical as well as customer handling skills.

The limitation of this methodology is that it takes into consideration only the benefit criteria and does not include the cost criteria. So there is scope for further research in these areas where the cost analysis will be taken into consideration along with the benefit criteria.

VIII. REFERENCES


