A combined method based on integration of fuzzy analytical network process and stochastic dominance degree for R&D project selection in the electrical distribution company

E. Ghasemi, M. Tajadod, A. Naderi

Abstract—Research and Development (R&D) project selection is a strategic decision making problem which a company in fast changing environments encounters. Therefore, R&D plays a key role in the successful performance for these firms. In this paper, for the suitable selection of R&D projects, a model has been introduced based on fuzzy analytic network process (ANP) and stochastic dominance degree (SDD). By using ANP, we determined the priority of the criteria and the sub-criteria and fuzzy number was used to overcome ambiguity in the expert view point. To rank the R&D projects, a stochastic method based on SDD matrix on pairwise comparisons of projects with respect to each sub-criterion was used. An electrical distribution company in Iran is selected as a case study and R&D projects has been ranked.

Keywords—Analytic network process, Electrical distribution company, Fuzzy sets, Stochastic dominance degree

I. INTRODUCTION

Research and Development (R&D) project selection and evaluation is a strategic decision making problem in the fully uncertain business environment. R&D is an ongoing process for forward thinking technology-based companies. Since 1950s that R&D project selection introduced, large numbers of methods were proposed by researchers to obtain the optimal selection. Against of those proposed methods for R&D project selection, this problem remains problematic, and few models have gained wide acceptance.

Reference [1] conducted an empirical study on the use of quantitative techniques for R&D project management. They found that most R&D organizations use one or more traditional financial methods (such as NPV, ROR, Benefit/cost analysis and etc.) for determining project returns. They also found that many managers do not believe that the available methods for project selection improve the quality of their decisions. Reference [2] showed that Limitations of existing R&D project selection models are: (1) Inadequate treatment of multiple, often interrelated, evaluation criteria. (2) An inability to handle non-monetary aspects and inadequate treatment of interrelationships among projects. (3) No explicit recognition and incorporation of the experience and knowledge of R&D managers. (4) Perceptions by R&D managers that these models are difficult to understand and use. Since mentioned reasons above R&D project selection and evaluation changed into Multi Criteria Decision making. Reference [3] developed a method for R&D project selection that allows for the consideration of important interactions among decision levels and criteria. This paper discusses the application of the analytic network process (ANP), a multi attribute approach for decision making that allows for the transformation of qualitative values into quantitative values and performing analysis on them. They used the small high-tech company as a case study for validation of the model and approach. Reference [4] supposed R&D projects are elements of programs with heterogeneous objectives. They proposed an ANP approach for R&D project evaluation based on interdependencies between research objectives and evaluation criteria. In this research criteria divided to benefit and cost. Reference [5] first proposed fuzzy ANP for the development of decision support systems. Reference [6] presented Fuzzy analytic network process (ANP) with fuzzy costs was in selection procedure of R&D projects. This work was implemented into the case of iron and steel industry in South East Asia. Reference [7] proposed a fuzzy analytic network process method to handle interdependency among evaluation criteria and integrate the divergent judgments of experts in a R&D project selection committee. Reference [8] proposed a fuzzy ANP based approach to evaluate a set of conceptual design alternatives developed in a new product development (NPD) environment in order to reach to the best one satisfying both the needs and expectations of customers, and the engineering specifications of company. In this paper, a integrated model based on the fuzzy analytic network process (ANP) and the stochastic dominance degree (SDD) for ranking R&D projects in electrical distribution company is introduced. The rest of paper is organized as follows. Section 2 describes the R&D project
II. R&D PROJECT SELECTION FRAMEWORK

In this article a combination of the Analytic Network Process model and Stochastic Dominance Degree method is proposed for R&D project selection. In the proposed model, the network relationship between the criteria and strategic goals of the electrical distribution company has been extended. Also the interdependence between the sub-criteria, the criteria and the strategic objectives is considered. The sub-criteria belonged to different criteria has been also compared with each other. By using fuzzy ANP, the priority of the criteria and the sub-criteria were determined. Furthermore, to rank the R&D project selection, a stochastic method based on pair-wise comparisons of projects with respect to each sub-criterion was used. Finally to obtain the ranking of strategies PROMETHEE-II was used. In the following section, any part of methodology is explained.

A. Fuzzy Analytic Network Process methodology

In this article, a fuzzy ANP method is applied to determine the weights of decision elements, except projects. In the other word, the ANP method with triangular fuzzy number is used to obtain the priorities of elements through pair-wise comparison between them. Table I shows the used linguistic variables (fuzzy triangular numbers). The ANP was first introduced by Saaty [9] for decision structuring and decision analysis. This model has been provided a more generalized model in decision-making field and solved the limitations of analytical hierarchy process (AHP) assumptions. AHP is one of the most commonly used multiple criteria decision-making (MCDM) methods. ANP is suitable to handle the problems having dependence among alternatives or criteria and sub criteria [9]. In ANP, hierarchy of AHP is replaced by network that represents more complex interrelationships and feedback among elements of decision.

<table>
<thead>
<tr>
<th>Linguistic variable</th>
<th>Fuzzy number</th>
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<tbody>
<tr>
<td>equally important</td>
<td>(1,1,3)</td>
</tr>
<tr>
<td>weakly important</td>
<td>(1,3,5)</td>
</tr>
<tr>
<td>essentially important</td>
<td>(3,5,7)</td>
</tr>
<tr>
<td>very strongly important</td>
<td>(5,7,9)</td>
</tr>
<tr>
<td>absolutely important</td>
<td>(7,9,9)</td>
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The used fuzzy ANP method is described as following main steps:

Step 1. Set up a team of experts as decision makers.

Step 2. Determine the strategic goals, criteria and sub-criteria and network relationship between them: The strategic goals, criteria and sub-criteria for the project selection are elicited among expert’s opinions, related scientific references and usable information that are published by central electrical distribution company. At the end, the network structure of elements is determined by team of experts.

Step 3. Use pair-wise comparison between strategic goals, criteria and sub-criteria: After determining the network relationship among elements, pair-wise comparison is conducted by the experts. In this study we used linguistic variable in the questionnaires.

Pair-wise comparison is conducted with respect to the network of ANP between all of the elements for each experts. In this step pair-wise comparison matrices are prepared (Fig. 1). Note that elements of these matrices are fuzzy triangular number (table I). In Fig. 1, \(a_{ijp} = \left(l_{ijp}, m_{ijp}, u_{ijp}\right)\) and means: comparision judgment of \(k\)th expert toward decision element \(i\) under decision element \(j\) respect to element \(p\), (generally \(i, j, p\) can be any of criteria, sub-criteria and strategic goals).

\[
A_k = \begin{bmatrix}
1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\
\tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
\tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \\
\end{bmatrix}, k \in [1,13]
\]

Fig. 1 Fuzzy pairwise comparison matrix of \(k\)th expert with respect to element \(p\)

Step 4. Elicit the estimated weights of the element from the fuzzy pair-wise comparison matrix: The fuzzy matrices are transformed to non-fuzzy matrix before of computing the weights. The triangular fuzzy numbers can be converted to crisp number using (1), (2):

\[
S_{ijp} = \begin{bmatrix} l_{ijp} & a_{ijp} & u_{ijp} \end{bmatrix} = \begin{bmatrix} m_{ijp} - l_{ijp} \end{bmatrix} + \begin{bmatrix} u_{ijp} - m_{ijp} \end{bmatrix} \forall \alpha \alpha
\]

\[
a_{ijp} = \frac{a_{ijp}}{\mu + (1-\mu)u_{ijp}} \forall \mu \in [0,1]
\]

\(a\) denotes confidence level and \(\mu\) denotes index of optimism and is determined by the decision maker [8]. After computing crisp numbers, the non-fuzzy comparison matrix is conducted for all decision makers (Fig. 2). For computing the weights of decision elements from non-fuzzy comparison matrix the eigenvector method is used [11].

Final weight of elements is obtained through numerical average of expert’s opinion that has been shown in (3). These weights are transmitted to the unweighted supermatrix.

\[
W_{ip} = \sum_{k=1}^{n} W_{ik} \frac{1}{k} \quad p,i = 1,2,3,...,n
\]

Fig. 2 The non fuzzy comparison matrix
Step 5. Form the unweighted suppermatrix/ weighted suppermatrix/ limit suppermatrix: The obtained weights from previous step is transported to unweighted suppermatrix. The weighted suppermatrix is constructed based on the unweighted suppermatrix that the sum of each column of it needs to be one. In other words, weighted suppermatrix is column stochastic. The limit suppermatrix can be obtained with raising the weighted suppermatrix to the power 2k+1, where k is an arbitrarily large number. All of the numbers in each rows of limit suppermatrix is equal and the final weight of each element is equal to the number in the relative row. Detailed information about fuzzy ANP can be found in [8], [9].

B. Stochastic Dominance Degree (SDD)

When the final weights of sub-criteria are calculated through ANP method, the rank of the alternatives (or projects) can be obtained. In this article, Stochastic Dominance Degree (the degree that one alternative dominates another) method was used to rank the R&D projects. This method can be described by following steps:

Step 1. At first The experts provide their preference evaluations on the projects in the form of scores 1-5 (1, the worst; 5, the best) with respect to each sub-criterion.

Step 2. The kind of stochastic dominance (SD) relation for each pair of projects with respect to each sub-criterion according to SD rules is determined. Let a and b ,a < b (1, 5, scores) be two real numbers, X and Y (alternatives or strategies) be two random variables, F(x) and G(x) be cumulative distribution functions of X and Y, respectively.

Furthermore SD1, SD2 and SD3 denote first, second and third degree stochastic dominance, respectively.

SD rules are:
1. F(x) SD 1 G(x) if and only if: \( F(x) \leq G(x) \) for all \( x \in [a, b] \) with strict inequality for some \( x \);
2. F(x) SD 2 G(x) if and only if:
\[ \int_a^x F(t)dt \leq \int_a^x G(t)dt \quad \text{for all} \quad x \in [a, b] \quad \text{with strict inequality for some} \quad x; \]
3. F(x) SD 3 G(x) if and only if:
\[ \int_a^x F(t)dt \leq \int_a^x G(t)dt \quad \text{for all} \quad x \in [a, b] \quad \text{with strict inequality for some} \quad x; \]

In the other word, If \( F(x)SD_h G(x) \), \( h \in \{1,2,3\} \), then alternative \( A_F \) dominates \( A_G \) (noted as \( A_F \gtrless A_G \)).

Step 3. At this stage, SD degree matrix is built through (4). The SDD matrices with respect to all the criteria are aggregated into an overall SDD matrix using the simple additive weighting method [12]. If \( F(x)SD_h G(x) \); \( h \in \{1,2,3\} \) then the stochastic dominance degree (SDD) of \( F(x)SD_h G(x) \) (noted as \( \psi(F(x)SD_h G(x)) \)) is given by

\[ \psi(F(x)SD_h G(i)) = \frac{\int \Theta \{ F(x) - G(x) \} dx}{\int G(x) dx}, \quad h \in \{1,2,3\} \] (4)

where \( \Omega = \{ x | x \in [a, b] \} \).

Step 4. To rank the alternatives based on the overall SDD matrix, an approach based on the idea of the PROMETHEE-II method is developed. After forming the overall SDD matrix, \( \Phi(A_i) \) and \( \tilde{\Phi}(A_i) \) is calculated. \( \Phi(A_i) \) indicated the dominant degree which is a measure that strategy \( A_i \) is dominating the other strategies (the average of overall SDD matrix row), and \( \tilde{\Phi}(A_i) \) showed the non-dominant degree which is a measure that strategy \( A_i \) is dominated by the other alternatives (the average of overall SDD matrix column). Finally the strategies are ranked based on \( \Phi(A_i) - \tilde{\Phi}(A_i) \) value.

III. CASE STUDY: R&D PROJECT SELECTION IN ELECTRICAL DISTRIBUTION COMPANY (IRAN-KERMAN)

An electrical distribution company in Iran has been selected as case study. To implement the proposed model for R&D project selection, fourteen experts were selected among managers of the electrical distribution company that play important roles in the project selection process. In a meeting with these experts, strategic goals, criteria, and sub-criteria and R&D projects for modeling R&D project selection problem in the company, were determined. The results of this meeting are described below.

 Determination of strategic goals to find the appropriate evaluation criteria/sub-criteria for R&D project selection problem is too necessary. Based on road map and mission of organization and expert's opinion, the strategic goal has been elicited, and classified to three categories: \( S_1 \): Improvement of customer satisfaction, \( S_2 \): Improvement of economical productivity, \( S_3 \): Improvement of technical stability.

Through expert's view point and relative references about research and development project selection, six groups of criteria with eighteen sub-criteria were determined. This criteria and sub-criteria are mentioned as follows and interdependencies among these elements are shown in Fig. 3:

1. Benefit criteria (\( B_1 \)) consist of: economical profit (\( B_{11} \)), energy and material saving (\( B_{12} \)), financial factors like Net Present Value (NPV) (\( B_{13} \)), social profit (\( B_{14} \)), consistency with strategy corporation (\( B_{15} \)). 2. Cost criteria (\( B_2 \)): initial cost of project (\( B_{21} \)), required time of project (\( B_{22} \)). 3. Risk criteria (\( B_3 \)): company risk (\( B_{31} \)), environmental risk (\( B_{32} \)), staff risk (\( B_{33} \)). 4. Aspects of project execution (\( B_4 \)): execution possibility (\( B_{41} \)), resource availability (\( B_{42} \)). 5. Scientific and technical merit (\( B_5 \)): creativity and advancement (\( B_{51} \)), standard fitness (\( B_{52} \)), technical improvement (\( B_{53} \)). 6. Quality of project (\( B_6 \)): capability of research team (\( B_{61} \)), customer satisfaction (\( B_{62} \)), staff satisfaction (\( B_{63} \)).

According to section 2.1 we follow the mentioned steps to find the weights of strategic goals, criteria and sub-criteria.
Final weights of strategic goals, criteria and sub-criteria are indicated in Table II. The results of proposed model based on ANP in an electrical distribution company showed that the most important strategic goal is improvement of economical productivity and the second goals with low difference from first goal is improvement of customer satisfaction. In addition, about criteria, quality of project and then benefit criteria are most important between criteria respectively. The important sub-criteria in benefit, cost, and risk, aspects of project execution, scientific and technical merit, and quality of project criteria are economical profit, initial cost of project, company risk, execution possibility, creativity and advancement and customer satisfaction respectively.

Furthermore the R&D projects were elicited from the priorities of research and development that published by central electrical distribution company. In this part of article, according to presented SDD method the R&D project are ranked. Fourteen R&D projects from the road map of company have been elicited and have been ranked through SDD methods.
This group is consists of: A1: Training, improvement and productivity evaluation of staff, A2: Revision and adjustment of the Employment system (managers or personnel), A3: Adjustment of Company road map and organization structure, A4: Budgeting and pricing adjustment, A5: Company policy adjustment, A6: Development of customer service mechanization, A7: Revision and adjustment of the electrical bylaws, A8: Cost management, A9: Information systems and network planning Development, A10: Development of reducing energy waste methods, A11: Revision and adjustment of information and communication technology (ICT) structure, A12: Foresight about ICT in electrical distribution, A13: Safety system and strategy revision, A14: Environmental cost reduction. priorities of R&D projects are shown in table III. As the result shows Cost management and Development of customer service mechanization are the projects with high priority and low priority respectively.

IV. CONCLUSION

In this study for ranking R&D projects, a combined method based on ANP and SDD methods is proposed. ANP method was used for obtaining the priority of sub-criteria and SDD method has been used for ranking the projects. We studied the selection of R&D project strategies in electrical distribution company as a case study. As the results showed the Cost management was selected as the most important R&D project in an electrical distribution company in Iran and proposed method is a simple and effective tool for tackling the uncertainty and imprecision associated with multiple criteria (R&D project selection) problem. Simple usage of the SDD method is excellence of this method in comparison to the other methods for ranking a large number of projects.

REFERENCES