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ORIGINAL ARTICLE

# A hybrid multi criteria decision making approach for consultant selection problem in ERP project

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**Abstract** Enterprise Resource Planning (ERP) projects are risk prone due to software complexity, budget overruns, long duration, poor project delivery and a broad range of organization transformation processes. Companies are hiring experienced external consultants to achieve successful implementation of ERP system. Proper selection of ERP consultant is challenging task for any top management of organization because consultant fees accounts a major portion of project cost and this problem may be considered as Multi criteria decision-making problem. This article presents the hybrid approach of Fuzzy Analytical hierarchy process (F-AHP) and COPRAS-G in selection process of ERP consultants. F-AHP is used to obtain the weight of selection criteria and COPRAS-G is used to get the final ranking of consultants based on utility degree. The proposed model is illustrated with a numerical example whose data has been collected from survey in Indian industries. Finally, sensitivity analysis was performed to determine the robustness of the approached. The result of F- AHP highlights that reputation, ERP project experience and partner of ERP vendor and cost is an important selection criterion for selecting consultant and rank reversal problem has been greatly reduced by COPRAS-G. This proposed hybrid technique is quite flexible and provides efficient decision making in the selection of an ERP consultant.

**Keywords** Consultant selection · COPRAS-G · ERP project · Fuzzy AHP · MCDM

## 1 Introduction

Companies are investing huge amount in information technology systems so as to meet the challenges of business organizations and smooth flow of information in the industries. ERP is an advanced information technology tool which supports business functions and information flow of an organization in a single software system. Shadi et al. (2019) has defined ERP is an Information Technology (IT) business solution which enables Organizations and their Stakeholders for management of project effectively & efficiently throughout the lifecycle of project. Thus, ERP system is amalgamation of business, technology and human resource.

Implementation of ERP system has been considered among the most challenging investment projects due to the high costs involved, complexity and higher duration (Yusuf et al. 2004). Continuous high failure rates of ERP projects are major concern in recent years. Aloini et al. (2007) highlighted the issue of ineffective consulting services in ERP project; hence, proper strategies/methodologies towards selection of consultant may be required. Consultant's industry experience, project management capabilities and experience in previous project in similar type industry and communication ability has been seen as desirable

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attributes in the selection of ERP consultant (Hung et al. 2012). Ram et al. (2013) have summarized recent ERP problems in organizations and failures as evidence for further reduce the failure levels. In order to avoid such failures, experienced external consultant is often required. Consultants are those who can apply their specific industry knowledge & experience to solve the business-related issue and impart training among stakeholders within the organization to reduce the burden of implementation (Plaza 2016).

The main aim of this work is to propose a MCDM Approach for solving the problem of consultant selection in ERP projects. In presented work, various criteria have been considered for Decision- Making (DM) process in selection of suitable ERP consultant; hence a hybrid MCDM approach based on F-AHP & COPRAS-G has been applied. The weight of criteria is considered by applying F-AHP & COPRAS-G is used to final ranking of consultant. The proposed methodology has been illustrated with a case example.

The article has been discussed in following sections. Section 2 shows the literature review, Sect. 3 shows the methodology used, Sect. 4 discusses the problem formulation, Sect. 5 shows the proposed solution approach, Sect. 6 deals with the studied case "ERP consultant selection problem", Sect. 7 shows SA and the last section deals with discussion & conclusion.

## 2 Literature review

### 2.1 ERP consultants

ERP implementation expertise is important when it comes to setting realistic goals and reviewing lessons learned from top success and bottom successes implementation in the industry. For this, 78% organizations are hiring services of consultancy (Panorama 2020). Hiring a suitable consultant to implement ERP system is a customary approach to procure expertise that is not available in client organization. A major recurring factor found in ERP implementation is consultant support (Sherry and Corbett 2007; Grabski and Stewart 2007). ERP consultant provides various services such as providing technical upgrades and business expertise, enhancing learning capabilities of client, helping in preparing technical specification of ERP software requirement, offering technical knowledge on the software, on the job training of users, streamlining procedures and protocols of the organization with system modules, providing assistance in customization and configuration of the system and suggesting appropriate solutions to adoptive customers (Nah et al. 2001; Wang et al. 2008). Alhakbani and Mohammed (2012) have analysed through their case study various consultant responsibilities, roles and scope of work involved for hiring ERP consultants in Saudi Arabia. Involvements of consultant have been carefully controlled to avoid serious budget overruns as consulting fees is major portion of project cost (Plaza and Rohlf 2008). Full commitment and project-oriented skill is more important than technical skill in External consultant, so selection of consultant is well versed in terms of business, process and technical know-how (Barth and Koch 2019). Chang et al. (2013) have explored the control mechanisms that are utilized in ERP projects for ensuring that the ERP consultant is working to fulfil the client's business needs. Thus, ERP consultant is a bridge between vendor and client organization.

### 2.2 Selection of ERP consultants

Choosing of ERP implementation partners is very important because these partners support in adoption, deployment and stabilization of the systems. Identification and elaboration of suitable selection criteria for consultant is important activities and need to be accessed in proper manner. Kumar et al. (2003) have proposed eight selection criteria for ERP consultant by respondents. Cheung et al. (2002) have utilized AHP technique in problems of architectural consultant selection based on different selection criteria such as: company profile, consultancy fee, project strategy, performance history and willingness to complete the task in hand. Golam and Sultana (2014) explored fuzzy AHP with PROMETHEE in consultant selection for total quality management. This MCDM hybrid approach is applied on the furniture manufacturing industry of Bangladesh and outcome indicates that the administrative/technical skills is the most important criterion and work experience is an important sub criterion. Tsai et al. (2007) have applied an AHP technique to select the suitable consultant based on three attributes namely ERP approaches. Ozalp et al. (2012) have proposed the ERP Consultant selection problem by AHP, ANP and F-AHP methodology. The findings suggest that AHP and Fuzzy AHP results led to same conclusion whereas ANP gives more correct weights of criteria due to considering the interactions. Simon et al. (2010) have developed Consulting service Maturity model (CSM) that includes prioritise best practices grouped under various factors such as consulting skills, customer focus, consulting skills, leadership, adaptability, profitability, project management practices and values. The outcome of the model may help organizations to improve the performance. Martinovic and Delibasic (2014) have integrated AHP-IBA model for the most suitable SAP consultant based on four attributes namely the level of education, cost, work experience and communication ability. The outcome of this project

suggests that logical interaction between criteria may provide better results.

## 3 Methodology used in research

### 3.1 AHP & F-AHP approach

The AHP is known as an efficient and flexible decision-making process used to model a complex problem in a hierarchical structure (Satty 1980). It uses a 9-point scale to compare the criteria pair-wise with the help of expert decision makers to evaluate the relative importance of each criterion. The AHP reduces a multidimensional problem into a one dimensional. Various applications of AHP have been published in the literature pertaining to ERP (Huang et al. 2004; Salmeron and Cristina 2010; Sudhaman and Sharma 2014). The ambiguity associated with mapping the human judgment to a number is not handled by AHP. (Cheng et al. 1999). To overcome this, many scholars have applied F-AHP to overcome its uncertainty. Chang (1996) used a triangular membership function in Fuzzy AHP approach for Pair Wise Comparison (PWC) of the criteria. Chan et al. (2000) has discussed that an expert provide assessments on the bases of their previous knowledge, work experience. Jain et al. (2018) have presented an approach for supplier selection through Attractive criteria. In this work approach they used a Fuzzy Kano model and MCDM approach for solving the same problem. The computational procedure of F-AHP has been adopted from the Singh et al. (2012) and steps are as follows:

Step 1: Construction of hierarchy structure
Step 2: Comparing score of performance
Step 3: Developing the fuzzy comparison matrix
Step 4: Estimating degree of optimism
Step 5: Solving the fuzzy Eigen value
Step 6: Determination of weights for criteria and checking the consistency

### 3.2 COPRAS-G methodology

COPRAS is one of the important methods MCDM which was developed by Zavadskas and Kaklauskas (1996). It can find out best alternative from a bunch of feasible alternatives.

In COPRAS, criterion weighs and ranking of alternative used the crisp numerical data. To convert the crisp value to the grey numbers, Grey System Theory (GST) is applied because in most of the cases, crisp data could not be suitable to handle the real-world situations. Deng (1989) has developed the GST as an effective method which has been used to solve problems with incomplete information and discrete data. A white system is the system whose system information is known properly, while a black system is the system whose information is not available properly. A grey system is the system that has partial known unknown information. A reference reading on grey theory and their operation has been described by (Li et al. 2008).

Zavadskas et al. (2008a) have proposed COPRAS-G, in which the attributes are reflected in periodic values, most suited for real-world DM and in the implementation of the grey theory. In past, this technique has been used by various researchers in various fields. Zavadskas et al. (2008b) have proposed COPRAS-G for selection of construction project managers. Zavadskas et al. (2010) have used COPRAS-G and TOPSIS grey for risk assessment problem in construction projects and compare the ranking of projects. Bindu Madhuri et al. (2010) have applied this method on website selection. Maity et al. (2012) have applied COPRAS-G to rank alternatives on the basis of their importance and usefulness. Nguyen et al. (2014) have used the hybrid methodology of Fuzzy ANP and COPRAS-G for selection of suitable machine tool. Thus, COPRAS-G is suitable for problem with uncertainty, subjective and imprecise data.

The steps of COPRAS-G are given as following (Nguyen et al. 2014; Zavadskas et al. 2010):

Step 1: Find out the important criteria to define alternatives.
Step 2: Construct the DM.

$$X = \begin{bmatrix} [x_{11}, b_{11}] & [x_{12}, b_{12}] & \cdots & [x_{1n}, b_{1m}] \\ [x_{21}, b_{21}] & [x_{22}, b_{22}] & \cdots & [x_{2n}, b_{2m}] \\ \vdots & \vdots & \ddots & \vdots \\ [x_{n1}, b_{n1}] & [x_{n2}, b_{n2}] & \cdots & [x_{nm}, b_{nm}] \end{bmatrix} \quad (1)$$

where i = 1, 2,.., n; j = 1, 2,.., m, and the interval value $x_{ij}$ and $b_{ij}$ denotes the smallest and highest value. Here n denotes the criteria and m denotes alternatives.
Step 3: Determination of weights of criteria's $q_j$.
Step 4: Normalization of DM data.

$$\overline{x}_{ij} = \frac{2x_{ij}}{\left[\sum_{i=1}^{m} x_{ij} + \sum_{i=1}^{m} b_{ij}\right]} \quad (2)$$

$$\overline{b}_{ij} = \frac{2b_{ij}}{\left[\sum_{i=1}^{m} x_{ij} + \sum_{i=1}^{m} b_{ij}\right]} \quad (3)$$

After normalizing the data, matrix is as:

**Table 1** Evaluation criteria for selection

| Notion | Criteria | References |
|---|---|---|
| C1 | Reputation | Kumar et al. (2003) |
| C2 | ERP project experience | Kumar et al. (2003) and Tsai et al. (2007) |
| C3 | Process Engineering experience | Kumar et al. (2003) |
| C4 | ERP implementation experience in similar industry | Tsai et al. (2007) |
| C5 | Project methodology / approach | Kumar et al. (2003) and Tsai et al. (2007) |
| C6 | Cost | Kumar et al. (2003) and Tsai et al. (2007) |
| C7 | Partner of ERP vendor | Kumar et al. (2003) |

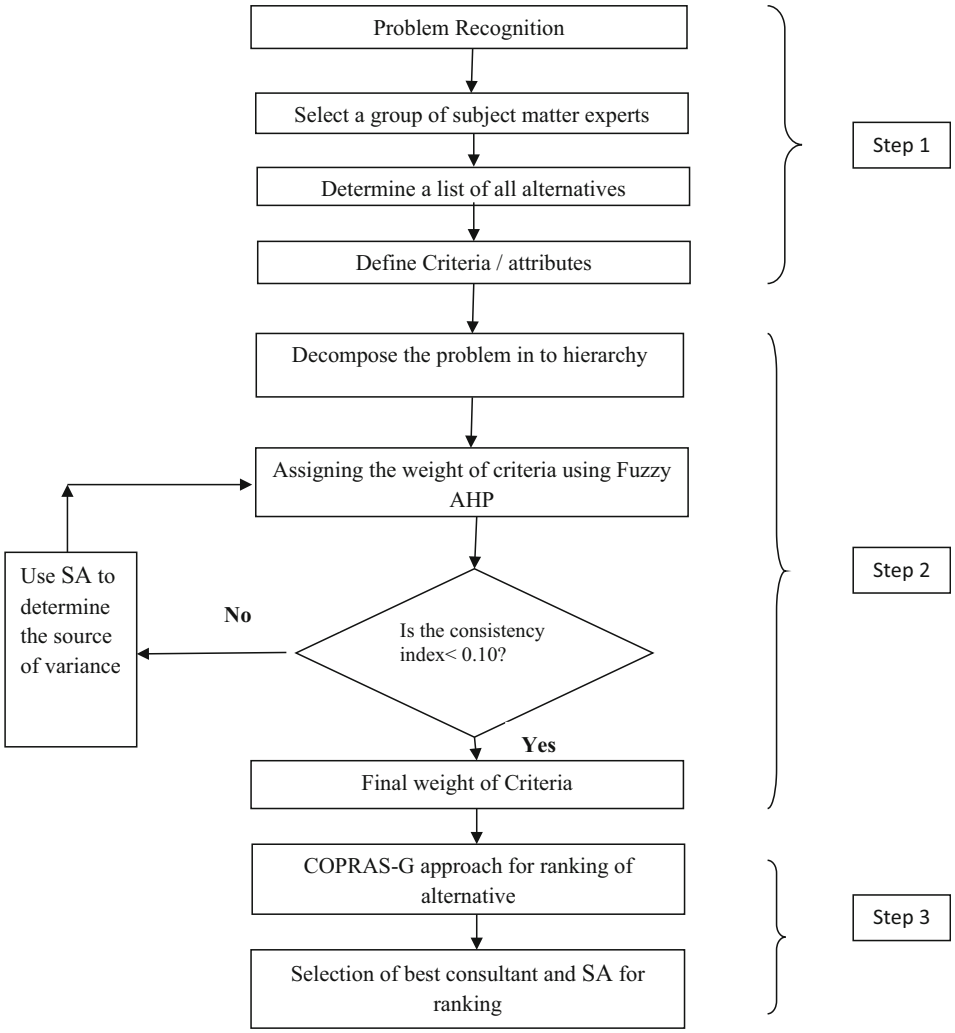


**Fig. 1** Proposed hybrid methodology for consultant selection in ERP project

$$\overline{X} = \begin{bmatrix} [\overline{x}_{11}, \overline{b}_{11}] & [\overline{x}_{12}, \overline{b}_{12}] & \cdots & [\overline{x}_{1n}, \overline{b}_{1n}] \\ [\overline{x}_{21}, \overline{b}_{21}] & [\overline{x}_{22}, \overline{b}_{22}] & \cdots & [\overline{x}_{2n}, \overline{b}_{2n}] \\ \vdots & \vdots & \ddots & \vdots \\ [\overline{x}_{m1}, \overline{b}_{m1}] & [\overline{x}_{m2}, \overline{b}_{m2}] & \cdots & [\overline{x}_{mn}, \overline{b}_{mn}] \end{bmatrix} \tag{4}$$

i = 1, 2……m; j = 1,2,…….n

Step 5: Determination of weighted normalized DM $\hat{X}$.

$$\hat{x_{ij}} = \overline{x}_{ij} \times q_j \tag{5}$$

$$\hat{b_{ij}} = \overline{b}_{ij} \times q_j \tag{6}$$

where i = 1, 2,.., n; j = 1, 2,.., m, and $q_j$ is the weight of $j^{th}$ attribute.

The matrix is as follows:

$$\hat{X} = \begin{bmatrix} [\hat{x}_{11}, \hat{b_{11}}] & [\hat{x}_{12}, \hat{b_{12}}] & \cdots & [\hat{x}_{1n}, \hat{b_{1n}}] \\ [\hat{x}_{21}, \hat{b_{21}}] & [\hat{x}_{22}, \hat{b_{22}}] & \cdots & [\hat{x}_{2n}, \hat{b_{2n}}] \\ \vdots & \vdots & \ddots & \vdots \\ [\hat{x}_{m1}, \hat{b_{m1}}] & [\hat{x}_{m2}, \hat{b_{m2}}] & \cdots & [\hat{x}_{mn}, \hat{b_{mn}}] \end{bmatrix} \tag{7}$$

Step 6: Evaluate the sums $P_i$ of attribute values.

$$P_i = \frac{1}{2} \sum_{j=1}^{k} \hat{x}_{ij} + \hat{b_{ij}} \tag{8}$$

Step 7: Calculate the sums $R_i$ of attribute values.

$$Ri = \frac{1}{2} \sum_{j=k+1}^{m-k} \hat{x}_{ij} + \hat{b_{ij}} \tag{9}$$

where (m–k) is a attribute's number those are to be to be minimized.

Step 8: Evaluate the minimum value of $R_i$:

$$R_{min} = \min R_i (i = 1, 2. \ldots, m) \tag{10}$$

Step 9: Determine the importance of each alternative $Q_i$ as given below:

$$Q_i = P_i + \frac{\sum_{i=1}^{m} Ri}{R_i \sum_{i=1}^{m} \frac{1}{R_i}} \tag{11}$$

Step 10: Determination of the alternative's maximum weight.

$$Q_{max} = \max Q_i (i = 1, 2. \ldots, m) \tag{12}$$

Step 11: Each alternative's utility degree is obtained:

$$U_i = \frac{Q_i}{Q_{max}} \tag{13}$$

It provides the optimal ranking of alternatives.

## 4 Problem formulation

The selection as well as implementation of ERP system is still a significant challenge for most of the organizations, though vendors and customers have acquired more experience and expertise in establishing the system. Based on literature review, it is utmost important to hire a consultant for achieving the project objective set by organization but no suitable methodology is available in literature for selection of consultant in ERP project. Selecting the most efficient consultant from a pool of consultants is tedious and time-consuming task because various technical and managerial attributes (mentioned in Table 1) has been involved during selection and this problem must be regarded a MCDM problem. Suitable decision-making methodology may select the best consultant who can enhance the quality of system and achieve the targeted goals of organizations.

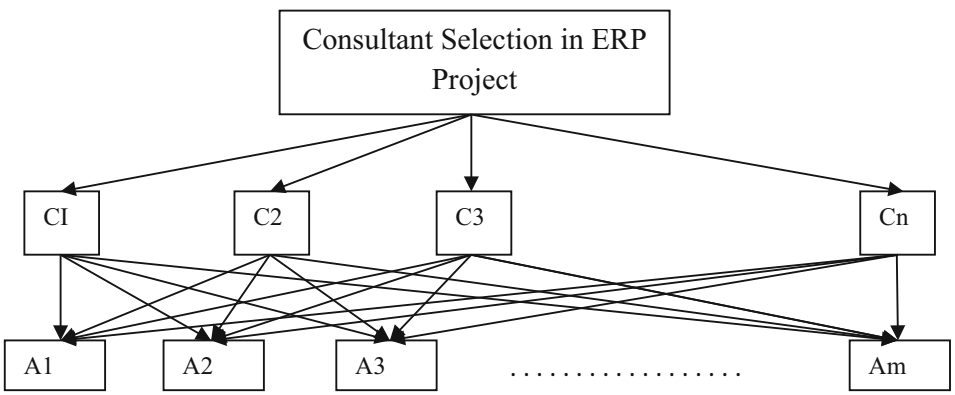


**Fig. 2** Hierarchy structure for evaluation of consultant selection

**Table 2** Definition and MF of Fuzzy Numbers

| Intensity of importance | Fuzzy number | Definition | Membership function |
|---|---|---|---|
| 1 | $\tilde{1}$ | Equally important/preferred | (1, 1, 3) |
| 3 | $\tilde{3}$ | Moderately more important/preferred | (1, 3, 5) |
| 5 | $\tilde{5}$ | Strongly more important/preferred | (3, 5, 7) |
| 7 | $\tilde{7}$ | Very strongly more important/preferred | (5, 7, 9) |
| 9 | $\tilde{9}$ | Extremely more important/preferred | (7, 9, 11) |

**Table 3** Fuzzy PWC matrix for criteria (CR = 0.09646, $\lambda$max = 7.7814)

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| C1 | 1 | $\tilde{3}$ | $\tilde{9}$ | $\tilde{9}$ | $\tilde{7}$ | $\tilde{5}$ | $\tilde{3}$ |
| C2 | $\tilde{3}^{-1}$ | 1 | $\tilde{7}$ | $\tilde{3}$ | $\tilde{5}$ | $\tilde{3}$ | $\tilde{3}$ |
| C3 | $\tilde{9}^{-1}$ | $\tilde{7}^{-1}$ | 1 | $\tilde{3}^{-1}$ | $\tilde{3}^{-1}$ | $\tilde{3}^{-1}$ | $\tilde{5}^{-1}$ |
| C4 | $\tilde{9}^{-1}$ | $\tilde{3}^{-1}$ | $\tilde{3}$ | 1 | $\tilde{3}$ | $\tilde{3}^{-1}$ | $\tilde{3}^{-1}$ |
| C5 | $\tilde{7}^{-1}$ | $\tilde{5}^{-1}$ | $\tilde{3}$ | $\tilde{3}^{-1}$ | 1 | $\tilde{5}^{-1}$ | $\tilde{5}^{-1}$ |
| C6 | $\tilde{5}^{-1}$ | $\tilde{3}^{-1}$ | $\tilde{3}$ | $\tilde{3}$ | $\tilde{5}$ | 1 | $\tilde{3}^{-1}$ |
| C7 | $\tilde{3}^{-1}$ | $\tilde{3}^{-1}$ | $\tilde{5}$ | $\tilde{3}$ | $\tilde{5}$ | $\tilde{3}$ | 1 |

**Table 4** Results OF F-AHP

| Criteria | Weights (w) | $\lambda$ max, $CI, RI$ | CR |
|---|---|---|---|
| C1 | 0.3978 | $\lambda$ max = 7.7814 | 0.09646 |
| C2 | 0.2189 | | |
| C3 | 0.0272 | | |
| C4 | 0.0619 | CI = 0.130233 | |
| C5 | 0.0386 | | |
| C6 | 0.1008 | | |
| C7 | 0.1547 | RI = 1.35 | |

**Table 5** Linguistic variables, fuzzy numbers and grey numbers

| Linguistic variable | TFNs | Gray numbers |
|---|---|---|
| Very low (VL) | (1, 1, 3) | [1, 2] |
| Low (L) | (1, 3, 5) | [2, 4] |
| Medium (M) | (3, 5, 7) | [4, 6] |
| High (H) | (5, 7, 9) | [6, 8] |
| Very high (VH) | (7, 9, 9) | [8, 9] |

## 5 Proposed research methodology

Consultant selection is most important activity in ERP Project. Hence, proper methodology for selection of consultant is essential. In presented article, a hybrid approach based on F-AHP and COPRAS-G is proposed. F-AHP evaluates the weights of criteria and COPRAS-G is applied to get the final ranking of consultants. The hybrid approach has been selected in this work because of its adequacy to methodology offer solutions in a complex MCDM environment. The proposed methodology has been shown in Fig. 1. The following steps of this methodology are as follows:

Step 1: Formation of a team of expert and selection of criteria

In this step, choose the decision makers who have knowledge and experience in ERP project and involved in consultant selection. Decision makers define the consultant requirement for their project and determine the consultant alternatives available in the market. They also find criteria in Table 1 for consultant selection on the basis of the consultation with the industry experts and literature review.

Step 2: Determine the weight of criteria described by Fuzzy AHP

In this step, a questionnaire has been designed for industrial experts for PWC matrices of criteria. These matrices are utilized by the F-AHP which is used to evaluate the weights of the criteria. Section 3.1 details the steps for deciding the criteria weights.

Step 3: Determine the ranking of consultants by COPRAS-G

In this step, best alternative is obtained by using the importance of alternatives that is evaluated by COPRAS-G.

**Table 6** DM for alternatives with grey numbers

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| A1 | [8, 9] | [6, 8] | [6, 8] | [4, 6] | [8, 9] | [2, 4] | [6, 8] |
| A2 | [8, 9] | [6, 8] | [6, 8] | [6, 8] | [8, 9] | [6, 8] | [8, 9] |
| A3 | [6, 8] | [6, 8] | [4, 6] | [8, 9] | [6, 8] | [4, 6] | [6, 8] |
| A4 | [6, 8] | [4, 6] | [6, 8] | [4, 6] | [6, 8] | [6, 8] | [6, 8] |
| Weight | 0.3978 | 0.2189 | 0.0272 | 0.0619 | 0.0386 | 0.1008 | 0.1547 |

**Table 7** The Weighted normalized DM for the consultant alternatives

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| A1 | [0.102658, 0.11549] | [0.050515, 0.067354] | [0.006277, 0.008369] | [0.00971, 0.014565] | [0.009961, 0.011206] | [0.009164, 0.018327] | [0.031464, 0.041953] |
| A2 | [0.102658, 0.11549] | [0.050515, 0.067354] | [0.006277, 0.008369] | [0.014565, 0.01942] | [0.009961, 0.011206] | [0.0274916, 0.036655] | [0.041953, 0.047197] |
| A3 | [0.076994 0.102658] | [0.050515, 0.067354] | [0.004185, 0.006277] | [0.01942, 0.021847] | [0.007471, 0.009961] | [0.018327, 0.027491] | [0.031464, 0.041953] |
| A4 | [0.076994 0.102658] | [0.033677, 0.050515] | [0.006277, 0.008369] | [0.00971, 0.014565] | [0.007471, 0.009961] | [0.027491, 0.036655] | [0.031464, 0.041953] |

**Table 8** Output of COPRAS-G for the alternatives

| Alternatives | $P_i$ | $R_i$ | $Q_i$ | $U_i$ | Rank |
|---|---|---|---|---|---|
| A1 | 0.234761 | 0.013745 | 0.275785 | 1 | 1 |
| A2 | 0.247482 | 0.032073 | 0.265064 | 0.961126 | 2 |
| A3 | 0.220049 | 0.022909 | 0.244663 | 0.887152 | 3 |
| A4 | 0.196807 | 0.032073 | 0.214388 | 0.777375 | 4 |

The procedure for COPRAS-G has been used ranking the consultants are described on Sect. 3.2. Finally, to confirm the robustness of proposed approach, SA has been performed for COPRAS-G.

## 6 Case study on ERP consultant selection problem

Step 1: Formation of a team of expert and selection of criteria

To demonstrate the application of this model in ERP consultant selection problem, five decision makers from 4 different Indian organizations were asked a set of questions pertaining to selection of ERP consultant. These decision makers were involved in choosing ERP consultants. Each decision makers were asked to identify the seven selection criteria from predefined list mentioned in Table 1.

**Table 9** Results of sensitivity analysis

| S. No | Experiment no | A1 | A2 | A3 | A4 |
|---|---|---|---|---|---|
| 1 | QQ12 | 0.274897 | 0.264176 | 0.252432 | 0.208395 |
| 2 | QQ13 | 0.273946 | 0.263225 | 0.232248 | 0.230481 |
| 3 | QQ14 | 0.249546 | 0.26517 | 0.280781 | 0.204403 |
| 4 | QQ15 | 0.275785 | 0.265064 | 0.244663 | 0.214388 |
| 5 | QQ16 | 0.315221 | 0.235431 | 0.250122 | 0.199126 |
| 6 | QQ17 | 0.266813 | 0.268453 | 0.247454 | 0.217179 |
| 7 | QQ23 | 0.275785 | 0.265064 | 0.229917 | 0.229134 |
| 8 | QQ24 | 0.2643 | 0.265893 | 0.254727 | 0.21498 |
| 9 | QQ25 | 0.27668 | 0.265959 | 0.236834 | 0.220428 |
| 10 | QQ26 | 0.292053 | 0.253867 | 0.241705 | 0.212276 |
| 11 | QQ27 | 0.273734 | 0.266278 | 0.242612 | 0.217276 |
| 12 | QQ34 | 0.278323 | 0.264881 | 0.239769 | 0.216927 |
| 13 | QQ35 | 0.275728 | 0.265007 | 0.244281 | 0.214883 |
| 14 | QQ36 | 0.265647 | 0.272042 | 0.240845 | 0.221366 |
| 15 | QQ37 | 0.279857 | 0.262654 | 0.238928 | 0.218461 |
| 16 | QQ45 | 0.271216 | 0.258668 | 0.236896 | 0.20982 |
| 17 | QQ46 | 0.267581 | 0.268957 | 0.248131 | 0.215231 |
| 18 | QQ47 | 0.27196 | 0.263799 | 0.253576 | 0.210564 |
| 19 | QQ56 | 0.267526 | 0.27127 | 0.24352 | 0.217585 |
| 20 | QQ57 | 0.280069 | 0.263445 | 0.24333 | 0.213055 |
| 21 | QQ67 | 0.284931 | 0.258935 | 0.245035 | 0.211 |

Respondent validated and agreed with all criteria reported in the list. The reputed consultants who were involved in ERP project of various organizations in India were selected as Decision makers. The names of consults are with-hold for the reason of privacy.

Step 2: Determine the weight of criteria

Weight of criteria has been evaluated by Fuzzy AHP method. A decision hierarchy is constructed and presented in Fig. 2 with 3 levels. The top level shows the goal of problem. Second level presents selection criteria and bottom level shows the alternatives.

After determining the decision hierarchy, experts were asked for providing their preference ($\widetilde{1}, \widetilde{3}, \widetilde{5}, \widetilde{7}$ and $\widetilde{9}$) through PWC of the criteria to relative importance of each selection criterion using Triangular Fuzzy Numbers (TFN) is presented in Table 2. After finalizing the evaluation of relative importance of selection criteria of ERP consultant, fuzzy comparison matrix for criteria is presented in Table 3.

The weight of each criterion evaluated by fuzzy AHP is mentioned in Sect. 3.1. The results are presented in Table 4. The consistency ratio is less than 0.1, that's why weights are consistent.

Step 3: Determine the final rank of ERP consultant

In this step, COPRAS-G approach is used for final ranking of ERP consultant. Decision makers form the DM mentioned in Table 6 by comparing each alternative with the criteria with grey number scale as presented in Table 5 (Nguyen et al. 2014) (Tables 5, 6).

The data of DM has been normalized by Eqs. 2 and 3. The weighted normalized DM is determined by Eqs. 5 and 6. Finally, alternative weight has been determined by Eqs. 8–13 and presented in Tables 7 and 8. It has been shown in Table 8 that higher the weight $Q_i$ for alternative, higher the rank of alternative. Hence, A1 consultant has highest rank, followed by A2, A3 and A4.

## 7 Sensitivity analysis

Investigating the impacts of the uncertainties to the model is the main aim of SA. To ascertain the robustness of the process and reduce the problem of rank reversal, this analysis has been performed for COPRAS-G. For the determination of the effect of the weights of criteria on decision making, this method has been used to create various scenarios by exchanging different criteria weights that may change the rank of alternatives (Senthil et al. 2014). To study the impact of weights on the selection of ERP consultants, 21 scenarios have been developed by switching the weights of 2 criteria from 7 criteria. In SA, different names are given in experiments such as QQ12 indicates that the weights of the attributes one and two are exchanged. QQ13 means the weight of attributes 1 and 3 are exchanged. Results of SA have been presented in Table 9. Table 9 and Fig. 3 shows that A1 consultant has scored highest 15 times first rank, A2 consultant scores 5 times first rank, A3 consultant scores 1 times first rank in 21 experiments. It shows robustness and low sensitivity of the presented approach to the criteria weights.

## 8 Discussion and conclusions

Appropriate consultant selection may help the organization to choose the right ERP software vendors and to implement ERP with the best approach. They also act as "change agents" right from the beginning of the project. Consultant selection is the combination of management and technical attributes. Here appropriate hybrid methodology of Fuzzy AHP and COPRAS-G has been proven useful to provide effective decision during selection of consultants in ERP project. In this methodology, first the criteria for selection of consultants are evaluated through literature review and discussion with industrial experts. Weight of criteria has been evaluated from Fuzzy AHP by pair wise comparison matrices of expert judgements by considering vagueness of expert opinion. Finally, COPRAS-G has been used for ranking of alternatives by allowing the uncertain information about the criteria. This method is very simple, accurate and flexible. It reduces the number of questions by pair wise comparison matrix as used in fuzzy AHP. Thus, implementation of proposed methodology could be used for solving large scale problems without any constraint. The result shows that top four important criteria for consultant selection in ERP project are reputation, ERP project experience, partner of ERP vendor and cost. The findings are consistent as compared to previous findings (Kumar et al. 2003; Tsai et al. 2007). Reputation is the most important attribute for a consultant selection. Previous ERP project experience of consultant adds advantage to an organization for proper implementation of ERP system. In present scenario, Most ERP system is sector specific, so consultant implementation experience in similar industry / specific industry proves to be good for an organization. Consultants often have good partnership with ERP software vendor, for proper implementation of system and reducing the customization issue. Cost factor is an important criterion as consulting fee accounts a major portion of ERP project cost. The results from SA show that hybrid model of F-AHP and COPRAS-G for selection of consultants in ERP project is very robust and manageable. ERP adapting organizations may utilize this hybrid approach for

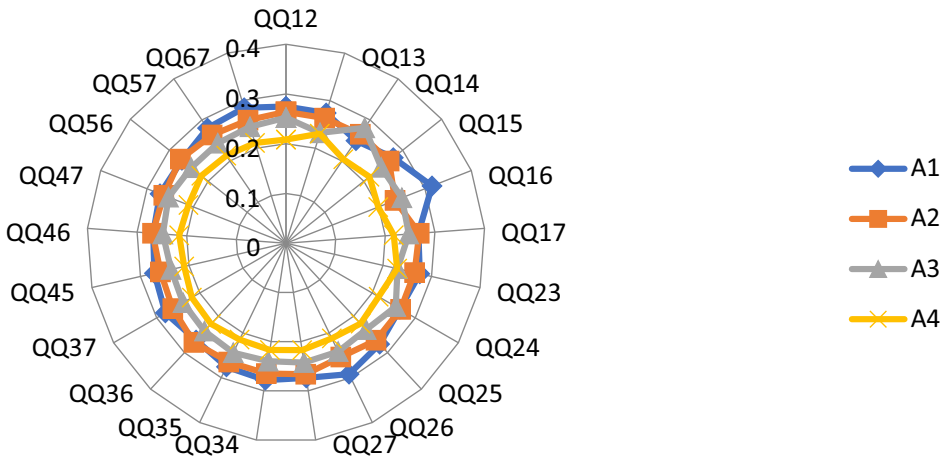


**Fig. 3** Sensitivity analysis in radar chart

selection of consultants. For future study, other MCDM approaches have been applied to solve the similar problem and develop the expert system for selection of consultants in ERP project.

The main limitation of the study is implementation of proposed approach on the consultant selection in ERP project of Indian fertilizer industries only. In Future work, this study could also be implemented on many different types of studies. Some other MCDM approaches could also be applied to solve the same and similar types of problem and to develop the expert system for selection of consultants in ERP project.

**Declarations**

**Conflict of interest** There is no conflict of interest.

**Research involving human participants and/or animals** These is no involvement of Human and/or Animal.

**Informed consent** It is not applicable in presented work.

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## References

Alhakbani NA, Mohammed AA (2012) Consultancy services to ERP systems: case studies from Saudi Arabia. J Theor Appl Inf Technol 37(1):116–124

Aloini D, Dulmin R, Mininno V (2007) Risk management in ERP project introduction: review of the literature. Inf Manag 44:547–567

Barth C, Koch S (2019) Critical success factors in ERP upgrade projects. Ind Manag Data Syst 119(3):656–675

Chan FTS, Chan MH, Tang NKH (2000) Evaluation methodologies for technology selection. J Mater Process Technol 107:330–337

Chang DY (1996) Application of extent analysis method on fuzzy AHP. Eur J Oper Res 95:649–655

Chang JYT, Eric TGW, James JJ, Klein G (2013) Controlling ERP consultants: client and provider practices. J Syst Softw 86(5):1453–1461

Cheng CH, Yang KL, Hwang CL (1999) Evaluating attack helicopters by AHP based on linguistic variable weight. Eur J Oper Res 116:423–435

Cheung FKT, Kuen JLF, Skitmore M (2002) Multi-criteria evaluation model for the selection of architectural consultants. Constr Manag Econ 20:569–580

Deng JL (1989) Introduction to grey system. J Grey Syst 1(1):1–24

Golam K, Sultana SR (2014) Integrating fuzzy analytic hierarchy process with PROMETHEE method for total quality management consultant selection. Prod Manuf Res 2(1):380–399

Grabski SV, Stewart AL (2007) Complementary controls and ERP implementation success. Int J Account Inf Syst 8(1):17–39

Huang SM, Chang IC, Li SH, Lin MT (2004) Assessing risk in ERP projects: identify and prioritize the factors. Ind Manag Data Syst 108(8):681–688

Hung WH, Ho CF, Jou JJ, Kung KH (2012) Relationship bonding for a better knowledge transfer climate: an ERP implementation research. Decis Support Syst 52(2):406–414

Jain N, Yadav VS, Narang HK, Singh AR (2018) Supplier selection through Attractive criteria: a Fuzzy Kano based integrated MCDM approach. In: Proceedings of the international conference on industrial engineering and operations management bandung. pp 1695–1704

Kumar V, Bharat M, Kumar U (2003) An investigation of critical management issues in ERP implementation: empirical evidence from Canadian organizations. Technovation 23:793–807

Li G-D, Yamaguchi D, Nagai M (2008) A grey-based rough decision-making approach to supplier selection. I J Adv Manuf Technol 36(9–10):1032–1040

Maity SR, Chatterjee P, Chakraborty S (2012) Cutting tool material selection using grey complex proportional assessment method. Mater Des 36:372–378

Martinovic N, Delibasic B (2014) Selection of the best consultant for SAP ERP project using combined AHP-IBA approach. Yugosl J Oper Res 24(3):383–398

Nah FF, Lau JL, Kuang J (2001) Critical factors for successful implementation of enterprise systems. Bus Process Manag 7:285–296

Nguyen HT, Dawal STM, Nukman Y, Aoyama H (2014) A hybrid approach for fuzzy multi-attribute decision making in machine

tool selection with consideration of the interactions of attributes. Expert Syst Appl 41:3078–3090
Ozalp V, Ozcan Y, Cunha MMC (2012) ERP consultant selection problem using AHP, fuzzy AHP and ANP: a case study in turkey. J Bus Manag Econ 3(3):106–117
Panorama Consulting group ERP Report (2020)
Plaza M (2016) Balancing the costs of human resources on an ERP project. Omega 59(Part B):171–183
Plaza M, Rohlf K (2008) Learning and performance in ERP implementation projects: a learning curve model for analysing and managing consulting costs. Int J Prod Econ 115:72–85
Ram J, David C, Wu ML (2013) Implementation critical success factors (CSFs) for ERP: do they contribute to implementation success and post implementation performance. Int J Prod Econ 144:157–174
Salmeron JL, Cristina L (2010) A multi criteria approach for risks assessment in ERP maintenance. J Syst Softw 83:1941–1953
Satty TL (1980) Analytic hierarchy process. McGraw-Hill, New York
Senthil S, Srirangacharyulu B, Ramesh A (2014) A robust hybrid multi- criteria decision making methodology for contractor evaluation and selection in third-party reverse logistics. Expert Syst Appl 41:50–58
Shadi AA, Abdulaziz A, Al-Hashbol A (2019) Implementing Enterprise Resource Planning (ERP) system in large Construction Company in KSA. Procedia Comput Sci 164:463–470
Sherry F, Corbett M (2007) ERP implementation: a compilation and analysis of critical success factors. Bus Process Manag J 13(3):329–347
Simon A, Schoeman P, Sohal AS (2010) Prioritised best practices in a ratified consulting services maturity model for ERP consulting. J Enterp Inf Manag 23(1):100–124
Singh AR, Mishra PK, Jain R, Khurana MK (2012) Robust strategies for mitigating operational and disruption risks: a fuzzy AHP approach. Int J Multicrit Decis Mak 2(1):1–28
Sudhaman P, Sharma S (2014) Determining ERP customization choices using nominal group technique and analytical hierarchy process. Comput Ind 65(6):1009–1017
Tsai WH, Lin TW, Chen SP, Hung SJ (2007) Users' service quality satisfaction and performance improvement of ERP consultants selections. Int J Bus Syst Res 1(3):280
Wang ETG, Shin SP, Jiang JJ, Klein G (2008) The consistency among facilitating factors and ERP implementation success: a holistic view of fit. J Syst Softw 81:1609–1621
Yusuf Y, Gunasekaran A, Abthorpe MS (2004) Enterprise information systems project implementation: a case study of ERP in Rolls-Royce. Int J Prod Econ 87(3):251–266
Zavadskas EK, Kaklauskas A (1996) Determination of an efficient contractor by using the new method of multi-criteria assessment. In: Langford DA, Retik A (eds) International Symposium for "The Organisation and Management of Construction". Shaping Theory and Practice, vol 2: Managing the Construction Project and Managing Risk, CIB W 65, London, Weinheim, New York, Tokyo, Melbourne, Madras, London: E and FN SPON, 1996, pp 94–104
Zavadskas EK, Kaklauskas A, Turskis Z, Tamošaitienė J (2008a) Selection of the effective dwelling house walls by applying attributes values determined at intervals. J Civ Eng Manag 14(2):85–93
Zavadskas EK, Turskis Z, Tamošaitienė J, Marina V (2008b) Multi criteria selection of project managers by applying grey criteria. Technol Econ Dev Econ 14(4):462–477
Zavadskas EK, Turskis Z, Tamošaitienė J (2010) Risk assessment of construction projects. J Civ Eng Manag 16(1):33–46