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Selecting "The Best" ERP system for SMEs using a combination of ANP and PROMETHEE methods

Huseyin Selcuk Kilic [a], Selim Zaim [b], Dursun Delen [c,*]

[a] Department of Industrial Engineering, Faculty of Engineering Marmara University, Kadikoy, Istanbul 34722, Turkey
[b] Department of Industrial Engineering, Faculty of Management Istanbul Technical University, Macka, Istanbul, Turkey
[c] Department of Management Science and Information Systems, Spears School of Business Oklahoma State University, Tulsa, OK 74106, USA

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ABSTRACT

Enterprise Resource Planning (ERP) system, which integrates all of the units within an organization at the information level, plays an important role for a successful enterprise. With the right ERP system, it is easier to provide coordination between the units, eliminate waste and make faster and better decisions. Adopting an ERP system is a significant investment decision for a firm, therefore a great deal of attention should be given to the selection of the right system. Since there are a large number of criteria to consider in selecting an ERP system, the process itself is regarded as a complex multi-criteria decision making problem. In this study, two prevalent multi-criteria decision making techniques, Analytic Network Process (ANP) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), are used in combination to better address the ERP selection problem. First, ANP is used to determine the weights of all criteria, and then, the obtained weights are used in the PROMETHEE method for optimal ranking of the alternative system choices. To demonstrate the viability of the proposed methodology, an application case is performed on the ERP selection problem for the Small Medium Enterprises (SMEs) in İstanbul, Turkey. The proposed hybrid methodology successfully ranked the alternatives and identified the best ERP system based on the information obtained from a number of SMEs participated in this study.

1. Introduction

ERP systems can be regarded as the backbone of the information systems in organizations (Yang, Wu, & Tsai, 2007). The roots of ERP systems date back to 1980s, on enterprise information systems like Materials Requirement Planning (MRP) and Manufacturing Resource Planning (MRP II) (Kumar, Maheshwari, & Kumar, 2003). ERP systems present the opportunity to rapidly adapt to the changes at the management levels by integrating and disseminating information to decision makers on an as needed basis (Park & Tran, 2012). The increase in the use of information systems has affected the computing applications in the organizations. Moreover, the complexity of the processes in the organizations has also increased, largely due to the increasing competition at the global scale. Because of these developments, ERP systems have gained importance and popularity as a solution and an enabling technology (Karsak & Özogul, 2009).

As enterprises have gotten bigger and become geographically distributed, the integration of their main activities and processes has become a necessity (Kulvatunyou & Wysk, 2000). Different and diverse pieces of information coming from different processes can be unified by ERP systems for better support of managerial decision making. Main corporate activities such as manufacturing, supply chain management, human resources and finance are integrated and automated by these ERP systems, providing many benefits such as easier reach to trustable information, the elimination of unnecessary information, time saving and low cost can be provided (Baki & Çakar, 2005).

ERP systems are common in large enterprises. Almost all of the big enterprises in the world have implemented some type of ERP system. Only recently (in the last ten years), ERP systems are being used in the small and medium enterprises and being considered as a way to improve efficiency to be (and to stay) competitive. With the use of ERP systems, information in different parts of the organization is combined and stored in a centralized database, by doing so, eliminate multiple data entries/storage, offer a single version of the truth, and provide a much better data visibility (Deep,

* Corresponding author at: Spears and Patterson Endowed Chairs in Business Analytics, Center for Health Systems Innovation, Department of Management Science and Information Systems, Spears School of Business, Oklahoma State University, 700 N. Greenwood Ave., Tulsa, OK 74106, USA. Tel.: +1 (918) 594 8283; fax: +1 (918) 594 8281.

E-mail address: dursun.delen@okstate.edu (D. Delen).

URL: http://spears.okstate.edu/~delen (D. Delen).

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Guttridge, Dani, & Burns, 2008). Recently, ERP has become a strategic tool for providing effective and efficient supply chain management operations in complex and uncertain global supply networks (Xu, 2010).

The ERP system life cycle consists of mainly three phases. These are selection, implementation and use. The activities in the ERP selection phase, which is considered to be the most critical (and perhaps the most time consuming phase) for a successful adaption, are problem identification (i.e., a detailed analysis and characterization of the business system, which would also include a need analysis), requirements specification (i.e., identification and explicit specification of the constraints in which the ERP system has to function), evaluation of options (i.e., identification of the alternative systems and their detailed characterizations) and selection of system (Forslund & Jonsson, 2010).

Numerous techniques such as scoring, ranking, mathematical optimization and multi-criteria decision analysis have been proposed for selection problems. Scoring and ranking methods are regarded as simple. However, within mathematical optimization, goal programming, 0–1 programming and non-linear programming have been used (Wei, Chien, & Wang, 2005). In addition to these analytical techniques, during the selection process a number of criteria need to be taken into consideration. Some of these criteria, as stated by Baki and Çakar (2005), include functionality, technical criteria, cost, service and support, vision, system reliability, compatibility with other systems, ease of customization, market position of the vendor, better fit with organizational structure, domain knowledge of suppliers, references of the vendor, fit with parent/allied organization systems, cross-module integration, implementation time, methodology of the software and consultancy.

Building on the previous research, this study makes a number of unique contributions to the extant literature. First, to the best of our knowledge, there is no research hitherto been recorded employing the ANP weighted PROMETHEE multi-criteria decision making tool in the selection of the ERP software. Our findings show that the combination of the two methods provides pleasingly surprising results where an optimal mapping between the needs/wants and the possible system alternatives can be achieved. Secondly, again to the best of our knowledge, this is the first study to apply ANP weighted PROMETHEE method to the ERP selection problem for SMEs. Lastly, as opposed to solving the selection problem for a single organization, in our study we applied the proposed methodology to a group of organizations (a number of SMEs within a region—Istanbul, Turkey).

Since the adoption/implementation of an ERP system is a costly and risky endeavor, the selection of the "right" ERP system is a critical and difficult decision for any organization. A combined methodology, which is based on ANP and PROMETHEE, is proposed in this study to mitigate this problem. Each of these decision analysis techniques brings capabilities to address specific characteristics of this decision situation, including it being a highly complex multi-criteria decision situation that requires the involvement of a group of decision makers and evaluation of network structure among the decision making system factors. The rest of the paper is organized as follows. A literature review is provided in Section 2. ANP and PROMETHEE methods are briefly explained in Sections 3 and 4, respectively. The proposed methodology and the application case are provided in Section 5. The final discussion and the conclusions are given in Section 6.

2. Literature review

Although the roots of the ERP systems go way back to MRP and MRP II (Kumar et al., 2003), the current manifestation of these systems has emerged in the 1990s. Therefore, the studies that dealt with the adoption and real-world implementation of ERP systems are not very old. As Aloini, Dulmin, and Mininno (2007) stated, the extent of literature review about ERP systems can be allocated into four main groups: ERP selection, ERP implementation, ERP risk management and general ERP projects. In order to stay within the scope of this study, in this literature review, we mainly focused on the previous studies that dealt with ERP selection problem, while partially covering other, somewhat indirectly related studies, in order to make a complete yet concise presentation of the state of the art.

The research literature that reports on ERP systems is quite large and rather fragmented; while many have dealt with the pre-adoption problems, many more have studied problems during and after the adoption of ERP systems. Few have tried to build simple taxonomies to better understand the extant literature on ERP system studies. For instance, Umble, Haft, and Umble (2003) presented the implementation procedures and determined the critical success factors for ERP systems and Genoulaz, Millet, and Grabot (2005) provided a literature review about ERP systems, where they have analyzed and categorized the literature into six groups: implementation of ERP, optimization of ERP, management through ERP, the ERP software, ERP for supply chain management and case studies. On a somewhat limited study that applies specifically to the pre- and during adoption of the ERP system, Ziaee, Fathian, and Sadjadi (2006) proposed an approach that consists of two stages. In their approach within the first stage the project teams are established, information about the possible ERP providers is gathered and all relevant ERP system properties are determined. In the second stage, a binary mathematical optimization model was proposed to minimize the total cost related to the expenses of procurement, implementation and integration of the system.

One of the key components in ERP system selection is the identification and assessment of the main factors to include in the decision making process. Sun, Yazdani, and Overend (2005) proposed a methodology about the critical factor assessment for the success of ERP adoption and implementation. Accordingly, they identified management/organization, process, technology, data and people as the most critical success factors. Similarly, Yang et al. (2007) determined and discussed a set of factors for the successful implementation of ERP systems. The factors that they have identified were coding system, working process reengineering, priority of ERP functionality, implementation, customization, participant roles, consultant role and performance level of the subcontractors. Olson (2007) looked at the problem slightly differently; instead of focusing on the procurement of the ERP system, he focused on outsourcing of these services. He analyzed and evaluated inherent factors of outsourcing option of ERP system and showed how multiple-criteria decision making techniques could be used for making such decision. Velcu (2007), on the other hand, looked at the after the adoption stage of the ERP systems by investigating the impact of ERP systems on the performance of the organizations by conducting a survey among the Finnish companies.

Use of analytical techniques for the selection of ERP systems problem has been a focal point of ERP studies since early 2000s. For instance, Ayağ and Özdemir (2007) used fuzzy ANP as the methodology for the selection of ERP software and presented a case study in a firm in electronics sector and Perçin (2008) also proposed ANP as a viable decision making tool for ERP selection problem. The criteria used in the study are divided into two groups: system factors (i.e., functionality, strategic fitness, flexibility, user friendliness, implementation time, total costs, and reliability) and vendor factors (i.e., market share, financial capability, implementation ability, R&D capability, and service support). With this study, they showed the utility and versatility of ANP for this complex selection problem. Similarly, Ünal and Güner (2009) and Cebeci (2009) proposed a methodology based on AHP and fuzzy

AHP respectively for ERP supplier selection for an organization in the textile industry. A similar application of fuzzy AHP was also performed in an automotive company for the selection of ERP outsourcing firm (Kahraman, Beskese, & Kaya, 2010). With another study, Şen, Baraçlı, Şen, and Başlıgil (2009) showed the viability of a combined decision making methodology for the ERP selection problem. Within the proposed methodology, the fuzzy set theory and random experiment based methods are combined and successfully applied to both quantitative and qualitative factors.

Hakim and Hakim (2010) presented a strategic modeling plan for the evaluation and selection of ERP systems. The decision making process adopted in this study has taken into account all three organizational levels: strategic, technical and executive. Malhotra and Temponi (2010) carried out a study where they aimed to recommend the best practices for the identification of critical organization decisions for the ERP selection and implementation problem. The critical organization decisions identified by their study included project team structure, implementation strategy, database conversion strategy, transition technique, risk management strategy and change management strategy.

The ERP system studies that successfully combined more than one multi-criteria decision making methods seemed to be the ones that have reported the most satisfying results. A representative example of such was executed by Lin, Chen, and Ting (2011). In their study they proposed a hybrid methodology that combined strengths of ANP, TOPSIS and LP. They successfully applied their methodology to the supplier selection problem, and embedded the model in the ERP system as a perpetual decision aid mechanism. Using a combination of methods, Maditinos, Chatzoudes, and Tsairidis (2011) investigated a wide range of the factors affecting ERP system implementation, claiming success that exceeds the user expectation. A hybrid methodology including ANP, Choquet integral (CI) and Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) was developed by Gürbüz, Alptekin, and Işıklar Alptekin (2012) to determine the best ERP package. Another hybrid methodology was proposed by Kilic, Zaim, and Delen (2014), they used fuzzy AHP and TOPSIS for the selection of ERP software for an airline company.

There are a large number of studies dealing with ERP system selection problem. What is covered in this section is just the tip of the iceberg. The recent literature included in this review serves for the purpose of designating our study as a novel contributor to the body of knowledge. Even though the literature on ERP system selection problems is large, to the best of our knowledge, there is no other study that synergistically combined ANP and PROMETHEE methods within the same framework to address the ERP selection problem, and no other study addressed the problem within the context of a collection of SMEs.

3. Analytic Network Process

Analytic Network Process (ANP) which is the method used to obtain the ranked importance (i.e., weights) of the ERP selection criteria was the first step of our proposed methodology. ANP is chosen because of its superiority in addressing the complex network structure exists in the ERP selection criteria. ANP, which is one of the widely used multi-criteria decision making techniques, was first proposed by Saaty (1996). It is a generalization of Analytic Hierarchy Process (AHP), which was also developed by Saaty (1980) (Lee, Kim, Cho, & Park, 2009). AHP has been used for a number of applications in a wide variety of fields that include performance evaluation (Kilic, 2011; Kilic & Cevikcan, 2012), environmental impact assessment (Kaya & Kahraman, 2011), job selection (Kilic & Cevikcan, 2011), maintenance strategy selection (Zaim, Turkyilmaz, Acar, Al-Turki, & Demirel, 2012), management of intellectual capital assets (Calabrese, Costa, & Menichini, 2013) and bank account selection (Ishizaka & Nguyen, 2013). The main difference between AHP and ANP is that ANP looks at the problem space more holistically by taking into consideration the dependence and feedback among the criteria (Saaty, 1996; Şevkli et al., 2012). Recently, there have been a lot of studies reporting on the application of ANP to variety of problems and industries that include the selection of logistics service provider (Jharkharia & Shankar, 2007), identification of core technologies (Lee et al., 2009), measurement of the sectoral competition level and performance (Dağdeviren & Yüksel, 2010; Tsai, Chou, & Leu, 2011), SWOT analysis for airline industry (Şevkli et al., 2012), R&D project evaluation (Jung & Seo, 2010), performance evaluation for hot spring hotels (Chen, Hsu, & Tzeng, 2011), evaluation of green suppliers (Büyüközkan & Çifçi, 2012), selection of non-traditional machining processes (Das & Chakraborty, 2011), evaluation of green supplier development programs (Dou, Zhu, & Sarkis, 2014), maintenance performance indicator selection (Horenbeek & Pintelon, 2014), machine tool selection (Nguyen, Dawal, Nukman, & Aoyama, 2014), product development (Zaim et al., 2014), just to name a few.

Generally speaking, there are four main stages in the application of ANP (Lee et al., 2009). These steps are (1) network model construction, (2) pairwise comparisons and priority vector creation, (3) supermatrix formation and transformation, and (4) determination of final rankings/priorities. Based on several previous reported successful applications of ANP (Yang, Chuang, & Huang, 2009; Yazgan, Boran, & Goztepe, 2009; Şevkli et al., 2012), the main steps of ANP used in this study are provided in Appendix A.

4. PROMETHEE

After obtaining the importance weights of the ERP selection criteria via ANP, PROMETHEE method is utilized to determine the best ERP system choice/firm. First developed by Brans (1982), PROMETHEE is one of the most prevalent multi-criteria decision making techniques. It consists of a family of outranking methods such as PROMETHEE I, II, III, IV, V and VI. Because of its proper match (which is determined based on the recent literature and extensive experimentation conducted herein), within the scope of this study, PROMETHEE II will be used. There are a number of interesting applications where PROMETHEE is successfully applied such as equipment selection (Yilmaz & Dağdeviren, 2011), stock trading (Albadvi, Chaharsooghi, & Esfahanipour, 2007), portfolio selection (Vetschera & Almeida, 2012), material selection (Peng & Xiao, 2013) and so on.

The steps used in the specific process of applying PROMETHEE method are provided in Appendix B (Behzadian, Kazemzadeh, Albadvi, & Aghdasi, 2010).

5. Proposed methodology and application case

The purpose of this study is to select the best ERP software with special emphasis on small and medium sized enterprises (SMEs) doing business in and around Istanbul, Turkey. For this aim, a three stage methodology including pre-evaluation, ANP and PROMETHEE stages is proposed as depicted in Fig. 1. Within the pre-evaluation stage and all other stages, as mentioned before, a group of experts including ERP consultants and practitioners who have been in the ERP sector for a long time are employed. All of the discussions, knowledge elicitations and evaluations related with the identification and comparison of criteria and selection alternatives were determined with the support of these experts. The other two stages are the core parts of the methodology including ANP and PROMETHEE techniques. The technical background about these techniques is provided in the previous sections. After determining the

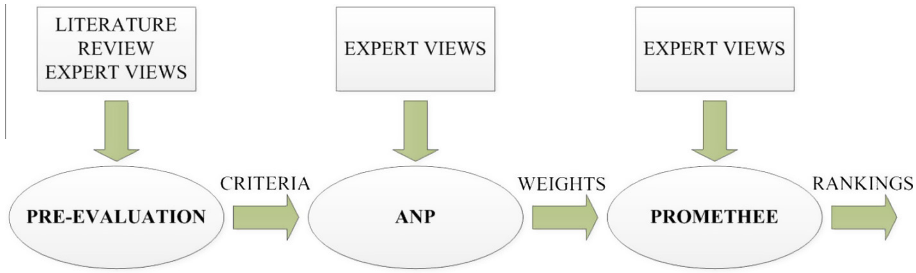

Fig. 1. Combined methodology based on ANP and PROMETHEE.

criteria and alternatives at the end of the pre-evaluation stage, the importance weights of the criteria are found using ANP method; then, the best alternative is determined via performing the required steps of PROMETHEE method.

The reason for choosing the combination of ANP and PROMETHEE is based on these decision modeling techniques' strengths and suitability to the current decision situation. Selecting the most suitable ERP system is a complex and challenging decision in any sector. Historically, more than half of the IT projects failed before realizing their projected ROI. Among the most prevailing reasons is the lack of suitability between the needs of the organization and the characteristics of the system. Furthermore, the additional challenges imposed upon SMEs industry due to the changing global economic conditions and big competition make such a decision even more complicated and challenging. Each of these decision analysis techniques brings capabilities to address specific characteristics of this decision situation, including it being a highly complex multi criteria decision situation that requires the involvement of a group of decision makers and evaluation of network structure among the decision making system factors. A methodology that synergistically combines the strengths of these techniques is proposed herein as a logical MCDM solution to this problem. Also, a large number of published studies, where some combinations of these multi-criteria decision making techniques are used successfully in various areas, are evidence to their strength and suitability.

The specific reason of combining these techniques in our study can be described as follows: within the first stage of the problem, where the underlying structure of the problem is determined, the decisions/tasks/choices are naturally judgmental. This is where we determine the criteria and the weights of the criteria, a technique that is capable of evaluating both tangible and intangible factors is needed, and at this point a highly regarded technique "ANP" which also incorporates interrelationships among the decision making factors is employed. In the following stage, another popular technique "PROMETHEE" is used to rank the alternatives from the best to the worst. There are several reasons for using PROMETHEE. First of all, it is an outranking method suitable for ranking the alternatives among conflicting criteria. The second is that PROMETHEE is a rather simple ranking method with respect to conception and application when compared with the other MCDM methods. Third one is the popularity of it, as Behzadian et al. (2010) state in its comprehensive literature review study, there is a noticeable increase in the number of practitioners applying the PROMETHEE method to various multi-criteria decision making problems.

Besides the strength and suitability of these techniques, another motivation of using these techniques collectively is that, to the best of our knowledge, this is the first study that uses ANP and PROMETHEE for ERP system selection problem. In the study of Behzadian et al. (2010), the use of PROMETHEE technique is analyzed in a variety of applications. Their study indicated that although there are a number of applications using PROMETHEE individually and collectively, there is not an application where all two are used collectively and on the ERP system selection problem.

The application of the proposed methodology is performed in SMEs which can be defined as an enterprise employing fewer than 250 employees according to both the Turkish State Institute of Statistics (SIS) and Turkish Small Business Administration. For many years as the most populated and the largest city in Turkey, Istanbul accounts for nearly 75% of total capital investment, generating close to 23% of Turkish GNP (Berköz & Eyüboglu, 2005). According to the KOSGEB (i.e., small and medium business administration) database, Istanbul accounts for 28% of all SMEs registered in Turkey.

Within the pre-evaluation stage, based on the review of the existing literature and semi-structured interviews undertaken with ERP experts, a list of clusters and related criteria were generated. The list of criteria determined this way was classified into three main groups which are listed and briefly described as below:

- ***Business criteria:*** Vision, brand image, references and market position.
- ***Cost criteria:*** Purchasing cost, implementation cost and service and support cost.
- ***Technical criteria:*** Functionality, reliability, compatibility and cross-module integration.

Besides the criteria, after a series of brainstorming and knowledge elicitation sessions, the scope of systems to evaluate is reduced to five ERP suppliers, coming from both international and local firms. These five firms were SAP, Oracle, Axapta, Uyumsoft and Workcube.

After determining the criteria and alternatives at the end of the pre-evaluation stage, the first step of ANP, network structure formation, is obtained. With the multi-session brainstorming and knowledge elicitation held with the formed group members (i.e., domain/industry experts), the criteria and the interdependencies among the criteria clusters were identified. At the beginning of the process, the opinion of each expert is collected individually, and then, several focus group studies have been performed until a consensus has been provided. Based on the consolidated findings, the final model (i.e., the network diagram) is developed. Fig. 2 shows relationship between clusters (outer dependency) and within the cluster (inner dependency) in a simple network diagram. The interdependencies among the clusters are shown by using two-way arrows. Regarding the business criteria cluster, vision of the company was found to have impact on brand image, market position and purchasing cost. On the other hand, reference criterion within the same cluster found to have impact on brand image, market position and reliability of the company. With respect to the cost criteria cluster, purchasing cost was found to have influence on implementation cost, service and support cost within the cost cluster, and brand image and market position in the business cluster, and functionality in the technical cluster.

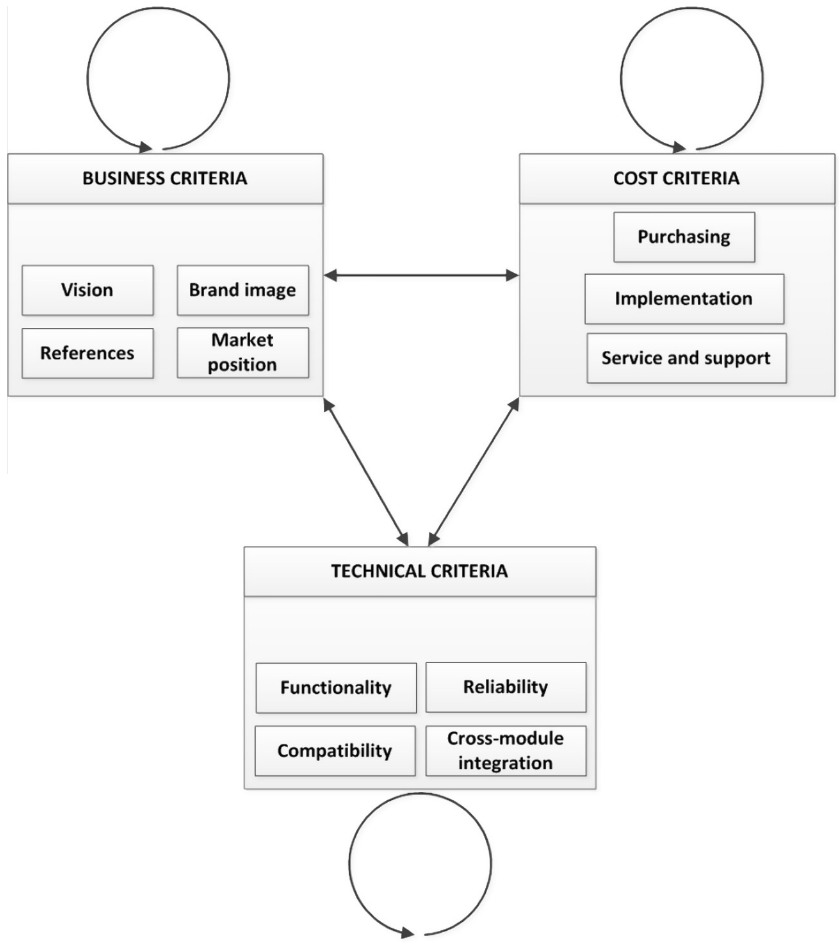

Fig. 2. The network diagram used in the study.

Implementation cost was found have an impact on compatibility and cross-module integration. Service and support cost criterion was found to have influence on brand image and references criteria. Regarding the technical cluster, cross-module integration criterion was found to have an effect on functionality in the same cluster and also purchasing, implementation and service and support cost criteria within the cost cluster; the reliability criterion was found to have an impact on implementation cost and references criteria. Functionality has influence on compatibility and each criterion in the cost cluster. On the other hand compatibility was found to affect functionality and cross-module integration.

After performing the first step of ANP which is the network structure formation, the second and the third steps of ANP are performed using a specialized software package. In short, the factor priority values are determined after assuring the consistency of comparison matrices and the unweighted super matrix, the weighted super matrix and the limit super matrix. The detailed findings of these two steps are summarized in tables and are shown in Tables C1–C3 in the appendix. Once the super matrixes are calculated, the final weights of the criteria are found, and are shown in Table 1.

After finding the aggregated weights of the criteria by applying ANP, the third stage PROMETHEE method was taken into consideration. For determining the related preference function of each criterion, a detailed study was conducted with a group of ERP experts. All of the preference functions were examined and their conformity to the properties of the ERP selection criteria was assessed. After this tedious evaluation process, it is decided to select and use V-shape preference function for all the criteria. Based on the results of our experimentations, the parameter value "*p*" of the V-shape function is set to 2 for all the criteria. Since there were qualitative criteria besides quantitative criteria, it is decided to use 1–5 scale for criteria evaluation. Within the scale, "1" indicated the worst situation and "5" indicated the best situation with respect to the related criterion. The evaluation of alternative ERP firms with respect to each criterion is performed based on the compromise assessments of experts. The selected preference functions and the values of the related parameters are given as in Table 2.

The evaluations of alternatives with respect to each criterion based on 1–5 scale are also shown in Table 3. To hide the names of the firms, they are shown as A, B, C, D and E.

Table 1
The weights of the criteria.

No	Criterion	Weight (%)
1	Brand image	10.99
2	Market position	4.39
3	References	3.61
4	Vision	1.25
5	Implementation cost	8.67
6	Purchasing cost	22.18
7	Service & support cost	12.40
8	Compatibility	10.16
9	Cross-module integration	7.72
10	Functionality	16.41
11	Reliability	2.22

Table 2
Preference function and parameter values for each criterion.

No	Criterion	Preference function	Parameter value
1	Brand image	V-shape	$p = 2$
2	Market position	V-shape	$p = 2$
3	References	V-shape	$p = 2$
4	Vision	V-shape	$p = 2$
5	Implementation cost	V-shape	$p = 2$
6	Purchasing cost	V-shape	$p = 2$
7	Service & support cost	V-shape	$p = 2$
8	Compatibility	V-shape	$p = 2$
9	Cross-module integration	V-shape	$p = 2$
10	Functionality	V-shape	$p = 2$
11	Reliability	V-shape	$p = 2$

Table 3
The score of alternatives with respect to each criterion.

Criterion	Alternatives				
	A	B	C	D	E
Brand image	4	4	3	2	2
Market position	5	2	3	2	2
References	5	3	3	2	1
Vision	4	4	3	2	3
Implementation cost	2	2	2	3	3
Purchasing cost	2	2	2	3	3
Service & support cost	1	2	2	4	4
Compatibility	3	3	4	2	2
Cross-module integration	5	4	4	3	2
Functionality	3	3	3	3	4
Reliability	3	3	3	2	2

Table 4
Outranking flows of the alternatives.

Alternative	$\Theta(+)$	$\Theta(-)$	$\Theta(\text{net})$
A	0.244	0.203	0.041
B	0.164	0.207	−0.044
C	0.185	0.220	−0.035
D	0.223	0.231	−0.008
E	0.292	0.247	0.046

The required operations of PROMETHEE method are accomplished and the detailed steps are shown in the D Tables in the Appendix. In short, the positive, negative and net outranking flows are obtained as shown in Table 4.

Regarding the net values (i.e., $\Theta(\text{net})$), it was concluded that the ranking of the ERP suppliers are to be E, A, D, C and B. Once the final rankings are obtained, a series of follow-up meetings are conducted with the domain experts to assess the validity of results. Based on the feedback received from the domain experts, the combined methodology worked very well in determining the best ERP vendors in a complex multi-criteria decision situation. Perhaps one of the most prevailing outcomes was the domain experts' high-level of confidence in the findings because of the collaborative and collective way the study was conducted.

6. Discussion and conclusions

ERP systems play a significant role in helping organizations to quickly adapt to the changing environment around them. In practice, ERP systems can be developed internally (e.g., via an in-house development of an integrated information systems using their computing resources), but due to the complexity and difficulty associated with this process vast majority of companies chose to procure it by either purchasing it from a third-party provider or simply outsource it to another IT company altogether. The cost of ERP systems can change between a few hundred-thousand dollars to hundreds of millions of dollars, based on the size and complexity of the system. For SMEs in Istanbul, Turkey, procurement of an ERP system costs a few million dollars, constituting approximately 10% of a mid-size SMEs' annual revenues (Olsen, 2004). Therefore, many SMEs consider the selection and implementation of and ERP system as a critical business endeavor.

One of the most important tools/enablers for a firm to be competitive in its sector is using the right ERP package that meets and exceeds the information needs and requirements. At this point, selecting the most suitable ERP package plays an important role. There are various studies in the recent literature proposing different techniques to provide a solution to this complex and critical selection problem. With this study, different from the existing ones, a combined methodology (based on ANP and PROMETHEE) that takes into account the strengths of both methods to "optimize" the search space under various criteria is proposed. An application case regarding several ERP suppliers for SMEs in Istanbul, Turkey was performed to show the viability and validity of the proposed methodology. In the first step, ANP was used to obtain the importance weights of the criteria. The network structure showing the relations between the criteria was constructed and the evaluation of experts for the comparison of criteria was processed to obtain the importance weights. The obtained importance weights were then used in the PROMETHEE method to find the optimal rankings of the ERP suppliers.

As it is shown in Table 1, cost, including implementation, purchasing and service & support, was found as the most important main criterion accounting for approximately 43% of all the criteria with respect to their importance. The importance weights of purchasing cost, service & support cost and implementation cost were found as 22.18%, 12.40% and 8.67% respectively. On the other hand, three criteria named as vision, reliability, and references were found to have the lowest importance weights as 1.25%, 2.22% and 3.61% respectively.

These results reflect the perception of ERP systems by SME's in Turkey. The reason of the cost being the most important criterion is that the decisions are mainly based on economic motives and often on short term goals. Since the decisions are not made for medium and long term goals, the criteria such as vision and reliability did not have the expected importance. That is probably why most of the ERP projects had failed in the past.

For further studies, different multi-criteria decision making techniques such as VIKOR, ELECTRE can be used and comparison of the results can be presented. Moreover, fuzzy decision making environment can also be considered in the selection models. Perhaps, the most serious limitation of this study is its narrow focus on Turkish SMEs. Regarding this situation, this study can be generalized for the other emerging countries as well as the other sectors such as service and government in the further studies.

Appendix A. The steps of ANP technique

Step 1 – Network structure formation: Given a comprehensive set of criteria, which determined from the application domain experts, first step involved in determining the relationships between/among the criteria, sub-criteria and alternatives, and are shown in a graphical network structure. The relationships captured in this step constitute both within clusters and between clusters.

Step 2 – Formation of pairwise comparisons and obtaining local priority values; Depending on the relations in the network structure, pair-wise comparisons are performed and the

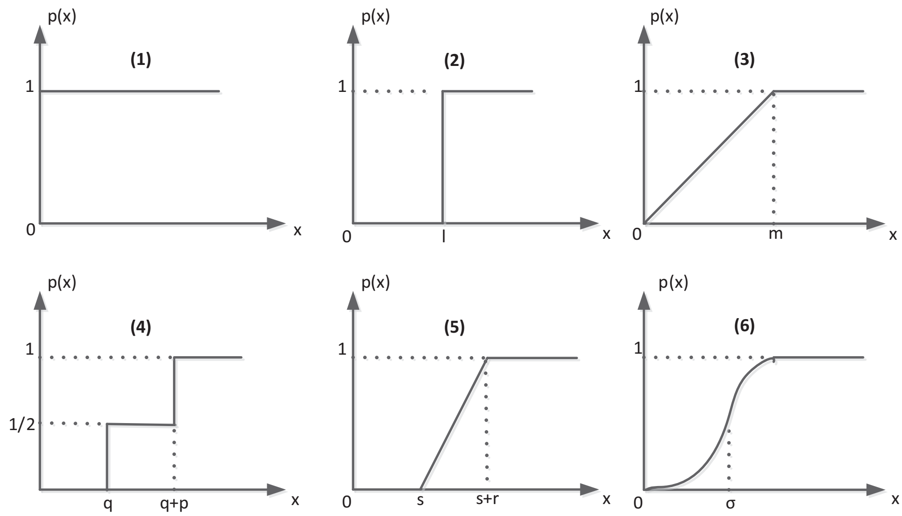

Fig. B1. Preference functions.

Table C1
Unweighted super matrix.

	Brand image	Market position	References	Vision	Implementation cost	Purchasing cost	Service & support cost	Compatibility	Cross-module integration	Functionality	Reliability
Brand image	0	0	0.24998	0.75	0	0.25	0.75	0	0	0	0
Market position	0	0	0.75002	0.25	0	0.75	0	0	0	0	0
References	0	0	0	0	0	0	0.25	0	0	0	1
Vision	0	1	0	0	0	0	0	0	0	0	0
Implementation cost	0	0.1958	0	0	0	0.24998	0	0	0.1958	0.24931	1
Purchasing cost	1	0.49339	0	1	0	0	0	0	0.49339	0.59363	0
Service & support cost	0	0.31081	0	0	0	0.75002	0	0	0.31081	0.15706	0
Compatibility	0	0	0	0	0.5	0	0	0	0	1	0
Cross-module integration	0	0	0	0	0.5	0	0	0.33333	0	0	0
Functionality	0	0	0	0	0	1	0	0.66667	1	0	0
Reliability	0	0	1	0	0	0	0	0	0	0	0

Table C2
Weighted super matrix.

	Brand image	Market position	References	Vision	Implementation cost	Purchasing cost	Service & support cost	Compatibility	Cross-module integration	Functionality	Reliability
Brand image	0	0	0.09662	0.21308	0	0.04895	0.75	0	0	0	0
Market position	0	0	0.28987	0.07103	0	0.14685	0	0	0	0	0
References	0	0	0	0	0	0	0.25	0	0	0	0.23245
Vision	0	0.2841	0	0	0	0	0	0	0	0	0
Implementation cost	0	0.14017	0	0	0	0.12334	0	0	0.1263	0.16081	0.76755
Purchasing cost	1	0.35321	0	0.7159	0	0	0	0	0.31825	0.38291	0
Service & support cost	0	0.22251	0	0	0	0.37005	0	0	0.20048	0.10131	0
Compatibility	0	0	0	0	0.5	0	0	0	0	0.35497	0
Cross-module integration	0	0	0	0	0.5	0	0	0.33333	0	0	0
Functionality	0	0	0	0	0	0.31081	0	0.66667	0.35497	0	0
Reliability	0	0	0.61351	0	0	0	0	0	0	0	0

priority value of each factor in the network structure is obtained. During this step, the following operations are utilized:

After assigning the values of pair-wise comparisons in the comparison matrix, local priority vector is calculated from eigenvector, which is calculated using Eq. (1). A, w and λ_{max} correspond to pair-wise comparison matrix, eigenvector and eigenvalue, respectively in the equation.

$$Aw = \lambda_{max} w \tag{1}$$

Table C3
Limit super matrix.

	Brand image	Market position	References	Vision	Implementation cost	Purchasing cost	Service & support cost	Compatibility	Cross-module integration	Functionality	Reliability
Brand image	0.10998	0.10998	0.10998	0.10998	0.10998	0.10998	0.10998	0.10998	0.10998	0.10998	0.10998
Market position	0.04394	0.04394	0.04394	0.04394	0.04394	0.04394	0.04394	0.04394	0.04394	0.04394	0.04394
References	0.03614	0.03614	0.03614	0.03614	0.03614	0.03614	0.03614	0.03614	0.03614	0.03614	0.03614
Vision	0.01248	0.01248	0.01248	0.01248	0.01248	0.01248	0.01248	0.01248	0.01248	0.01248	0.01248
Implementation cost	0.08667	0.08667	0.08667	0.08667	0.08667	0.08667	0.08667	0.08667	0.08667	0.08667	0.08667
Purchasing cost	0.22182	0.22182	0.22182	0.22182	0.22182	0.22182	0.22182	0.22182	0.22182	0.22182	0.22182
Service & support cost	0.12396	0.12396	0.12396	0.12396	0.12396	0.12396	0.12396	0.12396	0.12396	0.12396	0.12396
Compatibility	0.10157	0.10157	0.10157	0.10157	0.10157	0.10157	0.10157	0.10157	0.10157	0.10157	0.10157
Cross-module integration	0.07719	0.07719	0.07719	0.07719	0.07719	0.07719	0.07719	0.07719	0.07719	0.07719	0.07719
Functionality	0.16406	0.16406	0.16406	0.16406	0.16406	0.16406	0.16406	0.16406	0.16406	0.16406	0.16406
Reliability	0.02218	0.02218	0.02218	0.02218	0.02218	0.02218	0.02218	0.02218	0.02218	0.02218	0.02218

Table D1
Deviation $d_j(x,y)$ values based on the pair-wise comparisons.

	A–B	A–C	A–D	A–E	B–A	B–C	B–D	B–E	C–A	C–B	C–D	C–E	D–A	D–B	D–C	D–E	E–A	E–B	E–C	E–D
Brand image	0	1	2	2	0	1	2	2	−1	−1	1	1	−2	−2	−1	0	−2	−2	−1	0
Market position	3	2	3	3	−3	−1	0	0	−2	1	1	1	−3	0	−1	0	−3	0	−1	0
References	2	2	3	4	−2	0	1	2	−2	0	1	2	−3	−1	−1	1	−4	−2	−2	−1
Vision	0	1	2	1	0	1	2	1	−1	−1	1	0	−2	−2	−1	−1	−1	−1	0	1
Implementation cost	0	0	−1	−1	0	0	−1	−1	0	0	−1	−1	1	1	1	0	1	1	1	0
Purchasing cost	0	0	−1	−1	0	0	−1	−1	0	0	−1	−1	1	1	1	0	1	1	1	0
Service & Support cost	−1	−1	−3	−3	1	0	−2	−2	1	0	−2	−2	3	2	2	0	3	2	2	0
Compatibility	0	−1	1	1	0	−1	1	1	1	1	2	2	−1	−1	−2	0	−1	−1	−2	0
Cross-Module integration	1	1	2	3	−1	0	1	2	−1	0	1	2	−2	−1	−1	1	−3	−2	−2	−1
Functionality	0	0	0	−1	0	0	0	−1	0	0	0	−1	0	0	0	−1	1	1	1	1
Reliability	0	0	1	1	0	0	1	1	0	0	1	1	−1	−1	−1	0	−1	−1	−1	0

Table D2
Preference function $P_j(x,y)$ values.

	A–B	A–C	A–D	A–E	B–A	B–C	B–D	B–E	C–A	C–B	C–D	C–E	D–A	D–B	D–C	D–E	E–A	E–B	E–C	E–D
Brand image	0	0.5	1	1	0	0.5	1	1	0	0	0.5	0.5	0	0	0	0	0	0	0	0
Market position	1	1	1	1	0	0	0	0	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0
References	1	1	1	1	0	0	0.5	1	0	0	0.5	1	0	0	0	0.5	0	0	0	0
Vision	0	0.5	1	0.5	0	0.5	1	0.5	0	0	0.5	0	0	0	0	0	0	0	0	0.5
Implementation cost	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0	0.5	0.5	0.5	0
Purchasing cost	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0	0.5	0.5	0.5	0
Service & support cost	0	0	0	0	0.5	0	0	0	0.5	0	0	0	1	1	1	0	1	1	1	0
Compatibility	0	0	0.5	0.5	0	0	0.5	0.5	0.5	0.5	1	1	0	0	0	0	0	0	0	0
Cross-module integration	0.5	0.5	1	1	0	0	0.5	1	0	0	0.5	1	0	0	0	0.5	0	0	0	0
Functionality	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0.5	0.5
Reliability	0	0	0.5	0.5	0	0	0.5	0.5	0	0	0.5	0.5	0	0	0	0	0	0	0	0

Table D3
$\Pi(x,y)$ values.

	A–B	A–C	A–D	A–E	B–A	B–C	B–D	B–E	C–A	C–B	C–D	C–E	D–A	D–B	D–C	D–E	E–A	E–B	E–C	E–D
$\Pi(x,y)$	0,12	0,18	0,34	0,34	0,06	0,06	0,24	0,29	0,11	0,07	0,25	0,3	0,28	0,28	0,28	0,06	0,36	0,36	0,36	0,09

$$A = \begin{bmatrix} a_{11} & a_{12} & . & . & . & a_{1n} \\ a_{21} & a_{22} & . & . & . & a_{2n} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ a_{n1} & a_{n1} & . & . & . & a_{nn} \end{bmatrix}$$

The matrix (A), which is showing the pairwise comparison between the factors, is calculated using Eq. (2). In this equation, a_{ij} indicates the pairwise comparison value in the pairwise comparison matrix (A).

$$A = [a_{ij}]_{n\times n} \quad i = 1,2,\ldots,n \quad j = 1,2,\ldots,n \tag{2}$$

Then, the normalized pairwise comparison matrix B is obtained. The normalized matrix B consists of b_{ij} values, which are calculated using Eq. (3).

$$B = \begin{bmatrix} b_{11} & b_{12} & . & . & . & b_{1n} \\ b_{21} & b_{22} & . & . & . & b_{2n} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ b_{n1} & b_{n1} & . & . & . & b_{nn} \end{bmatrix} \quad (3)$$

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad i = 1,2,\ldots,n \quad j = 1,2,\ldots,n$$

The eigenvector (W) is obtained by obtaining the eigenvalues (w_i) using Eq. (4).

$$W = \begin{bmatrix} w_1 \\ w_2 \\ . \\ . \\ . \\ w_n \end{bmatrix}, \quad and \quad w_i = \frac{\sum_{i=1}^{n} b_{ij}}{n} \quad for \quad i = 1,2,\ldots,n \quad (4)$$

After that, $\lambda_{\max}$ is obtained using Eq. (5) and the consistency property is checked after performing the Eqs. (6) and (7). CI, RI and CR denote consistency indicator, random indicator and consistency ratio, respectively. RI is obtained from a standard random index table showing the random index values for different number of criteria regarded. Consistency ratio must be smaller than 0.10.

$$W' = AW = \begin{bmatrix} w'_1 \\ w'_2 \\ . \\ . \\ . \\ w'_n \end{bmatrix}, \quad and \quad \lambda_{\max} = \frac{1}{n}\left(\frac{w'_1}{w_1} + \frac{w'_2}{w_2} + \cdots + \frac{w'_n}{w_n}\right) \quad (5)$$

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1} \quad (6)$$

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \quad (7)$$

Step 3 – Formation of the unweighted, weighted and limit super matrixes and obtaining final priority values: By locating the local priority vectors on convenient columns, the super matrix (called as partition matrix) is obtained. In general, the sum of one column in super matrix is greater than 1. Unless a stochastic super matrix is obtained, the cluster is weighted and normalization is performed to obtain a stochastic matrix where the sum of column values is 1. This newly obtained super matrix is often called as weighted super matrix (Yazgan et al., 2009; Şevkli et al., 2012).

If k displays a big random number, an increase is provided in the supermatrix to power $2k + 1$ and so there becomes an approximation to limit, which is the importance weight. The new matrix is then called limit super matrix. By normalizing the each column in the super matrix, the priorities of the alternatives can be obtained (Yazgan et al., 2009; Şevkli et al., 2012).

Appendix B. The steps of PROMETHEE technique

Step 1: Based on the pair-wise comparisons, deviations are obtained as in the Eq. (8). $d_j(a,b)$ shows the difference of the alternatives' evaluations ($g_j(a)$ and $g_j(b)$) with respect to the criterion "j".

$$d_j(a,b) = g_j(a) - g_j(b) \quad (8)$$

Step 2: The chosen preference functions are utilized to obtain the preference of alternative "a" with regard to alternative "b" ($P_j(a,b)$) as shown in the Eq. (9).

$$P_j(a,b) = F_j[d_j(a,b)] \quad j = 1,\ldots,k \quad (9)$$

Six types of preference functions are used in the PROMETHEE method (Dağdeviren & Eraslan, 2008; Vincke & Brans, 1985). As shown in Fig. B1, these are usual criterion (1), U-shape criterion (2), V-shape criterion (3), level criterion (4), V-shape with indifference criterion (5) and Gaussian criterion (6).

One of the critical points while applying the PROMETHEE method is to determine the most suitable preference function. Depending on the function, parameters change and this can affect the solution. So a great attention should be taken while determining the preference functions.

Step 3: Global (overall) preference indexes are computed as in the Eq. (10). $\Pi(a,b)$ can be defined as the weighted sum of $p(a,b)$ (alternative "a" over alternative "b") of for each criterion and w_j shows the weight of the jth criterion.

$$\forall a,b \in A, \quad \Pi(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j \quad (10)$$

Step 4: Positive outranking flow $\phi^+(a)$ and negative outranking flow $\phi^-(a)$ values are computed as in the Eq. (11).

$$\phi^+(a) = \frac{1}{n-1}\sum_{x\in A}\Pi(a,x) \quad \phi^-(a) = \frac{1}{n-1}\sum_{x\in A}\Pi(x,a) \quad (11)$$

Step 5: Net outranking flows ($\phi(a)$) are determined for each alternative as in the Eq. (12).

$$\phi(a) = \phi^+(a) - \phi^-(a) \quad (12)$$

Appendix C. The matrices obtained within the application of ANP

Tables C1–C3

Appendix D. The detailed tables about the steps of PROMETHEE

Tables D1–D3

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