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ERP consultant selection problem using AHP, fuzzy AHP and ANP: A case study in Turkey

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In the information technology industry, projects are often carried out simultaneously and with limited human resources, being of major relevance to adequately allocate consultants (using either the company's own consultants or outsourcing) to each project. At the company analyzed, consultants' allocation to concurrent projects, especially when outsourcing is done, is complex. To solve the decision problem, the Project Resource Planning method (PRP), Analytic Hierarchy Process (AHP), fuzzy AHP and Analytic Network Process (ANP)-based methodologies were used. The experiments suggested that both AHP and fuzzy AHP led to the same results, but neither of these considered the interactions within decision elements during the selection process, while ANP, which takes into account these interactions, most correctly weighs the sub-criteria and gives the best composite weights.

Keywords: Analytic Hierarchy Process (AHP); Analytic Network Process (ANP); Consultant selection; fuzzy AHP; Multi-criteria decision making; Project management

INTRODUCTION

This paper discusses the application of Project Resource Planning (PRP) in Anadolu Bilişim Hizmetleri A.Ş. (ABH), one of the most prominent companies in the information technologies (IT) industry in Turkey, and one of the 50 fastest growing technology companies, according to the results of Deloitte Fast50 Turkey 2009 (Deloitte, 2009).

ABH offers project management, consultancy and application development (both structural and nonstructural) in different platforms. The company also provides support and training services in various fields from organizational IT planning, infrastructure design and operation, and optional custom application development to improving and optimization of business processes via Enterprise Resources Planning (ERP) solutions. Its activity is mostly based on consultants, here referred to as its resources. Each resource deals with several projects simultaneously, and each project is undertaken by a project team consisting of a number of resources. In brief, a consultant deals with more than one project with different team-mates in each, and hence the adequate assignment of resources to projects is critical and determinant to the success or failure of the project. It is, however, a complex problem, because of all the parameters involved, as this paper highlights. This study aims at supporting the selection and flow of consultants within various projects efficiently, via PRP applications, contributing to ABH's success with its projects in terms of the parameters time, cost and quality, suggested by Zarnekow *et al.*, (2006).

The word "project" with its broad meaning can be defined as a set of activities which occur only once, in a specified time frame, with specific goals and conditions; in other words, two projects cannot be completely equal (Project Management Institute, 2004). Different intervenients may be needed in different phases of the project, and are assigned according to the tasks requirements and consultants' skills (Madic et al., 2011; Sridhar et al., 2009). Besides the assignment issue, it is

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necessary to coordinate the participants' tasks in projects (Madic et al., 2011). Due to the characteristics of humans, they probably will not accomplish all their tasks with the same harmony (psychological effects on human beings, which do not affect machines, cultural differences, etc., should be considered). As a result, human resources management is a major factor influencing a project success (Belout and Gauvreau, 2004; Karen and Vasudevan, 1985; Zmud, 1980).

In companies, the size and duration of the projects and the number of people involved can be very high and face such complexities, that efficient and effective project management becomes vitally important. Consultants should be assigned or allocated in such a way that the efficiency of the projects in terms of time, cost and quality should be accomplished. To achieve this, a technique called PRP (Project Resource Planning) is used (Al-jibouri, 2002; Deckro and Hebert, 2003; Gollenbeck-Sunke and Schultmann, 2010; Hiermann and Höfferer, 2003).

Studies made in ABH using PRP were divided into two main parts. In the first part, the Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) were used, which enabled the company to manage the activities of projects effectively; to determine the critical activities required to finish the projects without any delay; at the same time, it was defined the possibilities to finish the projects within given time limits (Hebert and Deckro, 2011; Laslo, 2010). Supported by the studies of the first part, some criteria were determined in order to enable the project leader to assign consultants to the projects. By means of these and other criteria, Multi Criteria Decision Making (MCDM) techniques (Massam, 2002; Xu et al., 2007) were used in the second part to select the best consultant, where more than one alternative exists.

Decision making involves many criteria and sub-criteria used to rank the alternatives of a decision, analyzing dependencies between alternatives and implications of these in terms of higher goals (Power and Sharda, 2007; Saaty, 2008; Xu et al., 2007). Within the MCDM, the authors have defined a model to support the selection of the most suitable consultant using the Analytic Hierarchy Process (AHP) (Saaty, 1980, 2008), Fuzzy Analytic Hierarchy Process (Fuzzy AHP) (Chang, 1996) and Analytic Network Process (ANP) (Saaty, 1996, 2005) techniques. A method from the literature, called Fuzzy Analytic Network Process (Fuzzy ANP) (Kahraman et al., 2006), was not handled in detail due to its computational complexity.

Organizations need to have a tool to support decision-making concerning the "optimal" or the best possible allocation of resources to projects (Carazo et al., 2010; Gutjahr et al., 2010; Saremi et al., 2009; Yang and Chou, 2011), and literature offer many examples and case studies. By presenting this case study with the application of different techniques to the ERP consultants selection, this paper contributes to a better understanding of the methodologies to be used by organizations face with this complex problem.

The second section of the paper presents a literature survey on project scheduling and MCDM methods. Section three introduces the problem and section four is dedicated to the application of the methods. Section five presents and discusses some results and section six concludes the paper with some discussion about the outcomes.

LITERATURE REVIEW

The concept of PRP is newly established, so there are not many research studies directly related to it. Instead, various research articles are found about project scheduling and MCDM methods, which are important parts of PRP.

PRP for modeling project scheduling in situations involving diminishing returns was studied by several authors, e.g. (Deckro, 2003; Al-jibouri, 2002; Hebert, 2011). In project scheduling issues, PERT (Project Evaluation and Review Technique) is applied in multi-objective resource allocation problems (Azaron et al., 2006). After understanding the activities of the projects, efficient schedules are necessary to accomplish these activities within time limits. For this purpose, two commonly used project scheduling techniques, CPM and PERT, are used.

The AHP process, introduced by Saaty in the seventies, (Saaty, 1980) has been one of the most extensively used methods for MCDM and has been extensively studied and refined since then. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, relating these elements to overall goals, and for evaluating alternative solutions. AHP has been used to solve MCDM problems in several different areas such as economic planning, energy policy, project selection, budget allocation (Soh, 2010), software selection (Štemberger et al., 2009) among other.

ANP is a more general form of the AHP, used in MCDM. While AHP structures a decision problem into a hierarchy with a goal, decision criteria and alternatives, the ANP structures the problem as a network. Both then use a system of pair-wise comparisons to measure the weights of the components of the structure, and finally to rank the alternatives in the decision (Saaty, 2005).

Many valuable contributions in the MCDM field are mentioned in different literature (Daşdemir and Güngör, 2002; Ho et al., 2010), and the most relevant contributions are synthesized in Table 1.

Given that the main PRP solution approach is a broad concept, it is needed to focus on some closer approaches

Table 1: Relevant contributions to the MCDM from the literature

Authors	Contribution
Zadeh (1965)	Introduced the fuzzy set theory in situations with incomplete and uncertain information, in order to model the imprecision of human decision-making.
Saaty (1980)	First application and implementation of AHP.
Al-Harbi (2001)	Application and implementation of AHP in project management.
Felek et al. (2002)	Application of AHP and ANP in the determination of market share in mobile communication industry and comparison of results.
Başlıgil (2005)	Application of fuzzy AHP in the software selection.
Akman and Alkan (2006)	Application of fuzzy AHP to the evaluation of performance measurement of suppliers in the automotive industry.
Chang et al. (2007)	Utilization of AHP and ANP decision models in Evaluating digital video recorder systems
Liang et al. (2008)	Utilization of ANP in Enterprise information system project selection
Gümüş (2000)	Utilization of fuzzy AHP in the evaluation of hazardous waste transportation firms.
Wang et al. (2008)	Discussed the shortcomings of fuzzy AHP extent analysis method.
Gencer and Gürpınar (2007)	Discussed ANP application in a supplier selection problem.
Sevkli et al. (2008)	Proposed the analytical hierarchy process weighted fuzzy linear programming model (AHP-FLP)" for supplier selection problems.
Demirtas et al. (2008)	Utilization of ANP in supplier selection and definition of optimum quantities among selected suppliers to maximize the total value of purchasing and minimize the budget and defect rate.
Dağdeviren et al. (2008)	Implementation of fuzzy ANP to identify faulty behavior risk in work systems.
Saaty (2005)	Decision making with the ANP
Liu and Wang (2009)	An integrated fuzzy approach (fuzzy delphi, fuzzy inference, and fuzzy linear assignment) for providers evaluation and selection.

under the PRP concept and to examine these approaches in detail. For this purpose, the study includes two phases: (1) project scheduling issues and (2) MCDM methods. For the first phase - project scheduling issues -, CPM and PERT enables the company to manage the activities of projects effectively.

With the help of the analysis undertaken in the first phase, the project leader needs to know the details of the projects that she/he handles and in this way she/he may define the selection criteria for consultants for specific activities of the projects. After the definition of all the selection criteria, MCDM methods are used in a second phase to conduct to the optimal consultant selection.

Within the MCDM methods, the authors established a model to select the best consultant using AHP, fuzzy AHP and ANP. Fuzzy ANP was not handled in detail due to its computational complexity. ANP was selected due to its compatible structure with the structure of the selection problem and the existence of a useful software program to perform its mathematical calculations. Furthermore, the shortcomings of the other methods are explained in detail with examples.

PROBLEM Definition

As many projects are concurrent in time, it is very important to assign the most suitable resources to each project, considering simultaneously various constraints. These assignments can be performed in three ways: (1) Completely from inside the company, (2) Partially outsourcing, and (3) Totally outsourcing.

Here the word "outsourcing" means that the assignment of the consultants to the projects is performed by means of other IT companies, i.e., it consists of hiring consultants of other IT companies to take part in the projects of ABH Company. The business processes department of ABH Company has some problems with the identification of the adequate assignments and this fact becomes a relevant problem especially when outsourcing is performed.

The Problem Model

The problem has a hierarchy with four levels which are discussed in this section. The overall objective is placed at level 1, criteria at level 2, attributes at level 3, and the decision alternatives at level 4. The main objective here is the selection of the most suitable consultant for the sample company. The criteria to be considered in the selection are cost, work experience, education level, and communication ability. According to these decision elements, the hierarchy for the problem is presented in Figure 1.

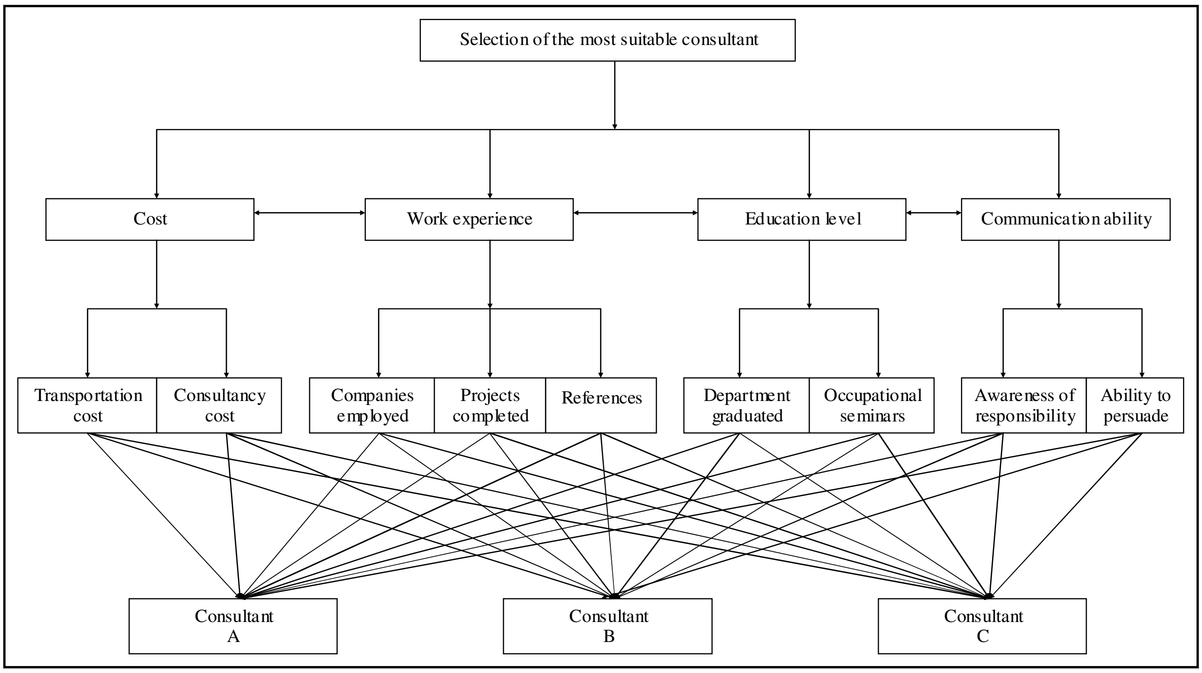

Figure 1. The hierarchy for the consultant selection problem

The Definition of Criteria

The most suitable consultant selection problem is modeled with decision making criteria, sub-criteria and alternatives. Alternatives are at the end of the hierarchy.

- **Cost (CO)**

  -Transportation Cost (TC): The cost that arises from the consultants transportation travel to the working place.
  -Consultancy Cost (CC): The payment made to the consultants due to their consultancy.

- **Work experience (WE)**

  -Companies Employed (CE): Defines in which companies consultants are employed.
  -Projects Completed (PC): Defines in which projects consultants have taken part.
  -References (R): Defines the references of the consultants.

- **Education level (EL)**

  -Department Graduated (DG): Points out the department from which the consultants graduated.
  -Occupational Seminars (OS): Points out the occupational seminars in which the consultants participated so far.

- **Communication ability (CA)**

  -Awareness of Responsibility (AR): Refers to the responsibility of the consultants in terms of their job.
  -Ability to Persuade (AP): Refers to the consultants´ ability to persuade customers in order to purchase IT products and implement IT projects.

Decision alternatives

The decision alternatives correspond to the set of consultants where the selection for a given project is to take place: Consultant A, Consultant B and Consultant C.

APPLICATION

The problem of selecting the most adequate consultant is systematically considered by the decision makers of the company under analysis. In this paper AHP, fuzzy AHP and ANP approaches were used to help in solving this problem. This section introduces the application of AHP,

Table 2. Comparison matrix for criteria using AHP

	Cost	Work experience	Education level	Communication ability
Cost	1	1/3	3	1/5
Work experience	3	1	5	1/3
Education level	1/3	1/5	1	1/3
Communication ability	5	3	3	1

Table 3. Fuzzy comparison matrix for criteria

	Cost	Work experience	Education level	Communication Ability
Cost	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/5, 1/2, 2/3)
Work experience	(2/3, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(2/3, 1, 3/2)
Education level	(2/3, 1, 3/2)	(2/5, 1/2, 2/3)	(1, 1, 1)	(2/3, 1, 3/2)
Communication ability	(3/2, 2, 5/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)

fuzzy AHP and ANP and compares the results obtained.

Application of AHP

As its name implies Analytic Hierarchy Process, considers the problem in a hierarchical way. At the top of the hierarchy there is a goal that is affected only by decision criteria, which are on the second level in hierarchy. If there exist sub-criteria (the third level in hierarchy), these are only affected by criteria, and finally, at the bottom of the hierarchy there will be alternatives, which are only affected by sub-criteria (if there are no sub-criteria, alternatives are affected by main-criteria).

After defining the relative importance of all the decision criteria via pair-wise comparisons, the results of the pair-wise comparisons are represented in a comparison matrix. Table 2 shows the comparison matrix for the criterion defined as the goal. It results from the analysis of the relative weight among all the possible combinations of decision criteria.

Then the normalization of this matrix is necessary in order to find the relative weights of all the decision criteria. The normalization process requires dividing the elements of each column by the sum of the elements of the same column. Up to this point, decision criteria were compared and their relative weights calculated. The normalization leads to the following weights: Cost 0.135; Work experience 0.284; Education level 0,085 and communication ability 0.496. Now, comparison and weighting of the sub-criteria in terms their main-criteria will be handled in the same way.

So far, comparison and weighting of decision criteria and sub-criteria were handled. Now it is time to compare all the decision alternatives with respect to each decision sub-criteria. After evaluating all the decision alternatives with respect to the decision sub-criteria the calculation of weights for each decision element in AHP is complete. All the weights are given in Figure 2. According to these weights, the composite weight for each consultant is calculated and consultants are ranked based on their composite weights.

Composite weight for Consultant A equals: 0.135 * (0.125*0.430 + 0.875*0.133) + 0.284 * (0.260*0.284 + 0.633*0.474+ 0.107*0.648) + 0.085 * (0.250*0.600 + 0.750*0.643) +0.496 * (0.500*0.230 + 0.500*0.455) = 0.372

In the same way, the composite weights for consultants B and C are 0.299 and 0.329 respectively. According to AHP, the best alternative is Consultant A.

Application of Fuzzy AHP

Fuzzy means imprecise or not being exact and fuzzy AHP is the fuzzy version of AHP. To understand fuzzy AHP better, it is needed to talk about fuzzy set theories. An everyday conversation contains many vague expressions such as “the girl next door is pretty” or “the man I saw in the street is fat” (Tanaka, 1996). As seen, these expressions are completely subjective and not true for everyone. The man on the street may not be fat or the girl next door may not be pretty depending on the perceptions of different people. Fuzzy sets were proposed to deal with such vague expressions. On the other hand, when exactly defined expressions are point of issue, it is *used the conventional* set theory called crisp sets. Table 3 shows comparison matrix for criteria with respect to the goal with fuzzy numbers. Using Table 3, fuzzy synthetic extent values are found as:

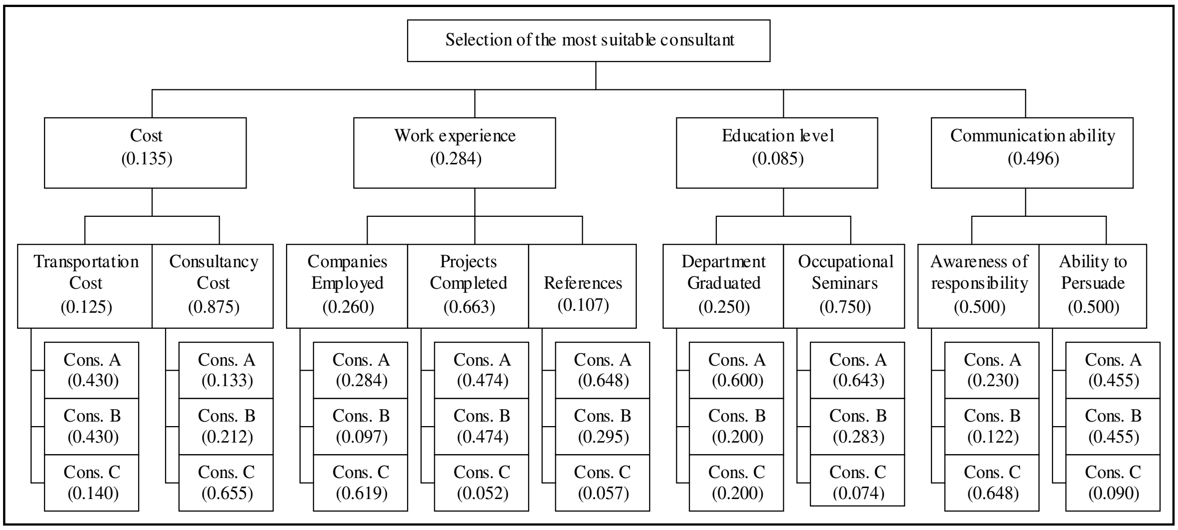

Figure 2. Relative weights of all decision elements in AHP

S_{CO} = (2.74, 3.50, 4.67)*(1/22.34, 1/17.00, 1/13.16) = (0.12, 0.21, 0.35);
S_{WE} = (3.84, 5.00, 6.50)*(1/22.34, 1/17.00, 1/13.16) = (0.17, 0.29, 0.49);
S_{EL} = (2.74, 3.50, 4.67)*(1/22.34, 1/17.00, 1/13.16) = (0.12, 0.21, 0.35);
S_{CA} = (3.84, 5.00, 6.50)*(1/22.34, 1/17.00, 1/13.16) = (0.17, 0.29, 0.49).
Then the possibility of one criterion being greater than or equal to another criterion is found as:
V ($S_{co} \geq S_{WE}$) = 0.69, V ($S_{co} \geq S_{EL}$) = 1.00, V ($S_{co} \geq S_{CA}$) = 0.69;
V ($S_{EL} \geq S_{Co}$) = 1.00, V ($S_{EL} \geq S_{WE}$) = 0.69, V ($S_{EL} \geq S_{CA}$) = 0.69;
V ($S_{WE} \geq S_{Co}$) = 1.00, V ($S_{WE} \geq S_{EL}$) = 1.00, V ($S_{WE} \geq S_{CA}$) = 1.00;
V ($S_{cA} \geq S_{CO}$) = 1.00, V ($S_{cA} \geq S_{WE}$) = 1.00, V ($S_{cA} \geq S_{EL}$) = 1.00.
According to the above possibilities (these are not probabilities, in fuzzy logic), non-normalized weighted matrix is found as W* = (0.69, 1, 0.69, 1), and after normalization, is obtained the normalized final matrix W = (0.204, 0.296, 0.204, 0.296).

According to extent analysis method, weights of Cost, Work Experience, Education Level and Communication Ability are 0.204, 0.296, 0.204 and 0.296 respectively.
In the same way, comparison of sub-criteria with respect to criteria and comparison of alternatives with respect to sub-criteria are performed in a hierarchical way and all the weights assigned to all decision elements are found out. The weight of sub-criteria Transportation Cost is zero because the three consultants present the same Transportation Cost (0.333). All the weights in fuzzy AHP are given in Figure 3.

According to these weights, is calculated the composite weight for each consultant and consultants are ranked based on their composite weights.
The composite weight for Consultant A equals:
0.204* (0*0.33 + 1*0.15) + 0.296* (0.33*0.47 + 0.45*0.50 + 0.22*0.58) + 0.204*(0.50*0.33 + + 0.50*0.58) + 0.296* (0.50*0.33 + 0.50*0.50) = 0.396
In the same way, the composite weights for consultants B and C are 0.314 and 0.290 respectively. According to fuzzy AHP the best alternative is Consultant A. The result is the same as in AHP. In both cases, Consultant A is the best alternative, but the second best alternative is not the same using the two methods. There is some conflict within two methods when the second best alternative is considered.

Application of ANP

Many decision problems cannot be built as in a hierarchical structure as modeled in both AHP and fuzzy AHP. Interactions and/or dependencies within the elements of the same hierarchy usually happen. Also the interactions may be in various levels of hierarchy, for instance the top level may affect the bottom level due to the structure of the model. In such situations, the ANP (Analytic Network Process) should be used, instead of AHP and fuzzy AHP. ANP is a quantitative judgment process like AHP, but it is based on the interactions among various levels in decision hierarchy (Wu and Lee, 2007).

In the modeling of this problem, interactions within sub-criteria are not considered. For instance, due to the high number of “Occupational Seminars” (OS), “References”

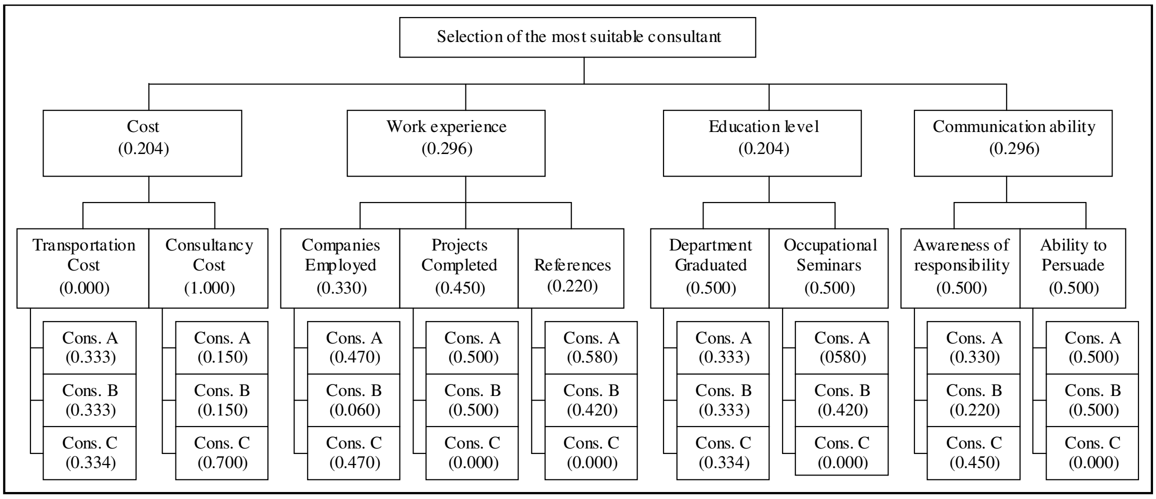

Figure 3. Relative weights of all decision elements in fuzzy AHP

(R) of a consultant may increase. In other words, References sub-criterion is affected by the Occupational Seminars sub-criterion. Moreover, due to fine “References” the consultant may be given “Occupational Seminars”. In this case Occupational seminars sub-criterion is affected by the References sub-criterion. This way, there is a mutual dependence within these two sub-criteria, which should be considered in the evaluations. In the same way, there are other influences within the sub-criteria and these are determined by the decision maker as stated in Table 4.

In this model, it is appropriate and enough to establish interactions only within the sub-criteria cluster, but in different models, there may be interactions among other clusters such as the alternatives and the main-criteria. In such a case, the decision maker should consider the interactions within alternative cluster in addition to criteria and/or sub-criteria clusters. However, for the selection of the best consultant model, it is not appropriate to assume such an interaction within alternatives, because these alternatives are independent from each other, the abilities of one of them do not affect the other two.

After introducing the influences among the sub-criteria in the model, sub-criteria will be pair-wise compared with respect to their effect to a specific sub-criterion. For instance, consider the “Consultancy Cost” (CC) sub-criterion. It is affected from TC, CE, PC, OS and AP. All of the TC, CE, PC, OS and AP will be pair-wise compared with respect to CC and their weights in terms of CC will be found. If “Transportation Cost” (TC) sub-criterion is examined, it is seen that it is only affected by CC; as a result no pair-wise comparisons can be made with respect to TC. CC will be given a weight of 1 with respect to TC. This procedure applied to “Consultancy Cost” and “Transportation Cost” sub-criteria, will be applied to all of other sub-criteria by using the affecting sub-criteria.

After weighting the sub-criteria by considering interactions among them, all of the decision alternatives will be pair-wise compared with respect to each of the sub-criterion. After these calculations, the weighted super matrix will be constructed and converted to the limit matrix in order to find out the constant effect of each sub-criterion on the other sub-criteria. Then the weights of sub-criteria will be combined with the weights assigned to each decision alternative with respect to each sub-criterion and will be found the composite weights for all the three alternatives.

Then, all these weights will be displayed in the weighted super-matrix given in Table 5.

From the weighted super matrix, it is seen that TC is affected only by CC; as a result, CC has a weight of 1 on TC. In the same way, CC is affected from TC, CE, PC, OS and AP with weights of 0.044, 0.246, 0.476, 0.096 and 0.138 respectively. Here be aware that, the total of each column must be equal to 1 and in order this condition to be satisfied, all of the criteria must be affected by at least one of the other or the same sub-criteria. When this is not true, that is, when a criterion is not affected from any of the criteria; the next step which is the establishment of limit matrix fails for this calculation type. In such cases, in order the limit matrix not to fail, Consultant A, Consultant B and Consultant C rows and columns must be added to the weighted matrix, which actually makes manual calculations more difficult.

After defining the weighted super-matrix, the limit matrix can be established as given in Table 6. By means of the limit matrix, the constant effect of each sub-criterion on all of the other sub-criteria is determined. To achieve this, a higher power of the weighted super-matrix

Table 4. Interactions within Sub-criteria in ANP

Affected Sub-Criteria	Affecting Sub-Criteria
Transportation cost (TC)	CC
Consultancy cost (CC)	TC, CE, PC, OS, AP
Companies employed (CE)	CC, PC, R, DG, OS, AR
Projects completed (PC)	CE, R, OS, AP
References (R)	CE, PC, OS, AR, AP
Department graduated (DG)	AR
Occupational seminars (OS)	CE, PC, R, DG
Awareness of responsibility (AR)	PC
Ability to persuade (AP)	PC, OS

Table 5. Weighted super-matrix in ANP

		Affected Sub-Criteria								
		TC	CC	CE	PC	R	DG	OS	AR	AP
Affecting Sub-Criteria	TC	0	0.044	0	0	0	0	0	0	0
	CC	1	0	0.180	0	0	0	0	0	0
	CE	0	0.246	0	0.269	0.060	0	0.164	0	0
	PC	0	0.476	0.365	0	0.475	0	0.617	1	0.250
	R	0	0	0.244	0.124	0	0	0.055	0	0
	DG	0	0	0.045	0	0	0	0.159	0	0
	OS	0	0.096	0.106	0.546	0.230	0	0	0	0.750
	AR	0	0	0.060	0	0.090	1	0	0	0
	AP	0	0.138	0	0.061	0.145	0	0	0	0

Table 6. Limit matrix in ANP

	65th power of weighted super-matrix									Final weights of sub-criteria
	TC	CC	CE	PC	R	DG	OS	AR	AP	
TC	0.001108	0.001106	0.001106	0.001105	0.001105	0.001108	0.001101	0.001106	0.001104	0.001
CC	0.025143	0.025111	0.025116	0.025078	0.025078	0.025001	0.025001	0.025110	0.025052	0.025
CE	0.133351	0.133184	0.133211	0.133010	0.133010	0.133345	0.132603	0.133178	0.132872	0.133
PC	0.311680	0.311288	0.311351	0.310883	0.10883	0.311666	0.309930	0.311274	0.310558	0.311
R	0.084073	0.083968	0.083985	0.083858	0.083858	0.084070	0.083501	0.083964	0.083771	0.084
DG	0.043005	0.042951	0.042960	0.042895	0.042895	0.043003	0.042764	0.042949	0.042851	0.043
OS	0.232393	0.232100	0.232147	0.231798	0.231798	0.232382	0.231088	0.232090	0.231556	0.232
AR	0.058647	0.058573	0.058585	0.058532	0.058532	0.058644	0.058317	0.058570	0.058436	0.059
AP	0.034716	0.034673	0.034680	0.034628	0.034628	0.034715	0.034521	0.034671	0.034592	0.034

must be calculated. If this is done, all the values in a row will converge to the same decimal. It is taken the 65th (2^6+1) power of the weighted super-matrix and seen that since the numbers in each row converge to the same decimal, the values in each row are nearly the same. Table 6 shows the limit matrix for the ANP method.

Nearly the same numbers in each row gives the final weight of that sub-criterion. For instance, the final weight of TC is approximately 0.001. This is an extremely small weight, because when interactions are modeled, it is decided that TC only affects CC with a weight of 0.044 and does not affect any other criteria. As a result, it has such an extremely low weight.

Now, it may be thought that eliminating the small effect of TC and what fuzzy AHP says is the same thing. Yes, after defining the interactions it is seen that TC has an extremely small weight and could be eliminated, but since fuzzy AHP does not consider the interactions within sub-criteria and decides the elimination of the effect of TC by only comparing it with CC, this method is not true. In brief, it is not a good idea to eliminate the small effect of TC in fuzzy AHP when it has the small effect in ANP. If TC was affected by more than one sub-criterion, its weight would be increased in ANP.

As stated in the limit matrix, the weights of each sub-criterion were determined. The total of the weights of sub-criteria is not equal to 1, it is 0.922. This variation is due to the calculations performed in the establishment of the limit matrix. It is assumed that the convergence in the 65th power of the weighted super matrix is enough to establish the limit matrix. If it was taken 32nd power of weighted super matrix, the total weight of the sub-criteria would be nearly 0.960 and again the three decimals would be the same for nearly all the rows, but since more precise values are desired in the rows (nearly 4 decimals are the same for each row) 65th power of the weighted super matrix is taken. On the other hand, it is not a big problem the total of weights not equal to 1. In such case the normalization of the weights are suggested and as a result, their total will be equal to one. As explained above, the normalized new weights of the sub-criteria are listed in Table 7.

Now, if the weights given to each decision alternative with respect to each decision sub-criterion are found, then it is easy to find the composite weight of each alternative (consultant). As stated in AHP, each decision alternative was evaluated with respect to each decision sub-criterion. The same weights assigned in AHP will be used. Table 8 lists the weights of consultants with respect to the decision sub-criteria and normalized weight of each sub-criterion.

From Table 8, the composite weight of consultant A is:

$$(0.001*0.430) + (0.027*0.133) + (0.144*0.284) + (0.337*0.474) + (0.091*0.648) + (0.047*0.600) + (0.252*0.643) + (0.064*0.230) + (0.037*0.455) = 0.485$$

Similarly the composite weights for Consultants B and C are 0.312 and 0.203 respectively. According to ANP, the best alternative is Consultant A.

RESULTS

This paper aimed to solve the consultant's assignment problem in the ABH Company. After interviews with employees, it is understood that the main problem in the assignment of consultants comes from the inability to select the best consultant when there are various alternatives. To solve the problem, the MCDM methods were studied. To support the MCDM methods and to enable the project manager to know about activities of the projects, project scheduling issues were explained and advised the company to use CPM and PERT methodologies.

Within the MCDM methods, three different methods namely AHP, fuzzy AHP and ANP were examined in detail. During the studies of AHP and ANP, decision making in crisp environment was handled. Then it was decided to reflect the indecisive nature of human-beings in decision making, by introducing fuzzy AHP. With the three methods, the selection problem was modeled and consultants were ranked based on subjective evaluations of the project leader with respect to the selected method. Rankings in all of the three methods are given in Table 9.

After studying the three methods, they were evaluated and some serious shortcomings were discussed. After evaluating the three methods, ANP is selected as the best one due to its totally compatible structure with the structure of the selection problem.

CONCLUSIONS

AHP is a basic method for the structure of selection of the best consultant problem. As it is applied to this problem, it can be applied to various kinds of decision problems, as we can see from Table 1. However, AHP has two shortcomings: one of them is not serious, but the other one must be handled to get more accurate results within the selection of best consultant problem.

The first shortcoming of AHP is that it does not allow the decision maker to make decisions in a broad environment; for instance, sometimes the decision maker thinks that one decision element is weakly more important than another one (represented by number "3" in AHP scale); but at the same time the decision maker may think that the mentioned decision element is somehow equally important and somehow weakly more important in terms of the other one (represented by number "2" in the AHP scale). In brief, the decision maker may be indecisive whether to represent the result of pair-wise comparison with the number 2 or 3. There is impreciseness in the situation. Unfortunately, according to the AHP, the decision maker must select only one number from the pair-wise comparison scale; s/he cannot model his/her decision with 2 numbers. In such cases, AHP does not allow the decision maker to make decisions in a broad environment. This may not be considered as an important shortcoming, as the decision maker should be enforced to select one of the numbers in the scale, 2 or 3 and the result will not be very different. But in order to eliminate the decision makers' indecisive

Table 7. Normalized weights of sub-criteria in ANP

Sub-criteria	Weights	Normalized-Weights
Transportation Cost (TC)	0.001	0,001
Consultancy Cost (CC)	0.025	0.027
Companies Employed (CE)	0.133	0.144
Projects Completed (PC)	0.311	0.337
References (R)	0.084	0.091
Department Graduated (DG)	0.043	0.047
Occupational Seminars (OS)	0.232	0.252
Awareness of Responsibility (AR)	0.059	0.064
Ability to Persuade (AP)	0.034	0.037
Total of Weights	**0,922**	**1**

Table 8. Weights of consultants with respect to sub-criteria and normalized weights of sub-criteria in ANP

Sub-Criteria	Normalized Weight of Sub-Criteria	Weight with respect to Sub-criteria		
		Consultant A	Consultant B	Consultant C
Transportation Cost (TC)	0.001	0.430	0.430	0.140
Consultancy Cost (CC)	0.027	0.133	0.212	0.655
Companies Employed (CE)	0.144	0.284	0.097	0.619
Projects Completed (PC)	0.337	0.474	0.474	0.052
References (R)	0.091	0.648	0.295	0.057
Department Graduated (DG)	0.047	0.600	0.200	0.200
Occupational Seminars (OS)	0.252	0.643	0.283	0.074
Awareness of Responsibility (AR)	0.064	0.230	0.122	0.648
Ability to Persuade (AP)	0.037	0.455	0.455	0.090

Table 9. Rankings of consultants

	Results of Consultant Selection		
Rank	AHP	Fuzzy AHP	ANP
1st	Consultant A (0,372)	Consultant A (0,396)	Consultant A (0,485)
2nd	Consultant C (0, 299)	Consultant B (0,314)	Consultant B (0,312)
3rd	Consultant B (0,329)	Consultant C (0,290)	Consultant C (0,203)

manner in such situations, fuzzy AHP, overcomes the limitation.

The second shortcoming of AHP is related to its structure. AHP considers the problem within a hierarchy and a decision element in any level of the hierarchy is affected only by the elements one level below of that element (the alternatives at the bottom of the hierarchy are only affected from one level upper elements). What is stated here is that in AHP interactions within the same level of hierarchy and among random levels of hierarchy are not allowed. For instance, when the hierarchy for selection of the best consultant problem in Figure 1 is examined carefully, the sub-criteria may affect some other sub-criteria and these interactions are not mentioned in AHP. To evaluate such additional interactions within decision elements, ANP should be used.

With the examinations, it is seen that the best consultant suggested by both AHP and fuzzy AHP are the same. In both cases, Consultant A is the best alternative, but the second best alternative is not the same. There is some conflict within two methods when the second best alternative is considered. But what is more important here are the definite shortcomings of the extent analysis method in fuzzy AHP when the weights assigned to decision elements are considered.

Furthermore, since fuzzy AHP is a hierarchical process, when there are interactions among the decision elements in different levels of hierarchy, extent analysis method in fuzzy AHP does not reflect the true composite weights of the alternatives due to interactions. Even if the decision maker uses a more complex fuzzy AHP method, because of its hierarchical structure, s/he does not take into account the interactions among decision elements and this situation causes not to reveal the true weights of decision elements.

Besides these shortcomings of fuzzy AHP extent analysis method, the authors do not know about any software program to perform its time consuming calculations which is an undesired situation for the project leader in the selection process.

In conclusion, all of the methods selected Consultant A as the best alternative, but neither AHP, nor fuzzy AHP considered the interactions within decision elements during the selection process. In the selection of the best consultant problem, there are various interactions within decision elements and ANP, which takes into account these interactions, most correctly weights the sub-criteria and gives the best composite weights in the ranking of alternatives. Other studies, some of them included in Table 1, led to similar conclusions.

REFERENCES

Akman G, Alkan A (2006). Tedarik zinciri yönetiminde bulanık AHP yöntemi kullanılarak tedarikçilerin performansının ölçülmesi: Otomotiv yan sanayiinde bir uygulama. İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi, 9, 23-46.

Al-Harbi K (2001). Application of AHP in project management. Int J Proj Manag, 19(1): 19-27.

Al-jibouri S (2002). Effects of resource management regimes on project schedule. Intl. J. Proj. Manage., 20 (4): 271-277.

Azaron A, Katagiri H, Sakawa M, Kato K, Memariani A (2006). A Multi-Objective Resource Allocation Problem in PERT Networks. Eur. J. Oper. Res., 172(3): 838-854.

Başlıgil H (2005). The fuzzy analytic hierarchy process for software selection problems. Sigma Dergisi, 3 (24-33).

Belout A, Gauvreau C (2004). Factors influencing project success: the impact of human resource management. Intl. J. Proj. Manage., 22 (1): 1-11.

Carazo AF, Gómez T, Molina J, Hernández-Díaz AG, Guerrero FM, Caballero R (2010). Solving a comprehensive model for multiobjective project portfolio selection. Comput. Oper. Res., 37 (4): 630-639.

Chang C-W, Wu C-R, Lin C-T, Lin H-L (2007). Evaluating digital video recorder systems using analytic hierarchy and analytic network processes. Inform. SciencesSci., 177 (16): 3383-3396.

Chang DY (1996). Application of extent analysis method on fuzzy AHP. Eur. J. Oper. Res., 9: 95-106.

Dağdeviren M, Yüksel İ, Kurt M (2008). A fuzzy analytic network process (ANP) model to identify faulty behavior risk (FBR) in work system. Safety. Sci., 46: 771-783.

Daşdemir İ, Güngör E (2002). Multivariate Decision-Making Methods and Their Using Areas in Forestry. Z.K.U. Bartin Journal of. Forest. Fakulty, 4 (4).

Deckro RF, Hebert JE (2003). Modeling diminishing returns in project resource planning. Comput. Ind. Eng., 44 (1): 19-33.

Deloitte (2009). 2009 Deloitte Technology Fast 50 announced. Book 2009 Deloitte Technology Fast 50 announced, vol. 2010. City: Deloitte, Retrieved April, 2010, from http://www.deloitte.com/view/en_GB/uk/industries/tmt/technology/d84ae173b7c74210VgnVCM100000ba42f00aRCRD.h, 2009.

Demirtas EA, Üstün Ö (2008). An integrated multiobjective decision making process for supplier selection and order allocation. Omega, 36 (1): 76-90.

Felek S, Yuluğkural Y, Aladağ Z (2002). Mobil iletişim sektöründe pazar paylaşımının tahmininde AHP ve ANP yöntemlerinin kıyaslanması. Endüstri Mühendisliği Dergisi, 18: 6-22.

Gencer C, Gürpınar D (2007). Analytic network process in supplier selection: A case study in an electronic firm. Appl. Math. Model., 31(11): 2475-2486.

Gollenbeck-Sunke N, Schultmann F (2010). Resource classification and allocation in project-based production environments. Intl. J. Project. Organisation andz. ManagementManage., 2 (2): 122-134.

Gümüş A (2000). Evaluation of hazardous waste transportation firms by using a two step fuzzy AHP and TOPSIS methodology. Expert. Syst. Appl., 36 (2): 4067-4074.

Gutjahr WJ, Katzensteiner S, Reiter P, Stummer C, Denk M (2010). Multi-objective decision analysis for competence-oriented project portfolio selection. Eur. J. Oper. Res. 205(3): 670-679.

Hebert JE, Deckro RF (2011). Combining contemporary and traditional project management tools to resolve a project scheduling problem. Comput. Oper. Res., 38(1): 21-32.

Hiermann W, Höfferer M (2003). A Practical Knowledge-based Approach to Skill Management and Personal Development. J. Univers. Comput. Sci., 9 (12): 1398-1409.

Ho W, Xu X, Dey PK (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. Eur. J. Oper. Res., 202(1): 16-24.

Kahraman C, Ertay T, Büyüközkan G (2006). A fuzzy optimization model for QFD planning process using analytic network approach. Eur. J. Oper. Res,., 171(2): 390-411.

Karen AG, Vasudevan R (1985). Between a dream and a nightmare: On the integration of the human resource management and strategic business planning processes. Hum. Resource. Manage., 24(4): 429-452.

Laslo Z (2010). Project portfolio management: An integrated method for resource planning and scheduling to minimize planning/scheduling-dependent expenses. Int. J. Proj. Manag., 28(6): 609-618.

Liang C, Li Q (2008). Enterprise information system project selection with regard to BOCR. Int. J. Proj. Manage., 26(8): 810-820.

Liu H-T, Wang W-K (2009). An integrated fuzzy approach for provider evaluation and selection in third-party logistics. Expert Systems with. ApplicationsAppl., 36 (3, Part 1): 4387-4398.

Madic B, Trujic V, Mihajlovic I (2011). Project portfolio management implementation review. Afr. J. Bus. Manage., 5(2): 240-248.

Massam BH (2002). Multi-Criteria Decision Making (MCDM) techniques in planning. Prog. Plann., 30(1): 1-84.

Power DJ, Sharda R (2007). Model-driven decision support systems: Concepts and research directions. Decis. Support. Syst., 43(3): 1044-1061.

Project Management Institute (2004). A guide to the project management body of knowledge (PMBOK guide) Newtown Square, PA: Project Management Institute, Inc.

Saaty TL (1980). The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. New York: McGraw-Hill.

Saaty TL (1996). Decision Making with Dependence and Feedback: The Analytic Network Process. Pennsylvania: RWS Publications.
Saaty TL (2005). Decision Making with the Analytic Network Process: Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks. Pittsburgh, Pennsylvania: RWS Publications.
Saaty TL (2008). Decision making with the analytic hierarchy process. Intl. J. Service.s SciencesSci., 1 (1): 83-98.
Saremi M, Mousavi SF, Sanayei A (2009). TQM consultant selection in SMEs with TOPSIS under fuzzy environment. Expert Syst Appl, 36(2): 2742-2749.
Sevkli M, Koh SCL, Zaim S, Demirbag M, Tatoglu E (2008). Hybrid analytical hierarchy process model for supplier selection. Ind. Manage. Data. Syst., 108(1): 122-142.
Soh S (2010). A decision model for evaluating third-party logistics providers using fuzzy analytic hierarchy process. Afr. J. Bus. Manage., 4(3): 339-349.
Sridhar V, Nath D, Malik A (2009). Analysis of User Involvement and Participation on the Quality of IS Planning Projects: An Exploratory Study. Journal of. Organizational and. End User Computing,., 21(3): 80-98.
Štemberger MI, Bosilj-Vukšić V, Jaklič J (2009). Business Process management Software Selection - two case studies. Economic Econ. ResearchRes.*, 22*(4), 84-99.
Tanaka K (1996). An Introduction to Fuzzy Logic for Practical Applications: Springer-Verlag, 2nd Edition, pp. 1-21.
Wang Y, Luo Y, Hua Z (2008). On the extent analysis method for fuzzy AHP and its applications. Eur. J. Oper. Res., 186(2): 735-747.
Wu W-W, Lee Y-T (2007). Selecting knowledge management strategies by using the analytic network process. Expert. Syst. Appl., 32(3): 841-847.
Xu L, Li Z, Li S, Tang F (2007). A decision support system for product design in concurrent engineering. Decis. Support. Syst., 42(4): 2029-2042.
Yang IT, Chou J-S (2011). Multiobjective optimization for manpower assignment in consulting engineering firms. Appl. Soft. Comput., 11(1): 1183-1190.
Zadeh LA (1965). Fuzzy Set. Inform. Control., 8(3): 338-353.
Zarnekow R, Brenner W, Pilgram U (2006). Integrated Information Management Applying Successful Industrial Concepts in IT In: H Osterle, R Winter, W Brenner (eds.). Integrated Information Management. Heidelberg, Germmany: Springer Berlin-Heidelberg.
Zmud R (1980). Management of Large Software Development Efforts. MIS Quart, 4(2): 45-55.