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Using Analytic Network Process in a Group Decision-Making for Supplier Selection

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Abstract. Nowadays most required products and services of companies are provided through other organisations. Outsourcing as a new approach has a significant role in management literature. Supplier should be selected by executives, when the organization decides to acquire a product or service from other organizations. Concerning supplier selection, the managers should consider more than one factor or criterion, which may be inconsistent and contradictory. Therefore, supplier selection is a multi-criteria decision-making issue. Analytic network process (ANP) is a technique to solve multi-criteria decision-making problems in which the criteria affect each other and have nonlinear correlation. In this study, the goal is to use ANP to select the supplier in a group decision-making.

Keywords: supply chain management, outsourcing, supplier selection, analytic network process, group decision-making.

1. Introduction

The achievement of a sustainable competitive advantage has long been the goal of companies and organizations. This "holy grail" has attracted widespread attention over the last few decades (Porter, 1985). Much of this attention has shifted to supply chain. Supply chain has become an important issue in organization management literature (Christopher, 1992). The importance of supply chain has increased so much that some researchers has claimed that competitive advantage may be gained through developing strong network of companies either through horizontal associations, joint venture agreements or through close supply relationships (Harland, 1996).

As evidence to afore-mentioned claim, some of the world's most successful organizations gain competitive advantage through their direct and indirect network of suppliers (Hines, 1997). Toyota is an example, which increased its productivity over 80% by effective use of its supplier networks (Esain and Hines, 1997).

Organizations usually provide their required materials, products or services in the supply chain by following three strategies:

1. Producing these materials or services by themselves.
2. Providing services or material through strategic partnerships.
3. Providing services or material through outsourcing.

Outsourcing is one of the methods to form supplier network and achieve competitive advantage. Outsourcing is a very successful and increasingly popular enterprise management strategy (Koszewska, 2004). It occurs when the execution of tasks, function and processes hitherto fulfilled in-house is commissioned to an external provider specializing in given area based on long-term cooperation. Outsourcing is also defined as the operation of shifting an internal transaction to an external supplier through a long-term contract (Quelin and Duhamel, 2003).

Outsourcing dates back to the 1970s. Initially it was only involved IT-related issues, but gradually more and more enterprises realized that they could not be experts in more than one or two fields. This made them cast aside various areas of activities and entrust them to specialists. According to a survey by Fortune magazine, over 90% of business organizations today take advantage of external service providers. This survey shows that only in the European market, the 2001 estimation of such services was US $27 billion, which is increasing from year to year. Originally, only large corporations used outsourcing, but nowadays it is becoming more and more popular among small-sized enterprises (Koszewska, 2004).

When an organization decides to acquire a product or service from other organizations, supplier selection will be an important issue. Indeed, decision-making in supplier selection is a crucial subject in outsourcing. Supplier selection is a multi-criteria decision-making problem since the decision-maker should consider various contradictory criteria. It means that optimizing one criterion may cause some other ones go far from optimization. Some of these criteria are quality, cost, satisfaction of customer and brand.

There are different methods to solve multi-criteria decision-making problems. AHP and ANP are two methods introduced by Tomas Saaty. AHP tries to solve the decision problem by modeling it in a hierarchy while ANP is used when the problem is so complex that cannot be modeled as a hierarchy. This complexity occurs because of the effect of criteria on each other or the effect of alternatives on criteria. Since in supplier selection criteria affect each other (for example changing in quality affects the costs), in this study ANP is used for the supplier selection.

In this study, the goal is to present a method to select supplier through (ANP) in a group decision-making. In the next part a review of studies using ANP or AHP in supplier selection is presented. In part three ANP is clarified through comparing with AHP. In the final part ANP is applied in a group decision-making to select supplier in a case study.

2. Literature Review

A quick review of supplier selection models in outsourcing literature shows that many researches proposed methods based on AHP and ANP to solve the supplier selection problems. In this section, a brief review of these works is presented.

Some of the researchers have proposed AHP to deal with the supplier selection problem: Akarte *et al.* (2001) developed a web-based AHP system to evaluate the casting suppliers with respect to 18 criteria. Muralidharan *et al.* (2002) proposed a five-step AHP-based model to aid decision makers in rating and selecting suppliers with respect to nine evaluating criteria. Chan and Chan (2004) applied AHP to evaluate and select suppliers. Liu and Hai (2005) applied AHP to evaluate and select suppliers; Similar to Chan (2003), the authors did not apply the AHP's pairwise comparison to determine the relative importance ratings among the criteria and sub-factors. Instead, the authors used Noguchi's voting and ranking method, which allowed every manager to vote or to determine the order of criteria instead of the weights. Chan *et al.* (2007) developed an AHP-based decision making approach to solve the supplier selection problem. Potential suppliers were evaluated based on 14 criteria. Hou and Su (2007) proposed an AHP-based decision support system for the supplier selection problem in a mass customization environment.

Some of the suggested approaches have used ANP to tackle the supplier selection problem: Sarkis and Talluri (2002) believed that supplier-evaluating factors would influence each other, and the internal interdependency needed to be considered in the evaluation process. Bayazit (2006) proposed an ANP model to tackle the supplier selection problem. There were ten evaluating criteria in the model, which were classified into supplier's performance and capability clusters. Gencer and Gurpinar (2007) implemented an ANP model in an electronic company to evaluate and select the most appropriate supplier with respect to various supplier-evaluating criteria, which were classified into three clusters. Lee *et al.* (2009a) proposed a model, which applies the ANP and the benefits, opportunities, costs and risks (BOCR) concept, is constructed to consider various aspects of buyer–supplier relationships. Multiple factors that affect the success of the relationship are analyzed by incorporating experts' opinions on their priority of importance, and a performance ranking of the buyer–supplier forms is obtained. Liao *et al.* (2010) by considering the interdependence among the selection criteria, applied the ANP to help Taiwanese TV companies to effectively select optimal program suppliers.

Some studies integrated AHP approaches to evaluate the performance of suppliers and select the best supplier. Chen and Huang (2007) integrated AHP and a multi-attribute negotiation mechanism for the supplier selection problem. Ramanathan (2007) suggested that Data Envelopment Analysis (DEA) could be used to evaluate the performance of suppliers using both quantitative and qualitative information obtained from the total cost of ownership and AHP. Saen (2007) proposed an integrated AHP–DEA approach to evaluate and select slightly non-homogeneous suppliers. Sevkli *et al.* (2007a) applied an integrated AHP–DEA approach for supplier selection. In the approach, AHP was used to derive local weights from a given pairwise comparison matrice, and aggregate local weights to yield overall weights. Ha and Krishnan (2008) applied an integrated approach in an auto parts manufacturing company for supplier selection. Twelve evaluating criteria were proposed for the selection problem. In the approach, AHP was used first to evaluate the performance of suppliers with respect to five qualitative factors. Then, the remaining seven quantitative criteria along with the scores for each supplier calculated by AHP were passed to DEA and artificial neural network (ANN) to measure the performance efficiency of each supplier. Cebi and Bayraktar (2003) proposed AHP to evaluate the relative performance of suppliers for every raw material with respect to 14 evaluating criteria. The weightings of suppliers were then used as the input of a Goal Programming (GP) model to select the best set of suppliers for a particular type of raw materials, and determine the amount of raw materials to be purchased. Similar to Cebi and Bayraktar (2003), Wang *et al.* (2004, 2005) applied an integrated AHP–GP approach for supplier selection. The only difference between them is due to the evaluating criteria used in AHP. The AHP weightings were incorporated into one of the goal constraints of the GP model. Percin (2006) applied an integrated AHP–GP approach for supplier selection. AHP was used first to measure the relative importance weightings of potential suppliers with respect to 20 evaluating factors. Kull and Talluri (2008) utilized an integrated AHP–GP approach to evaluate and select suppliers with respect to risk factors and product life cycle considerations. Mendoza *et al.* (2008) presented an integrated AHP–GP approach to reduce a large number of potential suppliers to a manageable number, rank the alternative suppliers with respect to five evaluating criteria, and determine the optimal order quantity. Yang and Chen (2006) applied AHP to compute relative importance weightings of qualitative criteria. The weightings were then used as coefficients of grey relational analysis model. Mendoza and Ventura (2008) proposed a two-stage method to deal with the supplier selection and order quantity problems simultaneously. Xia and Wu (2007) incorporated AHP into the multi-objective mixed integer programming model for supplier selection.

Some other approach integrated ANP with other mathematical technique to solve the supplier selection approach: Demirtas and Ustun (2008) developed an integrated ANP and multi-objective mixed integer linear programming approach to select the best set of suppliers, and to determine the optimal order allocation. Lin *et al.* (2011) applied a methodology of ANP, technique for order preference by similarity to ideal solution (TOPSIS) and linear programming (LP) in the supplier selection process. Demirtas and Ustun (2009) developed an integrated ANP and GP approach for supplier selection. Similar to Demirtas and Ustun (2008), potential suppliers were evaluated using ANP first. The weightings were then used as coefficients of one of the three objective functions. All evaluating criteria and objective functions are exactly the same as those in Demirtas and Ustun (2008). The only difference is that a GP model was constructed in which there were four goals. Lang et al. (2009) proposed a hierarchical evaluation framework to assist the expert group to select the optimal supplier in supply chain management strategy (SCMS). The rationales for the evaluation framework are based upon (i) multi-criteria decision making (MCDM) analysis that can select the most appropriate alternative from a finite set of alternatives with reference to multiple conflicting criteria, (ii) ANP and (iii) choquet integral a non-additive fuzzy integral that can eliminate the interactivity of expert subjective judgment problems.

3. Analytic Network Process (ANP)

3.1. *Introduction to ANP*

AHP models the decision-making problem as a hierarchy in a top-down approach. AHP have been applied in scientific researches for solving MADM problems. For instance Chang *et al.* (2007), Hsu and Pan (2009), Huang (2009), Huang *et al.* (2009), Kuo *et al.* (2008), Sevkli *et al.* (2007b), Sun *et al.* (2008), Levary (2008), Li *et al.* (2008), Hu *et al.* (2008), Naesens *et al.* (2009) and Tsai and Hung (2009) are some studies that used AHP to solve a MADM problem. Many decision-making problems couldn't be structured hierarchically because they involve the interaction and dependency of higher-level element. In these problems not only does the importance of the criteria determine the importance of the alternatives, but also the importance of the alternatives themselves determine the importance of the criteria (Saaty, 1996a). To solve these problems, ANP can be used. ANP, developed by Saaty in 1996, is the first mathematical theory that makes it possible for decision-maker to deal systematically with this kind of dependence and feedback (Ozturk, 2006)

3.2. *Using Network Instead of Hierarchy*

As mentioned, the advantage of ANP is the capability of solving the problems in which alternatives and criteria have such interactions that cannot be shown in a hierarchy. When the decision-maker decides to model a problem as a network, it is not necessary to specify levels (Bauyaukyazici and Sucu, 2003). A network contains clusters (components, nodes or criteria) and elements (sub criteria) in these clusters. However, in creating structures to represent problems there may be a system larger than components. According to size, there is a system that is made up of subsystems and each subsystem made up of elements (Saaty and Vargas, 2006). The differences between a hierarchy and a network are shown in Fig. 1 (Azis, 2003).

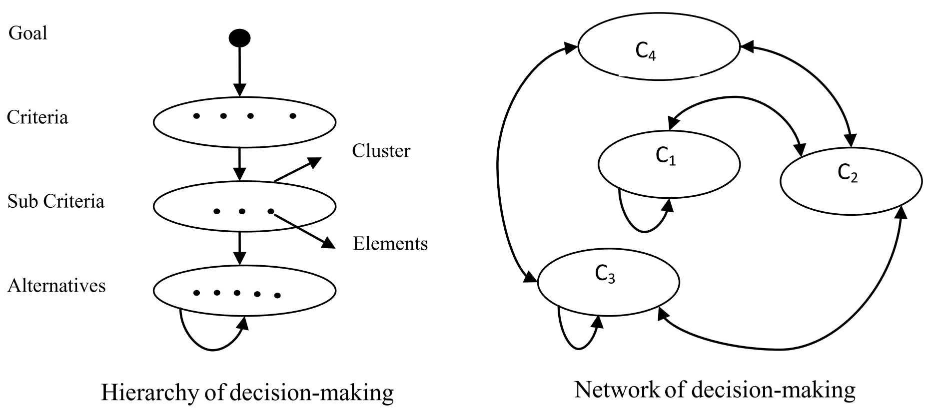

Fig. 1. The differences between hierarchy and network of decision-making.

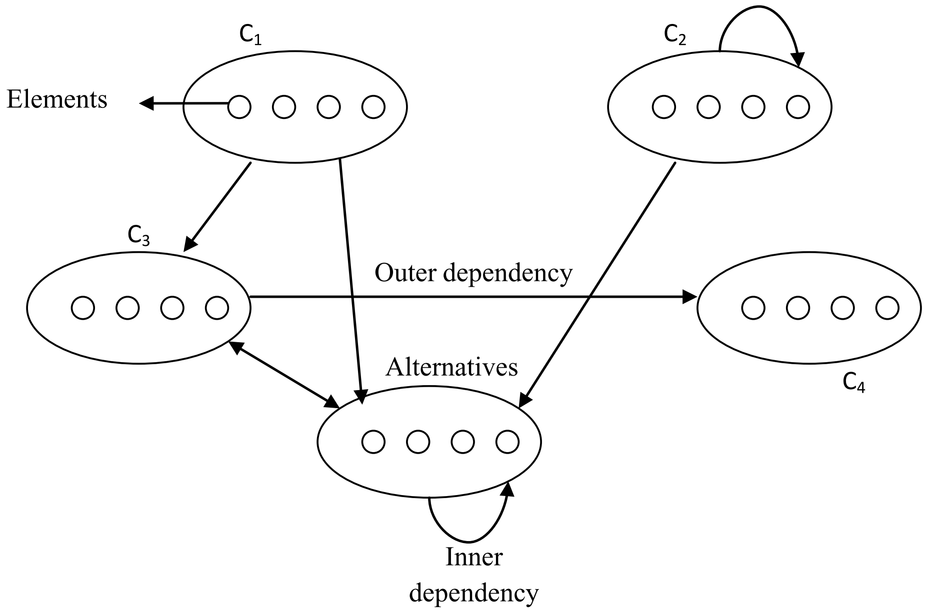

Fig. 2. Different kinds of cluster and dependency in a network.

As shown in Fig. 1, in AHP interactions and dependencies can start from the upper levels through lower levels. However, in ANP all of the elements of network can interact on each other. In fact, AHP uses a kind of network, interactions of which are only linear and top-down.

There are three kinds of clusters in a network. Those clusters with no enter arrows, are source clusters such as C_1 and C_2 (Fig. 2) and Those from which no arrow leaves are known as sink clusters such as C_4 and finally those which arrows enter and exit, are known as transient cluster such as C_3.

There are two kinds of dependency (interaction) in a network: inner dependency and outer dependency. Outer dependency occurs when the elements of a cluster affect the other cluster's elements and there is inner dependency when some elements of one cluster affect each other (sometimes called loop) (Saaty and Takizawa, 1986). Different kinds of dependency and components are shown in Fig. 2.

Classification of elements into clusters can be done according to their homogeneity. For example if you want to make a network for decision-making to buy a machine for production line, the different kinds of costs should be put in a cluster, containing elements such as purchasing and maintenance cost.

To detect the interaction and dependency, decision-maker can use input-output analysis. Leontief proposed the input-output analysis in analyzing the US economy. Input-output analysis explained the interconnection among sectors of complex economic systems, which may be national, regional, or enterprise type (Li and Liu, 2008).

3.3. *Supermatrix in ANP*

Although ANP and AHP are similar in the comparative judgment phase, they are different in the synthesizing phase. In the ANP, ratio scale priority vectors (derived from pair-wise comparison matrices) are not synthesized linearly as in AHP. Saaty has an improved "supermatrix" technique to synthesize ratio scales. Each ratio scale is appropriately introduced as a column in a matrice to represent the impact of elements in a cluster on an element in another cluster (outer dependence) or on elements of the cluster itself (inner dependence). In that case, the supermatrix is composed of several sub-matrices which each columns is a principal eigenvector that represents the impact of all elements in a cluster on each elements in another (or the same) cluster. Let the clusters of a decision system be $C_h,\ h = 1, 2, \ldots, n$, and each cluster h has n_h elements, denoted $c_{h1}, c_{h2}, \ldots, c_{hnh}$, then the supermatrix of such a network will be like Fig. 3 (Lee *et al.*, 2009b).

The i, j block of supermatrix is shown in Fig. 4. Vectors that form this matrix are ratio scale priority vectors derived by pair-wise comparison matrices. These comparison matrices demonstrate the judgment of decision-maker about the priority of elements. It is not necessary that every element of a cluster has an influence on an element in another cluster. In such a case, these elements are given a zero value for their contribution.

For deriving judgment of the decision-maker and establishing the comparison matrices, the scale that was suggested by Saaty for AHP and ANP can be used. These scales are shown in Table 1 (Lin *et al.*, 2008).

		C_1		C_h	A
		$c_{11}\ c_{12}\ \ldots.\ c_{1n_1}$	$\ldots$	$c_{h1}\ c_{h2}\ \ldots\ c_{hn_h}$	$A_1\ A_2\ A_3\ \ldots\ A_m$
	c_{11}				
	c_{12}				
C_1	$\vdots$	W_{11}	$\ldots$	W_{1h}	W_{1A}
	c_{1n_1}				
	$\vdots$	$\vdots$		$\vdots$	$\vdots$
	c_{h1}				
	c_{h2}				
C_h	$\vdots$	W_{h1}	$\ldots$	W_{hh}	W_{ha}
	c_{hn_h}				
	c_{N1}				
	c_{N2}				
C_N	c_{N3}	W_{N1}	$\ldots$	W_{Nh}	W_{Na}
	$\vdots$				
	c_{Nn_N}				

Fig. 3. A supermatrix of a network.

$$W_{ij} = \begin{vmatrix} W_{i1}^{j1} & W_{i1}^{j2} & \dots & W_{i1}^{jn_j} \\ W_{i2}^{j1} & W_{i2}^{j2} & \dots & W_{i2}^{jn_j} \\ \vdots & \vdots & \vdots & \vdots \\ W_{in_i}^{j1} & W_{in_i}^{j2} & \dots & W_{in_i}^{jn_j} \end{vmatrix}$$

Fig. 4. i, j block of a network's supermatrix.

Table 1

Scale for comparison matrice

Verbal scale	Intensity of importance
Extreme importance	9
Very strong importance	7
Strong importance	5
Moderate importance	3
Equal importance	1
Intermediate values	8, 6, 4, 2

3.4. *Group Decision-Making in ANP and AHP*

Some time it is necessary to make a decision by more than one person. In such cases, group decision-making technique is used to integrate the judgments of decision-makers. Xu (2000) suggested that a ratio scale priority vector for each decision-maker's comparison matrice should be calculated, then these calculated vectors could be integrated to achieve a single priority vector. But Lin *et al.* (2008) proved that, the comparison matrices should be integrated to achieve a final comparison matrice followed by calculation of priority vector for final comparison matrices.

Therefore in AHP and ANP a final comparison matrice indicating the judgments of decision-makers on the pair-wise comparisons should be calculated in group decision-making. Then, the ratio scale priority vectors of the final comparison matrice should be figured out. Now these caculated vectors should be put in their appropriate positions in the supermatrix. The elements of the final comparison matrice are calculated through the geometric mean of elements in comparison matrice of each decision-maker (see (1); Azar and Rajabzade, 2002).

$$A'_{ij} = \left(\prod_{k=1}^{m} A_{ij}^{w_k} \right)^{\frac{1}{\sum w_k}}. \tag{1}$$

In (1), w_i is the weight given to each decision-makers' opinion (matrice) and m is the number of decision makers. Each person's weight is determined by some factors such as the person's experience, knowledge, background, etc. A_{ij} indicates the elements of the decision-makers' comparison matrices and A'_{ij} indicates the elements of the final comparison matrice.

3.5. *Calculating the Final Weights of the Alternatives and the Criteria*

As mentioned before, the supermatrix has some blocks. Columns of each block is a vector indicating the impact of the elements of the left side corresponding cluster on the elements at the top of the supermatrix. To have a stochastic supermatrix, clusters should be compared with each other. The resulting priorities of the clusters are used to weight the corresponding blocks. Through this, the supermatrix becomes column stochastic (Saaty, 1996b).

It should be noted that only the direct interaction between elements are shown by synthesizing ratio scale priority vectors derived from pair-wise comparison matrices in a network. Elements could interact either directly or indirectly in systems-with-feedback. As an example, some four elements (as A, B, C and D) and their various impacts on each other are shown in Fig. 5.

The total impact of A on B consists of many components. The direct impact (or first order impact) of A on B is represented with a solid line in Fig. 5. All the first order impacts can be obtained directly from the supermatrix. There are also some indirect impacts of A on B through a third element. For instance, there is an impact of A on B through C. In Fig. 5, this second order impacts is represented with dotted gray lines. The contribution of this indirect impacts from the total second order impact of A on B can be obtained by multiplying the impact of A on C by the impact of C on B. Another second order impact of A on B is through D. This second order impact is represented with dotted black lines. The last second order impact of A on B is through the impact of A on itself and then on B. This second order impact is represented with solid gray lines. The total of the second order impacts can be obtained from the square of the supermatrix. As can be seen in Fig. 5, there

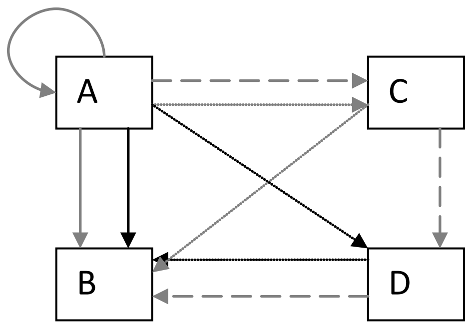

Fig. 5. Different kinds of interaction in a network.

is also a third order impact of A on B represented with dashed lines. The contribution of third order impact from the total third order impact of A on B can be obtained by multiplying the impact of A on C by the impact of C on D and by the impact of D on B. The total of third order impacts could be obtained from the third power of the supermatrix, and the fourth and next order impacts are obtained in the same way. Thus the limiting power of the supermatrix which is column stochastic should be computed. This concept is parallel to the Markov chain process (Meade and Sarkis, 1998). The limiting power of the supermatrix has an equilibrium distribution, as in the Markov chain process. Alternatives in the model can be ordered using limiting priorities obtained from the equilibrium distribution of the supermatrix.

4. Case Study

Fars Gas Company (FGC) provides many of its required products and services from outer suppliers. Gas counter is one of these products. Companies which own the required technology to produce gas counters, are Iran National Gas Industry (INGI), Iran Gas Industry (IGI), Gas Suzan (GS), Para Sanat (PS) and Hadid Saze Pishro (HSP). The authority of selecting the supplier is delegated to a committee called the Commercial and Technical Committee (CTC). Supplier was previously selected through CTC members only based on the suggested price of companies in tenders. Recently the company has faced problems with the gas counters provided in this way. An example of such a problem is repetitive failures in gas counters. Therefore, they decided to use another method to select gas counter supplier. As a contribution to the supplier selection process, the current study uses ANP to select the supplier regarding some other factors in addition to mere price factor. The process of supplier selection by ANP is described in the below stepwise manner:

Step 1. Weighting the CTC members

At the first stage, considering the experiment and knowledge of the six members of CTC, a weight was given to each of the members. Three members were given a weight equal to two and the other three members were given the weight one.

Step 2. Determining the important criteria to select the supplier

In this stage, interviews with CTC's members were conducted to determine the criteria for selecting the gas counter supplier. In these interviews, Delphi method was used. At last, thirteen criteria were recognized. After making sure that all the members of CTC have a common understanding of the criteria regarding the information obtained from the interviews, the criteria were classified in to three categories (clusters). These clusters were: (1) commercial criteria, (2) commercial and technical criteria and (3) technical criteria. The criteria and their definitions are shown in Table 2.

Table 2

Criteria and sub criteria for supplier selection in FGC

Criteria	Subcriteria	Definition
Commercial criteria	Price (P)	The price that the suppliers suggest in the tender
	Delivery insurance (DI)	How has the supplier fulfilled its commitments in the previous contracts considering time and quality factors of the delivery?
	Economic power (EP)	How does the supplier guaranty economically to deliver the ordered products in time?
Commercial and technical criteria	Quality assurance (QI)	How does the supplier respond to its quality assurance services?
	Long-term relations (LR)	The duration of the supplier's previous relations with FGC before this tender
	Management quality (MQ)	The ability of the supplier's management in communicating with FGC's management in previous contracts
	Experience (E)	How much is the supplier experienced in gas counter production?
Technical criteria	Technical equipment (TE)	The extent to which supplier updates its equipments
	Technical personals (TP)	The Technical knowledge and experience of the supplier's personnel
	Financial power (FP)	The financial power of the supplier for providing the needed technology and knowledge of counter production
	Satisfaction of FGC personals (SP)	The FGC's technical personnels' satisfaction degree from previous contracts
	Technical standards and quality (TSQ)	The quality of the supplier's product(s)
	Audit degree (AD)	The grade that CTC gives to the supplier after the anual audition

Step 3. Designing the network of decision

In this stage, an input-output analysis was made. To do this, interviews with CTC's members were conducted. Then, an input-output matrice (the entries or elements of which are zero and one) was designed. Number one symbolize the existence of corresponding row element impact on the corresponding column element and zero showed that there is no impact. With the help of input-output matrice, the network was designed as shown in Fig. 6.

Step 4. Deriving the CTC's members' judgments from comparison matrices and establishing the supermatrix

In this stage, considering the input-output analysis and decision network a questionnaire was designed to derive pair-wise comparison judgments.

The comparison matrices among the elements were integrated using equation1 after the CTC members answered the questionnaires. This led to the final comparison matrices to achieve the ratio scale vectors. The supermatrix was established after putting these ratio scale vectors in their appropriate positions (Table 3).

Table 3 (Part I)

The supermatrix of decision-making in FGC for supplier selection

		Goal	p	DI	EP	QI	LR	MQ	E	TE
	Goal	0	0	0	0	0	0	0	0	0
Commercial criteria	P	0.51472	0	0.38743	0.69098	0.27429	0.16952	0	0.47273	0.13595
	DI	0.24264	0.20521	0	0.30902	0.36285	0.41524	0.5	0.19299	0.20546
	EP	0.24264	0.79479	0.61257	0	0.36285	0.41524	0.5	0.33427	0.65859
Commercial and technical criteria	QI	0.35162	0.13901	0	0.12681	0	0.3469	0	0.31865	0.18608
	LR	0.1195	0.24078	0.388	0.25988	0.21115	0	0.38649	0.30323	0
	MQ	0.29938	0.22701	0.388	0.27782	0.5193	0.41333	0	0.37812	0.48946
	E	0.2295	0.39319	0.22401	0.3355	0.26954	0.23977	0.61351	0	0.32446
Technical criteria	TE	0.13713	0.27647	0.34045	0	0.19723	0.11136	0.20327	0	0
	TP	0.17661	0.22604	0.24594	0.41551	0.26995	0.11971	0.3341	0	0.36689
	FP	0.10331	0.20154	0.18417	0.37059	0.21351	0.16481	0.18552	0.49046	0.63311
	SP	0.14157	0	0.06643	0	0	0.16946	0	0	0
	TSQ	0.22644	0.29595	0.16301	0.2139	0.31932	0.20658	0.27711	0.50954	0
	AD	0.21494	0	0	0	0	0.22808	0	0	0
Alternatives	INGI	0	0.17386	0.08574	0.0494	0.21844	0.295	0.13476	0.28947	0.18472
	IGI	0	0.17137	0.18188	0.20959	0.30774	0.13844	0.31259	0.09211	0.25283
	GS	0	0.21898	0.4455	0.44461	0.31958	0.39043	0.3686	0.36842	0.29254
	PS	0	0.21681	0.10501	0.1482	0.07538	0.07485	0.08203	0.11842	0.13496
	HSP	0	0.21898	0.18188	0.1482	0.07886	0.10127	0.10201	0.13158	0.13496

Table 3 (Part II)

The supermatrix of decision-making in FGC for supplier selection

		TP	FP	SP	TSQ	AD	INGI	IGI	GS	PS	HSP
	Goal	0	0	0	0	0	0	0	0	0	0
Commercial criteria	P	0.22421	0.72727	0	0.43801	0	0.55051	0.17588	0.29591	0.13657	0.1616
	DI	0	0.09091	0.71472	0.11542	1	0.22474	0.39329	0.34168	0.33452	0.39584
	EP	0.77579	0.18182	0.28528	0.44658	0	0.22474	0.43083	0.36241	0.52892	0.44256
Commercial and technical criteria	QI	0.16098	0.20408	0.32042	0.24911	0.35203	0.1664	0.3872	0.23085	0.23363	0.29246
	LR	0.18075	0.42854	0.19204	0.16209	0	0.32792	0.19367	0.22367	0.2851	0.25251
	MQ	0.41087	0.36738	0.32042	0.4125	0.48293	0.19092	0.24546	0.28957	0.18303	0.24139
	E	0.2474	0	0.16713	0.17629	0.16504	0.31476	0.17367	0.25591	0.29824	0.21365
Technical criteria	TE	0.33901	0.52821	0.24543	0.25769	0.24616	0.18487	0.15885	0.16884	0.17759	0.15124
	TP	0	0.47179	0.24959	0.32901	0.28798	0.20553	0.1562	0.17462	0.20656	0.20355
	FP	0.66099	0	0.16335	0.21785	0.17787	0.16966	0.18725	0.16809	0.19608	0.16698
	SP	0	0	0	0.08634	0	0.10807	0.1196	0.14789	0.11213	0.16981
	TSQ	0	0	0.34163	0	0.28798	0.1656	0.14904	0.16884	0.19551	0.18436
	AD	0	0	0	0.1091	0	0.16627	0.22905	0.17171	0.11213	0.12406
Alternatives	INGI	0.14979	0.19962	0.18708	0.2325	0.21117	0	0	0	0	0
	IGI	0.19835	0.26509	0.22154	0.23661	0.23473	0	0	0	0	0
	GS	0.30475	0.34869	0.35049	0.29531	0.32602	0	0	0	0	0
	PS	0.16632	0.09208	0.08447	0.11472	0.09869	0	0	0	0	0
	HSP	0.18079	0.09451	0.15642	0.12086	0.12939	0	0	0	0	0

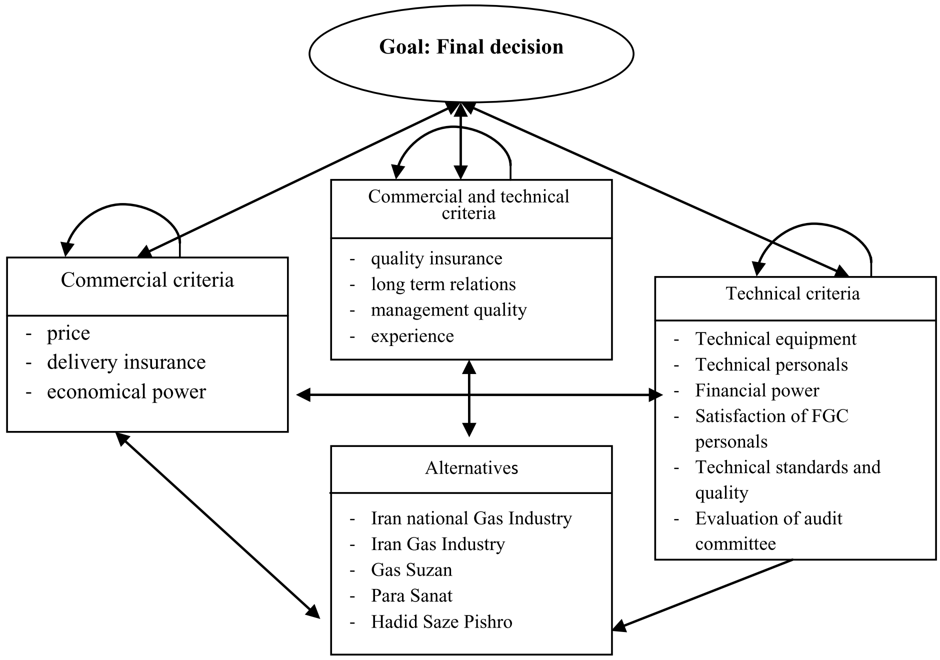

Fig. 6. The decision-making network for selecting supplier in FGC.

Step 5. Calculating the weighted supermatrix (stochastic supermatrix)

In the last part of the questionnaires, some questions were asked to find out the impact of the clusters on each other. The result of obtaining final comparison matrices and the ratio scale vectors are shown in Table 4. Then to obtain the weighted supermatrix or stochastic supermatrix, the Table 4 entries are multiplied by the elements of their corresponding blocks in the supermatrix (Table 3). The weighted supermatrix is shown in Table 5.

Step 6. Calculating the final weights of the alternatives and the criteria

In this stage, the powers of weighted supermatrix are calculated to obtain the limited supermatrix. After 17th iteration (17th power), the limited supermatrix is obtained as is shown in Table 6.

Each column of Table 6 determine the final ratio scale priority of elements in network. The final weight of each element and cluster is shown in Table 7. In this table, the cluster's ratio scale priority is equal to sum of its elements' ratio scale priority. The ratio scale priorities of the elements within their clusters (last column) are calculated by normalizing their ratio scale priority in the related cluster.

Table 7 indicates that the technical cluster has the most priority among all clusters in decision-making and within the technical cluster, the financial power factor has the most

Table 4
The weight of blocks of decision network in decision-making for supplier selection in FGC

	Goal	Commercial criteria	Commercial and technical criteria	Technical criteria	Alternatives
Goal	0	0	0	0	0
Commercial criteria	0.2623	0.209	0.2949	0.29	0.28401
Commercial and technical criteria	0.2816	0.281	0.1652	0.338	0.311494
Technical criteria	0.4561	0.442	0.4423	0.29	0.404496
Alternatives	0	0.067	0.0975	0.082	0

priority in decision-making. Among the clusters, the commercial and technical cluster has the second most priority in decision-making within which the factor of management quality has the most priority in decision-making. The commercial cluster has the least priority in decision-making while the factor of economic power has the most priority within this cluster. Its interesting that the price factor priority (a criterion that previously was the only criterion for selecting the supplier) has the second priority within its cluster and has the fifth priority among all elements. The limited supermatrix indicates that FGC should select Gas Suzan (GS) as its supplier while before this study, Iran National Gas Industry (INGI) should have been selected based on considering the price factor.

5. Conclusion

Sometimes managers face the decision-making problems, which require specific techniques to deal with complexity and interactions among important factors to select the best alternative. ANP is one of techniques suggested to solve complex decision-making problems. In this study ANP technique is applied to select the supplier in a group decision making process. Using ANP in a real world problem showed that the managers of the intended company should modify their decision-making method while previous method leads to an unsuitable supplier.

Table 5 (Part I)

The weighted supermatrix of decision-making for supplier selection in FGC

		Goal	p	DI	EP	QI	LR	MQ	E	TE
	Goal	0	0	0	0	0	0	0	0	0
Commercial criteria	P	0.135	0	0.08107	0.14459	0.08089	0.04999	0	0.13942	0.03946
	DI	0.06364	0.04294	0	0.06466	0.10701	0.12246	0.14746	0.05692	0.05964
	EP	0.06364	0.16631	0.12818	0	0.10701	0.12246	0.14746	0.09858	0.19118
Commercial and technical criteria	QI	0.09903	0.03912	0	0.03569	0	0.05732	0	0.05265	0.06285
	LR	0.03366	0.06777	0.1092	0.07314	0.03489	0	0.06386	0.05011	0
	MQ	0.08432	0.06389	0.1092	0.07819	0.08581	0.0683	0	0.06248	0.16531
	E	0.06464	0.11066	0.06305	0.09442	0.04454	0.03962	0.10138	0	0.10958
Technical criteria	TE	0.06254	0.12219	0.15046	0	0.08724	0.04926	0.08991	0	0
	TP	0.08055	0.0999	0.10869	0.18364	0.11941	0.05295	0.14778	0	0.10622
	FP	0.04712	0.08907	0.0814	0.16379	0.09444	0.0729	0.08206	0.21694	0.1833
	SP	0.06457	0	0.02936	0	0	0.07496	0	0	0
	TSQ	0.10327	0.1308	0.07204	0.09454	0.14124	0.09137	0.12257	0.22538	0
	EAC	0.09803	0	0	0	0	0.10088	0	0	0
Alternatives	INGI	0	0.01171	0.00577	0.00333	0.0213	0.02877	0.01314	0.02823	0.01523
	IGI	0	0.01154	0.01225	0.01411	0.03001	0.0135	0.03048	0.00898	0.02085
	GS	0	0.01475	0.03	0.02994	0.03116	0.03807	0.03594	0.03593	0.02412
	PS	0	0.0146	0.00707	0.00998	0.00735	0.0073	0.008	0.01155	0.01113
	HSP	0	0.01475	0.01225	0.00998	0.00769	0.00988	0.00995	0.01283	0.01113

Table 5 (Part II)

The weighted supermatrix of decision-making for supplier selection in FGC

		TP	FP	SP	TSQ	AD	INGI	IGI	GS	PS	HSP
	Goal	0	0	0	0	0	0	0	0	0	0
Commercial criteria	P	0.06508	0.21111	0	0.12715	0	0.15635	0.04995	0.08404	0.03879	0.0459
	DI	0	0.02639	0.20747	0.0335	0.29028	0.06383	0.1117	0.09704	0.09501	0.11242
	EP	0.2252	0.05278	0.08281	0.12963	0	0.06383	0.12236	0.10293	0.15022	0.12569
Commercial and technical criteria	QI	0.05437	0.06893	0.10822	0.08413	0.11889	0.05183	0.12061	0.07191	0.07278	0.0911
	LR	0.06105	0.14473	0.06486	0.05474	0	0.10214	0.06033	0.06967	0.08881	0.07866
	MQ	0.13876	0.12407	0.10822	0.13931	0.1631	0.05947	0.07646	0.0902	0.05701	0.07519
	E	0.08355	0	0.05644	0.05954	0.05574	0.09805	0.0541	0.07971	0.0929	0.06655
Technical criteria	TE	0.09815	0.15293	0.07106	0.07461	0.07127	0.07478	0.06426	0.0683	0.07184	0.06117
	TP	0	0.13659	0.07226	0.09525	0.08338	0.08314	0.06318	0.07063	0.08355	0.08233
	FP	0.19137	0	0.04729	0.06307	0.0515	0.06863	0.07574	0.06799	0.07931	0.06754
	SP	0	0	0	0.025	0	0.04371	0.04838	0.05982	0.04536	0.06869
	TSQ	0	0	0.09891	0	0.08338	0.06698	0.06029	0.0683	0.07908	0.07457
	AD	0	0	0	0.03159	0	0.06726	0.09265	0.06946	0.04536	0.05018
Alternatives	INGI	0.01235	0.01646	0.01543	0.01917	0.01741	0	0	0	0	0
	IGI	0.01636	0.02186	0.01827	0.01951	0.01936	0	0	0	0	0
	GS	0.02513	0.02876	0.0289	0.02435	0.02689	0	0	0	0	0
	PS	0.01372	0.00759	0.00697	0.00946	0.00814	0	0	0	0	0
	HSP	0.01491	0.00779	0.0129	0.00997	0.01067	0	0	0	0	0

Table 6 (Part I)

The limited supermatrix of decision-making for supplier selection in FGC

		Goal	p	DI	EP	QI	LR	MQ	E	TE
	Goal	0	0	0	0	0	0	0	0	0
Commercial criteria	P	0.08622	0.08622	0.08622	0.08622	0.08622	0.08622	0.08622	0.08622	0.08622
	DI	0.06582	0.06582	0.06582	0.06582	0.06582	0.06582	0.06582	0.06582	0.06582
	EP	0.11721	0.11721	0.11721	0.11721	0.11721	0.11721	0.11721	0.11721	0.11721
Commercial and technical criteria	QI	0.04775	0.04775	0.04775	0.04775	0.04775	0.04775	0.04775	0.04775	0.04775
	LR	0.0649	0.0649	0.0649	0.0649	0.0649	0.0649	0.0649	0.0649	0.0649
	MQ	0.09364	0.09364	0.09364	0.09364	0.09364	0.09364	0.09364	0.09364	0.09364
	E	0.06712	0.06712	0.06712	0.06712	0.06712	0.06712	0.06712	0.06712	0.06712
Technical criteria	TE	0.07489	0.07489	0.07489	0.07489	0.07489	0.07489	0.07489	0.07489	0.07489
	TP	0.09774	0.09774	0.09774	0.09774	0.09774	0.09774	0.09774	0.09774	0.09774
	FP	0.10757	0.10757	0.10757	0.10757	0.10757	0.10757	0.10757	0.10757	0.10757
	SP	0.01275	0.01275	0.01275	0.01275	0.01275	0.01275	0.01275	0.01275	0.01275
	TSQ	0.07404	0.07404	0.07404	0.07404	0.07404	0.07404	0.07404	0.07404	0.07404
	AD	0.01412	0.01412	0.01412	0.01412	0.01412	0.01412	0.01412	0.01412	0.01412
Alternatives	INGI	0.01377	0.01377	0.01377	0.01377	0.01377	0.01377	0.01377	0.01377	0.01377
	IGI	0.01668	0.01668	0.01668	0.01668	0.01668	0.01668	0.01668	0.01668	0.01668
	GS	0.0264	0.0264	0.0264	0.0264	0.0264	0.0264	0.0264	0.0264	0.0264
	PS	0.00914	0.00914	0.00914	0.00914	0.00914	0.00914	0.00914	0.00914	0.00914
	HSP	0.01023	0.01023	0.01023	0.01023	0.01023	0.01023	0.01023	0.01023	0.01023

Table 6 (Part II)

The limited supermatrix of decision-making for supplier selection in FGC

		TP	FP	SP	TSQ	AD	INGI	IGI	GS	PS	HSP
	Goal	0	0	0	0	0	0	0	0	0	0
Commercial criteria	P	0.08622	0.08622	0.08622	0.08622	0.08622	0.08622	0.08622	0.08622	0.08622	0.08622
	DI	0.06582	0.06582	0.06582	0.06582	0.06582	0.06582	0.06582	0.06582	0.06582	0.06582
	EP	0.11721	0.11721	0.11721	0.11721	0.11721	0.11721	0.11721	0.11721	0.11721	0.11721
Commercial and technical criteria	QI	0.04775	0.04775	0.04775	0.04775	0.04775	0.04775	0.04775	0.04775	0.04775	0.04775
	LR	0.0649	0.0649	0.0649	0.0649	0.0649	0.0649	0.0649	0.0649	0.0649	0.0649
	MQ	0.09364	0.09364	0.09364	0.09364	0.09364	0.09364	0.09364	0.09364	0.09364	0.09364
	E	0.06712	0.06712	0.06712	0.06712	0.06712	0.06712	0.06712	0.06712	0.06712	0.06712
Technical criteria	TE	0.07489	0.07489	0.07489	0.07489	0.07489	0.07489	0.07489	0.07489	0.07489	0.07489
	TP	0.09774	0.09774	0.09774	0.09774	0.09774	0.09774	0.09774	0.09774	0.09774	0.09774
	FP	0.10757	0.10757	0.10757	0.10757	0.10757	0.10757	0.10757	0.10757	0.10757	0.10757
	SP	0.01275	0.01275	0.01275	0.01275	0.01275	0.01275	0.01275	0.01275	0.01275	0.01275
	TSQ	0.07404	0.07404	0.07404	0.07404	0.07404	0.07404	0.07404	0.07404	0.07404	0.07404
	AD	0.01412	0.01412	0.01412	0.01412	0.01412	0.01412	0.01412	0.01412	0.01412	0.01412
Alternatives	INGI	0.01377	0.01377	0.01377	0.01377	0.01377	0.01377	0.01377	0.01377	0.01377	0.01377
	IGI	0.01668	0.01668	0.01668	0.01668	0.01668	0.01668	0.01668	0.01668	0.01668	0.01668
	GS	0.0264	0.0264	0.0264	0.0264	0.0264	0.0264	0.0264	0.0264	0.0264	0.0264
	PS	0.00914	0.00914	0.00914	0.00914	0.00914	0.00914	0.00914	0.00914	0.00914	0.00914
	HSP	0.01023	0.01023	0.01023	0.01023	0.01023	0.01023	0.01023	0.01023	0.01023	0.01023

Table 7
The relative importance of clusters and elements

Clusters	Elements	(1) Ratio scale priority in the network	(2) Ratio scale priority of clusters	(3) = (1)/(2) Ratio scale priority of of elements in their cluster
Commercial criteria	P	0.08622	0.269255	0.320215
	DI	0.06582		0.244456
	EP	0.11721		0.435329
Commercial and technical criteria	QI	0.04775	0.273414	0.174662
	LR	0.0649		0.237359
	MQ	0.09364		0.342475
	E	0.06712		0.245504
Technical criteria	TE	0.07489	0.381107	0.1965
	TP	0.09774		0.256458
	FP	0.10757		0.282262
	SP	0.01275		0.033464
	TSQ	0.07404		0.194268
	AD	0.01412		0.037048
Alternatives	INGI	0.01377	0.076224	0.180655
	IGI	0.01668		0.218892
	GS	0.0264		0.346346
	PS	0.00914		0.119888
	HSP	0.01023		0.134218

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Tiekėjo atranka, taikant analitinio tinklo procesų sprendimams grupėse priimti

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Turintys didžiausią paklausą produktai ir paslaugos šiandien tiekiami per kitas organizacijas. Darbų perkėlimas į kitą firmą yra naujas reiškinys, kuris yra plačiai nagrinėjamas literatūroje. Vadovai pasirenka tiekėją tada, kai organizacija nusprendžia nusipirkti produktą ar paslaugą iš kitos organizacijos. Pasirenkant tiekėją vadovai turėtų taikyti daugiau, nei vieną veiksnį ar kriterijų, tačiau jie gali būti nesuderinami ar prieštaringi. Analitinio tinklo procesas (ATP) – tai yra nauja metodika, leidžianti išspręsti sprendimų priėmimo uždavinius, kuriuose kriterijai turi poveikį vienas kitam ir tarp kriterijų yra netiesinė koreliacija. Šio tyrimo tikslas yra tiekėjo atranka, taikant ATP metodiką sprendimams grupėse priimti.