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Using ANP and AHP for the Supplier Selection in the Construction and Civil Engineering Companies; Case Study of Iranian Company

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Abstract

The experts of the construction and civil engineering companies are responsible for selecting an appropriate supplier. Evaluation and selection of appropriate suppliers may decrease quality deficiency, cost overrun, environmental problems and etc. In this research a decision support system is developed to select appropriate supplier for construction and civil engineering companies. The effective criteria on the supplier selection process have been investigated and accommodated to internal structure of the Iranian construction and civil engineering companies by questionnaire survey. For this purpose, the current research carries out among logistics managers of the first grade Iranian construction and civil engineering companies or those with having ISO certification. After completion of questionnaires, the effectiveness of criteria is evaluated using t-student test. Five criteria are excluded, and 18 criteria are selected as effective criteria. To select appropriate supplier, the AHP and ANP approaches are utilized simultaneously. Since, these two methods use a limited number of criteria, it is essential to prioritize criteria. So, Friedman test is applied and finally five of the most important criteria have been employed. Unfortunately environmental issues are not attended by construction and civil engineering companies. To illustrate concept and performance of proposed decision support system three candidate suppliers are ranked using AHP and ANP models. Although the final results of AHP and ANP methods are the similar, the values of variation between suppliers are different. Therefore, it is recommended to employ the ANP method considering internal relations between criteria.

Keywords: *supplier selection, construction and civil engineering company, Analytic Hierarchy Process (AHP), Analytical Network Process (ANP), construction management, Iranian companies*

1. Introduction

The experts of the construction and civil engineering companies are responsible for selecting an appropriate supplier. Most of the purchases are used as intermediate products in the process of manufacturing and service and lack of attention in the supplier selection may result in serious consequences. What is less clear is which criteria should be taken into account for supplier selection? Is it sufficient to accept just some well-known criteria such as price and cooperation experience? In most cases, the selected supplier did not meet the employer expectations in different issues such as quality deficiency, cost overrun, delay, environmental problems and etc. Therefore, an evaluation and selection of appropriate suppliers may decrease these problems. Monczka (1998) believes that around 50 percent of the quality problems are associated directly with improper selection and management of supply chain. Therefore, it is extremely important to select capable suppliers to satisfy demand of customer (Monczka *et al.*, 1998).

On the other hand, the effective criteria in the supplier selection vary from one customer to another one. For example, the importance of quality is not the same in dissimilar companies with various task fields. Therefore, the main objective of the supplier evaluation process is to reduce purchase risk for customers in various task fields. Accordingly, the construction and civil engineering companies should evaluate suppliers based on their criteria.

2. Literature Review

Since the purchase strategy is determined based on the company's strategy, the evaluation and selection process of supplier are affected by company's strategy. For a long time it was a common believe in the United State to employ a large number of suppliers to reduce the purchase risk. However, it is a well known fact that this idea is no longer popular. These days, most companies prefer to work with those suppliers who have had favorable performance during the past ten years. Optimization process of supply chain normally causes reduction in the number of suppliers (Huang *et*

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al., 2007).

Customers evaluate the potential of the supplier. For this purpose, three initial criteria, namely price, quality and delivery are utilized to evaluate suppliers. However, further researches and analysis are needed in the case of critical demands (Gencer *et al.*, 2007; Jharkharia *et al.*, 2007; Bayazit, 2006).

Dickson (1966) identified 23 criteria for the supplier selection based on a survey of 273 purchasing manager. He showed that quality was perceived to be most important criteria followed by delivery and performance history. Bache (1987) presented 51 criteria for the supplier selection and categorized them into the eight following groups: quality, planning, facilities, control, organization and management, willingness of supplier, supplier tools and responsibility. Weber *et al.* (1991) reviewed 74 articles which address the supplier selection criteria and they concluded that net price has received the greatest amount of attention.

With the fast growth in Multi Criteria Decision Making (MCDM) models, several researchers have used these models to optimize supplier selection. Ghodsypour and Obrien (1998) presented a method which applies the linear programming and Analytical Hierarchy Process (AHP) to concentrate on both qualitative and quantitative criteria in supplier selection.

A web-based AHP method was applied by Akarte *et al*. (2001) to assess the casting suppliers. In this method, suppliers had to register and enter their casting qualifications. Based on these qualifications, the relative importance weightings for the criteria were determined by purchasers. A five-step AHP model was developed by Muralidharan *et al.* (2002) to rate and select appropriate suppliers. The suggested model involved various sections of the company, such as quality control, stores, purchasing and etc in the selection process. Handfield *et al*. (2002) used the environmental criteria to supplier assessment with AHP. Bhutta and Huq (2002), Chan and Chan (2004), Chan *et al*. (2007) and Hou and Su (2007) applied AHP to evaluate and select appropriate supplier in different field such as the advanced technology industry, the mass customization environment, in the airline industry and etc.

Since the factors of supplier assessment would affect on each other, Sarkis and Talluri (2002) and Bayazit (2006) applied Analytic network process (ANP) in supplier selection. Gencer and Gürpinar (2007) developed an ANP model in an electronic firm to assess and select the best supplier.

As indicated in aforementioned research, more investigations are required for determining suitable suppliers in construction projects. This fact is more influential in developing countries with high rate of development. In Iran for instance, investigations are more concentrated on industrial suppliers (Kasirian, 2009; Mirkiaei *et al*., 2007; Javanmardi *et al*., 2009; Ghodsypour *et al*., 2001; Haery *et al.*, 2008). On the other hand special criterion such as quality which in developed countries are guaranteed by reliability of the suppliers, are more important in developing countries. Therefore, this study presents a Decision Support System (DSS) to the supplier selection in the construction and civil engineering companies. An important issue in generating this DSS is identification of the supplier selection criteria that are embedded specification of the construction and civil engineering companies. Since the factors of supplier selection may affect on each other a DSS should be capable to consider interaction among criteria.

3. Proposed Decision Support System

The proposed decision support system for the supplier sellection in the construction and civil engineering companies includes two systematic steps:

1. Identification of effective criteria for the supplier selecetion
2. Using appropriate decision making model to select the best supplier among a number of suppliers.

3.1 Criteria Identification

In this section, the effective criteria on the supplier selection process have identified by using present information and evidences data from the literature (Akarte *et al*., 2001; Muralidharan *et al.*, 2002; Handfield *et al*., 2002; Bhutta *et al*., 2002; Chan *et al*., 2004; Chan *et al*., 2007; Hou *et al.*, 2007; Sarkis *et al.*, 2002; Bayazit 2006; Gencer *et al*., 2007; Kasirian, 2009; Mirkiaei *et al*., 2007; Javanmardi *et al*., 2009; Ghodsypour *et al*., 2001; Haery *et al*. 2008). Then based on Delphi method, some interviews have been carried out with experts so as to adopt these criteria with internal structure of the construction and civil engineering companies and complete the information.

The Delphi method is a structured communication technique, originally developed as a systematic, interactive forecasting method and interactive decision-making which relies on a panel of experts. In the standard version, the experts answer questionnaires in two or more rounds. The person coordinating the Delphi method can be known as a facilitator, and facilitates the responses of their panel of experts, who are selected for a reason, usually that they hold knowledge on an opinion or view. The facilitator sends out questionnaires, surveys etc. and if the panel of experts accept, they follow instructions and present their views. Responses are collected and analyzed, then common and conflicting viewpoints are identified. After each round, a facilitator provides an anonymous summary of the experts' forecasts from the previous round as well as the reasons they provided for their judgments. If consensus is not reached, the process continues through thesis and antithesis, to gradually work towards synthesis, and building consensus.

Thus, experts are encouraged to revise their earlier answers in light of the replies of other members of their panel. It is believed that during this process the range of the answers will decrease and the group will converge towards the "correct" answer. Finally, the process is stopped after a pre-defined stop criterion (e.g., number of rounds, achievement of consensus, and stability of results) and the mean or median scores of the final rounds determine the results (Linstone *et al*., 1975; Rowe *et al*., 1999). The Delphi method is used only in criteria identification. In this step the divergence nature in experience and expertise of people results in comprehensive identification and challenge in determining the criteria. Therefore the divergence of experience in the step causes no problems. Finally, to collect the information and determine the importance of these criteria, questionnaire has been utilized. The proposed criteria are listed in Table 1.

The questionnaire survey has been performed among first grade construction and civil engineering companies which are certificated by President Deputy Strategic Planning and Control or those with ISO certification. The responders are asked to specify the effectiveness of each criterion on their decisions using a spectrum scaled 1-9. A score of 1 indicates very low effect whereas a score of 9 indicates very high effect.

Reliability is the consistency of a set of measurements or measuring instrument, often use to describe a test. The reliability ranges between 0 and 1. Reliability may be estimated through a variety of methods. In this research, Cronbach's α method has been employed (Cronbach 1951). Cronbach's math (alpha) is a statistic. It has an important use as a measure of the reliability of a psychometric instrument. Cronbach's α is defined as:

$$\alpha = [K/(K-1)] \times [1-(\sum S_k^2/S_t^2)] \quad (1)$$

Where K is the number of questions (items of test), S_k^2 is the variance of the observed answers to question k, and S_t^2 is the variance of observed score of questionnaire t.

To determine reliability of this research, 10 pre-test questionnaires were completed and Cronbach's á was calculated to be 0.86 by means of SPSS Software. This score shows that the reliability of this research is reasonable.

As stated previously, 23 of the most effective criteria have been examined within a questionnaire by experts of 50 qualified firms. Two questionnaires were removed from further analysis because they were not fully completed, and then the information of remaining samples was evaluated by SPSS Software.

Table 1. Effective Criteria on the Supplier Selection

Effective factors
Appropriateness of the price
Receiving discount for specific purchase
Possibility of selecting the way to pay the order
Same quality of products in the multi-stage orders
Variety of the products
Low number of defective parts in the deliver orders
Exchange of defective parts
Possibility of ordering products in desired volume
Delivery of products according to order
Delivery of products according to schedule
Possibility of rapid delivery of order in emergency cases
Possibility of producing product according to buyers demand
Providing technical consultation
Possibility of delivery of order in desired location
Having different representatives all around the country
Reputation of company in the market
Cooperation experience with manufacturer
Great history of company in the market
Great history of company to produce the desired product
Market share
Considering environmental issues
Domestic certifications
International certifications

3.1.1 T-Student Test

A t-test is any statistical hypothesis test in which the test statistic follows a Student's t distribution if the null hypothesis is supported. It is most commonly applied when the test statistic would follow a normal distribution if the value of a scaling term in the test statistic were known. When the scaling term is unknown and is replaced by an estimate based on the data, the test statistic (under certain conditions) follows a Student's t distribution (O'Mahony, 1986; Press *et al.*, 1997). In this study, t-student test has been applied to evaluate the effects of criteria on the decision making process. This test implies the acceptance or rejection of a hypothesis using the obtained results from questionnaires (Zimmerman, 1997; Press, 1992). In fact, there is always possibility that a wrong decision may be made.

In order to investigate the effect of criteria on the decision making process, t parameter may be defined as:

$$t = \frac{\overline{X}-\mu}{S_{\overline{X}}} \quad (2)$$

$$S_{\overline{X}} = \frac{S}{\sqrt{n}} \quad (3)$$

Where based on what mentioned earlier, H_0 and H_1 hypothesis are expressed as follows:

- H_0: Criteria affect on the decision making process
- H_1: Criteria do not affect on the decision making process

Based on the statistical concepts, the required information for hypothesis test are as follows:

- Test is one-sided because the mean of a sample drawn form a normal population as an estimate of the (unknown) mean of this population
- The number of samples is 48 and accordinghly the degree of freedom is equal to 47
- Level of significance is 5%
- Accoring to the related table, the critical point is 1.679.

On the basis of above information, the test statistic should be determined. If test statistic is located in the critical region, H_0 hypothesis will be rejected with the probability of 95% and H_1 hypothesis will be accepted.

The value of t is presented in Table 2 for all criteria and can be simply compared with the value of 1.679. Those criteria with the value lower than 1.697 are located in the critical region and not acceptable.

After excluding 5 criteria in which the value of t was lower than specified value, 18 criteria are selected as effective criteria.

3.1.2 Friedman Test

The Friedman test is a non-parametric statistical test developed by the U.S. economist Milton Friedman. It is used to detect differences in treatments across multiple test attempts. The procedure involves ranking each row (or block) together, then considering

Table 2. Result of t-Student Test

required information for hypothesis test	Test Value = 5					Rank of criteria
	95% Confidence Interval of the Difference		Mean Difference	df	t	
	Lower	Upper				
Appropriateness of the price	2.43	3.24	2.833	47	14.133	4
Receiving discount for specific purchase	0.87	1.97	1.417	47	5.197	12
Possibility of selecting the way to pay the order	1.44	2.48	1.958	47	7.597	9
Same quality of products in the multi-stage orders	2.46	3.37	2.917	47	12.881	5
Variety of the products	-.39	.98	0.292	47	0.856	-
Low number of defective parts in the deliver orders	2.75	3.42	3.083	47	18.354	2
Exchange of defective parts	2.18	3.07	2.625	47	11.821	7
Possibility of ordering products in desired volume	1.43	2.57	2.000	47	7.080	10
Delivery of products according to order	2.84	3.74	3.292	47	14.648	3
Delivery of products according to schedule	2.84	3.49	3.167	47	19.637	1
Possibility of rapid delivery of order in emergency cases	2.62	3.63	3.125	47	12.489	6
Possibility of producing product according to buyers demand	1.84	2.91	2.375	47	8.939	8
Providing technical consultation	0.77	1.98	1.375	47	4.581	13
Possibility of delivery of order in desired location	0.44	1.81	1.125	47	3.281	17
Having different representatives all around the country	-1.28	0.36	-.458	47	-1.123	-
Reputation of company in the market	1.07	2.26	1.667	47	5.616	11
Cooperation experience with manufacturer	0.86	2.39	1.625	47	4.267	14
Great history of company in the market	0.59	1.99	1.292	47	3.707	15
Great history of company to produce the desired product	0.47	1.94	1.208	47	3.314	16
Market share	-.17	1.17	0.500	47	1.508	-
Considering environmental issues	-1.67	-.24	0.958	47	-2.692	-
Domestic certifications	0.48	2.02	1.250	47	3.254	18
International certifications	-.74	0.91	0.083	47	0.203	-

the values of ranks by columns. The Friedman test is a non-parametric test for testing the difference between several related samples. The Friedman is used when the same parameter has been measured under different conditions on the same subjects (Schaich *et al*., 1984; Conover, 1980; Bortz *et al*., 2000). Classic example of use is: *n* wine judges each rate k different wines. Are any wines ranked consistently higher or lower than the others?

Since in the next section Analytic Network Process (ANP) method and Analysis Hierarchal Process (AHP) method will be used to specify the appropriate supplier and these two methods use a limited number of criteria, it is essential to prioritize criteria. So, Friedman test would be utilized for ranking of other criteria. The results are presented in Table 3.

In accordance with the Table 3, the top five criteria are perceived to be the most important criteria, and as a result, would be used in the next steps.

The results reveal that contrary to popular belief, price obtained the sixth rank. This means that market is moving toward competition and price is no longer the main factor. Environmental issues are also not attended by construction and civil engineering companies and this does not seem favorable at all in suffering from energy waste and environmental pollution. Besides, lack of attentions to mentioned issues by construction and civil engineering companies adds a new level of difficulty and it is essential to incorporate some provisions. Low importance assigned to the

Table 3. Ranking of Hypothesis using Friedman Test

Research hypothesis	Result of Friedman test
Delivery of products according to order	18.25
Delivery of products according to schedule	17.40
Possibility of rapid delivery of order in emergency cases	17.17
Same quality of products in the multi-stage orders	16.42
Low number of defective parts in the deliver orders	16.38
Appropriateness of the price	15.15
Exchange of defective parts	14.90
Possibility of producing product according to buyers demand	14.23
Possibility of selecting the way to pay the order	13.08
Possibility of ordering products in desired volume	12.54
Reputation of company in the market	11.96
Cooperation experience with manufacturer	11.96
Receiving discount for specific purchase	11.17
Domestic certifications	10.63
Providing technical consultation	10.58
Great history of company to produce the desired product	10.19
Great history of company in the market	10.02
Possibility of delivery of order in desired location	9.63
Market share	8.04
Variety of the products	7.81
International certifications	7.73
Having different representatives all around the country	6.52
Considering environmental issues	4.27

market share by construction and civil engineering companies can be promising for small business executives. Unpredictable changes in the market affect much the companies' decision. So, delivery of products according to order and scheduling are a top priority for construction and civil engineering companies.

3.2 Application of Decision Making Methods

The supplier selection process is the kind of Multi Attribute Decision-Making (MADM) model. The MADM model is the choosing model and it is applied for choosing the most appropriate selection among different alternatives. For solving the introduced supplier selection model, different MADMs methods can be developed such as: Analytic Network Process (ANP), Analysis Hierarchal Process (AHP), Technique for Order Preference by a Similarity to Ideal Solution (TOPSIS), Simple Additive Weighting (SAW) and Elimination ET Choice Translation Reality (ELECTRE). According to the theories of the supplier selection for solving the problem, the method of AHP and ANP is used.

Analytical hierarchy process maintains a unidirectional hierarchical relationship among decision level and also weights the alternatives by pair-wise comparison of elements of the hierarchical structure. In other words, since alternatives should be evaluated by each criterion, thus a lot of pair-wise comparisons will be made and consequently the accuracy of this method would be more than other methods like simple weight method.

Since there are some internal relations between criteria, Analytic Network Process (ANP) has also been applied. The ANP developed by Thomas L. Saaty (1999) is a more general form of the AHP and includes the AHP as a special case and can be used to treat more sophisticated decision problems than the AHP. A decision problem that is analyzed with the ANP is often studied through a control hierarchy or network. A decision network involves clusters, elements, and links. A cluster is a collection of relevant elements within a network or sub-network. Saaty (2004) suggested the usage of AHP to solve the problem of independence on alternatives or criteria and the usage of ANP to solve the problem of dependence among alternatives or criteria. The structural difference between AHP (hierarchy) and ANP (network) is also shown in Figs. 1 and 2. As it can be seen from the figure, AHP structures a decision problem into a hierarchy with a goal, decision criteria, and alternatives, while the ANP structures it 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 2009).

In the AHP, each element in the hierarchy is considered to be independent of all the others – the decision criteria are considered to be independent of one another, and the alternatives are

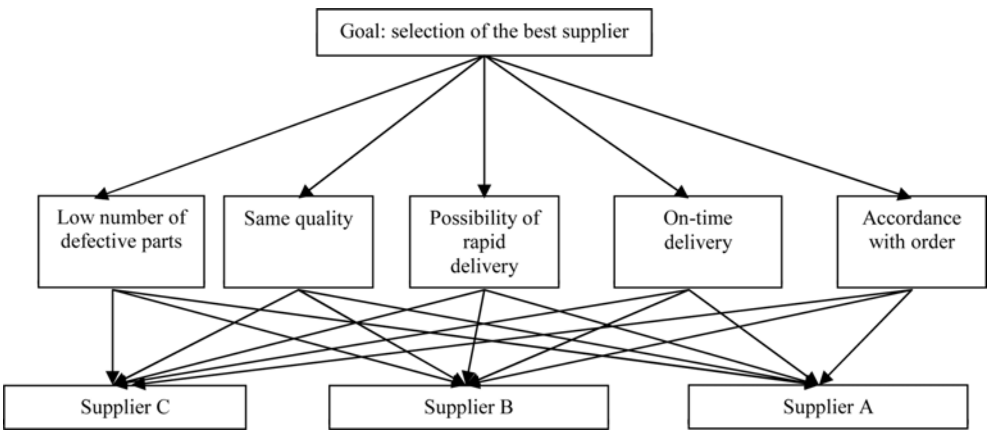

Fig. 1. The AHP Structure used in the Case Study

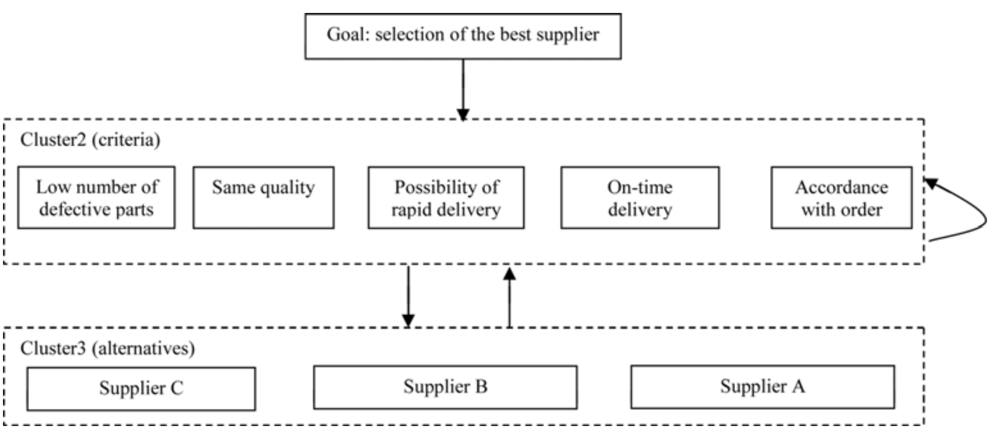

Fig. 2. The ANP Structure used in the Case Study

considered to be independent of the decision criteria and of each other. But in many real-world cases, there is interdependence among the items and the alternatives. ANP does not require independence among elements, so it can be used as an effective tool in these cases (saaty 2005).

To illustrate this, consider a simple decision about buying an automobile. The decision maker may want to decide among several moderately-priced full-size sedans. He might choose to base his decision on only three factors: purchase price, safety, and comfort. Both the AHP and ANP would provide useful frameworks to use in making his decision.

The AHP would assume that purchase price, safety, and comfort are independent of one another, and would evaluate each of the sedans independently on those criteria.

The ANP would allow consideration of the interdependence of price, safety, and comfort. If one could get more safety or comfort by paying more for the automobile, the ANP could take that into account. Similarly, the ANP could allow the decision criteria to be affected by the traits of the cars under consideration. If, for example, all the cars are very, very safe, the importance of safety as a decision criterion could appropriately be reduced (saaty 2006).

In general, in order to solve a problem using AHP and ANP, three following steps should be followed:

- Building hierarchy
- Determining weights
- Determining consistency rate

The existing interaction between elements in a network leads to form pair-wise comparison matrices that can be used to determine the relative importance of criteria and priority of alternatives. The existing elements in the matrix are pair-wise compared using a control factor.

In a similar manner to that in AHP, ANP employs 1-9 scales to make pair-wise comparison among suppliers. The relevant explanations are summarized in Table 4.

After completing the pair-wise comparisons matrices, the relevant vectors and values should be determined. The result of the above process is an un-weighted super matrix which shows the pair-wise comparisons of the criteria. The score of each alternative and the best one would be obtained from super matrix.

In general, the acceptable inconsistency rate of a system or matrix depends on the decision maker. Saaty (2004) adopted 1 as an acceptable limit and believes that if the inconsistency rate exceeds 1, revision in the decision-making process is vital. During forming the pair-wise comparison matrix procedure, consensus of expert groups is utilized. In this approach the pair-wise comparison of parameters is debated in expert groups and after assigning the values to pair-wise comparison matrix, the inconsistency of Matrix is evaluated. Using the same expert group the inconsistency is investigated by re-assigning concurred new values.

Table 4. The Fundamental Scale for Pair-wise Comparisons

Intensity of importance	Definition
1	Equal
2	Between Equal and Moderate
3	Moderate
4	Between Moderate and Strong
5	Strong
6	Between Strong and Very Strong
7	Very Strong
8	Between Very Strong and Extreme
9	Extreme

4. Case Study

To illustrate the concept and the performance of the proposed decision support system, ANP and AHP have been applied to select one supplier from three Iranian suppliers for construction materials by one Construction Company. Both methods use pair-wise comparison and Super Decision Software for the selection of supplier. The main steps of the AHP include:

- Step 1: Set up the hierarchical system by decomposing the problem into a hierarchy of interrelated elements.
  According to the results of Friedman test in the previous section, the criteria corresponding to the first to fifth ranks are selected to be used in the ANP and AHP. The hierarchy structure used in this example is illustrated in Fig. 1.
- Step 2: Compare the comparative weights between the attributes of the decision elements to form the reciprocal matrix.
- Step 3: Synthesize the individual subjective judgments and estimate the relative weights.
  Due to the space limitation, it will not be possible to present the related tables to the pair-wise comparison and only the super matrix is mentioned (Table 5). In AHP, the cluster has no influence to other, so the most of the values of criteria and alternatives are 0 in super matrix. The obtained results from these matrices are used as an input for Super Decision Software so as to evaluate the compatibility of comparisons.
- Step 4: Aggregate the relative weights of the decision elements to determine the best alternatives/strategies
  After determination of coefficients, suppliers are ranked as shown in Table 6.

The main steps of the ANP include:

- Step 1: To derive the local weights using the ANP. In a similar manner to AHP, the same five criteria and pair-wise comparisons have been employed in the ANP (Fig. 2).
- Step 2: To formulate the super matrix according to the results of the local weights and the network structure. The difference between these two methods lies in the number of comparisons made between and within clusters (Fig. 3). Outer-relations are usually considered between clusters. Therefore, when comparing the ANP model with corresponding AHP model, the importance of alternatives relating to criteria is shown using the feedbacks of clusters 2 and 3. Tables 7 and 8 depict the resulting values.
  Inter-relations are usually defined as interactions between parameters in a cluster. The curved arrow in Fig. 2 shows the inter dependencies between criteria in cluster number 2. The

Table 5. Super Matrix Obtained from Pair-wise Comparison in AHP

Super matrix		Goal	Criteria					Alternatives		
		Supplier selection	Accordance with order	Same quality	Possibility of rapid delivery	On time delivery	Low number of defective parts	Supplier A	Supplier B	Supplier C
Goal	Supplier selection	0	0	0	0	0	0	0	0	0
Criteria	Accordance with order	0.22	0	0	0	0	0	0	0	0
	Same quality	0.22	0	0	0	0	0	0	0	0
	Possibility of rapid delivery	0.11	0	0	0	0	0	0	0	0
	On time delivery	0.22	0	0	0	0	0	0	0	0
	Low number of defective parts	0.22	0	0	0	0	0	0	0	0
Alternatives	Supplier A	0.16	0.64	0.53	0.69	0.64	0.59	0	0	0
	Supplier B	0.27	0.26	0.53	0.22	0.26	0.25	0	0	0
	Supplier C	0.12	0.1	0.14	0.09	0.1	0.16	0	0	0

Table 6. Rank of Each Supplier using AHP

Supplier	Rank	Coefficient	Score (percent)
Supplier A	First	0.61	100
Supplier B	Second	0.27	44
Supplier C	Third	0.12	19

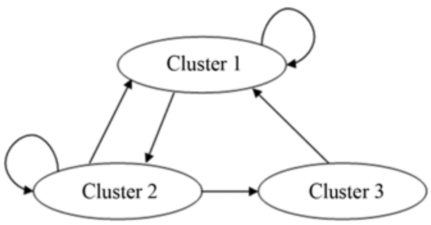

Fig. 3. The ANP Network Structure and Clusters

corresponding values are tabulated in Tables 9 and 10.

This is clearly illustrated in the general form of the super matrix which is shown in Fig. 4. In this figure C_m denotes the mth cluster, e_{mn} denotes the nth element in the mth cluster, and W_{ij} is the local priority matrix of the influence of the elements compared in the jth cluster to the ith cluster. In addition, if the jth cluster has no influence to the ith cluster, then $W_{ij}=0$. As clear, the number of tables for ANP is higher than that for AHP. As can be seen from Table 9 and 10, ANP method provides the possibility of internal comparison on the basis of criteria. The super matrix showing all comparisons for ANP method is illustrated in Table 11. After forming the super matrix, the weighted super matrix can be derived by transforming all columns sum to unity exactly, i.e., form a

Table 9. Pair-wise Comparison Matrix: Accordance with Order as Control Criterion

Control criterion: Accordance with order	Same quality	Possibility of rapid delivery	On time delivery	Low number of defective parts
Same quality	1	1	3	1
Possibility of rapid delivery	–	1	1	1.3
On time delivery	–	–	1	1.2
Low number of defective parts	–	–	–	1

Table 10. Pair-wise Comparison Matrix: Low Number of Defective Parts as Control Criterion

Control criterion: Low number of defective parts	Accordance with order	Same quality	Possibility of rapid delivery	On time delivery
Accordance with order	1	2	2	3
Same quality	–	1	3	2
Possibility of rapid delivery	–	–	1	2
On time delivery	–	–	–	1

Table 7. Pair-wise Comparison Matrix: Supplier A as Control Criterion

Control criterion: Supplier A	Accordance with order	Same quality	Possibility of rapid delivery	On time delivery	Low number of defective parts
Accordance with order	1	2	2	2	2
Same quality	–	1	1.3	1.2	1.3
Possibility of rapid delivery	–	–	1	3	1.3
On time delivery	–	–	–	1	2
Low number of defective parts	–	–	–	–	1

Table 8. Pair-wise Comparison Matrix: Supplier B as Control Criterion

Control criterion: Supplier B	Accordance with order	Same quality	Possibility of rapid delivery	On time delivery	Low number of defective parts
Accordance with order	1	1.2	3	1.3	1.3
Same quality	–	1	3	3	1.3
Possibility of rapid delivery	–	–	1	1.3	3
On time delivery	–	–	–	1	1.3
Low number of defective parts	–	–	–	–	1

$$
\begin{array}{c}
\qquad\qquad C_1 \qquad\qquad C_2 \qquad \cdots \qquad C_m \\
\qquad e_{11} \cdots e_{1n_1}\; e_{21} \cdots e_{2n_2} \cdots e_{m1} \cdots e_{mn_m}
\end{array}
$$

$$
W = \begin{array}{cc}
C_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1n_1} \end{array} \\
C_2 & \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2n_2} \end{array} \\
\vdots & \vdots \\
C_m & \begin{array}{c} e_{m1} \\ e_{m2} \\ \vdots \\ e_{mn_m} \end{array}
\end{array}
\begin{bmatrix}
W_{11} & W_{12} & \cdots & W_{1m} \\
W_{21} & W_{22} & \cdots & W_{2m} \\
\vdots & \vdots & \vdots & \vdots \\
W_{m1} & W_{m2} & \cdots & W_{mm}
\end{bmatrix}
$$

Fig. 4. The General form of the Super Matrix

stochastic matrix.

- Step 3: To raise the weighted super matrix to limiting powers for obtaining the global priority vectors or called weights. The rank of each supplier is cited in Table 11.

However the results of ranking in the AHP and ANP methods are similar, there are significant different between score of suppliers. As shown for the AHP-based method, the difference between the first and second supplier is 56%. This value for ANP-based method is 40%. This significant difference indicates notable difference between two suppliers. Although the final results of this example are similar, these values and also ranking may change as the number of suppliers increase. Therefore, it is recommended to employ ANP method considering internal relations between criteria. However, AHP method is more efficient when the volume of comparisons is notable and high accuracy is not needed.

5. Conclusions

One of the main tasks of purchase manager in the construction companies is evaluation and selection of appropriate suppliers. This paper is aimed at presenting a Decision Support System (DSS) to the supplier selection in the construction and civil engineering companies especially in the developing countries with high rate of development such as Iran. Some interviews have been carried out with experts so as to adopt these criteria with internal structure of construction companies in the developing countries with high rate of development such as Iranian construction companies and complete information. Finally, the effect of criteria was determined through a questionnaire survey. T-student test has been employed for statistical evaluation of questionnaires. After excluding ineffective criteria, the remaining criteria were prioritized by Friedman test. The following conclusions are drawn from the evaluation of questionnaires:

Contrary to popular belief, price obtained the sixth rank. This means that market is moving toward competition and price is no longer the main factor.

Environmental issues are not attended by construction and civil engineering companies and this does not seem favorable at all in suffering from energy waste and environmental pollution. Besides, lack of attentions to mentioned issues by construction and civil engineering companies adds a new level of difficulty and it is essential to incorporate some provisions.

Low importance assigned to the market share by buyers can be promising for small business executives.

Unpredictable changes in the market affect much the construction companies' decision.

Then, the method of AHP and ANP was applied to select appropriate supplier by effective criteria. Although the final results of AHP and ANP methods were the similar, the values of variation between suppliers were totally different. Therefore, it is recommended to employ ANP method considering internal relations between criteria. On the other hands, the destination of developed ANP model comparing to AHP model is the inclusion of inter dependencies between criteria and considering their impact on relative importance of alternatives to criteria. Comparison of relevant super matrixes indicated that in order to use advantages

Table 12. Rank of Each Supplier using ANP

Supplier	Rank	Coefficient	Score (percent)
Supplier A	First	0.54	100
Supplier B	Second	0.32	60
Supplier C	Third	0.14	26

Table 11. Super Matrix Obtained from Pair-wise Comparison in ANP

Super matrix		Goal	Criteria					Alternatives		
		Supplier selection	Accordance with order	Same quality	Possibility of rapid delivery	On time delivery	Low number of defective parts	Supplier A	Supplier B	Supplier C
Goal	Supplier selection	0	0	0	0	0	0	0	0	0
Criteria	Accordance with order	0.36	0	0.56	0.42	0.48	0.41	0.3	0.12	0.39
	Same quality	0.18	0.31	0	0.23	0.25	0.3	0.8	0.24	0.23
	Possibility of rapid delivery	0.25	0.18	0.2	0	0.18	0.17	0.21	0.7	0.09
	On time delivery	0.1	0.15	0.09	0.23	0	0.12	0.18	0.17	0.17
	Low number of defective parts	0.11	0.36	0.15	0.12	0.9	0	0.23	0.4	0.11
Alternatives	Supplier A	0.54	0.65	0.53	0.57	0.5	0.58	0	0	0
	Supplier B	0.32	0.25	0.53	0.28	0.26	0.31	0	0	0
	Supplier C	0.14	0.1	0.14	0.15	0.24	0.11	0	0	0

of ANP, it is required to consider subsidiary factors. However, AHP method is more efficient when the volume of comparisons is notable and high accuracy is not needed.

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