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CONSTRUCTION COST MANAGER SELECTION WITH ANALYTICAL NETWORK PROCESS (ANP)

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Abstract

In planning, designing and constructing a project, cost is of prime importance. Construction Cost Management is the establishment of realistic capital costs of construction projects. It embodies detailed cost planning and cost control services to ensure construction projects are bid, documented and completed within a pre-agreed cost framework and in the most economical manner consistent with program requirements and aesthetic considerations. Such a choice has the characteristics of a multi-criteria decision-making process. The Analytical Network Process (ANP) was used as the selection method. ANP method, taking into account the interactions between the elements involved in the decision making process, which does not take into account the Analytical Hierarchy Process (AHP), eliminates the necessity of structuring the problem from a top-down hierarchy. ANP expresses problems as a network by defining the relationships and aspects between the elements. The aim of this study is to select a cost manager to work in a construction project. After the preliminary evaluations, the most suitable among the three candidates will be preferred. The findings showed that ANP method can be used successfully in the selection of construction cost manager.
1. Introduction

Construction costs form part of the overall costs incurred during the development of a built asset such as a building. Very broadly, construction costs will be those costs incurred by the actual construction works themselves, and on some projects may be determined by the value of the contract with the main contractor.

The costs of a constructed facility to the owner include both the initial capital cost and the subsequent operation and maintenance costs. Each of these major cost categories consists of a number of cost components. The capital cost for a construction project includes the expenses related to the initial establishment of the facility:

- Land acquisition, including assembly, holding and improvement
- Planning and feasibility studies
- Architectural and engineering design
- Construction, including materials, equipment and labor
- Field supervision of construction
- Construction financing
- Insurance and taxes during construction
- Owner's general office overhead
- Equipment and furnishings not included in construction
- Inspection and testing...

The magnitude of each of these cost components depends on the nature, size and location of the project as well as the management organization, among many considerations. The employer and contractor are interested in achieving the lowest possible overall project cost that is consistent with its investment objectives [2].

In planning, designing and constructing a project, cost is of prime importance. This is true today more than ever due to rampant escalation. Cost considerations are continually present from concept budget, through to successful building occupation and use. Construction Cost Management is the establishment of realistic capital costs of construction projects. It embodies detailed cost planning and cost control services to ensure construction projects are bid, documented and completed within a pre-agreed cost framework and in the most economical manner consistent with program requirements and aesthetic considerations. All construction projects should have an independent, unbiased, professional Cost Manager onboard through the duration of the contract to police and
overview the procedures in order to protect the financial interests of the employer and contractor. A Cost Manager uses his engineering judgment and experience in the application of scientific principles and techniques to analyze and develop the best course of action in regard to cost estimation, cost control and profitability of the project. Using cost management principles, the Cost Manager ensures a project is designed within budget objectives and meets performance and quality goals [3].

Decision-making is that the decision-maker (s) select one or more of the options available that best suit their purpose or purpose. "Decision Making with Multiple Criteria (CKKV); definition of problem, determination of criteria related to the problem and determination of compliance of alternatives with selected criteria. The CCKV process consists of defining the decision problem in the most general way, determining the evaluation criteria, preparing and standardizing the criteria layers, determining the criteria weight and applying the decision analysis. In many areas such as planning, disaster risk analysis, selection and resource management, there are a number of criteria which are used to determine the suitable places and alternatives for a specific purpose. In the decision analysis, after the problem is defined, the evaluation criteria must be determined first.

Criteria must be measurable so as to be able to meet the objectives of the decision problem and be expressed by a number indicating the preferences of the decision-maker for each class of the criteria. The evaluation criteria should not be incomprehensible or ambiguous. The MCC problems are a process that requires selection from many alternatives and may include criteria that vary according to the decision-maker. The purpose of determining the criteria weights is to determine the importance of each criterion according to the others. The weights to be given to the criteria determined in a decision problem are very effective on the results. In addition to determining whether a criterion is more or less important than others, the relative importance of each criterion relative to the other should be expressed numerically. Even small changes in weight values change significantly over time. Therefore, determination of benchmark weights is one of the most important stages of decision analysis.

In almost all problems, the criteria for comparison of alternatives have become widespread. In other words, for many problems, decision makers
want to solve the multi-criteria decision making problem. Multi-criteria decision-making is a methodological tool that allows decision-makers to select the best alternative by optimizing multiple criteria. Multi-criteria decision-making methods include ANP, AHP, TOPSIS, MACBETH, PROMETHE, MOORA, UTA, STEM, PAPRIKA, VIKOR, ELECTRE etc.

2. Analytic Network Process (ANP)

It was developed by Saaty with the generalization of AHP and found the opportunity to practice in many fields [4]. This method, taking into account the interactions between the elements involved in the decision making process, which does not take into account the AHP, eliminates the necessity of structuring the problem from a top-down hierarchy. ANP expresses problems as a network by defining the relationships and aspects between the elements. Thanks to this structure, indirect interactions and feedbacks that are not directly related to the elements are taken into consideration [5]. ANP is a more general form of AHP, which enables quantitative information as well as qualitative information.

The superiority of ANP over AHP is caused by the ability to determine the interactions between the elements and the elements formed by the elements. These interactions between inter-cluster and inter-cluster interactions is called. If there is interaction between the elements in the same cluster, there is intergroup interaction (internal dependency), inter-cluster interaction (external dependency) if there is interaction between the elements in different clusters [6]. In a hierarchy, the upper-level elements interact with the lower-level elements. This situation leads to the emergence of interdependencies. Therefore, many decision issues that need to be solved cannot be created in a hierarchical structure. On the other hand, it is not possible for all the elements to interact with all the elements in the other clusters and the cluster in a decision network structure [7].

Fig. 1. shows a network structure [6]. This network consists of five clusters. A set of network structure affects only cluster B. A set of B affects A and C clusters but also their own there is also interaction. The cluster C affects the D and E clusters.
The cluster D affects the A and E clusters. The cluster E affects the A, C, D clusters, but at the same time there is interaction within themselves.

It is a generic form of AHP that allows for more complex interdependent relationships among elements. As shown in Fig. 2, interdependence can occur in several ways [8]:

1. Uncorrelated elements are connected;
2. Uncorrelated levels are connected; and
3. Dependence of two levels is two-way (i.e., bidirectional).
By incorporating interdependencies through adding feedback loops in the model, a supermatrix was developed. The supermatrix adjusted the relative importance weights in individual matrices to form a new overall matrix with the eigenvectors of the adjusted relative importance weights. Four main steps are involved in ANP computation [9]:

1. Conduct pair-wise comparisons on the elements at the cluster and subcluster levels;
2. Place the resulting relative importance weights (eigenvectors) in submatrices within the supermatrix;
3. Adjust the values in the supermatrix so it can achieve column stochasticity; and
4. Raise the supermatrix to various powers until weights have converged and remained stable.

According to literature, construction contractor selection received considerable attention from researchers for the last two decades. However, uncertainty and interdependency among the various levels and across the same level of criteria and subcriteria have not yet been studied. Hence, an essential need exists to develop a model that considers the uncertainty and interdependency among criteria. The ANP alleviates the shortcomings of the discussed approaches used in contractor selection. The ANP deals with multiple criteria and further studies the interdependencies between these criteria and measures them quantitatively; it does not rely on binary decision.

2.1. ANP Analysis Process

ANP method examines problems in four steps;

1) Defining the Problem and Establishing the Model
2) Binary Comparison Matrices and Priority Vectors
3) Super Matrix Creation
4) Choosing the Best Alternatives

1) Defining the problem and establishing the model:

At this stage, the decision-making problem should be clearly defined and rationally separated in the form of a network. This structure can be obtained by using the ideas of decision makers through brainstorming or other separation methods.
2) **Binary Comparison Matrices and Priority Vectors:**
In ANP, as in AHP, factors affecting each decision are subjected to double comparisons, thus determining the importance weights of factors. Decision-makers compare the two factors at the same time by answering a series of questions in binary comparisons and determine how they contribute to the goal. In order to establish the paired comparison matrices in ANP and to determine their relative significance weights, 1-9 scale of significance recommended by Saaty as in AHS is used. As in AHP, binary comparisons in ANP are done under a matrix framework and the local priority vector is determined by the self vector obtained by solving the equation \( A^*w = \lambda_{\text{max}} * w \). Where \( A \) = double comparison matrix, \( w \) = eigen vector, \( \lambda_{\text{max}} \) is the largest eigenvalue of \( A \). Saaty recommended the normalization algorithm for the approximate solution of \( w \).

3) **Super Matrix Creation:**
In order to achieve global priorities in a system with interdependent effects, local priority vectors are written to the columns of a matrix known as super matrix. As a result, a supermatrix is in fact a fragmented matrix, wherein each matrix segment represents the relationship between two factors in a system. Here, the groups \( Ch (h = 1,2,3, h n) \) and \( h m \) of each group are denoted by \( e1h1, e1h2, ... e1hm \). \( Wij \) shows the basic eigenvector of the interaction of the elements in group \( j \). If \( j \) does not have any effect on group \( i \), then \( Wij = 0 \). General form of supermatrix is;

![Super Matrix Diagram](image-url)
4) Choosing the Best Alternatives:

The limit super-matrix determines the significance weights for alternatives or the factors being compared. The alternative which has the highest importance in the selection problem is the best alternative, while the factor that has the highest importance in the weighting problem is the most important factor affecting the decision process.

2.2. The Main Features of ANP Method

- ANP is based on AHP.
- ANP can go beyond AHP by providing dependence, however, it may include independence as an AHP.
- ANP is a dependency on a set of elements (internal dependency) and the dependency between clusters of different elements (external dependency).
- ANP's network structure allows a decision problem to be displayed easily, as well as in a hierarchical structure, regardless of what has happened before and after what has happened.
- ANP is a non-linear structure consisting of resources, loops and targets. It has a linear structure with a goal at the highest level and options at the lower levels in a hierarchy.
- ANP can determine superiority not only for elements but also for groups or groups of elements.

Some of the studies conducted with ANP method about Construction Management area are as follows;

disputes in the construction industry using analytical network process [16], Contractor selection model for highway projects using Integrated Simulation and Analytic Network Process [17].

3. Aim and Method

The aim of this study is to select a cost manager to work in a construction project. After the preliminary evaluations, the most suitable among the three candidates will be preferred. Such a choice has the characteristics of a multi-criteria decision-making process. The Analytical Network Process (ANP) was used as the selection method. The following is the use of this method in the selection of construction cost manager.

4. Construction Cost Manager Selection with Analytical Network Process

The criteria and sub-criteria for the selection of construction cost manager are given below with the expert opinions and the opinions of the company managers;

1. University which graduated
   1.1. The world ranking of the university
   1.2. Validity of the Diploma
2. Graduated Faculty / Department
   2.1. Course Contents
   2.2. Grade average
3. Work Experience
   3.1. Working time in entered jobs
   3.2. Working positions
4. Grammar
   4.1. Know the current professional languages
   4.2. Professional language proficiency
5. Computer Programs Information
   5.1. Professional programs
   5.2. The degree to which he / she knows the programs
6. Personal Features
   6.1. Attention and focus ability
   6.2. Ability of numerical solution
   6.3. Be solution-oriented
   6.4. Expectation
   6.5. The city where he lives and the ability to travel
7. Professional Qualification
   7.1. Professional Certificates
The steps after determining the criteria are resolved in the program called SuperDecisions. The hierarchy model is created as follows (Fig. 3.);

![Hierarchy model]

**Fig. 3. Hierarchy model**

There are three alternatives in the hierarchy model. Alternatives; Eyüp Bey, Cihat Bey and Enes Bey. All of the criteria depend on the purpose, ie, the problem. The links between them, depending on the criteria, are also included in the program. The next stage is to compare the criteria between the two by making comparisons and determining their importance.

The screenshot below shows the severity of the criteria relative to each other (Fig. 4.);
As a result of the scoring, the program calculated the consistency ratio and percent distribution of criteria (Fig. 5.). The value shown as 3 inconsistency. In the picture below is “consistency ratio and is calculated as 0.06603. That is, the value of less than 0.1 indicates that the comparisons are consistent.

![Materiality comparison scores](image-url)
Fig. 5. Consistency ratio and percent distribution of criteria

Considering the percentage distribution of criteria; the highest distribution criteria was “Digital Solution Capability” with 14.24%. This was followed by criteria “Accounting and Finance Knowledge” with 14.188% (Fig. 6.).
Fig. 6. Percentage distribution of criteria

In the next step, alternatives were compared among each other for each criterion, and percent severity distributions were calculated for each criterion (Fig. 7.).

Fig. 7. Percent severity distributions for each criterion
In the final stage, the percent distribution of the alternatives was calculated in the program. The following screenshot shows the values.

![Percent distribution of the alternatives](image)

**Fig. 8. Percent distribution of the alternatives**

### 5. Results

It is known that the ANP method helps to make more effective decisions than other multi-criteria decision-making methods because it takes into consideration the inter-criteria dependence. In addition, since the ANP approach takes into account the dependent relationships between the decision criteria and alternatives, it can offer much more realistic results than other methods.

Study: It was carried out in three stages, namely the creation of the network model by utilizing the paired comparisons matrix as a result of the interviews conducted with the decision-makers, the completion of the double comparisons questionnaire by face-to-face interviews with the decision-makers and the calculations with the help of Super Decisions software.

In the application, it was tried to choose contract manager by using ANP method. Eyüp Bey was chosen as the best alternative by reaching the highest result distribution with 39.5% in three alternatives. Enes Bey followed the Eyüp Bey with 33.5% and Cihat Bey with 27% percentages.
Although the developed model presents a general model that can be used to find a solution to the construction cost manager selection problem, this study has some limitations, as in all studies. First, the criteria and subcriteria in the model may not cover all variables in the literature. Depending on the decision makers, additional criteria and interactions between them may be included. However, it should be noted that more time and effort are needed to evaluate additional criteria and interactions between them. Second, the results of this model, in which both quantitative and qualitative characteristics are compared, depend on the judgment of the decision-makers.

A complex problem, which seems to be difficult to solve with the ANP method and the SuperDecisions program, has been made less streamlined. This resulted in a faster solution.

REFERENCES

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