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Preface

Nowadays we live in a world of continuous and necessary decisions in every moment of our lives. We have to make choices each moment in scenarios of a multitude of existing conflictual criteria and situations. Life requires ability to decide according to the multiple alternatives that exist in the day-to-day *operandi*. Recently, multiple criteria models appear in a flourishing position when allocating alternatives to predefined ordered categories considering the defined preference order on criteria scales, becoming MCDM a particularly important subfield of Operations Research and Management Sciences.

This book, "MCDM methods for Business and Management", comprises the work of a set of important scientists and scholars, who contribute with their vision and their experience with methods in this area, applied to business and management. These methodologies, and their application within MCDM areas, are applied in a very pragmatic way. This book responds to this kind of needs. It integrates a set of methods and conceptualizations that help to find solutions for problems within Multi-criteria Decision Making Methods.

In the book, very different problems are considered and by using the context, the framework and illustrating problems, authors apply appropriate MCDM techniques and methods to propose solutions for these problems. This book embraces an innovative way for decision-making, considering the Methodology as a very first objective to work out problems.

In fact, this book is about Methods. Authors present procedures of a method (MCDM) and then use it giving then the necessary steps to apply it to a concrete case. After the presentation of the procedures of the studied MCDM methods, each one applies to an example in a specific area of business and management.

The book is organized in a sequence of problems/chapters, with a proposed solution after applying a specific method for the particular problem. The book is composed by the following chapters:

1. Analytic Hierarchy Process Method for Antivirus Software Selection (Mehmet Kabak and Ahmet Aktaş);
2. Analytic Network Process Method for Staff Selection of a Public Institution Selection (Mehmet Kabak and Ahmet Aktaş);
3. On the use of the MOORA method in the selection of investment projects (José António Filipe and António Bento Caleiro);
4. PROMETHEE Method for a Machine Selection Problem (Metin Dagdeviren and Aylin Adem);
5. Using the Fuzzy Linguistic Computing in the Evaluation of the value creation in an innovative product (M. I. Pedro, M. Sarmento, Marta Silva and José António Filipe);
6. ELECTRE Method in Education: A School Selection Problem (Tuğba Kıral);
7. Using DEA approach for the efficiency assessment of waste resources (Miguel Rocha de Sousa and Cátia Borges);
8. Measuring the Sustainable Development of Countries: A Cross Country Comparison using VIKOR Method (Semin Paksoy);
9. The MACBETH Approach to Evaluate Strategies for the Conservation of Architectural Heritage (Stefania Stellacci, Vasco Rato and Rosário Laureano);
10. Fuzzy TOPSIS Method for a Tourism Destination (Tolga Genç and Jose António Filipe);
11. Fuzzy Techniques applied in Finance Market: Findings and Implications (Renato A. Aguiar).

Authors apply MCDM methods to very different areas as shown in the referred chapters. These chapters show the diversity of phenomena to which this kind of methodology can be applied and the interesting solutions that can be obtained with.

In general, the book aims to reach specialists in many different entrepreneurial areas, academicians and other decision makers in any social area. As this book is much about Methods, academics may also consider the book valuable for their students in order to understand the widespread aspects of these methodologies. The new contexts in current economies and societies demand new visions in decision-making processes. With this book, agents who want to be informed and use scientific methodologies to support their decisions may consider this book important for the future. In modern life, decision makers often need mathematical methods in decision-making processes. Lapses in the decision making practice often become costly and irrevocable. Anyway, citizens in general who want to be well informed about the new waves in this area also may demand information provided by this book.

The Editors,

José António Filipe

Tolga Genç

Foreword

"Multiple-criteria decision-making (**MCDM**)", also almost equivalently referred to as "multiple-criteria decision analysis (**MCDA**)", is a branch of operational research in which multiple conflicting criteria are appreciated and valued within the decision-making process.

It is therefore one of its prime objectives to regularize, with a view to its clarification, the decision-making process when it is necessary to apply conflicting, even contradictory, criteria.

The first reference, related to decision-making supported by multiple criteria, is from Benjamin Franklin (1706-1790). More recently, when Kuhn and Tucker formulated optimality conditions for nonlinear programming in 1951, also thought in problems with multiple objectives.

Despite this antiquity, the concept has not lost, but on the contrary has gained an ever-increasing timeliness and usefulness. Many decision makers and scientists have studied and applied it. The study and experience of its applications have contributed to the creation of new tools, and improvement of existing ones. The concept itself enriched and acquired new and startling perspectives.

The editors of "MCDM Methods for Business and Management" were very timely in promoting their elaboration. With the collaboration of a notable group of contributors, they produced a breathtaking, scientifically rigorous and pedagogically interesting work.

The various chapters are a careful selection of themes from a multitude of possibilities. They give a close panorama of the state of the art, and the applications of some are quite surprising.

In short, an interesting reading book, very useful for both academics and professionals.

Manuel Alberto M. Ferreira

(Full Professor at ISCTE-IUL)

ISCTE-IUL, 09.18.2019

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Analytic Hierarchy Process for the Antivirus Software Selection Problem

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Abstract

With the increasing popularity of internet, security problems for personal computers become an important danger. People are trying to prevent these security issues by using antivirus software. There are different alternative antivirus programs and each software has strengths in terms of different aspects. Since taking different aspects of programs into account is necessary and existence of a number of alternatives, using multiple criteria decision making methods for antivirus software selection is possible. This chapter deals with applying of a multi criteria decision making method to select antivirus software for a personal computer.

Keywords: Analytic Hierarchy Process, Antivirus, Software Selection.

1. Introduction

In 1946, a digital computer called as ENIAC was invented by Pennsylvania University (Griger, 1996). ENIAC is the first computer similar to the today's computers. Its weight is about 50 tons and it covers an area of 167 square meters. Because of technological progress over time, size of computers has been reduced and computers have become more and more accessible by people. IBM has constructed first personal computers in 1981. The number of computers has been sold from the start of 2017 is more than 150 Million and every passing day it increases.

People use computers in today's world for different activities. Some people play games on computers, some people watch movies, some of them prepare documents for their business. Furthermore, computers are used for accessing to the internet. By using internet, it is possible to manage bank accounts, personal documents and commercial secret processes. Hence, using computers for daily activities causes some security problems for personal secret information. At this point, users need antivirus software.

Antivirus software is the generic name of the protection programs that are written to perform cleanup and recovery processes against computer viruses (Mamaghani, 2002). Each antivirus software uses different techniques for catching and deleting viruses and the performance of the software depends on these techniques. Moreover, software prices vary from one software to the other. So, antivirus software selection decision needs to be made after some analyses.

Before making some decisions, decision makers should consider various criteria. In many cases, these criteria are conflicting with each other and making the decision becomes difficult. To handle this difficulty, multiple criteria decision making (MCDM) techniques are used. MCDM techniques are suitable for decision making problems with conflicting criteria and a finite number of alternatives. In this study, the antivirus software selection is considered as a MCDM problem. Since, antivirus software selection requires considering about conflicting criteria over different alternatives, modeling the problem by using MCDM techniques seems sensible. In this context, Analytic Hierarchy Process (AHP) (Saaty, 1980) is used to determine the best antivirus software.

The rest of this chapter continues as follows: some recent applications of AHP are summarized in the second part. Next, the AHP method is introduced in the third part. Mathematical notations related to AHP are given in the fourth part. Applicability of the method is demonstrated on an example of antivirus software selection is presented in the fifth part. This chapter is concluded in the sixth part by giving discussions and suggestions for researchers.

2. The literature review for AHP

The AHP method is a very popular method for researchers in last decade. Almost 11000 documents are indexed on Web of Science database from 2008 to 2017. The reason that AHP is such popular is its flexibility. AHP can be applied on almost every decision problem, so it has taken attention of researchers. Another reason of AHP's popularity is that AHP can be integrated with different methods such as Linear Programming, Geographic Information Systems, Fuzzy Set Theory and other MCDM methods. Some of the AHP studies in the last 10 years' literature can be summarized as follows:

Dagdeviren (2008) proposed a decision making methodology for equipment selection problem. In this methodology, AHP is integrated with PROMETHEE. AHP is used to construct the problem structure and to determine weights of selection criteria. Alternatives are evaluated by using the PROMETHEE method.

Tabari et al. (2008) used AHP with triangular fuzzy numbers to determine the best facility location. Five alternative locations are evaluated via Fuzzy AHP method.

Green supplier selection for high-tech industry is made by using Fuzzy Extended AHP method (Lee et al., 2009). The authors firstly determine 11 main-criteria and 41 sub – criteria to evaluate suppliers, but they reduce the number of criteria to 6 main – criteria and 23 sub – criteria by using Delphi technique. Selection of the best green supplier is made among 3 alternatives.

Amiri (2010) developed a decision making methodology for National Iranian Oil Company to assess alternative projects. AHP is integrated with Fuzzy TOPSIS method in the methodology. 6 criteria are taken into account for project assessment and the applicability of the AHP – Fuzzy TOPSIS method is demonstrated on an example of assessment among 5 alternative projects.

Amer and Daim (2011) considered selection of energy generation technology for Pakistan as a MCDM problem. Wind energy, solar photovoltaic, solar thermal and biomass energy options are evaluated by using AHP technique by taking 5 main and 20 sub – criteria into account. Biomass energy is determined as the best energy generation technology for Pakistan.

Ishizaka et al. (2012) proposed AHP can also be used as a solution methodology for sorting problems, besides it is used in choice and ranking problems. They propose a sorting technique named as AHPSort, which requires less comparisons than AHP and they present a case study of supplier selection for demonstrating the applicability of their methodology. By applying the steps of algorithm, suppliers are firstly classified into accepted and rejected groups, and then one of the accepted suppliers is presented as the best supplier.

AHP is used in the study of Ergu et al. (2013) for resource allocation and task scheduling in cloud computing environment. Resources are allocated to n tasks by considering four criteria (network bandwidth, complete time, task expenses and task reliability). 2 examples of resource allocation are presented.

In the literature, there are some approaches to determine priorities in AHP, such as vector normalization, eigenvector method, etc. Kou and Lin (2014) proposed a new method called as cosine maximization for priority vector derivation in AHP. Their study also consists three examples to test the proposed method based on two performance measures.

Podgorski (2015) proposed to utilize AHP for determining the key performance indices for measuring the performance of occupational health and safety management systems. At the end of the study, 109 performance indicators that are explored from the literature are reduced to 20 key performance indicators.

A hybrid decision making methodology for Lithuania's electricity generation technology choice is proposed by Streimikiene et al. (2016). Their methodology combines AHP with ARAS (Adaptive Ratio Assessment method). Six alternative technologies are evaluated by considering 5 main and 20 sub-criteria and nuclear power plant is found as the best alternative.

Kokangul et al. (2017) combined AHP with Fine Kinney method, which is used to determine acceptability of occupational health and safety risks. Their methodology determines priorities of risks via AHP and evaluates the acceptability via Fine Kinney method. An application of machine manufacturing industry is also provided.

Kabak and Keskin (2018) consider hazardous material warehouse selection problem. To determine the best location for hazardous materials, they propose a decision model integrating AHP with Geographical Information Systems (GIS). They indicate that this decision requires considering nine criteria simultaneously and they used AHP to determine importance degree of each criterion. Obtained importance degree values are used in GIS to aggregate digital map layers in GIS and the best location is determined.

Nikkhah et al (2019) proposed a life cycle assessment (LCA) model for agricultural products. Iranian tobacco production system is taken into consideration and used AHP for obtaining weights of various impact categories. Data of 225 farms are evaluated by using AHP weights, which are calculated by 12 experts' opinion and rank of negative environmental impacts on tobacco production is determined.

Yildirim and Bediroglu (2019) developed an economic and eco-friendly route determination model for high speed railway. Their model combines AHP with least-cost-path analysis in GIS. By using the proposed model, they determined an economic and environmentally friendly high speed railway route between Erzincan and Trabzon cities in Turkey.

3. Analytic Hierarchy Process Method

The AHP method is proposed by Thomas L. Saaty in 1980 (Saaty, 1980). The basic idea of the method is to derive ratios from pairwise comparisons. AHP is a mathematical method that takes priorities of individuals or groups into account and evaluates qualitative and quantitative variables together.

AHP is used by researchers in a wide variety of decision problems related to business, education, industry and government fields. By using AHP, decision makers are able to find the decision alternative that suits their goal best. In AHP, a hierarchical structure of decision problem is constructed firstly. By this way, representation and quantification of decision elements from the problem goal to the alternatives is made.

First step in an AHP application is the decomposition of decision problem into hierarchical structure. This step makes it easier to handle decision problem by dividing into sub-problems. Problem elements in hierarchical structure can represent any aspect related to the decision, which can be defined by tangible or intangible terms.

After the construction of hierarchy, decision elements are evaluated by pairwise comparisons. These comparisons are usually made by judgments of decision makers about the elements' relative importance over the other element in comparison. The main strength of AHP is performing the evaluations of decision elements by using the pairwise comparisons based on judgments.

Evaluations in pairwise comparisons are converted into numerical values for processing. After some computations, an evaluation value, which is called as weight, priority or importance degree, is derived. Elements of hierarchy are divided from each other according to weights, which are rational and consistent numbers. AHP is separated from other decision making techniques with this property.

Last step of the AHP is calculation of the priorities of decision alternatives. Priority value represents the relative ability of the alternative in views of decision goal. The best alternative is determined according to highest priority value.

4. Mathematical Notations of the AHP method

AHP is a quantitative method that is used by researchers commonly in decision problems concerning with selection among alternatives by considering their relative performance in terms of several criteria. The main advantage of AHP is to handle complex decision problems in a hierarchical structure. By this way, obtaining the solution of decision problem becomes easier. Importance degree of criteria and priorities of alternatives are being determined through pairwise comparisons and these obtained values are used to make the decision. The decision process via AHP involves six steps:

Step 1. Describing the decision problem,
Step 2. Determination of decision criteria and alternatives,
Step 3. Construction of pair wise comparison matrices,
Step 4. Calculation of priorities of decision criteria and alternatives,
Step 5. Determination of the consistency index of the matrix,
Step 6. Making the decision.

Steps of AHP are explained in detail as follows:

Step 1. Describing the decision problem

First step of AHP is the description of the decision problem. Goal of the problem should be explained precisely in this step. The decision maker must make a clear definition of what is expected to be obtained at the end of the solution.

Step 2. Determination of decision criteria and alternatives

Second step of AHP consist determination of decision criteria and alternatives. Decision criteria and alternatives can be determined by asking experts of the field of decision problem or by conducting a literature review for the studies related to the decision problem.

Problem description in the AHP method is made by using a one-way hierarchical structure from the goal to decision criteria and to alternatives as shown in Figure 1. This hierarchy represents a decision problem with n criteria and m alternatives.

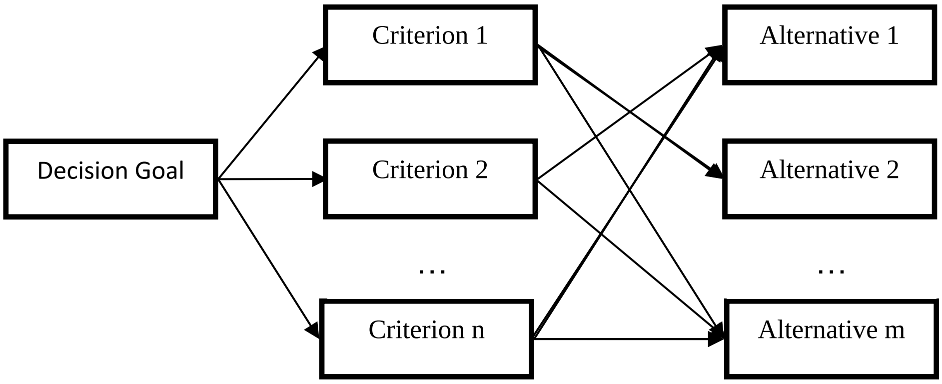

Figure 1. Hierarchical structure of a MCDM problem with n criteria and m alternatives

Step 3: Construction of pair wise comparison matrices

Pairwise comparison matrices are constructed by using 1 – 9 scale proposed by Saaty (Saaty and Ozdemir, 2005). Elements of 1 – 9 scale and their definitions are given in Table 1 as follows:

Table 1. 1 – 9 scale for pairwise comparisons

Importance Score	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Absolute importance
2, 4, 6, 8	Intermediate values

Comparisons are made through from the row element to column element in the pairwise comparison matrix. Symmetrical elements in the pairwise comparison matrix are multiplicative inverse of each other. Elements on the main diagonal, which means the comparison of element with itself are equal to 1.

Step 4: Calculation of priorities of decision criteria and alternatives

There are different approaches to obtain criteria weights. Some of them can be listed as follows:

- Logarithmic least squares method
- Least squares method
- Eigenvector/eigenvalue method
- Matrix operations method

In this chapter, Eigenvector/eigenvalue method is explained among these four methods. Priority is obtained by Eigenvector/eigenvalue method by applying the following steps:

Step 4.1: Column elements of the pairwise comparison matrix is added.

Step 4.2: Elements of pairwise comparison matrix are normalized by column sums.

Step 4.3: Priority values are the average of elements in each row.

Sum of priority values must be equal to 1. Obtained priorities can be corrected by this way.

Step 5: Determination of consistency index of the matrix

Consistency index is calculated according to the following steps:

Step 5.1: Column elements of the pairwise comparison matrix is multiplied by the weight of the element. Then, row elements are added. At the end of this step weighted sums vector is obtained.

Step 5.2: Elements of weighted sums vector is divided by the corresponding weight values.

Step 5.3: The average of the values obtained in Step 4.2 is calculated. This average value is called as λ_{max}. λ_{max} is called as the maximum equivalent of the pairwise comparison matrix. The closer value of λ_{max} to n means the pairwise comparison matrix is more consistent.

Step 5.4: Consistency index (CI) is calculated according to the following formula:

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

Step 5.5: Consistency ratio (CR) is determined by the following formula.

$$CR = \frac{CI}{RI}$$

Where the RI (Random Index) values are presented in the Table 2 as follows:

Table 2. Random Index (RI) values

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.48

If the consistency ratio is less than 0.1, the pairwise comparison matrix is consistent. Otherwise, the pairwise comparison matrix is inconsistent and a new pairwise comparison matrix must be constructed.

Step 6: Making the decision

In the AHP, decision is made according to the relative weights of alternatives vector. Relative weights of alternatives vector is calculated by the matrix product of alternative weights based on each criteria matrix and criteria weights vector. The best alternative is the alternative with the highest priority value.

5. The Applicability of the AHP Method

The mathematical notation of the AHP method was explained above and in this part; we will demonstrate how we can apply it to an antivirus software selection problem. Application steps of AHP goes on as follows:

Step 1. Describing the decision problem

Let's assume that an academician needs an antivirus software for his PC. There are different antivirus software programs can be chosen. The choice requires considering some criteria such as price, performance, false alarms, etc. Our aim is to determine the best program among a number of alternatives.

Step 2. Determination of decision criteria and alternatives

Decision makers should consider a number of criteria simultaneously before making a selection among antivirus software alternatives. In this study, antivirus selection was made by considering on-demand detection of malicious software (C1), price (C2), performance (C3), false alarms (C4) and on-demand detection of potentially unwanted applications (C5). These criteria were determined after reading some blog pages about antivirus software programs.

4 different antivirus software are considered for evaluation and these alternatives were named as Antivirus–1 (A1), Antivirus–2 (A2), Antivirus–3 (A3) and Antivirus–4 (A4), respectively. Because of the commercial issues the real names of alternatives weren't given in this paper.

Hierarchical structure of the problem can be presented as it seen in Figure 2 as follows:

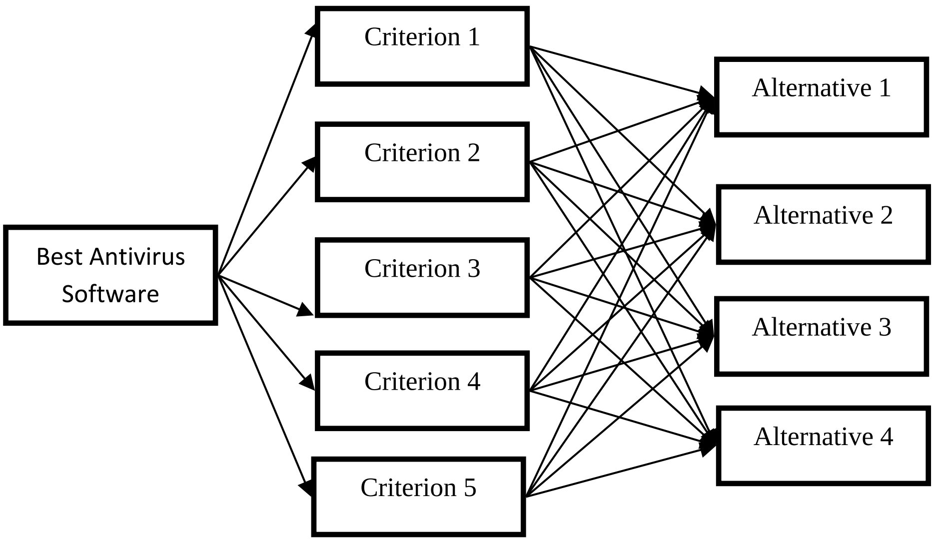

Figure 2. The hierarchical structure for antivirus software selection application

Step 3: Construction of pair wise comparison matrices

Pairwise comparison matrix for criteria evaluation is presented in Table 3 as follows:

Table 3. Pairwise comparison of criteria respect to goal

Goal	**C1**	**C2**	**C3**	**C4**	**C5**
C1	1	1/3	1/3	3	1
C2	3	1	1	3	3
C3	3	1	1	4	3
C4	1/3	1/3	1/4	1	1
C5	1	1/3	1/3	1	1

The elements of pairwise comparison matrix shows the relative importance degree of row element over column element. For example, according to the pairwise comparison above, C2 has moderate importance than C5 for goal. This information is interpreted from the 2nd row, 5th column element of the table. Similarly, from the 4th row 1st column element of the table, we can say C1 has moderate importance over C4. Pairwise comparison matrices are organized for row elements and symmetric elements are multiplicative inverse of each other.

Pairwise comparison of alternatives in views of C1 is given in Table 4 as follows:

Table 4. Pairwise comparison of alternatives respect to C1

C1	A1	A2	A3	A4
A1	1	5	3	9

A2	1/5	1	3	5
A3	1/3	1/3	1	3
A4	1/9	1/5	1/3	1

It can be seen that from Table 4 that in views of C1, A1 is strongly important than A2, moderately important than A3 and absolutely important than A4, respectively.

Pairwise comparison of alternatives in views of C2 is presented in Table 5 as follows:

Table 5. Pairwise comparison of alternatives respect to C2

C2	A1	A2	A3	A4
A1	1	1/3	1/3	1
A2	3	1	5	5
A3	3	1/5	1	3
A4	1	1/5	1/3	1

We can interpret from Table 5 that, A2 is the best alternative in views of C2. As it seen from A2 row of the table, A2 has moderate importance over A1, strong importance over A3 and A4, respectively.

Pairwise comparison of alternatives in views of C3 is presented in Table 6 as follows:

Table 6. Pairwise comparison of alternatives respect to C3

C3	A1	A2	A3	A4
A1	1	3	1/3	5
A2	1/3	1	1/7	3
A3	3	7	1	5
A4	1/5	1/3	1/5	1

In views of C3, the best alternative seems as A3 and the worst alternative seems as A4.

Pairwise comparison of alternatives in views of C4 and C5 are given in Table 7 and Table 8 as follows, respectively:

Table 7. Pairwise comparison of alternatives respect to C4

C4	A1	A2	A3	A4
A1	1	3	1/3	5
A2	1/3	1	1/7	3
A3	3	7	1	5
A4	1/5	1/3	1/5	1

Table 8. Pairwise comparison of alternatives respect to C5

C5	A1	A2	A3	A4
A1	1	1/3	1	1
A2	3	1	5	3
A3	1	1/5	1	1/3
A4	1	1/3	3	1

Similar interpretations to previous tables can be made on Table 7 and Table 8. A3 seems the best alternative respect to C4 and A2 is the best respect to C5. Numerical values of these interpretations can be seen in detail from the importance degree of criteria and alternatives.

Step 4: Calculation of priorities of decision criteria and alternatives

By using the Eigenvector/eigenvalue method priorities of decision criteria are calculated as follows:

Step 4.1: Addition of column elements are presented in Table 9 as follows:

Table 9. Sum of columns for pairwise comparison matrix of criteria

Goal	C1	C2	C3	C4	C5
C1	1	1/3	1/3	3	1
C2	3	1	1	3	3
C3	3	1	1	4	3
C4	1/3	1/3	1/4	1	1
C5	1	1/3	1/3	1	1
Sum of Column	8.33	3	2.92	12	9

Step 4.2: Normalized pairwise comparison matrix is presented in Table 10 as follows:

Table 10. Normalized pairwise comparison matrix of criteria

Goal	C1	C2	C3	C4	C5
C1	0.12	0.11	0.11	0.25	0.11
C2	0.36	0.33	0.34	0.25	0.33
C3	0.36	0.33	0.34	0.33	0.33
C4	0.04	0.11	0.09	0.08	0.11
C5	0.12	0.11	0.11	0.08	0.11

Step 4.3: Priority of an element is the average of corresponding row. In Table 11, row averages are presented as priority values as follows:

Table 11. Priorities of criteria

Goal	C1	C2	C3	C4	C5	Priority
C1	0.12	0.11	0.11	0.25	0.11	0.141
C2	0.36	0.33	0.34	0.25	0.33	0.324
C3	0.36	0.33	0.34	0.33	0.33	0.341
C4	0.04	0.11	0.09	0.08	0.11	0.086
C5	0.12	0.11	0.11	0.08	0.11	0.108

The criterion with the highest priority value is called as the most important criterion. Performance criterion (C3) has the highest priority and it is followed by price (C2). Importance order of other criteria goes as on-demand detection of malicious software (C1), on-demand detection of potentially unwanted applications (C5) and false alarms (C4), respectively.

Priorities for alternatives respect to each criterion can be calculated by following the steps of Eigenvector/eigenvalue method. The calculation processes for these priorities are not given here, just the obtained results are presented in Table 12, as follows:

Table 12. Priorities of alternatives respect to decision criteria

Goal	C1	C2	C3	C4	C5
A1	0.571	0.117	0.260	0.193	0.158
A2	0.240	0.550	0.115	0.069	0.525
A3	0.139	0.235	0.558	0.193	0.109

A4	0.050	0.098	0.066	0.544	0.208

The interpretations we made after pairwise comparisons can be corrected from Table 12. As we say, alternative orders are changing from one criterion to another. Thus, the selection decision should be made by aggregating all criteria.

Step 5: Determination of the consistency index of the matrix

An example of the consistency index calculation is presented for pairwise comparison of alternatives respect to C2 in this part. Consistency indexes for the other matrices are also calculated, but calculation processes for those matrices are not given here. The steps of the consistency index calculation goes on as follows:

Step 5.1: Weighted sums vector is obtained by adding weighted row elements of pairwise comparison matrix. Weighted sum vector for pairwise comparison of alternatives respect to C2 is presented in Table 13 as follows:

Table 13. Weighted sum vector for pairwise comparison of alternatives respect to C2

Alternative	Weighted Sum
A1	0.476
A2	2.564
A3	0.988
A4	0.403

An example calculation for elements in Table 13 for A2 is given as follows:

$$A_2 = 3*0.117 + 1*0.550 + 5*0.235 + 5*0.098 = 2.564$$

Step 5.2: Elements of weighted sum vector are divided by corresponding priority values. Obtained values are presented in Table 14 as follows:

Table 14. Values for the ratio of weighted sums to corresponding weights

Alternative	Weighted Sum/Weight
A1	0.476 / 0.117 = 4.077
A2	2.564 / 0.550 = 4.659
A3	0.988 / 0.235 = 4.204
A4	0.403 / 0.098 = 4.128

Step 5.3: Average of the obtained values in Step 5.2 is called as λ_{max}. λ_{max} is called as the maximum equivalent of the pairwise comparison matrix and is found as λ_{max} = 4.267.

Step 5.4: Consistency index is calculated by using the CI formula presented in the fourth part. Consistency index of the pairwise comparison matrix is:

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{4.267 - 4}{4-1} = 0.089$$

Step 5.5: Consistency ratio shows whether the pairwise comparison matrix is consistent or not. Consistency ratio is calculated by dividing consistency index by random index. Since this pairwise comparison matrix consists 4 elements, random index is taken as 0.90 and consistency ratio is found as:

$$CR = \frac{CI}{RI} = \frac{0.089}{0.90} = 0.099$$

Since CR = 0.099 < 0.1, we can say that the pairwise comparison matrix is consistent. Consistency ratio of other pairwise comparison matrices in this application are presented in Table 15.

Table 15. Consistency ratio of other pairwise comparison matrices

Pairwise comparison	Consistency Ratio
Criteria respect to goal	0.030
Alternatives respect to C1	0.098
Alternatives respect to C3	0.090
Alternatives respect to C4	0.003
Alternatives respect to C5	0.043

As it seen from Table 15, all of the pairwise comparison matrices are consistent. There is no need for constructing new pairwise comparison matrices. We can proceed to the last step.

Step 6: Making the decision

The decision is made by using the relative priorities vector, which is the matrix product of alternative priorities matrix and criteria weights vector. Relative priorities vector of the application is calculated as follows:

$$\begin{bmatrix} 0.571 & 0.117 & 0.260 & 0.193 & 0.158 \\ 0.240 & 0.550 & 0.115 & 0.069 & 0.525 \\ 0.139 & 0.235 & 0.558 & 0.193 & 0.109 \\ 0.050 & 0.098 & 0.066 & 0.544 & 0.208 \end{bmatrix} \times \begin{bmatrix} 0.141 \\ 0.324 \\ 0.341 \\ 0.086 \\ 0.108 \end{bmatrix} = \begin{bmatrix} 0.2409 \\ 0.3141 \\ 0.3144 \\ 0.1306 \end{bmatrix}$$

According to the relative priorities vector, the best alternative is A3. Because, the highest relative priority shows us the best alternative. A3 is followed by A2 with a small difference. Third best alternative is A1 and the last alternative is A4.

6. Conclusions

We examined the AHP method as a MCDM methodology in order to choose the best antivirus software for an academician. We explained the notations of the method first to be familiar with process and then we described how to apply it over a decision problem.

Antivirus software selection requires considering conflicting criteria simultaneously and there are different alternatives, which have advantages over the other in views of different aspects. To cope with the difficulty on making this decision, we used the AHP method. The AHP method is a commonly used MCDM approach in different decision problems. The main advantage of AHP is the ease of expressing tangible and intangible values in evaluating criteria and alternatives. By using pairwise comparison matrices, relative importance of decision elements are assessed by decision makers. So, decision is made by aggregating relative importance of decision elements.

Performance criterion is determined as the most important among antivirus software selection criteria. Price criterion follows performance with a small weight difference. These two criteria are determined as the most importance aspects for antivirus selection decision. Moreover, as we determine the third software to be the best alternative, the second software's priority is almost equal to the third.

The main limitation of this application is the limited number of selection criteria and alternatives. An extensive research may be conducted on evaluation of a greater number of alternatives by considering different aspects of antivirus software selection in further studies.

This chapter can be used to as a methodology for any business and management problem, such as, automobile selection, supplier selection, inventory classification, etc.

References

[1] Amer, Muhammad, Daim, Tugrul U.. “Selection of renewable energy technologies for a developing county: A case of Pakistan” *Energy for Sustainable Development, 15,* 2011, 420–435.

[2] Amiri, Morteza Pakdin. “Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods” *Expert Systems with Applications, 37,* 2010, 6218–6224.

[3] Dağdeviren, Metin. “Decision making in equipment selection: an integrated approach with AHP and PROMETHEE” *Journal of Intelligent Manufacturing, 19*, 2008, 397–406.

[4] Ergu, Daji, Kou, Gang, Peng, Yi, Shi, Yong, Shi, Yu. “The analytic hierarchy process: task scheduling and resource allocation in cloud computing environment” *Journal of Supercomputing 64*, 2013, 835–848.

[5] Griger, David Alan. “The ENIAC, the Verb “to program” and the Emergence of Digital Computers”, *IEEE Annals of the History of Computing, 18*, 1996, 51-55.

[6] Ishizaka, Alessio, Pearman, Craig, Nemery, Philippe. “AHPSort: an AHP-based method for sorting problems” *International Journal of Production Research, 50:17*, 2012, 4767-4784.

[7] Kabak, Mehmet, Keskin, Ibrahim. “Hazardous Materials Warehouse Selection Based on GIS and MCDM” *Arabian Journal for Science and Engineering, 43,* 2018, 3269–3278.

[8] Kokangül, Ali, Polat, Ulviye, Dagsuyu, Cansu. “A new approximation for risk assessment using the AHP and Fine Kinney methodologies” *Safety Science, 91,* 2017, 24–32.

[9] Kou, Gang, Lin, Changsheng. “A cosine maximization method for the priority vector derivation in AHP” *European Journal of Operational Research, 235,* 2014, 225–232.

[10] Lee, Amy H.I., Kang, He-Yau, Hsu, Chang-Fu, Hung, Hsiao-Chu. “A green supplier selection model for high-tech industry” *Expert Systems with Applications, 36,* 2009, 7917–7927.

[11] Mamaghani, Farrokh. "Evaluation and selection of an antivirus and content filtering software", *Information Management & Computer Security, 10*, 2002, 28-32.

[12] Nikkhah, Amin, Firouzi, Saeed, Assad, M. El Haj, Ghnimi, Sami. “Application of analytic hierarchy process to develop a weighting scheme for life cycle assessment of agricultural production”, *Science of the Total Environment, 665*, 2019, 538–545.

[13] Podgórski, Daniel. “Measuring operational performance of OSH management system – A demonstration of AHP-based selection of leading key performance indicators” *Safety Science, 73,* 2015, 146–166.

[14] Saaty, Thomas Lloyd. “The analytic hierarchy process: Planning, priority setting, resource allocation”. McGraw-Hill, 1980.

[15] Saaty, Thomas Lloyd, Özdemir, Müjgan Sağır. “The Encyclicon: A Dictionary of Applications of Decision Making with Dependence and Feedback Based on the Analytic Network Process”. RWS Publications, 2005.

[16] Streimikiene, Dalia, Sliogeriene, Jurate, Turskis, Zenonas. “Multi-criteria analysis of electricity generation technologies in Lithuania” *Renewable Energy, 85,* 2016, 148 – 156.

[17] Tabari, Mojtaba, Kaboli, Amin, Aryanezhad, M.B., Shahanaghi, Kamran, Siadat, Ali. “A new method for location selection: A hybrid analysis” *Applied Mathematics and Computation, 206,* 2008, 598–606.

[18] Yildirim, Volkan, Bediroglu, Sevket. “A geographic information system-based model for economical and eco-friendly high-speed railway route determination using analytic hierarchy process and least-cost-path analysis” *Expert Systems*, *36*, 2019, 12376.

Analytic Network Process Method for Staff Selection of a Public Institution

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Abstract

Staff selection is one of the most challenging issues related to human resources management. Human resources managers have to consider conflicting criteria and a number of applicants before choosing the person for a job. In such situations, multiple criteria decision making approaches support decision makers to cope with decision criteria and different alternatives. Staff selection decisions generally contain interactions between decision elements. In such kind of decision problems, Analytic Network Process is a suitable method to find an aggregated decision. In this chapter, Analytic Network Process method is explained and an application of industrial engineer selection for a public institution in Turkey. Importance degree of five criteria is calculated and the best candidate is determined by pairwise comparisons.

Keywords: Analytic Network Process, Staff Selection, Human Resources Management

1. Introduction

Because of the competition between organizations in today's world, organizations should manage their processes successfully. In the globalizing world, organizations are growing rapidly and management of organizational processes becomes always harder every passing day. Because of this growth, organizational processes are being divided into several parts such as production, marketing, quality, human resources, finance, etc.

Human resources management is one of the most important factors for organizational success. Organizational success mostly depends on the people who works for the organization and human resources management works for managing the processes related to personnel in the organization, such as hiring, training, determination of wages, promotion, performance management, etc.

Among all their works in the organization, hiring is possibly the most difficult decision for human resources managers. Hiring is the process of finding the best applicant for a job. The difficult process can also be named as staff selection and different elimination stages occur in this process. Some organizations expect applicants to have some exam scores and some organizations expect applicants to have certificates for their abilities. Some organizations make interviews and some organizations need recommendations for applications. Staff selection process varies from one organization to another, but all organizations have some elimination processes.

The common hiring approach for public institutions in Turkey is ranking of applicants by using the score they get from the public institution personnel selection exam. However, exam scores are not significant to show the suitability of the person to the job. Unless the suitability of job and person is ensured, the performance of the staff will not be at the desired level. So, staff selection process should be arranged again by adding some processes that measures the suitability of job and person. At that point, importance degree of each sub-process should be considered. For example, having a driving license is an important ability for a driver, but it is not necessary for a manager assistant or a cleaning person.

In this study, staff selection for an industrial engineer position of a public institution in Turkey is considered. Industrial engineering jobs require analytical thinking ability, ability of using computer programs related to statistical analysis, optimization, office programs, etc., communication and language skills. Moreover, grade point average (GPA) and public staff selection exam score should be taken into consideration. It is considered that there are some interactions about these abilities and scores. So, analytic network process (ANP) is used to solve staff selection problem.

The rest of this chapter continues as follows: in the second part recent studies from literature related to ANP is summarized. Basic descriptions and advantages of the method are given in the third part. Next, the decision making process with ANP is explained in the fourth part. In the fifth part, an application of staff selection is presented to show the utilization of the steps of the methodology on a decision problem. The chapter is concluded in the sixth part by giving a summary of chapter and further research directions for readers.

2. The Literature Review

The ANP is very popular among multiple criteria decision making methods. Researchers develop decision models based on ANP for a wide range area of application. Some studies from recent years are summarized as follows:

Atmaca and Basar (2012) evaluated power plants in Turkey by using an ANP based multiple criteria decision making model. They consider 14 sub-criteria related to 4 main criteria and evaluated six different types of power plants. Nuclear power plant is seemed as the best alternative after evaluation.

Business strategy selection of green supply chain management is considered by Chen et al. (2012). The proposed ANP model in this study supports decision makers' evaluations on determining the most important actions related to different business functions. A sensitivity analysis is also given for discussion of weight change in the most important two clusters.

Lee et al. (2012) used ANP for implementation of five forces model of strategic management in industry. By using the method, they construct an analytic approach to calculate the state of industry competition index. The proposed approach is tested on a case study in Korea.

Choice of the most preferred website is analyzed by Keramati and Salehi (2013) via ANP. Website success factors' importance degree values are determined from thoughts of 383 academic internet users and a data analysis is conducted. Significant success factors are presented and the ANP is found to be a suitable tool for website ranking in case of interdependencies of success factors.

Milani et al. (2013) studied on material selection for non-metallic gears under multifunctional design requirements. Design requirements are considered as decision criteria and the problem is modeled as a MCDM problem. An ANP model is proposed because of the existence of interdependencies between criteria. This case is compared without existence of interdependencies by using an AHP model and it is concluded that ANP offers a greater degree of freedom in structuring the decision problem.

Choice of the best cloud computing service by evaluation of quality is considered by Choi and Jeong (2014). Importance degree of quality attributes are assessed by using ANP in the proposed model and by this way determination of the best alternative becomes easier.

Alternative facility layout plans of a wood company is evaluated by aggregating 6 main and 19 sub-criteria by El-Hawari et al. (2014). Interdependencies between criteria are taken into account by modelling the problem with ANP. Robustness of the results are investigated by conducting a sensitivity analysis in the study.

Lin and Huang (2015) used ANP to analyze the factors affecting passenger choice of low cost carriers. They considered 4 main and 16 sub-criteria for evaluation and results of the study and indicated that the results can influence managers of low cost carriers in developing passenger policies.

An application of ANP for ergonomics is made by Ocampo and Seva (2016). Their study is about evaluation of text entry methods in a touch keyboard smartphone. Five alternative text entry method is evaluated by considering 6 criteria and they also present a stochastic sensitivity analysis for investigating uncertainty in decision making. QWERTY method is selected as the best among the evaluated five text entry methods.

Aminu et al. (2017) integrated ANP with geographic information systems (GIS) to develop a spatial decision support tool. The developed tool is used for sustainable tourism planning in Malaysia. By using ANP, importance degree of evaluation factors is determined and alternative places are evaluated by using GIS.

Jeon et al. (2017) proposed an evaluation model for Acquisition and Development (A&D) candidates by considering 25 criteria. To show the interdependencies between evaluation criteria, ANP is used in the model. Applicability of the methodology is demonstrated on a case study in semiconductor manufacturer firm.

Cayir Ervural et al. (2018) proposed a hybrid methodology using Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis for energy planning in Turkey. In the proposed methodology ANP is integrated with fuzzy TOPSIS and ANP is used to determine the weights of SWOT factors. Alternative energy policies are evaluated by using fuzzy TOPSIS.

Chen and Lin (2018) used a hybrid methodology based on Decision Making Trial and Evaluation Laboratory (DEMATEL) and ANP to analyze determinants of promoting emerging technologies. They consider 10 criteria related to 5 dimensions and determine the interdependencies by using DEMATEL. Obtained decision network is evaluated via ANP and criteria and dimension weights are determined.

Kyriakidis et al. (2018) indicated the 80% of railway accidents are caused of human errors and developed a human performance assessment model for railway operations. They used ANP to integrate interdependencies between performance shaping factors into the assessment model and ANP is integrated with Success Likelihood Index Methodology. They obtain some findings to improve safety of railway operations by using the model.

Khan et al. (2019) used ANP method to evaluate the suitability of existing energy plants in the region China Pakistan Economic Corridor. Coal, Hydro, Solar, and wind type plants are evalulated in views of four essential criteria of Technical, Economic, Life Quality, and Socioeconomic and 11 sub-criteria. Hydro plants are seemed to be the most suitable among four alternative plant types.

Mustafa and Kar (2019) proposed a risk prioritization methodology for digital services. To do so, ANP approach is used to evaluate 18 risks of digital services which can be classified into seven groups. Privacy risk is seemed to be the risk with highest priority.

Sagnak and Kazancoglu (2019) integrated Fuzzy ANP with 0-1 goal programming approach to determine the best Enterprise Resources Planning software. An application of selection among five alternative software by considering four goals of a company is presented to demonstrate the applicability of the proposed approach.

3. The ANP Method

In the Analytic Hierarchy Process (AHP) method of Saaty, assessments are made by using relative measures with absolute scales of criteria based on the judgment decision makers. The main concern of the mathematics of AHP method is to measure intangible decision elements. In the end of AHP computations, decisions are made by using a number for the best alternative or by using a priority vector that gives the rank of alternatives.

The ANP is a generalized form of the AHP which considers the dependence between the elements of the hierarchy. Some decision problems involve elements with interactions and dependences and these kind of problems cannot be structured in a hierarchy. That is why, ANP is proposed to the literature (Saaty, 1996). In ANP, decision problem is represented by a network, rather than a hierarchy. By this way, more realistic solutions of decision problems can be obtained.

The main advantages of ANP can be listed as;

(1) Criteria weights are calculated by pairwise comparison of decision makers by using 1-9 scale of Saaty;

(2) Both of quantitative and qualitative values can be used in pairwise comparisons;

(3) No special knowledge is required to apply ANP on a decision problem. ANP can be simply applied;

(4) It is possible to utilize ANP on either individual or group decision making process;

(5) Feedback and interdependence effects among criteria are included in calculations.

4. Mathematical Notations of the ANP Method

Solution of decision problems with the ANP method consists six steps (Yuksel and Dagdeviren, 2007). These steps are expressed as follows:

Step 1: Construct the model and structure the decision problem: Decision problem should be stated clearly and be structured in a rational representation, e.g. like a network. Network structure of the model can be constructed by opinions of decision makers or by using some appropriate methods. An example of network representation is given in Fig. 1.

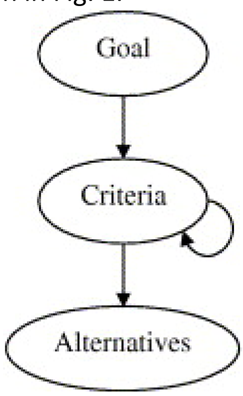

Fig.1 The network representation

Step 2: Construct pairwise comparison matrices and calculate priority vectors by considering interdependencies: In this step, local and global weights of the criteria by considering interdependencies are calculated. Pairwise comparison matrices can be constructed and weights of criteria and consistency ratio of matrix can be calculated easily by using "Super Decision" software. In this chapter, all the calculations are made using Microsoft Excel in order to explain the ANP in detail. Decision makers evaluate decision elements by using the Saaty's 1 to 9 scale, which is given in Table 1 to construct pair-wise comparisons.

Table 1. Importance scale of Saaty (Saaty and Ozdemir, 2005)

Importance degree	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Absolute importance
2, 4, 6, 8	Intermediate values

The values given in Table 1 represents the importance level of one element (row cluster in the matrix) compared to the other one (column cluster in the matrix). For inverse comparisons reciprocal values are assigned. If a_{ij} is used for expressing importance of decision element i over decision element j, $a_{ji}=1/a_{ij}$ denotes the importance of element j over element i. Similar to the AHP method of Saaty, priority vector can be derived by using Eigenvector method. Consistency of pairwise comparison matrices can also be computed as it is in the AHP method.

If the value of Consistency Ratio for a pairwise comparison matrix is smaller than 10 %, the decision makers' consistency for the evaluations within the matrix is acceptable. If this ratio is greater than or equal to 10 %, pairwise comparisons within the matrix must be evaluated again.

Step 3: Construct pairwise comparison matrices and calculate priority vectors by assuming decision elements are independent: In this step, interdependencies are ignored and pairwise comparisons are made again. The process in this step is same with the criteria evaluation in AHP.

Step 4: Determine final weights of criteria: Criteria weights by considering interdependencies, which are obtained in Step 2, and by assuming the criteria are independent which are obtained in Step 3 are multiplied. The resulting vector of this multiplication is the final weights of criteria.

Step 5: Evaluate the alternatives: To make a decision among alternatives, relative importance of alternatives are determined by forming pairwise comparisons respect to each criterion. By using Eigenvectors, priority of alternatives in views of decision criteria are calculated. Obtained priority vectors are collected in a matrix.

Step 6: Select the best alternative: Selection of the best alternative is made by calculating the final priorities of alternatives. Final priority of alternatives are calculated by multiplication of alternative priorities matrix, which is obtained in the Step 5 and final criteria weights vector, which is obtained in the Step 4. The alternative with the maximum overall priority value is selected, as it is the best alternative.

5. The Application of the ANP on the Staff Selection

The mathematical notation of ANP method was explained in the previous part. In this part, we will demonstrate how we can apply it to a staff selection problem. Application steps of ANP go on as follows:

Step 1. Construct the model and structure the decision problem

The decision problem in this chapter is selection of the best staff among a number of candidate for a public institution. The public institution needs a new industrial engineer and there are some applicants for this position. The decision must be made by considering some criteria expressing technical and social abilities of candidates. Our aim is to determine the best person among applicants.

The industrial engineer selection decision requires taking some criteria into account simultaneously. In this application, Public Institutions Personnel Selection Exam Score (C1), ability of using computer programs related to industrial engineering skills (C2), communication skills (C3), grade point average (C4) and language skills (C5) are taken into consideration.

There are four applicants as candidates of this engineer job and they are named as Applicant 1 (A1), Applicant 2 (A2), Applicant 3 (A3) and Applicant 4 (A4).

Interactions between decision elements are presented in the network representation of the model and are given in Figure 2 as follows:

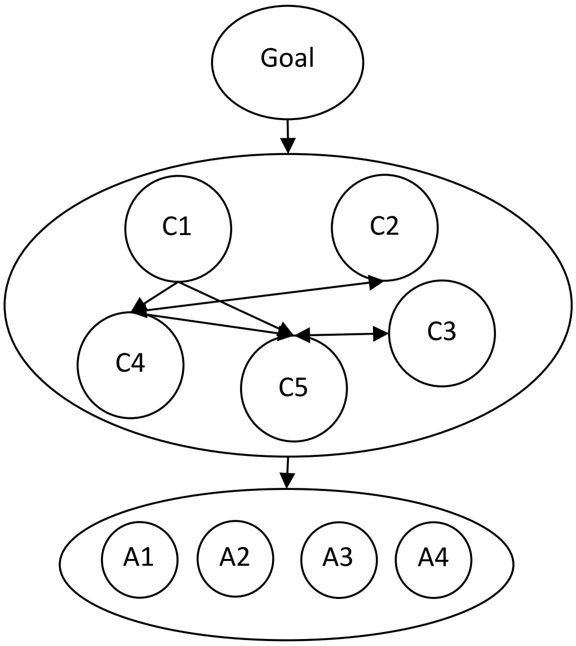

Figure 2. Network representation of staff selection application

Step 2. Construct pairwise comparison matrices and priority vectors by considering interdependencies

The pairwise comparison matrix for criteria evaluation under interdependency and influencing assumption is constructed in this step. Priority vectors that obtained from the pairwise comparison of clusters in which decision elements affect the other decision elements are collected to form interdependency matrix. When we consider the network model presented in Figure 2, pairwise comparisons of interdependencies are given in Table 2 and Table 3. Since there is no factors effecting C2, C3 and C5, there is no comparisons for these criteria.

Table 2. Pairwise comparison of influencing criteria with respect to C1

C1	C4	C5	Priority
C4	1	1/3	0.250
C5	3	1	0.750

Table 3. Pairwise comparison of influencing criteria with respect to C4

C4	C2	C5	Priority
C2	1	1/5	0.167
C5	5	1	0.833

Pairwise comparison matrices are organized for row elements and symmetric elements are multiplicative inverse of each other. The elements of pairwise comparison matrix shows the relative importance degree of row element over column element. For example, according to the pairwise comparison matrix given in Table 3, C5 has strong importance over C2 with respect to C4. This information is interpreted from the 5th row, 2nd column element of the table. Consistency values for 2 element comparisons are equal to 0. So, these values are not provided in this step. Calculated priorities are collected to form interdependency matrix of criteria and this matrix is given in Table 4 as follows:

Table 4. Interdependency matrix of criteria

	C1	C2	C3	C4	C5
C1	1.000	0.000	0.000	0.000	0.000
C2	0.000	1.000	0.000	0.167	0.000
C3	0.000	0.000	1.000	0.000	1.000
C4	0.250	1.000	0.000	1.000	0.000
C5	0.750	0.000	1.000	0.833	1.000

Step 3. Construct pairwise comparison matrices and priority vectors without interdependency assumption

Pairwise comparison matrix for criteria evaluation without interdependencies is constructed and priority values of decision criteria are calculated in this step. This calculation is the same of criteria evaluation in AHP method. Comparison matrix of criteria and priority values without interdependency assumption are presented in Table 5 as follows:

Table 5. Criteria evaluation and priorities without interdependency

	C1	C2	C3	C4	C5	Priority
C1	1	3	5	1/3	1	0.236
C2	1/3	1	3	1	1/3	0.143
C3	1/5	1/3	1	1/5	1/5	0.048
C4	3	1	5	1	1	0.298
C5	1	3	5	1	1	0.274
					CR	0.090

Step 4. Determine final weights of criteria:

Final weights of criteria are calculated by the multiplication of criteria priorities determined in Step 3 by the interdependency matrix obtained in Step 2. Final weights of criteria are determined as follows:

$$\begin{bmatrix} 1.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 1.000 & 0.000 & 0.167 & 0.000 \\ 0.000 & 0.000 & 1.000 & 0.000 & 1.000 \\ 0.250 & 1.000 & 0.000 & 1.000 & 0.000 \\ 0.750 & 0.000 & 1.000 & 0.833 & 1.000 \end{bmatrix} \times \begin{bmatrix} 0.236 \\ 0.143 \\ 0.048 \\ 0.298 \\ 0.274 \end{bmatrix} = \begin{bmatrix} 0.118 \\ 0.096 \\ 0.161 \\ 0.250 \\ 0.374 \end{bmatrix}$$

We can interpret that from the result of multiplication that the most important criterion is C5 (language skills) for the problem since it has the highest priority. Grade point average is following C5 with 0.250 priority value. Importance of the other criteria goes as C3, C1 and C2, respectively.

Step 5. Evaluate the alternatives in views of criteria:

In this step, priority of alternatives with respect to each criteria is determined. To do so, pairwise comparison matrices are constructed for alternative evaluation for each criterion. These matrices are presented in Table 6-10 as follows with the obtained priority values.

Table 6. Alternative evaluation with respect to C1

C1	A1	A2	A3	A4	Priority
A1	1	7	5	1	0.421
A2	1/7	1	1/3	1/7	0.052
A3	1/5	3	1	1/5	0.106
A4	1	7	5	1	0.421
				CR	0.028

It can be seen that from Table 9 that in views of C1, A1 and A4 has the highest priority. Order of alternatives is goes on as A3 and A2, respectively.

Pairwise comparison of alternatives in views of C2 is presented in Table 7 as follows:

Table 7. Pairwise comparison of alternatives respect to C2

C2	A1	A2	A3	A4	Priority
A1	1	1/9	3	1/3	0.093
A2	9	1	9	5	0.661
A3	1/3	1/9	1	1/5	0.047
A4	3	1/5	5	1	0.199
				CR	0.069

We can interpret from Table 7 that, A2 is the best alternative in views of C2. As it also seen from A2 row of the table, A2 has absolute importance over A1 and A3, strong importance over A5. The other alternatives ordered as A4, A1 and A3, respectively.

Pairwise comparison of alternatives in views of C3 is presented in Table 8 as follows:

Table 8. Pairwise comparison of alternatives respect to C3

C3	A1	A2	A3	A4	Priority
A1	1	1/3	1	3	0.201
A2	3	1	3	5	0.519
A3	1	1/3	1	3	0.201
A4	1/3	1/5	1/3	1	0.079

CR 0.016

In views of C3, the best alternative seems as A2 and the worst alternative seems as A4. Pairwise comparison of alternatives and obtained priorities in views of C4 and C5 are given in Table 9 and Table 10 as follows, respectively:

Table 9. Pairwise comparison of alternatives respect to C4

C4	A1	A2	A3	A4	Priority
A1	1	1/5	1/3	3	0.117
A2	5	1	3	9	0.576
A3	3	1/3	1	5	0.256
A4	1/3	1/9	1/5	1	0.051
				CR	0.029

Table 10. Pairwise comparison of alternatives respect to C5

C5	A1	A2	A3	A4	Priority
A1	1	3	1/9	1/5	0.083
A2	1/3	1	1/9	1/7	0.044
A3	9	9	1	3	0.593
A4	5	7	1/3	1	0.280
				CR	0.067

All the matrices for alternatives are consistent, since the CR values less than 0.1. Priority values obtained by pairwise comparisons are collected in alternative priority matrix. Alternative priority matrix is given in Table 11 as follows:

Table 11. Alternative priorities matrix

	C1	**C2**	**C3**	**C4**	**C5**
A1	0.421	0.093	0.201	0.117	0.083
A2	0.052	0.661	0.519	0.576	0.044
A3	0.106	0.047	0.201	0.256	0.593
A4	0.421	0.199	0.079	0.051	0.280

It is clear to say making a decision by considering only one criterion is not significant. Each alternative has advantages in views of different criteria. Using an analytic approach for an aggregated decision is sensible.

Step 6. Select the best alternative

The decision is made by using the relative priorities vector, which is the matrix product of alternative priorities matrix and criteria weights vector. Relative priorities vector of the application is calculated as follows:

$$\begin{bmatrix} 0.421 & 0.093 & 0.201 & 0.117 & 0.083 \\ 0.052 & 0.661 & 0.519 & 0.576 & 0.044 \\ 0.106 & 0.047 & 0.201 & 0.256 & 0.593 \\ 0.421 & 0.199 & 0.079 & 0.051 & 0.280 \end{bmatrix} \times \begin{bmatrix} 0.118 \\ 0.096 \\ 0.161 \\ 0.250 \\ 0.374 \end{bmatrix} = \begin{bmatrix} 0.151 \\ 0.314 \\ 0.335 \\ 0.199 \end{bmatrix}$$

The highest relative priority shows us the best alternative. According to the relative priorities vector, the best alternative is A3. A3 is followed by A2 with a small difference. Third best alternative is A4 and the last alternative is A1.

6. Conclusions

We examined an ANP as a MCDM method in order to have a multi criteria approach for choosing the best Industrial Engineering candidate for a public institution in Turkey. We explained the notations of the method first to be familiar with process and then we described how to apply it over a decision problem.

Staff selection decisions require considering conflicting and interdependent criteria simultaneously and there are different alternatives, which have advantages over the other in views of different aspects. To cope with the difficulty on making this decision, we used the ANP method. The ANP method is a commonly used MCDM approach in different decision problems. The main advantage of ANP is to be able to model decision problems in a network structure and to contain elements that influencing each other. By using pairwise comparison matrices, relative importance of decision elements is evaluated by decision makers. Then, assessment of criteria and alternatives are aggregated and the decision is made by using overall relative importance of alternatives.

Language skills criterion is determined as the most important among selection criteria. The effect of language skills on other criteria is the main reason for its importance. If we ignore the interactions between criteria, C4 is more important than C5. However, the effect of language skills on other criteria makes it more important than all other criteria. Existence of interactions between criteria makes ANP method useful for decision problems. Therefore, in such kind of decisions ANP method should be preferred.

This chapter can be used to as a methodology for any business and management problem, such as, software selection, risk evaluation, service provider selection, etc.

References

[1] Al-Hawari, Tarek, Mumani, Ahmad, Momani, Amer. “Application of the Analytic Network Process to facility layout selection” *Journal of Manufacturing Systems, 33,* 2014, 488–497.

[2] Aminu, Mansir, Matori, Abdul Nasir, Yusof, Khamaruzaman Wan, Malakahmad, Amirhossein, Zainol, Rosilawati Binti. “Analytic network process (ANP)-based spatial decision support system (SDSS) for sustainable tourism planning in Cameron Highlands, Malaysia” *Arabian Journal of Geosciences*, *10*, 2017, 286.

[3] Atmaca, Ediz, Basar, Hasan Burak. “Evaluation of power plants in Turkey using Analytic Network Process (ANP)” *Energy*, *44,* 2012, 555-563.

[4] Cayir Ervural, Beyzanur, Zaim, Selim, Demirel, Omer F., Aydin, Zeynep, Delen, Dursun. “An ANP and fuzzy TOPSIS-based SWOT analysis for Turkey’s energy planning” *Renewable and Sustainable Energy Reviews, 82,* 2018, 1538–1550.

[5] Chen, Chiau-Ching, Shih, Hsu-Shih, Shyur, Huan-Jyh, Wuc, Kun-Shan. “A business strategy selection of green supply chain management via an analytic network process” *Computers and Mathematics with Applications, 64,* 2012, 2544–2557.

[6] Chen, Shih-Hsin, Lin, Wei-Ting. “Analyzing determinants for promoting emerging technology through intermediaries by using a DANP-based MCDA framework” *Technological Forecasting & Social Change, 131,* 2018, 94–110.

[7] Choi, Cheol-Rim, Jeong, Hwa-Young. “Quality evaluation and best service choice for cloud computing based on user preference and weights of attributes using the analytic network process” *Electronic Commerce Research, 14,* 2014, 245–270.
[8] Jeon, Jeonghwan, Kim, Jieun, Park, Yongtae, Lee, Hakyeon. “An analytic network process approach to partner selection for acquisition and development” *Technology Analysis & Strategic Management, 29,* 2017, 790–803.
[9] Keramati, Abbas, Salehi, Mona. “Website success comparison in the context of e-recruitment: An analytic network process (ANP) approach” *Applied Soft Computing, 13,* 2013, 173–180.
[10] Khan, Muhammad Aamir, Ali, Ahmad, Husnain, Muhammad Iftikhar ul, Zakaria, Muhammad. “Analysis of power plants in China Pakistan economic corridor (CPEC): An application of analytic network process (ANP)” *Journal of Renewable and Sustainable Energy, 10*, 2018, 065905.
[11] Kyriakidis, Miltos, Majumdar, Arnab, Ochieng, Washington Y. “The human performance railway operational index —a novel approach to assess human performance for railway operations” *Reliability Engineering and System Safety, 170,* 2018, 226–243.
[12] Lee, Hakyeon, Kim, Moon-Soo, Park, Yongtae. “An analytic network process approach to operationalization of five forces model” *Applied Mathematical Modelling, 36,* 2012, 1783–1795.
[13] Lin, Hsiu-Fen, Huang, Yi-Wen. “Factors affecting passenger choice of low cost carriers: An analytic network process approach” *Tourism Management Perspectives, 16,* 2015, 1–10.
[14] Milani, A.S., Shanian, A., Lynam, C., Scarinci, T. “An application of the analytic network process in multiple criteria material selection” *Materials and Design, 44,* 2013, 622–632.
[15] Mustafa, Syed Ziaul, Kar, Arpan Kumar "Prioritization of multi-dimensional risk for digital services using the generalized analytic network process", *Digital Policy, Regulation and Governance, 21*, 2019, 146-163.
[16] Ocampo, Lanndon A., Seva, Rosemary R. “Using analytic network process for evaluating mobile text entry methods” *Applied Ergonomics, 52*, 2016, 232-241.
[17] Saaty, Thomas Lloyd, Özdemir, Müjgan Sağır. “The Encyclicon: A Dictionary of Applications of Decision Making with Dependence and Feedback Based on the Analytic Network Process”. RWS Publications, 2005.
[18] Sagnak, Muhittin, Kazancoglu, Yigit. “Integrated Fuzzy Analytic Network Process And 0-1 Goal Programming Technique For Enterprise Resource Planning (ERP) Software Selection” *Ege Academic Review, 19*, 2019, 75-88.
[19] Yuksel, Ihsan, Dagdeviren, Metin. “Using the analytic network process (ANP) in a SWOT analysis – A case study for a textile firm” *Information Sciences, 177,* 2007, 3364-3382.