

THE ANALYTIC HIERARCHY & THE ANALYTIC NETWORK PROCESSES IN MULTICRITERIA DECISION MAKING: A COMPARATIVE STUDY

Ali Kamil TASLICALI

Turkish Air Force Academy
Aeronautics and Space Technologies Institute
Yeşilyurt, Istanbul
aliktaslicali@gmail.com

Sami ERCAN

Istanbul Commerce University,
Eminönü, Istanbul
sercan@iticu.edu.tr

ABSTRACT

The objective of this investigation is to identify the critical benefits and factors of decision making models in a changing technological environment. Decision making models are helping tools for the managers or decision makers to make future plans by using qualitative or quantitative data. In this research; a general idea about decision making models and, comparison between the two important models, Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP), are introduced. The research was done by using the information in the literature and expert judgment. This paper can be used by academics as a foundation for further research and development in the area of decision making models. Managers can use this paper for choosing the right decision making method in a variety of constraints, such as time, budget, human resources etc. Also it can be used for further development in establishing standard operational decision making procedures in crisis situations.

Keywords : Multi Criteria Decision Making, Analytic Hierarchy Process, Analytic Network Process.

1. INTRODUCTION

Normal day decisions range from the elementary decision a child makes when he/she decides to eat something he/she likes from the two, to the complex systems that engineers deal with [1].

The decision-maker usually confronts a complex system of interrelated components such as resources, desired outcomes or objectives, persons or groups of persons, etc. Also he/she is stimulated by the necessity to predict or to control, and he/she is interested in examining the system. Apparently the better he/she understand this intricacy the better his/her prognostications or decisions will be [2].

A decision maker faces the challenging situation of selecting the right solution for a given decision making problem.

A scientific decision making process can be recognized by;

1. Identifying the problem,
2. Gathering the quantitative data,

3. Making analysis using appropriate scientific models,
4. Structuring the alternatives which will be a base to objective decisions and presenting to the decision maker [3].

There are diverse kinds of methods that aid the decision maker to select the best decision under situations characterized for having more than one criterion (i.e., multiple-criteria) but there are few studies about the challenge of selecting the best decision making method for a specific situation, specifically in decision making methods that take into consideration multiple criteria.

Two of the most important methods of Multi Criteria Decision Making (MCDM) are; the Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP). Other methods may be named as the Weight Sum Model (WSM), the Weight Product Model (WPM), Elimination and Choice Translating Reality (ELECTRE), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and Revised (Multiplicative) AHP (RAHP-MAHP) [4].

In the following sections, a brief comparison of these two techniques over other MCDM methods, the advantages of the ANP over the AHP and the managerial advantages of the ANP over the AHP are going to be explained. Then the research questions will be defined as well as the conceptual model, and the research hypothesis. The paper will be concluded with the test results of the research hypotheses and by providing implications of the results for engineering managers and decision makers.

2. LITERATURE REVIEW

Past studies on these methods have concentrated upon particular implementations of these methods [5, 6]. In spite of this and many other studies, few investigations compare the two MCDM methods (i.e., ANP and AHP) [7, 8, 9, 10, and 11].

A. General advantages of the Analytic Hierarchy Process and the Analytic Network Process over other Multi Criteria Decision Making methods

There are few studies about the advantages of the AHP/ANP method over other MCDM methods, and in one of these, Sarkis and Surrandaj claimed that, “the AHP/ANP approach offers several advantages over the other techniques, despite certain drawbacks such as rank reversal and the number of judgment elicitations that are needed [9]”.

First, as compared to other MCDM approaches, AHP/ANP is not proportionately complicated, and this helps improve management understanding and transparency of the modeling technique.

Second, they have the supplemental power of being able to mix quantitative and qualitative factors into a decision.

Third, this approach can be fit together with other solution approach such as optimization, and goal programming.

Fourth, AHP/ANP may use a hierarchical structuring of the factors involved. The hierarchical structuring is universal to the composition of virtually all complex systems, and is a natural problem-solving paradigm in the face of complexity.

Fifth, in AHP/ANP, judgment elicitations are completed using a decompositional approach, which has been shown in experimental studies to reduce decision-making errors.

Sixth, AHP has also been validated from the decision-makers perspective as well in recent empirical studies.

Seventh and last, AHP/ANP is a technique that can prove valuable in helping multiple parties (stakeholders) arrive at an agreeable solution due to its structure, and if implemented appropriately can be used as a consensus-building tool [9].

B. General advantages of Analytic Network Process over Analytic Hierarchy Process

Because the ANP (1996) is newer than the AHP (1980), there are a limited number of studies on this topic. Despite of this lack of research, there are studies that have shown that there are advantages of the ANP over the AHP [9]:

The AHP requires a strict hierarchical structure and relationship among factors and this requirement does not allow for the possibility of having top-to-bottom and bottom-to-top interdependent relationships among group of factors, or for interdependent relationships within a cluster of factors. Research has shown that the ANP goes beyond linear relationships among elements and allows interrelationships among elements [11]. Instead of a hierarchy, the ANP based system is a network that replaces single direction relationships with dependence and feedback [12, 13, and 14]. Therefore, ANP is more powerful than AHP in the decision environment with uncertainty and dynamics.

Second, in the ANP rank reversal problem is appeased, thereby it is more accurate and useful (than the AHP) as a decision support instrument for intricate situations. While the ANP and the AHP are based on user-supplied preferences among the factors and provide utility weights for the alternatives, they differ from each other in the number and types of pairwise comparisons, and also in the manner by which utility weights are actually computed [15].

For example, in Information Strategy (IS) selection problems, if the objectives of information strategy applications have been identified, the decision on the optimal candidate projects can be made by simply applying the AHP to the problem. However, in the changing environment with uncertainty and dynamics, the decision objectives cannot be easily identified because they correlate with other elements that also cannot be identified clearly. In this case, ANP comes to rescue [11].

In a research conducted by Garuti and Sandoval about the shift work problem resolutions using ANP and AHP, they suggest that; “the ANP modeling process replaces the many criteria of the hierarchy by proper network relationship ‘connectivity’ between elements and clusters, so the problem is represented in a closer way to what occurs in real life” [8, p. 8]. They note that almost similar good results were obtained with the AHP model as with the more realistic ANP model.

This was because of their comprehensive AHP model of more than 500 factors that comprises the Shift work Asset Software.

Garuti and Sandoval add to their report that the ANP modeling process provides a way to clear all the relationships among variables, decreasing significantly the breach between model and reality. The way that ANP deals with the relations among variables (through pair comparisons), helps to direct the attention to a given connection at a time, allowing a more precise and inclusive analysis. The simplification level needed to build hierarchy models requires an unusual effort to identify and handle the multiple interconnections between components that the real problem has. In the shift work AHP model developed by Fulcrum Engineering [16], it took almost one year of work to separate each criterion (approximately 500 criteria in total for the largest one), checking that interrelations and feedbacks were properly handled. This task was much easier in the ANP modeling, considering that it allows representing interactions in an explicit, graphical and direct way. As a result, the model developing time was remarkably reduced. This advantage is particularly important in complex problems which deal with biological, psychological or/and anthropological matters.

In addition to what Garuti and Sandoval suggested, Sarkis and Surrandaj concurred to the ideas of Garuti and Sandoval regarding to the use of the dependencies between the clusters and the elements in the ANP by giving an example of time and cost influencing each other. Also they emphasized that; “it relies on the accumulated experience and knowledge of senior managers, instead of merely supplying them with data that may provide little decision support [10, p.48].

Last, but not least, one research questioned both AHP and ANP processes, so this will help the company to use the resources efficiently and help decision makers to select the best alternative [7]. In that study, the supplier selection problem investigated by Dagdeviren and Eren [17] was further investigated and the Analytic Network Process approach was suggested for its solution. After the application of these two methods to the same problem, the results of these two methods have been compared and commented on.

Dagdeviren and colleagues also showed that, most of the decision making problems could not be structured hierarchically because in these kinds of problems, there was a dependency and interaction between higher level variables and lower level variables.

A decision making problem which includes a functional connectivity may be built between the factor groups with feedback. For example, there are technical interdependencies, resource and profit

dependencies in information system projects' selection problems and not taking these dependencies into consideration may lead to selecting the wrong alternative(s), which may result in reducing resources and profit [18, 19]. Like the other researchers [8, 9, 10, and 11] Dagdeviren suggested that; the AHP was not enough to model this problem with using the dependencies.

Dagdeviren and colleagues noted that order change was another problem in the AHP. Order change is the change of alternative priorities when a new alternative is added or subtracted. This problem was minimized using the ANP suggesting that is an appropriate decision making method for supplier selection problems among the possible potential MCDM methods [20].

C. Managerial advantages of Analytic Network Process over Analytic Hierarchy Process

Sarkis and Surrandaj suggested implications for management when applying the methodology [9, p.13].

“First, the ANP process facilitates inter-functional and inter-level discussions. For example, a project manager evaluating the factors given in this paper must consider operational issues as well, although at an abstracted level.

The ANP also provides a structured decompositional method for addressing the wide array of factors, instead of relying purely on intuition to evaluate all the intangible factors (for these reasons, the significant amount of time needed in answering the ANP questions can be justified).

Third, except for the eigenvector calculations for which tools are not freely available, all the other ANP calculations can be done on a managerial tool such as a spreadsheet.

Finally, the model can be used by a manager to seek the most appropriate amount of funding”.

The current gaps in the literature are:

1. There are a limited number of investigations on the comparison of AHP and ANP in MCDM [7, 8].
2. There are different examples about only one model selection and sensitivity analysis, but there is limited number of applications about the comparison of AHP and ANP in organizational structures.

3. CONCEPTUAL MODEL and HYPOTHESES

The conceptual research model for this study is shown in Figure 1. This model shows the proposed relationships between AHP, ANP and MCDM that will be examined in this study.

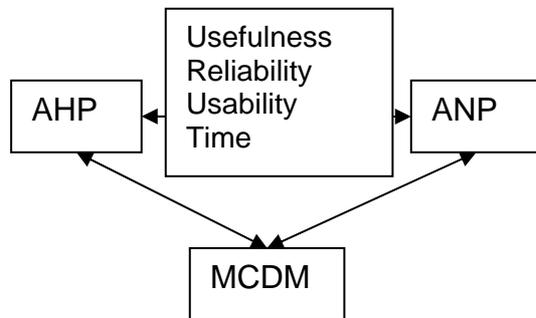


Figure 1. Conceptual model

- **Reliability:** The extent to which an MCDM method yields consistent, stable, and uniform results over repeated observations or measurements under the same conditions each time.
- **Usefulness:** The quality of having utility and especially practical worth or applicability.
- **Usability:** Convenient and practicable for use.
- **Time effectiveness:** A process which requires less time, and consequently less money to complete.

Based on the available literature and conceptual model, the following hypotheses were formulated using the stated research questions as a guide:

H1. ANP modeling process represents reality in decision making process better than AHP.

H2. The results obtained from the Analytic Network Process method are as useful for decision making as the results obtained from the Analytic Hierarchy Process method under a decision making situation characterized by a limited budget.

H3. The results obtained from the Analytic Network Process are as reliable as the results obtained from the Analytic Hierarchy Process model under a decision making situation characterized by a lack of skilled decision making manpower.

H4. The results obtained from the Analytic Network Process are as reliable as the results obtained from the Analytic Hierarchy Process model under a decision making situation characterized by a lack of decision making infrastructure (e.g., computers, software).

H5. The Analytic Network Process is more time effective than the Analytic Hierarchy Process for

similar decision making problems (e.g., same number of alternatives, criteria).

H6. The results of the Analytic Network Process provide an easier capability of further decision making analysis and conclusions than the results of the Analytic Hierarchy Process.

H7. The Analytic Network Process is more user friendly than the Analytic Hierarchy Process.

Up to this point a base for the two methods were structured. In the next section the method of this study will be explained.

4. METHODOLOGY

The following 9 steps represent the overall research method for this study:

1. Define research questions
2. Literature review
3. Generate conceptual model
4. Define research scope
5. Operationalize the research
6. Develop data collection instrument
7. Data collection
8. Data analysis
9. Interpret and product final results

A self-administered survey of 25 questions was used as a data collection instrument. The first 17 questions were chosen to be the priority questions. The questions from 11 through 18 were the comparison questions. The last 8 questions were demographic questions. In the preparation phase, the questions were based on the hypothesis. So the outcomes of the survey will directly affect the body of knowledge about the topic.

In total, 161 contacts that had an expertise in these areas (the members of the Scientific Support Centers of Turkish Air, Navy and Army Forces) and also the ones who joined to the Symposium of 8th Analytic Hierarchy Process in June 2005 in Hawaii, US received a message with the electronic link that would give access to the on-line questionnaire. But from the 52 respondents that began to complete the survey, only 42 finished, representing a rate of response of 81%. This rate of return was over the 70% rate of return recommended in literature to pose no threat of bias. E-mails were the communication media used to distribute the link for the on-line survey. The software and website used to administer the survey online was SurveyMonkey.com. The software was relatively good to collect data. Table 1 provides descriptive statistics of the characteristics of the organizations.

Table 1. Descriptive statistics of the characteristics of the organizations

| Characteristic of the Organization | Statistic | Value |
|------------------------------------|--------------------|---------|
| Time in Operation (in years) | Mean | 19.195 |
| | Mode | 20 |
| | Minimum value | 4 |
| | Maximum value | 50 |
| | Standard Deviation | 12.073 |
| Number of Employees (people) | Mean | 186.756 |
| | Mode | 300 |
| | Minimum value | 5 |
| | Maximum value | 2000 |
| | Standard Deviation | 310.49 |
| Number of Decision Makers (people) | Mean | 5.794 |
| | Mode | 4 |
| | Minimum value | 2 |
| | Maximum value | 30 |
| | Standard Deviation | 5.202 |

After closing the survey from SurveyMonkey.com, the survey results were downloaded, and then the data was revised by grouping the answers under the same question (e.g., under the same column).

Then the data was started to be processing by sorting the answers depending on each hypothesis. Second, the data of the respondents whom did not answer the question and the ones who could not answer the question was deleted. Finally we got the raw data.

After doing this, SPSS-v14 was started to be used to do the statistical calculations. A one-sample one-tailed t-test was selected as the statistical procedure to test the hypotheses. One-tailed was used; because the analysis focuses on one side of the distribution (i.e., to observe if the lower limit (LL) of the distribution falls within the acceptance level of the hypothesis). The rejection and acceptance intervals were defined as follows: from 1 through 2.5 as rejection; from 2.5 through 3.5 as neutral (i.e., we can not reject or accept the hypothesis); and from 3.5 through 5 as acceptance. These intervals depend on the scale used to elicit answers from the questions asked to the respondent on each hypothesis.

Different confidence intervals (CL) were used to determine the level of confidence that give a lower limit of the t-test distribution that falls within the

acceptance interval. Trial and error technique was done to find a confidence interval that provides us with a value of the lower limit added to the test value that was greater than 3.5 (e.g., 3.501). The confidence intervals that range from 90% to 97.5% were used. If the result was not over 3.5 then it was to conclude that the hypothesis could not be accepted or rejected with this analysis.

After this, the data was analyzed by t-test, and the mean of the acceptance interval (4.25) was used as the initial test value. It is important to mention that SPSS-v14 does not provide the capability to do a one-tailed t-test, thus the results had to be modified to achieve the one-tailed answers.

In the next section the results of the analysis for each hypothesis will be presented.

5. RESULTS

A. Hypotheses

Hypothesis 1:

The results of the data analysis demonstrated that the mean value was 4.0238 and this corresponded in the acceptance interval and there was not a significant difference (0.118) between the test value and observed mean at the 0.05 significance level. This empirical finding supports the suggestion that the ANP modeling represents reality in decision making process better than the AHP.

Table 2. Analysis of the Distribution of the hypothesis 1

| CL | Test Value | LL | >3.5? |
|-------|------------|-------|-------|
| 90% | 4.25 | -0.47 | 3.78 |
| 92.5% | 4.25 | -0.50 | 3.75 |
| 95% | 4.25 | -0.54 | 3.71 |
| 97.5% | 4.25 | -0.61 | 3.64 |

As mentioned before, the ANP modeling process replaces the many criteria of the hierarchy by proper network relationship between elements and clusters, so the problem is represented in a closer way to what occurs in real life. The model helps to show all the relations between the alternatives, and the criteria.

Hypothesis 2:

The results of the data analysis for the second hypothesis showed that the mean is in the neutral interval with 3.6279 and after adding the lower limits to the test value (4.25) the hypothesis cannot be rejected or accepted. Also there was a significant

difference (0.0005) between their reported agreement and the test value.

Table 3. Analysis of the Distribution of the hypothesis 2

| CL | Test Value | LL | >3.5? |
|-------|------------|-------|-------|
| 90% | 4.25 | -0.84 | 3.41 |
| 92.5% | 4.25 | -0.87 | 3.38 |
| 95% | 4.25 | -0.91 | 3.34 |
| 97.5% | 4.25 | -0.96 | 3.29 |

The rationale is based on the fact that the importance of the budget in every organization may differ from each other (e.g., limited budget may not be the most important criterion for government and military organizations in some projects). For example, the importance in military organizations may be on safety or the accomplishment of the mission (i.e., budget is not important), whereas in private companies or project-based organizations there might be a focus on budget compliance. Consequently, based on the distribution of the types of organizations in the sample it is suggested the hypothesis cannot be accepted or rejected based on the answers collected from the sampled organizations.

Hypothesis 3:

The results of the third hypothesis were headed to the mean of 3.7442 which was also in the neutral zone but after adding the lower limit to the test value, only with 90% confidence level the hypothesis was accepted.

Table 4. Analysis of the Distribution of the hypothesis 3

| CL | Test Value | LL | >3.5? |
|-------|------------|-------|-------|
| 90% | 4.25 | -0.73 | 3.52 |
| 92.5% | 4.25 | -0.76 | 3.49 |
| 95% | 4.25 | -0.80 | 3.45 |
| 97.5% | 4.25 | -0.86 | 3.39 |

The observed group was from different organizations and, human resources or the assigned groups for decision making for these organizations were differing from 4 to 30. Despite the diversity of the number of decision makers in an organization, with 90% of confidence, the analysis for the third hypothesis headed to the conclusion that the results obtained from the Analytic Network Process are as reliable as the results obtained from the Analytic Hierarchy Process model under a decision making situation characterized by a lack of skilled decision making manpower.

Hypothesis 4:

The analysis for the fourth hypothesis demonstrated that the results obtained from the Analytic Network Process may or may not be as reliable as the results

obtained from the Analytic Hierarchy Process model under a decision making situation characterized by a lack of decision making infrastructure (e.g., computers, software) because the mean was in the neutral zone with 3.5366. Also with all confidence levels after adding the lower limits to the test value, the hypothesis was neither accepted nor rejected

Table 5. Analysis of the Distribution of the hypothesis 4

| CL | Test Value | LL | >3.5? |
|-------|------------|-------|-------|
| 90% | 4.25 | -0.95 | 3.30 |
| 92.5% | 4.25 | -0.98 | 3.27 |
| 95% | 4.25 | -1.01 | 3.24 |
| 97.5% | 4.25 | -1.07 | 3.18 |

The ANP software is being introduced to organizations recently, so the reliability of the ANP over the AHP is not clear yet. So the answers for this hypothesis showed diversity again from the sampled organizations.

Hypothesis 5:

The mean for the fifth hypothesis was 3.3095 and with all confidence levels the results were in the neutral zone of 2.501-3.5.

Table 6. Analysis of the Distribution of the hypothesis 5

| CL | Test Value | LL | >3.5? |
|-------|------------|-------|-------|
| 90% | 4.25 | -1.20 | 3.05 |
| 92.5% | 4.25 | -1.24 | 3.01 |
| 95% | 4.25 | -1.28 | 2.97 |
| 97.5% | 4.25 | -1.35 | 2.90 |

One of the answers for this hypothesis was that, the AHP was flawed in rank reversals but the ANP was not. So time spent for the ANP was quite less than the time spent for the AHP. The decision maker does not need to go over for the criteria and the alternatives and their dependencies again and again, so reserving time for himself/herself so for the organization. Because time is also a major constraint for the projects and/or for the organizations, the more the decision maker spends time on the project for a specific process, the more it costs for the organization. But this comment was not the only comment.

Also the other comment on this hypothesis represents that, it depends on the number of alternatives and the criteria. If the number of the alternatives and the criteria is not high, both of the processes might need the same time for the planning. But if the number of the alternatives and the criteria get higher in amount, the time spend for the processes progressively will differ. As a conclusion, this hypothesis is neither accepted nor rejected.

The analysis for the fifth hypothesis demonstrated that the Analytic Network Process may or may not be more time effective than the Analytic Hierarchy Process for similar decision making problems (e.g., same number of alternatives, criteria), because of the different numbers of the alternatives, criteria and the imperfectness of the AHP.

Hypothesis 6:

The sixth hypothesis' mean was 3.4651 and after adding the lower limit to the test value the results were in the neutral zone again.

Table 7. Analysis of the Distribution of the hypothesis 6

| CL | Test Value | LL | >3.5? |
|-------|------------|-------|-------|
| 90% | 4.25 | -1.02 | 3.23 |
| 92.5% | 4.25 | -1.05 | 3.20 |
| 95% | 4.25 | -1.09 | 3.16 |
| 97.5% | 4.25 | -1.15 | 3.10 |

The ANP hierarchies are stable and flexible. Stable in that small changes have small effect and flexible in that additions to a well-structured hierarchy does not disrupt the decision. The changes on parameter of the decision making process may be in further part of the decision making process and this may affect the whole results, but also the changes may be in the earlier phases of the decision making process resulting in minor effects to the overall process (i.e., planned decision making costs).

Also in the supplier selection problem that was mentioned for both processes, the results were totally different. It seems that, by using the ANP the decision maker may see the dependencies and the effects of the dependencies over the criteria better. But every project is unique so we can not conclude that the results of the Analytic Network Process always provide an easier capability of further decision making analysis and conclusions than the results of the Analytic Hierarchy Process.

Hypothesis 7:

In the last hypothesis the mean was to be the lowest mean of all (2.86) and after adding the lower limit to the test value, the results showed that with 97.5% confidence level, it was (2.44) below the neutral zone.

Table 8. Analysis of the Distribution of the hypothesis 7

| CL | Test Value | LL | >3.5? |
|-------|------------|-------|-------|
| 90% | 4.25 | -1.66 | 2.59 |
| 92.5% | 4.25 | -1.70 | 2.55 |
| 95% | 4.25 | -1.74 | 2.51 |
| 97.5% | 4.25 | -1.81 | 2.44 |

So it is concluded that it needs to be further studied to find if it can be rejected. Another t-test with new test value (1.75), which was the mean of the rejection interval, was implemented, and instead of adding the lower limit to the test value, the upper limit (UL) was added to the new test value to see if the result gives a value above rejection value of 2.5. But after running the test and adding the upper limits the results showed the values between 3.13 and 3.28, so it is concluded that the values were referred to the neutral zone.

Table 9. Analysis of the Distribution of the hypothesis 7

| CL | Test Value | UL | >3.5? |
|-------|------------|------|-------|
| 90% | 1.75 | 1.38 | 3.13 |
| 92.5% | 4.25 | 1.42 | 3.17 |
| 95% | 4.25 | 1.46 | 3.21 |
| 97.5% | 4.25 | 1.53 | 3.28 |

Absolutely the steps of the ANP (i.e., 9 steps) are much higher than the steps of the AHP (i.e., 4 steps). It takes much time for a decision maker to process the data by using the ANP. The results obtained were below the neutral value with a mean of 2.43 (i.e., towards to strongly disagree threshold). However, due to the newness of ANP, some respondents could find it difficult to use because they are in the beginning of the learning curve, whereas others more experienced with the method and software can find it more usable. This large variability leads to the conclusion that the hypothesis cannot be rejected or accepted. There might be other factors that affect the perception of the usability of the methods that were not taken into consideration.

B. Managerial Implications of the Results

The way of expressing reality in decision making by using the ANP, and also the reliability that was obtained by using the ANP are two important outcomes of the investigation. These findings suggest that managers of multi-project organizations and project managers have an opportunity to see the dependencies close to real life as well as the reliability.

Also another finding is that, the data is the base for the overall decision making process. Consequently, a decision maker needs highly experienced personnel who have expertise that aligns well with the goals of the organization to be able to efficiently and effectively create the pairwise comparison matrix.

Another finding from the preparation questions is that, if the number of criteria and alternatives are relatively high, and reliability is not considered as much, then the use of the ANP may be avoided. Because the process will take much time to come to a conclusion for the decision maker.

Further results suggest that most of the respondents use both of the methods in planning stage of the project life cycle. Also MCDM methods were used once a month in most of the organizations; whereas the AHP was used once a year mostly.

Another finding is that, the strongest enabler for both of the methods is skilled workforce

However, the findings are also limited in some noteworthy ways. First the data are self-reported and, therefore, potentially subject to hindsight and other biases. In addition, the time period used for the survey was quite short (14 days) to gather efficient amount of data. Even if the sample size of the survey is over the sample size that is advised by the literature, in order to get more confidence on the survey, the research needs to be enhanced. Also in addition to the contacts that were from the International Symposium of the Analytic Hierarchy Process, the contacts might be extended including the lower management users of the two methods especially the ANP. Finally, all of the respondents were educated about both AHP and ANP but, some of them did not get into the usage of the ANP in detail so this might affect the overall findings.

6. FUTURE RESEARCH

Future research on the comparison of the Analytic Hierarchy Process and the Analytic Network Process must include:

First, even though the ANP method was found to be acceptable to the real-world setting that was studied; more research must be done on the adaptability of the method to organizations of different sizes and types.

Second, the ANP method that considers operational issues, but only from an upper-managements perspective, may lack details. It would, therefore, be important to evaluate details of the operational issues by potential users of the system.

Third, future investigations need to develop a comparison plan for the MCDM methods that are newly developed.

Fourth and last, the need to evaluate the use of these methods in crisis management projects should be considered due to fast and effective decision making.

7. CONCLUSIONS

In this investigation a research methodology was designed and implemented. 9 steps were executed in a 7 months timeframe. A literature review of MCDM, AHP and ANP were conducted.

The research model identified led to the development of seven hypotheses. A self-administer survey, a data

collection and data analysis plan were designed and implemented.

The results of this investigation demonstrated that the ANP model represents reality as well as reliability better than the AHP model.

The results suggest that, the managerial implications of the execution of ANP and AHP are factors that vary from organization to organization, but that need to be taken into consideration for an effective and efficient use of decision making resources.

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APPENDIX SURVEY

1. Greetings!

This survey has been developed to understand some managerial aspects of decision making models, specifically, the Analytic Hierarchy Process and the Analytic Network Process.

Please answer the following questions taking in consideration the organization or work unit to which you work for or worked the last time you were employed. We will refer the organization in our questions as “your work unit”.

This survey will take approximately 10 minutes to complete.

The answers of these questions are anonymous and only aggregates of the answers of these questions will be communicated. The results of this investigation will be used in Aeronautics and Space Technologies Institute in the Turkish Air Force Academy. The faculty advisor is Dr. Sami ERCAN. I really appreciate your willingness to contribute to my investigation. Your inputs are critical for the completion of my education.

Thank you!

2. Questions about Multi Criteria Decision Making:

1. To the extent of your knowledge, approximately how often does your work unit uses multi-criteria decision making methods to aid in their decision processes?

- Never
- Daily
- Once a week
- Once a month
- Once a year
- Do not know
- Other (Please specify).

2. To the extent of your knowledge, approximately how often does your work unit uses an officially established multi-criteria decision making process/system?

- Never
- Daily
- Once a week
- Once a month
- Once a year
- Do not know
- Other (Please specify).

3. Questions about the Analytic Hierarchy Process

3. To the extent of your knowledge, approximately how often does your work unit uses the Analytic Hierarchy Process as a decision making method?

- Never
- Daily
- Once a week

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- Once a month
- Once a year
- Do not know
- Other (Please specify).

4. If you had implemented the Analytic Hierarchy Process in a project management environment, at which project management stage do you think the Analytic Hierarchy Process is more useful for making decisions?

- Conceptual or Design
- Planning
- Execution and Control
- Closure

5. To the extent of your knowledge, which one of the following factors represents the strongest enabler to manage the implementation of the Analytic Hierarchy Process in your work unit?

- Operational and administrative costs
- Skilled workforce
- Start-up time
- I cannot answer the question
- Other (Please specify).

6. To the extent of your knowledge, how often do the results of the Analytic Hierarchy Process methods were taken into consideration in very important decisions in your work unit?

- Never
- Almost never
- Sometimes
- Almost always
- Always

4. Questions about the Analytic Network Process

7. To the extent of your knowledge, approximately how often does your work unit uses the method Analytic Network Process as a decision making method?

- Never
- Daily
- Once a week
- Once a month
- Once a year
- Do not know
- Other. Please specify.

8. If you had implemented the Analytic Network Process in a project management environment, at which project management stage do you think the Analytic Network Process is more usable for making decisions?

- Conceptual or Design
- Planning
- Execution and Control
- Closure
- I can not answer this question

9. To the extent of your knowledge, which one of the following factors represents the strongest enabler to manage the implementation of the Analytic Network Process in your work unit?

- Operational and administrative costs
- Skilled workforce
- Start-up time
- I cannot answer the question
- Other (please specify)

10. To the extent of your knowledge, how often do the results of the Analytic Network Process methods were taken into consideration in very important decisions in your work unit?

- Never
- Almost never
- Sometimes
- Almost always
- Always

5. Questions about comparison of the Analytic Hierarchy Process and the Analytic Network Process

11. In your opinion, do you agree that the Analytic Network Process method represents reality in a decision making process better than the Analytic Hierarchy Process method?

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I cannot answer the question. (please specify)

12. To the extent of your knowledge, are the results obtained from the Analytic Network Process method as useful for decision making as the results obtained from the Analytic Hierarchy Process method under a decision making situation characterized by a limited budget?

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I cannot answer the question. (please specify)

13. To the extent of your knowledge, are the results obtained from the Analytic Network Process, as reliable as the results obtained from the Analytic Hierarchy Process model under a decision making situation characterized by a lack of skilled decision making manpower?

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I cannot answer the question. (please specify)

14. To the extent of your knowledge, are the results obtained from the Analytic Network Process, as reliable as the results obtained from the Analytic Hierarchy Process model under a decision making

situation characterized by a lack of decision making infrastructure (e.g., computers, software)?

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I cannot answer the question. (please specify)

15. To the extent of your knowledge, do you agree that the Analytic Network Process is more time effective than the Analytic Hierarchy Process for similar decision making problems (e.g., same number of alternatives, criteria)?

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I cannot answer the question. (please specify)

16. In your opinion, do the results of the Analytic Network Process provide an easier capability of further decision making analysis and conclusions than the results of the Analytic Hierarchy Process?

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I cannot answer the question. (please specify)

17. To the extent of your knowledge, is the Analytic Network Process more user friendly than the Analytic Hierarchy Process?

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- I cannot answer the question. (please specify)

6. Demographic Questions

18. What is the approximate number of employees of your work unit?

19. Approximately for how long has your work unit been operating?

20. What is the approximate average number of members in a decision making team within your work unit?

21. Does your work unit have a special group of people dedicated to apply multi-criteria decision making process?

22. What is the title of your position in your work unit (e.g., project manager, engineer)?

23. Have you ever being trained, educated, or coached in the application of decision making methods in general?

24. Have you ever being trained, educated, or coached in the application of the Analytic Hierarchy Process method?

25. Have you ever being trained, educated, or coached in the application of the Analytic Network Process method?

VITAE

Ali Kamil TASLICALI

received his B.Sc. degree in industrial engineering from the Turkish Air Force Academy, Istanbul, Turkey, in 1996. He attended to the Aeronautics and Space Technologies Institute (ASTIN), Istanbul, in 2004. He is currently a graduate student in the Old Dominion University in Norfolk, Virginia, USA by an exchange program. His main research interests include multi criteria decision making and crisis project management.

Sami ERCAN

He is a professor in the Istanbul Trade University, Istanbul, Turkey. He received his B.S. in Industrial Engineering Middle East Technical University, Ankara, Turkey in 1961. He received his first M. S. from Graduate School of Business And Public Administration, Cornell University, Ithaca, New York, USA in 1964, and second M.B.A. in Industrial and Systems Engineering Chicago, IL, USA in 1969. He received his Ph. D. in Industrial and Systems Engineering from Illinois Institute Of Technology (I.I.T), Chicago, IL, USA in 1970. He received his tenure from Roosevelt University, Chicago, IL, USA in 1972 and he became a professor in Roosevelt University, Chicago, IL, USA in 1976. His research interests include Total Quality Management, Management Decision Making. He was a member of Alpha PI MU, American Istitute for Industrial Engineers, American Association of Science, American Institute of Decision Sciences, Naval Research Logistics Quarterly, Operations Research Society of America, The Institute of Management Sciences, and Turkish American Cultural Alliance.