JOURNAL OF AERONAUTICS AND SPACE TECHNOLOGIES
JULY 2011 VOLUME 5 NUMBER 2 (1-12)

APPLICATION OF ANALYTIC NETWORK PROCESS: WEIGHTING OF SELECTION CRITERIA FOR CIVIL PILOTS

Ebru YAZGAN*

Anadolu University,
School of Civil Aviation
Eskişehir, Turkey
eyazgan@anadolu.edu.tr

A.Korkut ÜSTÜN

Eskişehir Osmangazi University
Faculty of Engineering
Industrial Engineering Department
Eskişehir, Turkey
korkutustun@ogu.edu.tr

Received: *02nd May 2011,* ***Accepted:*** *29th July 2011*

ABSTRACT

Pilot selection process has been a focal point of many researchers in aviation literature. Selection of candidate pilots is very important because training of pilots is very costly and time consuming process. In this study, we try to determine the weights of selection criteria for civil pilots. Criteria determined in this study are classified into three main clusters: "Technical Criteria", "Non Technical Criteria", "Job Related Criteria". These main clusters include 15 sub-criteria such as personality traits, spatial ability, team work aptitude etc. Then these criteria are weighted by using Analytic Network Process (ANP) tool. ANP is a multi-criteria decision making technique that take into consideration also qualitative factors in decision making problems. ANP model including dependency between these criteria is developed. Then pair-wise comparisons of criteria are done by instructors. The result of this study shows that intelligence, decision making and problem solving ability and psychomotor skills are the three most important selection criteria.

Keywords: *Pilot Selection Criteria, Analytic Network Process, Multi-Criteria Decision Making*

ANALİTİK SERİM SÜRECİNİN UYGULAMASI: SİVİL PİLOTLAR İÇİN SEÇİM KRİTERLERİN AĞIRLIKLANDIRILMASI

ÖZET

Pilot seçim süreci havacılık literatüründe pek çok araştırmacının odak noktası olmuştur. Aday pilotların seçimi çok önemlidir çünkü pilotların eğitimi çok maliyetli ve zaman alan bir süreçtir. Bu çalışmada, sivil pilotlar için seçim kriterlerinin ağırlıklarını belirlemeye çalıştık. Çalışmada belirlenen kriterler, üç ana küme içinde sınıflandırılmaktadır: "Teknik Kriterler", "Teknik Olmayan Kriterler", "İşle İlgili Kriterler". Bu ana kümeler kişilik özellikleri, uzaysal yeteneği, ekip çalışması yeteneği gibi 15 alt kriteri içerir. Bu kriterler daha sonra Analitik Serim Süreci (ANP) aracını kullanarak ağırlıklandırılmıştır. ANP karar verme problemlerinde nitel faktörleri de dikkate alan çok kriterli karar verme tekniğidir. Bu kriterler arasında bağımlılığı içeren ANP modeli geliştirilmiştir. Kriterlerinin ikili karşılaştırmaları öğretmen pilotlar tarafından yapıldı. Bu çalışmanın sonucu zekâ, karar verme ve problem çözme yeteneği ve psikomotor becerilerinin en önemli üç seçim kriteri olduğunu gösterir.

Anahtar Kelimeler: *Pilot Seçim Kriteri, Analitik Serim Süreci, Çok Kriterli Karar Verme*

1. INTRODUCTION

Pilots have different characteristics, such as abilities, attitudes, skills and motivations. Ensuring the most suitable pilot fill a job position is good not only for airline organizations, in terms of lower costs and wasted time but also for individuals in terms of loss of self esteem. Although costs to the pilot candidate might be difficult to calculate, some studies have been presented to estimate cost to the organizations. For example for US Air Force the cost of each candidate who fails undergraduate pilot training is estimated to be $ 50000-80000 [1].

There are many papers in literature about pilot selection. Firstly, [2] studied the characteristics that a

* Corresponding Author

successful pilot should have. They emphasized that personality, ability is needed for the success of a pilot. Situational awareness, memorization, reasoning, perceptual speed, time sharing selective attention, response orientation, spatial orientation, divided attention, psychomotor coordination, control precision and visualization are the ability factors of their study.

According to research in aviation psychology, basic aptitudes and personality traits are important factors to determine the professional reliability of human operators such as pilot [3].

[4] performed to 678 Air Force pilot training candidates a paper and pencil aptitude battery and computer-administered tests. These tests include psychomotor skills, information processing and attitude toward risk. In this study the best predictors of the criteria were found the paper and pencil tests.

All NATO member countries apply some form of psychometric testing as part of military pilot selection. The measurement of mental traits, abilities and processes are included in psychometric testing. Common examples of aptitude tests involve traditional paper- and-pencil tests, psychomotor tests and computer based tests. The published literature on pilot selection methods generally concerns military pilot selection. However a few studies involving commercial aviation are available. Commercial selection procedures will have to become like the military procedures. For Example; Us Air Carriers used a combination of several different selection methods involving interviews, aptitude tests, flight checks, clinical psychological assessment, reference checks, and biographical checks. The most commonly used selection methods were interviews (96%), reference checks (93%), and flight checks (76%). The DLR (German) pilot selection system for ab initio training at non germen applicants, five separate stages:1) paper and pencil tests (English proficiency, cognitive ability, personality), 2) apparatus tests (multiple task performance, psychomotor coordination, choice reaction time), 3) additional oral English exam, 4) medical exam, 5) psychological interview are included by IBERIA Airlines [4]. [5] defined a 4 stage process used by Air France for selecting pilots. In the stages there are measurements of 1) general knowledge (e.g., mathematics, physics, mechanics, English proficiency), 2) "height" (e.g., attention, concentration, multi-tasking, perceptual speed, vigilance), and 4) psychological evaluation (e.g., personality, interviews).

When the research studies about the criteria in selection of pilots were analyzed, it was seen that in addition to personality, ability is necessary to be a successful pilot. In these studies, situational awareness, memorization, calculating, perceptual speed, spatial orientation, divided attention, psychomotor coordination and visualization were seen as ability factors. And it was expressed that intelligence, psychomotor and personality traits are important while examining the pilot selection criteria. In these studies, criteria in selection of pilots are seen. These criteria are identified with experience intuitively. However none of these studies mention weighting of pilot selection criteria with Analytic Network Process (ANP).

Many applications of ANP have been seen to literature because of commonly used in decision making problems. For example; [6] develop the ANP model including interdependencies of the personnel selection factors. They estimate global weights of the personnel factors in the model and also develop an evaluation scale as to the assessment of personnel selection factors. [7] develop the ANP model for supplier selection. Their proposed model is implemented in electronic company. [8] is used ANP within a zero–one goal programming (ZOGP) model to select candidate projects of information system.

In addition to these studies [9] study to evaluate research & development project selection; [10], to measure the long-term performance of a manufacturing firm; [11], to construct ANP model for strategic supplier selection; [12] to combine ANP and goal programming approach in quality function deployment process; [13] to use application of ANP for selection of product mix in a semiconductor fabricator.

We could not encounter any ANP application in pilot selection problems in literature. In this study ANP model for weighting of pilot selection criteria is developed. Firstly pilot selection criteria are classified into three main clusters: "Technical Criteria", "Non Technical Criteria" and "Job Related Criteria". These main clusters include 15 sub-criteria such as personality traits, spatial ability, team work aptitude etc. Then these criteria are weighted by using ANP tool. ANP model including dependency between these criteria is developed. Then pair-wise comparisons of criteria are done by instructors. The results of this study shows intelligence, decision making and problem solving ability and psychomotor skills are the three most important criteria.

2. ANALYTIC NETWORK PROCESS

The Analytic Network Process (ANP) is a multi-criteria decision making tool used to derive relative priority scales of absolute numbers from individual judgments [14]. It is introduced by Saaty.

Many real world decision problems cannot be constructed hierarchically because of the interaction and dependence of higher-level elements in a hierarchy on lower-level elements [15].

The Analytic Network Process (ANP) is a generalization of the Analytic Hierarchy Process (AHP) by considering the dependence between the elements of the hierarchy [15]. Figure 1 shows the ANP structure. The ANP involves directions and cycles between clusters and loops within the same clusters. As shown the figure below, arc from component C4 to C2 indicates the outer dependence of the elements in C2 on the elements in C4 with respect to a common property. Also, loop in a component indicates inner dependence of the elements in that component with respect to a common property [14].

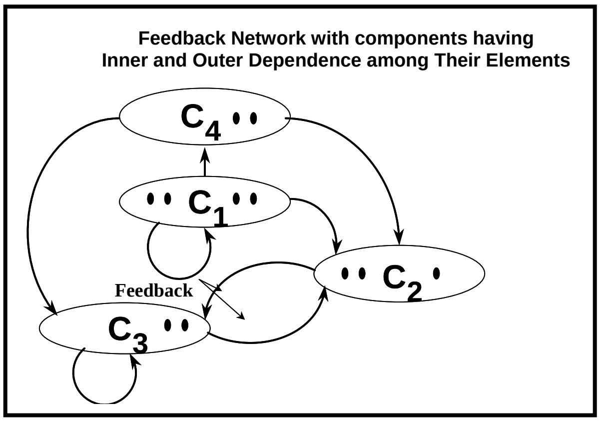

Figure 1. The ANP Structure [14].

The process of ANP comprises four major steps [6]; [13]; [9]; [11]; [16]:

***Step 1: Model construction and problem structuring**:* The problem should be stated clearly and decomposed into a rational system like a network. The structure can be obtained by the opinion of decision makers through brainstorming or other appropriate methods. An example of the format of a network is as shown in Figure 1.

***Step 2: Pair-wise comparisons matrices and priority vectors**:* In ANP, like AHP, decision elements at each component are compared pair-wise with respect to their importance towards their control criterion, and the components themselves are also compared pair-wise with respect to their contribution to the goal. Decision makers are asked to respond to a series of pair-wise comparisons where two elements or two components at a time will be compared in terms of how they contribute to their particular upper level criterion [9]. In addition, if there are interdependencies among elements of a component, pair-wise comparisons also need to be created, and an eigenvector can be obtained for each element to show the influence of other elements on it. The relative importance values are determined with Saaty's 1-9 scale (Table 1), where a score of 1 represents equal importance between the two elements and a score of 9 indicates the extreme importance of one element (row component in the matrix) compared to the other one (column component in the matrix) [9].

Table 1. Saaty's 1-9 Scale for AHP/ANP Preference Index [10].

Intensity of importance	Definition	Explanation
1	Equal importance	two activities contribute equally to the objective
3	Moderate importance	experience and judgment slightly favor one over another
5	Strong importance	experience and judgment strongly favor one over another
7	Very strong importance	activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	importance of one over another affirmed on the highest possible order

A reciprocal value is assigned to the inverse comparison; that is, $a_{ij}=1/a_{ji}$, where a_{ij} (a_{ji}) denotes the importance of the *i*th (*j*th) element. Like AHP, pair-wise comparison in ANP is made in the framework of a matrix, and a local priority vector can be derived as an estimate of relative importance associated with the elements (or components) being compared by solving the following equation:

$$A \times w = \lambda_{max} \times w \quad (1)$$

where A is the matrix of pair-wise comparison, *w* is the eigenvector, and λmax is the largest eigenvalue of A. Saaty (1980) proposes several algorithms for approximating *w*. In this paper, the following three-step procedure is used to synthesize priorities [13].

1. Sum the values in each column of the pair-wise comparison matrix.
2. Divide each element in a column by the sum of its respective column. The resultant matrix is referred to as the normalized pair-wise comparison matrix.
3. Sum the elements in each row of the normalized pair-wise comparison matrix, and divide the sum by the *n* elements in the row. These final numbers provide an estimate of the relative priorities for the elements being compared with respect to its upper level criterion. Priority vectors must be derived for all comparison matrices.

***Step 3: Supermatrix formation**:* The supermatrix concept is similar to the Markov chain process [16].

To obtain global priorities in a system with interdependent influences, the local priority vectors are entered in the appropriate columns of a matrix. As a result, a supermatrix is actually a partitioned matrix, where each matrix segment represents a relationship between two nodes (components or clusters) in a system [9]. Let the components of a decision system be C_k, k=1,2,…,n, and each component k has m_k elements, denoted by $e_{k1}, e_{k2},\ldots,e_{kmk}$. The local priority vectors obtained in Step 2 are grouped and located in appropriate positions in a supermatrix based on the flow of influence from a component to another component, or from a component to itself as in the loop. A standard form of a supermatrix is given Figure 2 [16].

$$
\begin{array}{cc}
 & \begin{array}{ccccccccccc} & C_1 & & & & C_k & & & & C_n & \\ e_{11} & e_{12} & \cdots & e_{1m1} & \cdots & e_{k1} & e_{k2} & \cdots & e_{k\,mk} & \cdots & e_{n1}\; e_{n2} \cdots e_{n\,mn} \end{array} \\
W = \begin{array}{cc} C_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1m1} \end{array} \\ \vdots & \vdots \\ C_k & \begin{array}{c} e_{k1} \\ e_{k2} \\ \vdots \\ e_{k\,mk} \end{array} \\ \vdots & \vdots \\ C_n & \begin{array}{c} e_{n1} \\ e_{n2} \\ \vdots \\ e_{n\,mn} \end{array} \end{array} & \begin{bmatrix} W_{11} & \cdots & W_{1k} & \cdots & W_{1n} \\ \vdots & & \vdots & \vdots & \vdots \\ W_{k1} & \cdots & W_{kk} & \cdots & W_{kn} \\ \vdots & & & \vdots & \\ W_{n1} & \cdots & W_{nk} & \cdots & W_{nn} \end{bmatrix}
\end{array}
$$

Figure 2. A Standard Form of a Supermatrix

As an example, the supermatrix representation of a hierarchy with three levels as shown in **Figure 3(a)** is follows [16].

$$
W_h = \begin{bmatrix} 0 & 0 & 0 \\ w_{21} & 0 & 0 \\ 0 & W_{32} & I \end{bmatrix} \tag{2}
$$

where w_{21} is a vector that represent the impact of the goal on the criteria, W_{32} is a matrix that represents the impact of criteria on each of the alternatives, I is the identity matrix, and entries of zeros corresponding to those elements that have no influence.

The matrix shown in Figure 2 is the general form of a super matrix and the matrix that is shown as I is the specific super matrix of the hierarchic structure that is given in figure 3. That is the result of hierarchic structure. In order for hierarchies that are given in figure 3 to refer to the square matrix, identity matrix is added.

For the above example, if the criteria are interrelated among themselves, the hierarchy is replaced by a network as shown in Figure 3(b). The entry of W_n given by W_{22} would indicate the interdependency, and the supermatrix would be [16].

$$
W_n = \begin{bmatrix} 0 & 0 & 0 \\ w_{21} & W_{22} & 0 \\ 0 & W_{32} & I \end{bmatrix} \tag{3}
$$

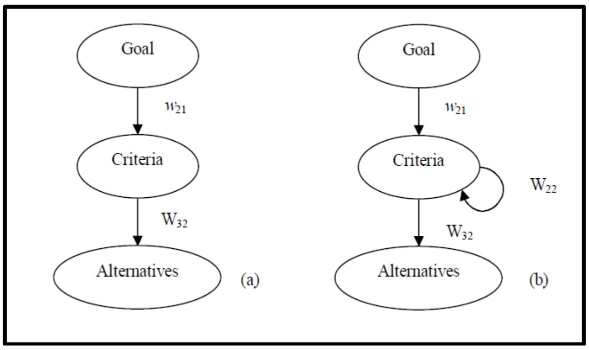

Figure 3. Hierarchy and Network
(a) a Hierarchy; (b) a Network [6];[13].

Note that any zero in the supermatrix can be replaced by a matrix if there is an interrelationship of the elements in a component or between two components. Since there usually is interdependence among clusters in a network, the columns of a supermatrix usually sum to more than one. The supermatrix must be transformed first to make it stochastic, that is, each column of the matrix sums to unity. A recommended approach by [16] is to determine the relative importance of the clusters in the supermatrix with the column cluster (block) as the controlling component [9]. That is, the row components with nonzero entries for their blocks in that column block are compared according to their impact on the component of that column block [16]. With pair-wise comparison matrix of the row components with respect to the column component, an eigenvector can be obtained. This process gives rise to an eigenvector for each column block. For each column block, the first entry of the respective eigenvector is multiplied by all the elements in the first block of that column, the second by all the elements in the second block of that column and so on. In this way, the blocks in each column of the supermatrix are weighted, and the result is known as the weighted supermatrix, which is stochastic. Raising a matrix to powers gives the long-term relative influences of the elements on each other. To achieve a convergence on the importance weights, the weighted supermatrix is raised to the power of $2k$+1, where k is an arbitrarily large number, and this new matrix is called the limit supermatrix [16]. The limit supermatrix has the same form as the weighted supermatrix, but all the columns of the limit supermatrix are the same. By normalizing each block of this supermatrix, the final priorities of all the elements in the matrix can be obtained.

***Step 4: Selection of best alternatives**:* If the supermatrix formed in Step 3 covers the whole network, the priority weights of alternatives can be found in the column of alternatives in the normalized supermatrix. On the other hand, if a supermatrix only comprises of components that are interrelated, additional calculation must be made to obtain the overall priorities of the alternatives. The alternative with the largest overall priority should be the one selected.

3. A PROPOSED MODEL FOR PILOT SELECTION

In this section, criteria required in pilot selection process were weighted according to ANP method. The Super Decision package program (www.superdecisions.com) trial version is used in this study. The proposed ANP model algorithm for pilot selection is given in Figure 4.

The first step of the algorithm given in Figure 4 is the analysis of the pilot selection process. The aim of the pilot selection problem is to weight the criteria of pilot selection.

The second step is the determination of the goal and pilot selection criteria. Total 15 criteria with three main criteria clusters given below are determined by receiving support from instructor pilots in Turkey. These main clusters are:

- Technical Criteria
- Non-Technical Criteria
- Job Related Criteria

All of the criteria and sub-criteria are given a code letter. These codes, which are given in Table 2 will be used in the super matrix of ANP model.

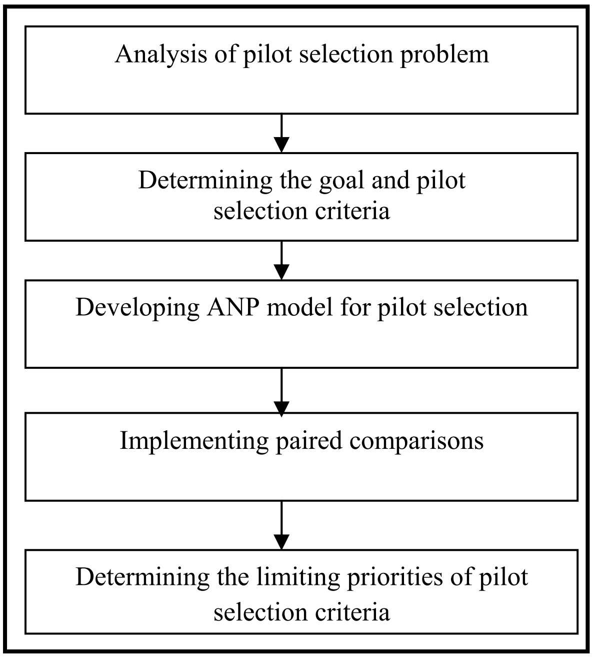

Figure 4. The Algorithm of ANP Model for Pilot Selection.

Table 2. Criteria Code Letter, Definition and Description.

Criteria code letter	Criteria definition	Description
J	Job Related Criteria	the criteria dealing with occupational
N	Non -Technical Criteria	the criteria dealing with not characteristic of or skilled in applied aviation
T	Technical Criteria	the criteria dealing with characterizing or showing skill in or specialized knowledge of applied aviation
J1	Spatial Ability	refers to skill in perceiving the visual world, transforming and modifying initial perceptions, and mentally recreating spatial aspects of one's visual experience without the relevant stimuli.
J2	Visual Memory Ability	the ability to recall accurately an object no longer in view and then to relate its characteristics to other objects either in view or nor in view.
J3	Psychomotor Skills	defined as voluntary muscular movements involving both mental and motor processes
J4	Auditory Memory Ability	the ability to retain and recall auditory information
J5	Interview	a formal meeting for the assessment of a candidate or applicant

Table 2. Criteria Code Letter, Definition and Description (continued).

N1	Personality Traits	personality characteristic, one of the qualities which characterizes the individual
N2	Communication Ability	the ability to use language (receptive) and express (expressive) information
N3	Team Work Aptitude	working as part of a group in which there is a shared goal and to achieve this different members of the team take on different roles
N4	Decision Making and Problem Solving	process of deciding and organizing information in order to arrive at and evaluate possible solutions
N5	Intelligence	the ability to learn or understand or to deal with new or trying situations
T1	University Entrance Exam Score	an examination score given to determine if a candidate is qualified to be admitted to a university
T2	The Knowledge of Basic Physics	the knowledge that deals with matter and energy and their interactions
T3	English Language Ability	the ability of an individual to speak or perform in an acquired English language
T4	The Knowledge of Basic Mathematics	the knowledge that deals with numbers and number patterns and forms; mathematical aspects of something
T5	The Knowledge of Basic Aviation	the knowledge that deals with the operation and production of aircraft

GOAL is represented by "R" and "R" means Ranking Pilot Selection Criteria

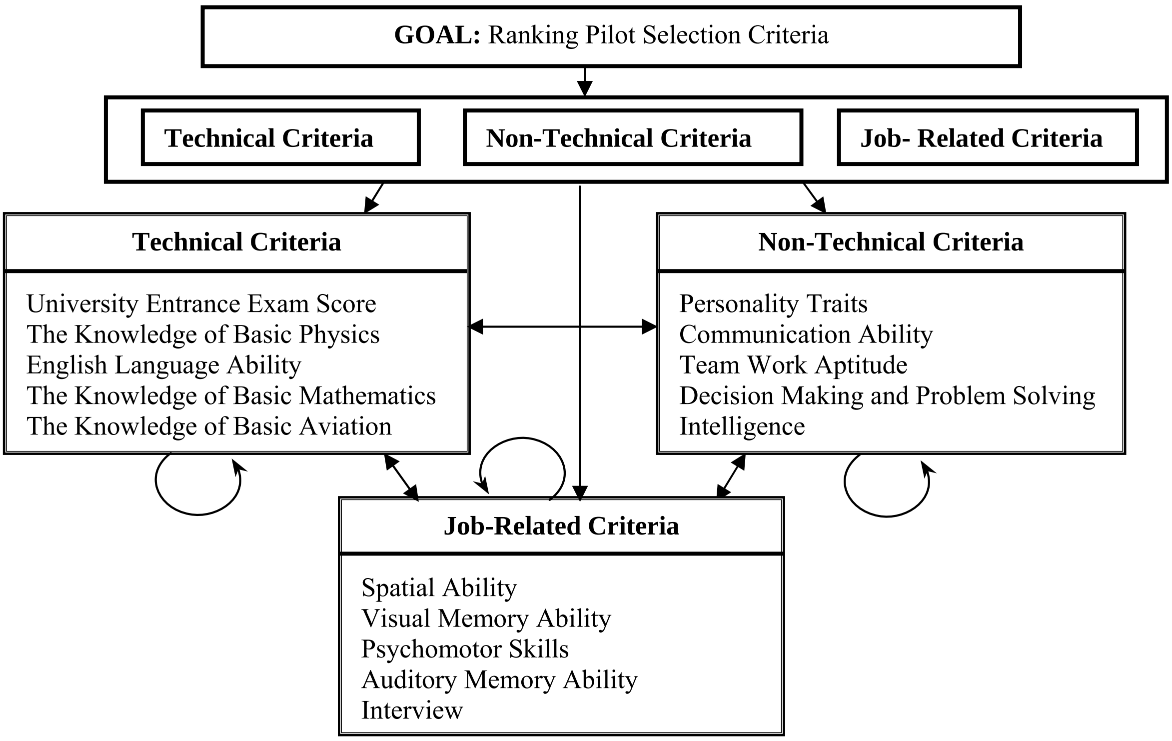

Figure 5. The Proposed ANP Model for Pilot Selection.

In the third step, the connections between and within clusters are determined. The proposed ANP model for pilot selection is given in Figure 5. As shown the figure; *Technical Criteria cluster* has interaction between other clusters. In addition, loop in the cluster of Technical Criteria indicates inner dependence of the elements in that cluster. For instance; *University Entrance Exam Score* sub criteria has inner dependence between *The Knowledge of Basic Physics and The Knowledge of Basic Mathematics sub criteria.* All of interactions can be seen in the Figure 5.

Pair-wise comparisons of criteria are done by 5 instructors with group decision making method using 1-9 Scale developed by Saaty in the fourth step. Instructor pilots in School of Civil Aviation are responsible for theoretical ground course, flight simulator and flight training. These instructor pilots are retired military pilots. They are experienced for the selection of pilot candidates. Instructor pilots evaluate student pilot flight performance and abilities with the help of flight evaluation forms. In this step the consistency of each comparison is checked. In order to measure the consistency of pair-wise comparisons, the program calculates inconsistency ratio. Inconsistency must be precisely one order of magnitude less important than consistency, or simply 10% of the total concern with consistent measurement. If it were larger it would disrupt consistent measurement and if it were smaller it would make insignificant contribution to change in measurement [17]. Pair-wise comparison matrix based on interview exhibits the priorities of criteria belonging to non-technical cluster is given in Table 3.

Table 3. Pair-wise Comparisons Matrix Based on Interview Criteria.

	N1	N2	N3	Relative Priorities
N1 : Personality Traits	1	3	3	1,000
N2 : Communication Ability	1/3	1	1/2	0,265
N3 : Team Work Aptitude	1/3	2	1	0,420

Inconsistency ratio: 0, 0516

Inconsistency ratio of the matrix is 0, 0516 and it can be said that pair-wise comparisons are consistent since this value is less than 0.1. According to the network structure in Figure 5, all pair-wise comparisons were made in this way for each criteria that had been defined to have relation with other criteria and the priorities were calculated.

In the last step, according to these pair-wise comparisons, the unweighted, weighted, limit super matrixes are constructed. The unweighted super matrix is given in Table 5. Then clusters' priority weights were calculated by using experts' opinion. Multiplying this priority weights by the unweighted super matrix we had the weighted super matrix which is presented in Table 6. The limiting priorities of the weighted super matrix are calculated. This limiting super matrix is given in Table 7.

4. RESULTS

The proposed decision model of pilot selection was implemented for 15 criteria with three main criteria cluster. In the implementation, the proposed ANP model which is shown in Fig. 5 was used. The paired comparisons were made by taking instructors opinion working in the School of Civil Aviation. Also all the calculations were performed by using Super Decision package program. The results of our ANP model are seen in Table 4. As shown the Table 4, the most important criteria *intelligence.* Also the least essential criteria that affect pilot selection are *the knowledge of basic aviation and English language ability.*

It can be said that results of this study are consistent since inconsistency ratio of all pair wise comparisons is less than 0.1.

Table 4. Priorities of Pilot Selection Criteria.

Criteria Name	Limiting Value
Spatial Ability	0,028
Visual Memory Ability	0,063
Psychomotor Skills	0,086
Auditory Memory Ability	0,039
Interview	0,066
Personality Traits	0,046
Communication Ability	0,024
Team Work Aptitude	0,015
Decision Making and Problem Solving	0,124
Intelligence	0,414
University Entrance Exam Score	0,010
The Knowledge of Basic Physics	0,042
English Language Ability	0,005
The Knowledge of Basic Mathematics	0,033
The Knowledge of Basic Aviation	0,005

5. CONCLUSION

Pilot selection, which is one of the most important issues in aviation, must be systematically considered from the decision makers. For this reason, pilot selection is studied by researchers.

In this paper, pilot selection is considered as a multi criteria decision problem and a model is proposed by using ANP method.

When the research studies about the criteria in selection of pilots, it was expressed that intelligence, psychomotor and personality traits are important. In these studies the criteria in selection of pilot candidates are seen. In this study the evaluation criteria are taken from literature about pilot selection and expert opinions. The priorities of these criteria are identified commonly with experience intuitively. However none of these studies mention weighting of pilot selection criteria with ANP.

The determined weights of criteria by using ANP are also approved from the instructors in aviation school.

This study shows that, ANP is a good decision tool by determining weighting of pilot selection criteria to select the most appropriate pilot candidates.

Our main important finding is that the proposed model can be used for selecting pilot candidates. These model findings are important especially for aviation school instructors and administration of aviation schools, and airway companies.

The results of this study suggest that intelligence, decision making and problem solving ability and psychomotor skills are the three most important criteria.

This paper can be extended by implementing in any aviation school examination. Also additional pilot selection criteria can be considered. These additional criteria can affect the proposed model.

While choosing students for School of Civil Aviation pilotage department; it is extremely important to identify and select the candidates who have a low risk of failure. The overall success ranking is formed as a result of **multiplication of contribution rate** of selection criteria about the approval in School of Civil Aviation **and exam results.** And according to this ranking whether the candidate will be accepted to pilotage department or not is determined. But the difficulty of evaluation of knowledge and necessary sensory skills in acceptable levels is known. In design, production and operating, the fact that human factors oriented approach to every incident and situation must be accepted as priority in use of air vehicles. In that study, the priorities of selection criteria that were specified intuitively are analyzed and authorities are guided not to allow the ones who have a failure potential in proactive manner.

In that study, the priorities of criteria can be determined with new ANP model by both increasing the known selection criteria and the number of instructor pilots.

REFERENCES

[1] Rainford, D.J., Gradwel, D.P., "Ersting's Aviation Medicine", Fourth Edition, Hodder Education.London: pp. 309-321, 2006.

[2] Caretta, T.R., Rodgers, M.N., Hansen, I., "The Identification of Ability Requirements and Selection Instruments for Fast Jet Pilot Training", Euro-NATO ACHFWG Technical Report-2,1996.

[3] Goeters, K.M., Timmermann, B., Maschke, P., "The Construction of Personality Questionnaires for Selection Of Aviation Personnel", International Journal of Aviation Psychology, 3, 2, 123-141,1993.

[4] Carretta, T.R., Ree, M.J., "Pilot-Candidate Selection Method: Sources of Validity", The International Journal of Aviation Psychology, 4, 2, 103-117, 1994.

[5] Doat, B., "Need of New Development in Air France Selection", In N. Johnston, R. Fuller, and N. McDonal (Eds.), Aviation pscychology:Training and selection, Proceedings of the 21st Conference of the European Association for Aviation Psychology (EAAP), Vol.2 (pp. 182-187). Aldershot, England: Avebury Aviation.Damos DL. Pilot selection batteries: shortcomings and perspectives. The International Journal of Aviation Psychology 1996; Volume 6, Issue 2 : 199 – 209,1995.

[6] Dağdeviren, M., Yüksel, İ., 2007, "Personnel Selection Using Analytic Network Process", İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi, Yıl: 6 Sayı: 11: 99–118, 2007.

[7] Gencer, C., Gürpinar, D., "Analytic network process in supplier selection: A case study in an electronic firm", Applied Mathematical Modeling, Volume 31, Issue 11: 2475–2486, 2007.

[8] Lee, J.W., Kim, S.H., "Using Analytic Network Process and Goal Programming for Independent Information System Project Selection", Computers & Operations Research, Volume 27, Issue 4: 367-382, 2000.

[9] Meade, L.M., Presley, A., "R&D Project Selection Using The Analytic Network Process", IEEE Transactions on Engineering Management, Volume 49, No. 1:59–66, 2002.

[10] Yurdakul, M., "Measuring Long-Term Performance of a Manufacturing Firm Using the Analytical Network Process (ANP) Approach", International Journal of Production Research, Volume 41, Number 11: 2501-2529, 2003.

[11] Sarkis J, Talluri S. "A Model for Strategic Supplier Selection", Journal of Supply Chain Management, Volume 38, Issue 1:18–28, 2002.

[12] Karsak, E.E., Sozer, S., Alptekin, S.E., " Product Planning in Quality Function Deployment Using a Combined Analytic Network Process and Goal Programming Approach", Engineering, Volume 44, Issue 1:171–190, 2003.

[13] Chung, S.H., Lee, A.H.I., Pearn, W.L., "Analytic Network Process (ANP) Approach for Product Mix Planning in Semiconductor Fabricator", International Journal of Production Economics, Volume 96, Issue 1: 15-36, 2005.

[14] Saaty, T.L., "Theory and Applications of The Analytic Network: Decision Making With Benefits, Opportunities, Costs And Risks" page.47, RWS Publication USA, 2005.

[15] Saaty, T.L., "Applications of Analytic Network Process in Entertainment", Iranian Journal of Operations Research, Volume 1, No. 2: 41-55, 2009.

[16] Saaty, T. L., "Decision Making With Dependence and Feedback: The Analytic Network Process", RWS Publications, Pittsburgh, 1996.

[17] Saaty,T.L., " Decision Making–The Analytic Hierarchy and Network Processes (AHP/ANP)", Journal of Systems Science and Sytems Engineering, Volume 13, No1, 1-34, 2004.

VITAE

Dr. Ebru YAZGAN

She was born in 1977 in Eskişehir. She graduated from Istanbul Technical University- Mechanical Engineering Department in 1999. She had worked at Arçelik Refrigerator Factory as product development engineer between 1999–2000. Then she had worked at TEI (Tusaş Engine Industry) as process engineer between 2000–2004. She took a MS degree in Eskişehir Osmangazi University- Industrial Engineering Department in 2005. She received her PhD degree from Institute of Natural and Applied Scientific Science of the Eskişehir Osmangazi University- Industrial Engineering Department in 2010. She is now the Quality Specialist at the Anadolu University -School of Civil Aviation since 2005. Her research interest includes ergonomics, human factors, human error and pilot error.

Abdullah Korkut ÜSTÜN

He was born in Eskişehir on 26/12/1976. He graduated from Istanbul University- Industrial Engineering Department. He took a MS degree in Boğaziçi University- Industrial Engineering Department in 2004. He has been a Phd Student at Eskişehir Osmangazi University –Industrial Engineering Department since 2006. He also works as a research assistant in the same department.

APPENDIX

Table 5. Unweighted supermatrix of pilot selection by using ANP

	J	N	T	R	J1	J2	J3	J4	J5	N1	N2	N3	N4	N5	T1	T2	T3	T4	T5
J	0.00000	0.00000	0.00000	0.50000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N	0.00000	0.00000	0.00000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T	0.00000	0.00000	0.00000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
R	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
J1	0.16362	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.20000	0.00000	0.00000	0.00000	0.00000	0.00000	0.50000
J2	0.16362	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.20000	0.00000	0.66667	0.75002	0.00000	0.00000	0.00000
J3	0.35743	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.40000	0.00000	0.00000	0.00000	0.00000	0.00000	0.50000
J4	0.15172	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.20000	0.00000	0.33333	0.24998	0.00000	0.00000	0.00000
J5	0.16362	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N1	0.00000	0.41867	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.59365	0.00000	0.33333	0.33333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N2	0.00000	0.08836	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.15705	0.00000	0.00000	0.66667	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N3	0.00000	0.08836	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.33333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N4	0.00000	0.17787	0.00000	0.00000	1.00000	0.00000	0.50000	0.00000	0.24930	0.00000	0.00000	0.00000	0.00000	0.00000	0.24998	0.24998	0.00000	0.24998	0.00000
N5	0.00000	0.22673	0.00000	0.00000	0.00000	1.00000	0.50000	1.00000	0.00000	0.00000	0.33333	0.00000	1.00000	0.00000	0.75002	0.75002	1.00000	0.75002	1.00000
T1	0.00000	0.00000	0.17630	0.00000	0.00000	0.00000	0.00000	0.00000	0.50000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T2	0.00000	0.00000	0.31328	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.50000	0.00000	0.50000	0.00000	0.00000	1.00000	0.00000
T3	0.00000	0.00000	0.09857	0.00000	0.00000	0.00000	0.00000	0.00000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T4	0.00000	0.00000	0.31328	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.50000	0.00000	0.50000	1.00000	0.00000	0.00000	0.00000
T5	0.00000	0.00000	0.09857	0.00000	0.00000	0.00000	0.00000	0.00000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table 6. Weighted supermatrix of pilot selection by using ANP

	J	N	T	R	J1	J2	J3	J4	J5	N1	N2	N3	N4	N5	T1	T2	T3	T4	T5
J	0.00000	0.00000	0.00000	0.50000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N	0.00000	0.00000	0.00000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T	0.00000	0.00000	0.00000	0.25000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
R	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
J1	0.16362	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.10792	0.00000	0.00000	0.00000	0.00000	0.00000	0.32251
J2	0.16362	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.10792	0.00000	0.35974	0.40472	0.00000	0.00000	0.00000
J3	0.35743	0.00000	0.00000	0.00000	0.64503	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.21585	0.00000	0.00000	0.00000	0.00000	0.00000	0.32251
J4	0.15172	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.10792	0.00000	0.17987	0.13489	0.00000	0.00000	0.00000
J5	0.16362	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.53961	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N1	0.00000	0.41867	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.17629	0.00000	0.33333	0.33333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N2	0.00000	0.08836	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.04664	0.00000	0.00000	0.66667	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N3	0.00000	0.08836	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.33333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N4	0.00000	0.17787	0.00000	0.00000	0.35497	0.00000	0.50000	0.00000	0.07403	0.00000	0.00000	0.00000	0.00000	0.00000	0.07423	0.07423	0.00000	0.16125	0.00000
N5	0.00000	0.22673	0.00000	0.00000	0.00000	1.00000	0.50000	1.00000	0.00000	0.00000	0.33333	0.00000	0.29696	0.00000	0.22273	0.22273	1.00000	0.48378	0.35497
T1	0.00000	0.00000	0.17630	0.00000	0.00000	0.00000	0.00000	0.00000	0.08171	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T2	0.00000	0.00000	0.31328	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.08171	0.00000	0.08171	0.00000	0.00000	0.35497	0.00000
T3	0.00000	0.00000	0.09857	0.00000	0.00000	0.00000	0.00000	0.00000	0.04086	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T4	0.00000	0.00000	0.31328	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.08171	0.00000	0.08171	0.16342	0.00000	0.00000	0.00000
T5	0.00000	0.00000	0.09857	0.00000	0.00000	0.00000	0.00000	0.00000	0.04086	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table 7. Limiting supermatrix of pilot selection by using ANP

	J	N	T	R	J1	J2	J3	J4	J5	N1	N2	N3	N4	N5	T1	T2	T3	T4	T5
J	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
R	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
J1	0.02777	0.03191	0.03191	0.02777	0.03191	0.00000	0.03191	0.00000	0.02777	0.00000	0.00000	0.00000	0.03191	0.00000	0.03191	0.03191	0.00000	0.03191	0.03191
J2	0.06296	0.07514	0.07514	0.06296	0.07514	0.00000	0.07514	0.00000	0.06296	0.00000	0.00000	0.00000	0.07514	0.00000	0.07514	0.07514	0.00000	0.07514	0.07514
J3	0.08574	0.10483	0.10483	0.08574	0.10483	0.00000	0.10483	0.00000	0.08574	0.00000	0.00000	0.00000	0.10483	0.00000	0.10483	0.10483	0.00000	0.10483	0.10483
J4	0.03861	0.04632	0.04632	0.03861	0.04632	0.00000	0.04632	0.00000	0.03861	0.00000	0.00000	0.00000	0.04632	0.00000	0.04632	0.04632	0.00000	0.04632	0.04632
J5	0.06641	0.00000	0.00000	0.06641	0.00000	0.00000	0.00000	0.00000	0.06641	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N1	0.04591	0.00000	0.00000	0.04591	0.00000	0.00000	0.00000	0.00000	0.04591	0.00000	0.33333	0.33333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N2	0.02423	0.00000	0.00000	0.02423	0.00000	0.00000	0.00000	0.00000	0.02423	0.00000	0.33333	0.33333	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N3	0.01497	0.00000	0.00000	0.01497	0.00000	0.00000	0.00000	0.00000	0.01497	0.00000	0.16667	0.16667	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N4	0.12384	0.14834	0.14834	0.12384	0.14834	0.00000	0.14834	0.00000	0.12384	0.00000	0.00000	0.00000	0.14834	0.00000	0.14834	0.14834	0.00000	0.14834	0.14834
N5	0.41447	0.49824	0.49824	0.41447	0.49824	0.00000	0.49824	0.00000	0.41447	0.00000	0.16667	0.16667	0.49824	0.00000	0.49824	0.49824	0.00000	0.49824	0.49824
T1	0.01006	0.00000	0.00000	0.01006	0.00000	0.00000	0.00000	0.00000	0.01006	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T2	0.04198	0.05360	0.05360	0.04198	0.05360	0.00000	0.05360	0.00000	0.04198	0.00000	0.00000	0.00000	0.05360	0.00000	0.05360	0.05360	0.00000	0.05360	0.05360
T3	0.00503	0.00000	0.00000	0.00503	0.00000	0.00000	0.00000	0.00000	0.00503	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
T4	0.03299	0.04162	0.04162	0.03299	0.04162	0.00000	0.04162	0.00000	0.03299	0.00000	0.00000	0.00000	0.04162	0.00000	0.04162	0.04162	0.00000	0.04162	0.04162
T5	0.00503	0.00000	0.00000	0.00503	0.00000	0.00000	0.00000	0.00000	0.00503	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000