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APPLICATION OF ANALYTIC NETWORK PROCESS IN EVALUATING INITIAL TRAINING AIRCRAFT

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ABSTRACT

In this study, alternative trainer aircraft are evaluated and ranked according to the specific criteria. Analytic Network Process is used as the multi-criteria decision making method. Five alternatives are chosen among popular trainers all around the world. Six main criteria and twenty-two sub-criteria are determined, so the solution matrix consists of twenty-seven columns and rows. Because of the complexity of the problem, a software called Super Decisions is used. Criteria are based on the ones used by flight instructors, managers of flight training organizations and researchers who are expert in this field. In the light of gathered data, criteria are weighted and alternative trainers are evaluated. Cirrus SR20 with 0.30 weight is estimated as the most feasible solution.

INTRODUCTION

Technological advancements in aviation have influenced the flight training systems and designs of basic trainers, and have given new opportunities to assess new concepts of flight training. Along with technological developments, some new systems are integrated to the flight training aircraft. Including these or similar systems into the flight education programs, the trained pilots are expected to have improved quality of education. The need for enhanced flight training programs inspire the development of new trainer designs with, for instance, newly developed avionic systems.

Nowadays, millions of passengers travel via airlines all over the world. The concerns related to the safety and cost in aviation increase the importance of flight training much more than the past. Modern flight training is both a demanding and costly progress. Advancement in aircraft performance results in the need of modernizing the flight training systems. The most significant component of modern flight training organization is to train the pilots with the adapted education for the advanced commercial aircraft.

The growth of the aviation industry has affected entrepreneurs to start new businesses. To meet the demand in educated pilots, new flight training organizations are joining the business day by day. That makes also these organizations to compete heavily in this sector. To be one step ahead of others in this competition, the key factor is probably to decrease the costs and increase the profits. These organizations should also consider new investments. Purchasing

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trainer aircraft and operational costs related to these are the primary part of these investments. Therefore, it is quite important for trainers to meet the needs of all design requirements and low operational costs. Under these conditions, it is necessary to study trainer's specifications regarding the flight and maintenance.

Alternative trainers are evaluated and ranked according to specific criterions. ANP (Analytic Network Process) will be used as the multi criteria decision making method. The five alternatives are chosen among popular trainers, which are used in many countries. A group of expert flight instructors, flight training organizations' managers and researchers who study in this area, determine criterions. In the light of gathered data, criterions will be weighted and alternatives will be rated.

METHODOLOGY

Multi Criteria Decision Making (MCDM) is a popular approach in decision-making process. It is a class of operational research model, which deal with multiple criteria and many alternatives [Pohekar at al, 2004]. Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) are decision making methods which are proposed by Thomas L. Saaty [Saaty, 1999]. The major characteristic of the AHP method is the use of pair-wise comparisons, which are used both to compare the alternatives with respect to the various criteria and to estimate criteria weights [Loken, 2007]. ANP is a general form of the AHP method. ANP provides help to make decisions without making assumptions about independence of different levels of elements. Main difference of ANP from AHP is the network system of ANP [Saaty, 2001]. ANP is usually used in project selection problems, product planning, supplier selection, green supply chain management, and optimal scheduling problems. There are four steps in general in ANP method. These steps include model structure, pairwise comparisons, supermatrix and limit supermatrix calculations and result of the decision problem.

For the ANP method, the steps should be taken as;

1. Analyze the problem, determine the goal.
2. Determine all the criteria and sub-criteria in depth.
3. Determine the alternatives for the solution of the problem.
4. Determine interactions between criteria, sub-criteria and alternatives.
5. Make paired comparisons and create the supermatrix.
6. Calculate the weighted supermatrix from supermatrix
7. Calculate the limit supermatrix
8. Choose the best alternative with using final matrix

In the past, MCDM methods has been used to solve decision problems, including Evaluating Company [Nedjati, at al. 2013], Enterprise Resource Planning (ERP) Software Selection [Kilic, at al., 2015], Supplier Selection [Wang, at al. 2017], Waste Energy Recovery [Xingyu, at al. 2013]. Saaty's ANP method [Saaty, 2001] is used for a Flight Training Organization's trainer selection problem.

BASIC TRAINER SELECTION USING ANALYTIC NETWORK PROCESS

In this study, selection problem is chosen and ANP method is used. Trainer selection is very important for every Flight Training Organization (FTO). Directly or indirectly, economic situation of the FTO is mostly depend on trainer's performance and operational characteristics. Therefore, in this study we studied on the selection of basic trainer with ANP method.

For this problem; criteria, sub-criteria and alternatives are defined within a group, which consists of flight instructors, FTO managers and experts in this field. All these elements of the problem can be seen below on Table 1.

Table 1. Elements of the Problem

BASIC TRAINER SELECTION WITH ANP						
Criteria	Technical	Weights	Speeds	Engine	Operational	Maintenance
Sub-Criteria	Max. Endurance	Max. Takeoff Weight	Max. Speed	Power	Safety	Engine TBO
	Max. Climb Rate	Useful Load	Max. Cruise Speed	Fuel Consumption	Warranty	Propeller TBO
	Takeoff Distance	Empty Weight	Stall Speed	Fuel Type	Price	Service Center
	Landing Distance	Usable Fuel Weight				
	Max. Range					
	Service Ceiling					
Alternatives	**Cessna 172**	**Cirrus SR20**	**Diamond DA40**	**Piper PA28**	**Tecnam P2010**	

As shown in Table 1, we determined six main criteria and twenty-two sub-criteria. As alternatives, we studied FTOs in Europa and determined five most popular aircraft manufacturers for basic trainers. These manufacturers have also many types of trainer, so we tried to choose as alternatives, which are mostly used and have well-known specifications. The six main criteria are explained as follows:

<u>Technical</u>: This main criterion includes the sub-criteria indicating about trainer's technical specifications. Sub-criteria under this main criterion include "Maximum Endurance", "Maximum Climb Rate", "Takeoff Distance", "Landing Distance", "Maximum Range" and "Service Ceiling".
<u>Weights</u>**:** Weights criterion includes the criteria about aircraft's weight which has significant effect on its performance and operability. Under this main criterion, there are four sub-criteria; "Maximum Takeoff Weight", "Useful Load", "Empty Weight" and "Usable Fuel Weight".
<u>Speeds</u>: Under speeds main criterion, there are three sub-criteria to be evaluated: "Maximum Speed", "Maximum Cruise Speed" and "Stall Speed".
<u>Engine</u>: Engine main criterion consists of four sub-criteria, "Engine Power", "Engine Fuel Consumption" and "Fuel Type".
<u>Operational</u>: Under operational criterion there are three sub-criteria: "Safety", "Warranty" and "Price". Safety sub-criterion's value is obtained by taking into consideration of aircraft's accident per 100.000 flight hours. Warranty sub-criterion is evaluated with aircraft manufacturer warranty agreements.
<u>Maintenance</u>: Maintenance criterion includes the sub-criteria; "Engine TBO", "Propeller TBO", and "Service Center". TBO is abbreviation of Time Between Overhaul means a detailed maintenance for related aircraft part. Service center sub-criterion is evaluated with existence of center in the country and in case of absence of service center closeness to the country is taken into consideration.

As alternatives, we studied FTOs in Europa and determined five most popular aircraft manufacturer for basic trainer. These manufacturers have also many types of trainer so we tried to choose mostly used ones which have similar specifications. Figure 1 shows how many FTOs in Europa prefer aircraft manufacturers.

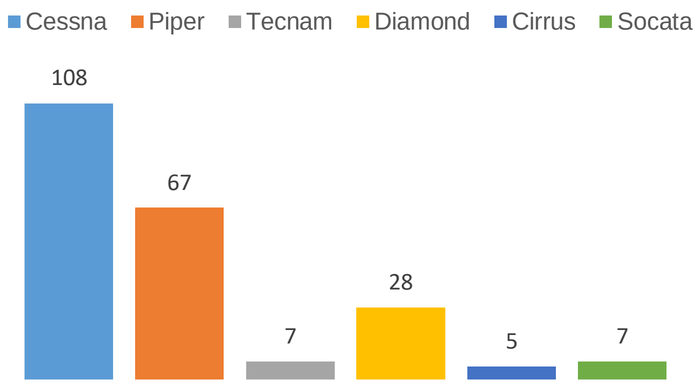


Figure 1. FTOs preferences on manufacturers

After determining the elements of the ANP method, the interactions are considered and the network system is established as shown in Figure 2. Afterwards, the pairwise comparisons are made and the supermatrix are created with these weights.

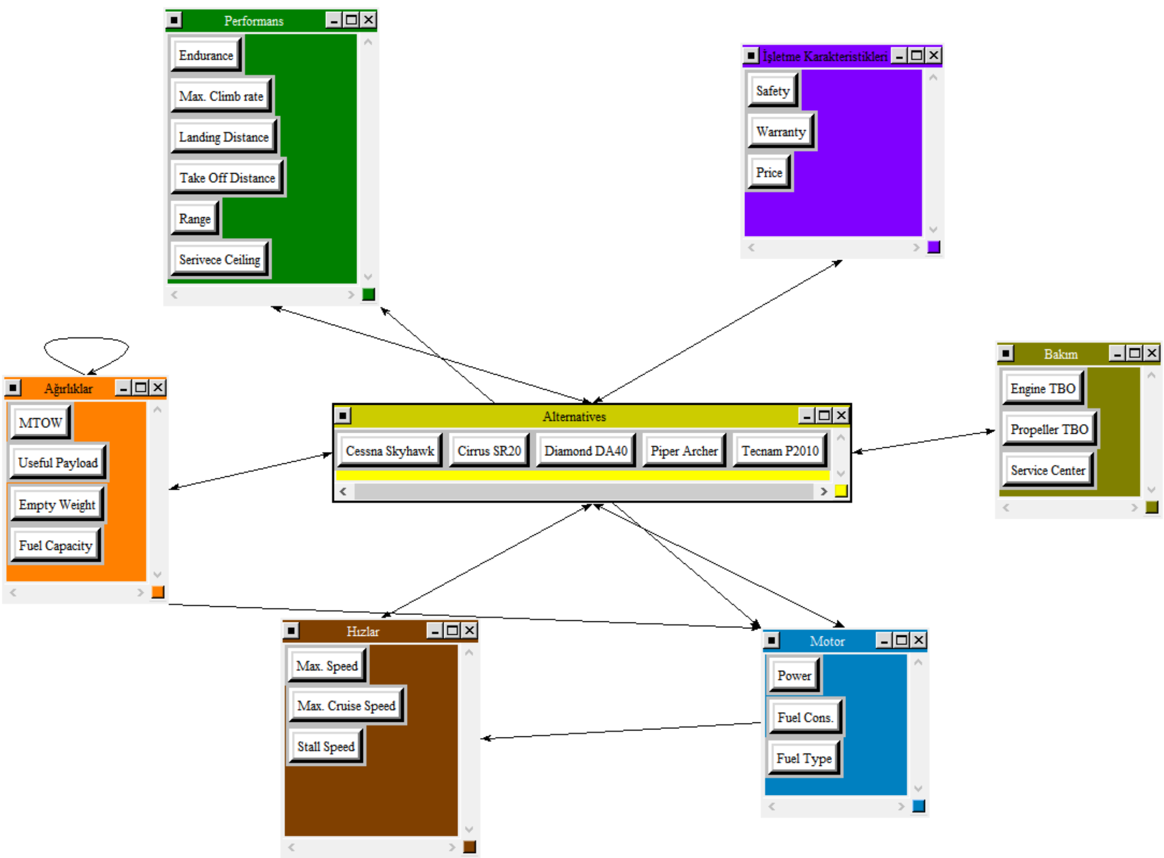


Figure 2. ANP method's network of the problem

The supermatrix has twenty-seven columns and rows in total. Each element of the system has a column and a row. So, all the comparisons can be seen from this supermatrix. Because of the all parts of the supermatrix come from different matrices, it needs to be normalized. After normalizing, the supermatrix is weighted. In order to reach converged values, the weighted supermatrix is then increased to a significantly large power. Finally, the limit supermatrix is converged to the desired priorities of the elements.

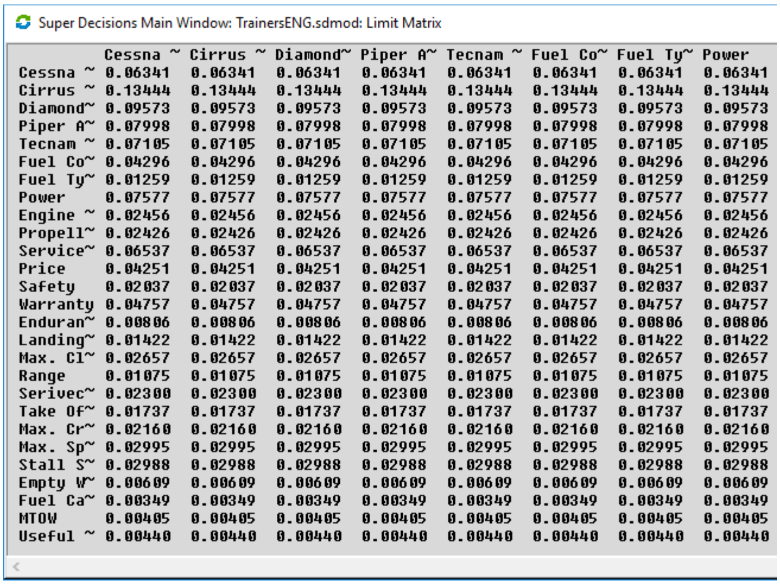
Pairwise comparison means that the two criteria/alternatives are compared with each other and is based on the judgment of the decision maker. Pairwise comparatives are designed to establish priority distributions of decision criteria and alternatives. More precisely, the elements in the hierarchy are compared in pairs to determine their relative importance to the related element. Table 2 shows the numbers that indicate how many times more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared [Saaty, 2008].

Table 2. The scale used with pairwise comparisons

Intensity of Importance	***Definition***
1	Equal Importance
2	Weak or slight
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance
Reciprocals of above	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.

RESULTS

The pairwise comparisons are the eigenvalue vectors of the matrices obtained as a result. This matrix is called unweighted supermatrix. The matrix obtained by dividing each element of this matrix by the column sum is called the weighted supermatrix. The weighted supermatrix is not stable again so the weighted supermatrix is then raised to a significantly large power in order to have the converged or stable values [Velmurugan, at al. 2012]. The values of this limit matrix are the desired priorities of the elements with respect to the goal. The supermatrix has twenty-seven columns and rows. All elements of the system have a column and a row. Finally, we can read all priorities and weights from this last limit matrix.


Super Decisions Main Window: TrainersENG.sdmod: Limit Matrix

	Cessna ~	Cirrus ~	Diamond~	Piper A~	Tecnam ~	Fuel Co~	Fuel Ty~	Power
Cessna ~	0.06341	0.06341	0.06341	0.06341	0.06341	0.06341	0.06341	0.06341
Cirrus ~	0.13444	0.13444	0.13444	0.13444	0.13444	0.13444	0.13444	0.13444
Diamond~	0.09573	0.09573	0.09573	0.09573	0.09573	0.09573	0.09573	0.09573
Piper A~	0.07998	0.07998	0.07998	0.07998	0.07998	0.07998	0.07998	0.07998
Tecnam ~	0.07105	0.07105	0.07105	0.07105	0.07105	0.07105	0.07105	0.07105
Fuel Co~	0.04296	0.04296	0.04296	0.04296	0.04296	0.04296	0.04296	0.04296
Fuel Ty~	0.01259	0.01259	0.01259	0.01259	0.01259	0.01259	0.01259	0.01259
Power	0.07577	0.07577	0.07577	0.07577	0.07577	0.07577	0.07577	0.07577
Engine ~	0.02456	0.02456	0.02456	0.02456	0.02456	0.02456	0.02456	0.02456
Propell~	0.02426	0.02426	0.02426	0.02426	0.02426	0.02426	0.02426	0.02426
Service~	0.06537	0.06537	0.06537	0.06537	0.06537	0.06537	0.06537	0.06537
Price	0.04251	0.04251	0.04251	0.04251	0.04251	0.04251	0.04251	0.04251
Safety	0.02037	0.02037	0.02037	0.02037	0.02037	0.02037	0.02037	0.02037
Warranty	0.04757	0.04757	0.04757	0.04757	0.04757	0.04757	0.04757	0.04757
Enduran~	0.00806	0.00806	0.00806	0.00806	0.00806	0.00806	0.00806	0.00806
Landing~	0.01422	0.01422	0.01422	0.01422	0.01422	0.01422	0.01422	0.01422
Max. Cl~	0.02657	0.02657	0.02657	0.02657	0.02657	0.02657	0.02657	0.02657
Range	0.01075	0.01075	0.01075	0.01075	0.01075	0.01075	0.01075	0.01075
Serivec~	0.02300	0.02300	0.02300	0.02300	0.02300	0.02300	0.02300	0.02300
Take Of~	0.01737	0.01737	0.01737	0.01737	0.01737	0.01737	0.01737	0.01737
Max. Cr~	0.02160	0.02160	0.02160	0.02160	0.02160	0.02160	0.02160	0.02160
Max. Sp~	0.02995	0.02995	0.02995	0.02995	0.02995	0.02995	0.02995	0.02995
Stall S~	0.02988	0.02988	0.02988	0.02988	0.02988	0.02988	0.02988	0.02988
Empty W~	0.00609	0.00609	0.00609	0.00609	0.00609	0.00609	0.00609	0.00609
Fuel Ca~	0.00349	0.00349	0.00349	0.00349	0.00349	0.00349	0.00349	0.00349
MTOW	0.00405	0.00405	0.00405	0.00405	0.00405	0.00405	0.00405	0.00405
Useful ~	0.00440	0.00440	0.00440	0.00440	0.00440	0.00440	0.00440	0.00440

Figure 2. A part of the Limit Supermarix

At this point reached, the weights of the main and sub-criteria are determined through the limit supermatrix. The criterion with the highest priority in the limit supermatrix should be perceived as the most important factor affecting the decision process. In the limit equilibrium distribution of the supermatrix, it is seen that each row of the matrix is identical to each other. These rows contain the result weights that express the contribution of each criterion that has an effect on final decision.

The final part of the limit supermatrix is seen in Table 2. It shows the desires weights for all elements of the problem.

Table 2. Priorities of the Elements

Name	Normalized By Cluster	Limiting
Cessna Skyhawk	0.14261	0.063407
Cirrus SR20	0.30238	0.134439
Diamond DA40	0.21532	0.095731
Piper Archer	0.17989	0.079981
Tecnam P2010	0.15981	0.071051
MTOW	0.22471	0.004052
Useful Payload	0.24407	0.004401
Empty Weight	0.33762	0.006088
Fuel Capacity	0.19360	0.003491
Engine TBO	0.21507	0.024560
Propeller TBO	0.21248	0.024264
Service Center	0.57245	0.065372
Max. Speed	0.36776	0.029948
Max. Cruise Speed	0.26526	0.021601
Stall Speed	0.36698	0.029884
Safety	0.18440	0.020365
Warranty	0.43073	0.047570
Price	0.38488	0.042506
Power	0.57702	0.075775
Fuel Cons.	0.32714	0.042961
Fuel Type	0.09583	0.012585
Endurance	0.08061	0.008058
Max. Climb rate	0.26576	0.026567
Landing Distance	0.14227	0.014222
Take Off Distance	0.17379	0.017373
Range	0.10751	0.010747
Service Ceiling	0.23008	0.023000

Figure 4 shows the weights of the alternatives. As a result of the decision problem Cirrus SR20 is the best option for trainer aircraft. Diamond DA40, Piper Archer, Tecnam P2010 and Cessna Skyhawk are the other alternatives, respectively.

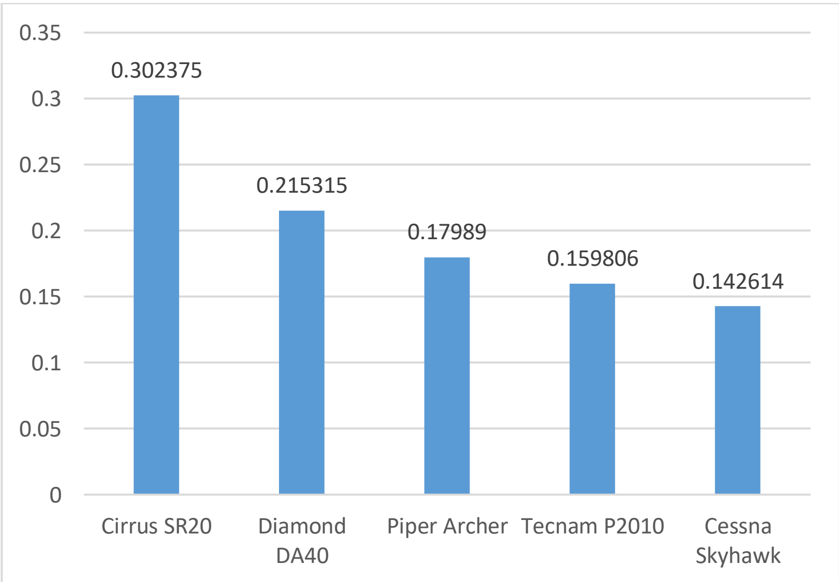


Figure 3. Weights of the alternatives

Weights of the criteria can be seen in Figure 5. Criteria that make the most contribution to the decision are the Engine Power, Service and Warranty. The least effective criteria are Range, Fuel Type and Endurance.

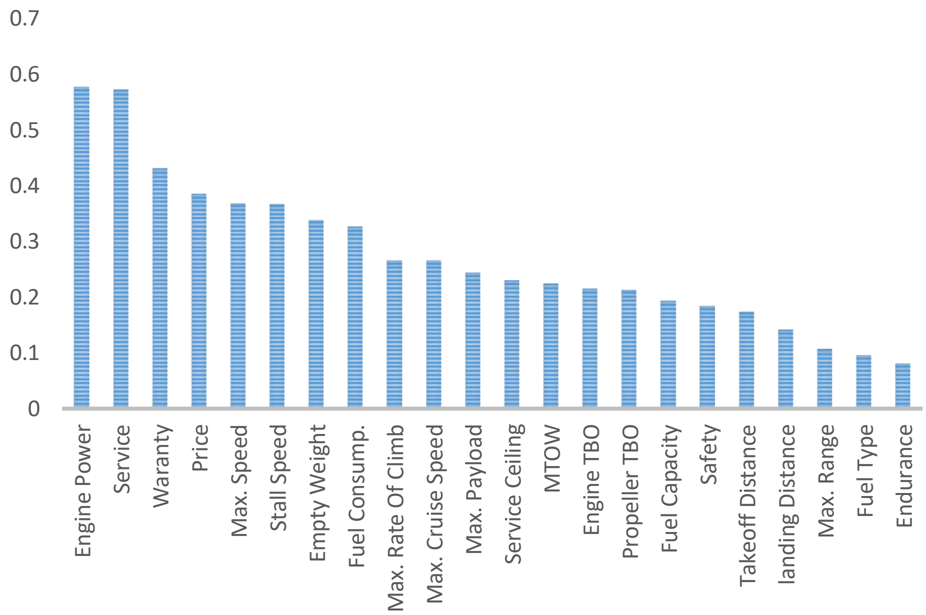


Figure 4. Weights of the criteria

CONCLUSION

We organized the study on the trainer selection, which is regarded as one of the most struggling problems of the FTOs. Cirrus SR20 with 0.30 weight is estimated as the most feasible solution. The others, namely Diamond DA40, Piper PA28, Tecnam P2010 and lastly Cessna 172 is found to have 0.22, 0.18, 0.16 0.14 weights, respectively. Among the selected criteria, service center and the engine power have the largest weights, so they can affect the solution much more than the other criteria.

In the upcoming studies, the research problem will be solved with other MCDM methods and solutions of this problem will be compared. Also, fuzzy ANP or ANP with integrated neural network is planned to apply on the same problem.

References

H. S. Kilic, S. Zaim, and D. Delen,(2015) *Selecting the best ERP system for SMEs using a combination of ANP and PROMETHEE methods*, Expert Systems with Applications, vol. 42, p: 2343-2352, April 2015.

Liang, X., Sun, X., Shu, G., Sun, K., Wang, X., & Wang, X. (2013). Using the analytic network process (ANP) to determine method of waste energy recovery from engine. Energy Conversion and Management, Vol. 66, p: 304-311. Feb 2013.

Løken, E. (2007). *Use of multicriteria decision analysis methods for energy planning models.* Renewable and Sustainable Energy Reviews , Vol. 11, p:1584-1595,

Nedjati A. Izbirak G. (2013) *Evaluating the Intellectual Capital by ANP Method in a Dairy Company,* Procedia - Social and Behavioral Sciences, Vol. 107, p: 136-144, Dec 2013

Pohekar, S.D., Ramachandran (2004). *Application of multi-criteria decision making to sustainable energy planning—A review*, Renewable and Sustainable Energy Reviews, Vol. 8, p: 365-381, Jan 2004

Saaty, T.L. (1999) *Fundamentals of the analytic network process*. ISAHP 1999. August 1999

Saaty, T.L. (2001). *Decision Making with Dependence and Feedback: The Analytic Network Process*. RWS Publications.

Saaty, T.L. (2008) *Decision making with the analytic hierarchy process,* Int. J. Services Sciences, Vol. 1, No. 1, p: 83–98.

Velmurugan, R., & Selvamuthukumar, S. (2012). *The analytic network process for the pharmaceutical sector: Multi criteria decision making to select the suitable method for the preparation of nanoparticles*. DARU Journal of Pharmaceutical Sciences, Vol. 20(1), p: 59.

Wan, S.P.; Xu, G.L.; Dong, J.Y.(2017) *Supplier selection using anp and electre ii in interval 2-tuple linguistic environment*. Information Sciences, Vol. 385, p: 19–38, April 2017.