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Advanced Jet Trainer and Light Attack Aircraft Selection Using Composite Programming in Multiple Criteria Decision Making Analysis Method

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***Abstract*—**In this paper, composite programming is discussed for aircraft evaluation and selection problem using the multiple criteria decision analysis method. The decision criteria and aircraft alternatives were identified from the literature review. The importance of criteria weights was determined by the standard deviation method. The proposed model is applied to a practical decision problem for evaluating and selecting advanced jet trainer and light attack aircraft. The proposed technique gives robust and efficient results in modeling multiple criteria decisions. As a result of composite programming analysis, Hürjet, an advanced jet trainer and light attack aircraft alternative (a_3), was chosen as the most suitable aircraft candidate.

***Keywords*—**composite programming, additive weighted model, multiplicative weighted model, multiple criteria decision making analysis, MCDMA, aircraft selection, advanced jet trainer and light attack aircraft, M-346, FA-50, Hürjet.

I. Introduction

The composite programming method was introduced to address the multiple criteria decision making analysis (MCDMA) problems. This method is a combination of additive weighted model and multiplicative weighted model. Thus, the relative importance of each attribute is simply determined, and then, the alternatives are evaluated and prioritized. This mathematical compensatory technique was applied in aircraft selection [1].

The MCDMA approach is a quantitative method for ranking decision alternatives and selecting the best alternative when the decision maker has multiple evaluation criteria. In the MCDMA method, the decision maker selects the alternative that best meets the decision criteria and develops a numerical score to rank each decision alternative based on how well each alternative meets them. Human judgments and decisions about alternatives can be partial and often difficult to choose the best alternatives in decision making process.

Out of many MCDMA methods, only a few are mentioned such as composite programming [1], compromise programming [1], preference analysis for reference ideal solution (PARIS) [2-5], analytical hierarchical process (AHP) [6-8], VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) [9-11], preference ranking organization method for enrichment evaluation (PROMETHEE) [12-15], technique for order of preference by similarity to ideal solution (TOPSIS) [16-19], ÉLimination et Choix Traduisant la REalité (ELECTRE) [20-21], and fuzzy decision making, and so on.

Fuzzy [22-28], intuitionistic [29], and neutrosophic [30] decision making techniques are widely used in the evaluation of uncertainty problems. MCDMA approaches usually combine both quantitative and qualitative factors to evaluate a decision making problem to arrive at optimum solutions. Therefore, decision maker takes into account both type of factors influencing the classification, ranking and selection problem.

Evaluating and selecting an appropriate aircraft model is important to increase the effectiveness of the operation schemes. Aircraft selection problem is one of the most important strategic decisions due to its cost and flight effects. The objective of this study is to present a new composite programming approach based on additive weighted model, and multiplicative weighted model for the selection of potential aircraft candidates.

The aircraft selection problem is constructed as a multiple criteria decision making analysis problem. The multiple criteria evaluation methodology captures the uncertainty which characterizes the decision context of decision makers. The MCDMA method employed presents a refined and improved way of dealing with uncertainty in aircraft evaluation and selection decision problems [1-5, 31-35].

In order to deal with the complex evaluation and selection problems that arise in the decision environment, various MCDMA methods are proposed to handle the decision making process. In general, every evaluation and selection problem basically consists of four main components, namely (a) alternatives, (b) attributes/criteria, (c) relative importance (weight) of each attribute, and (d) performance measures of alternatives according to different attributes.

Therefore, this type of selection problem with the desired structure is quite suitable for solving using MCDMA techniques. Therefore, the main objective of any MCDMA approach is to select the best option from a set of feasible alternatives in the presence of various conflicting criteria.

In this study, a composite programming approach based on the additive weighted model and multiplicative weighted model was proposed for multiple criteria decision making. The ranking results are compared using the compromise programming technique. Uncertainty of inaccurate information is an important aspect to express uncertain information in multiple criteria decision making. While the uncertainty problem in the aircraft selection problem is examined on the same decision data set with the varying

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values of the λ and q parameters, the importance weights (ω_j) of the decision criteria are assigned with the standard deviation technique.

In the composite programming approach, the additive weighted method is combined with the multiplicative weighted method to increase the robustness of the optimum solutions. This method can be easily applied to calculate the utility functions of each weighted alternative.

The classical additive weighted model and the multiplicative weighted model, which enable reaching the highest accuracy of estimation, were aggregated using the composite programming method. Also, the composite programming's accuracy is more advantageous than using only the additive weighted model or multiplicative weighted model.

This MCDMA study has two primary goals, whereby the first objective relates to the possibility of improving the methodology for the treatment of uncertainty when it comes to the field of multiple criteria decision making analysis through the development of the composite programming approach. The second goal of this study is to enrich the evaluation methodology and selection of aircraft through a new approach to the treatment of uncertainty that is based on a composite programming model.

The remainder of this paper is organized as follows: Section 2 presents the composite programming methodology based on the combined additive weighted model and multiplicative model. Section 3 presents a case study for the aircraft evaluation and selection problem, the experimental results, and analysis, and presents results and discussion. Finally, the conclusion is presented in Section 4.

II. Methodology

A. Composite Programming

The concept of the composite decision process is developed as a general model to formulate discrete multiple criteria decision making analysis (MCDMA) problems. This composite programming model provides a good framework for representing decision making problem so that it can be usefully used to find the optimum solutions. The main advantage of the composite programming method is its high degree of reliability.

Composite programming is a multiple criteria decision analysis method, which is a compensatory approach that combines the results of two MCDMA models, the additive weighted model, and the multiplicative weighted model. Alternatives are ranked according to the value of the combined optimality criteria calculated according to the results of these two models.

The method can check the consistency of alternative rankings by performing a sensitivity analysis in its operation. This method is recommended as the most suitable MCDMA method for verifying or verifying accuracy using these two methods. MCDMA method steps are given as below [1]:

Step 1. Perform linear normalization of performance values as in the following:

$$r_{ij} = \begin{cases} \dfrac{x_{ij}}{\max\limits_i x_{ij}} & if \quad j \in B \\ \dfrac{\max\limits_i x_{ij}}{x_{ij}} & if \quad j \in C \end{cases} \tag{1}$$

where $i = 1,...,m,...,I$ (set of alternatives), and $j = 1,...,n,...,J$ (set of criteria), B and C are the sets of benefit and cost criteria.

Step 2. Compute the measures of additive weighted model (Q_i^a) and multiplicative weighted model (Q_i^m) for each alternative using the following:

$$Q_i^a = \left\{ \left(\sum_{i=1}^{I} \omega_j (r_{ij})^q \right)^{1/q} \right\} \tag{2}$$

$$Q_i^m = \left\{ \left(\prod_{i=1}^{I} ((r_{ij})^q)^{\omega_j} \right)^{1/q} \right\} \tag{3}$$

Step 3. Compute the aggregated measure of the composite method for each alternative using the following expression:

$$Q_i = \lambda Q_i^a + (1-\lambda) Q_i^m \tag{4}$$

where λ is the parameter of the composite method. It can take values in the range of $\lambda \in [0,1]$. When $\lambda = 1$, the composite method is transformed to an additive weighted model, and $\lambda = 0$ leads to a multiplicative weighted model.

Step 4. Rank the alternatives according to decreasing values of Q_i

B. Determination of Criteria Weights

The standard deviation method determines the objective weights of criteria.

$$\omega_j = \frac{\sigma_j}{\sum_{j=1}^{J}\sigma_j} = \frac{\frac{1}{m}\sqrt{\sum_{i=1}^{I}(r_{ij}-\overline{r_j})^2}}{\sum_{j=1}^{J}\frac{1}{m}\sqrt{\sum_{i=1}^{I}(r_{ij}-\overline{r_j})^2}} \quad (5)$$

where $i = 1,...,m,...,I$ is the number of alternatives, $j = 1,...,n,...,J$ is the number of decision criteria/attributes, r_{ij} is normalized elements of decision matrix, $\overline{r_j}$ is the average value of the *j*th criterion, σ_j is the standard deviation for criterion *j*, and ω_j is the weight or importance of criteria.

C. Advanced Jet Trainer and Light Attack Aircraft Alternatives

M-346 (a_1): The Aermacchi M-346 is the most advanced jet trainer and has been designed for a wide range of training capabilities, long-term reliability and cost-effective operations. Central element of a technologically advanced Integrated training system, the M-346 is the most modern solution to train new generation pilots. The aircraft is in service with the Air Forces of Italy, Republic of Singapore, Israel and Poland with 80 aircraft already ordered [36].

FA-50 (a_2): Based on the T-50 trainer's superior performance and an armament storing capability, the FA-50 aircraft is further developed and upgraded with tactical data link, Precision guided munitions, and self protection subsystem. Featuring a fighter jet-class flight performance, the FA-50 aircraft has been deployed and operated in the Republic of Korea Air Force (ROKAF) since 2013[37].

HÜRJET (a_3): Advanced Jet Trainer and Light Attack Aircraft HÜRJET is a single engine, tandem-seat with modern avionics and high-performance features, fulfills a critical role in modern pilot training through its superior performance characteristics. Combat variant provides a battlefield force multiplier through a wide range of mission capabilities and an extensive payload. HÜRJET project has started to fulfil international and Turkish Air Force requirements by replacing aging T-38s as advanced jet trainers (AJT) and F-5s as acrobatic team aircrafts with a modern high performance multirole aircraft.Being used as Advanced Jet Trainers due to the increasing number of 5th generation aircrafts (TFX, F-35, etc.) and their changing configurations.Considering the multirole aircraft market, Turkish Aerospace has started HÜRJET program with the intention of targeting the potential in the market by benefiting from its experience and skills on cost effective design / production of trainer / light aircraft / system [38].

III. Application

In order to show the application of the proposed method, a practical MCDMA example is used to illustrate the aircraft selection problem. A model for aircraft selection is proposed based on composite programming and compromise programming methods. In Table 1, the specifications of the aircraft candidate alternatives to be selected are given.

For the case study, three advanced jet trainer and light attack aircraft { Leonardo: M-346 (a_1), KAI: FA-50 (a_2), TAI: Hürjet (a_3)} were selected for multiple criteria evaluation problem. The decision criteria are thrust (g_1, kN), maximum speed (g_2, km/h), range (g_3, km), service ceiling (g_4, km), and rate of climb (g_5, m/s)

Table 1. Decision matrix of the selected aircraft's specifications

	g_1	g_2	g_3	g_4	g_5
a_1	79	1090	1925	13716	112
a_2	56	1838	1851	14630	198
a_3	79	1729	2222	13716	198

Table 2. Normalized decision matrix

	g_1	g_2	g_3	g_4	g_5
a_1	1,0000	0,5930	0,8663	0,9375	0,5657
a_2	0,7089	1,0000	0,8330	1,0000	1,0000
a_3	1,0000	0,9407	1,0000	0,9375	1,0000

The standard deviation technique assigns objective weights of importance to each decision criterion. The calculated objective criteria weights (ω_j) are given in Table 3.

Table 3. The objective criteria weights (ω_j)

criteria	g_1	g_2	g_3	g_4	g_5
ω_j	0,1874	0,3002	0,1207	0,0493	0,3424

where J is the number decision criteria (g_j), and ω_j is assigned objective criterion weight, $\sum_{j=1}^{J}\omega_j = 1$, $j = 1,...,n,...,J$.

The importance weights of the decision criteria calculated by the standard deviation method are given in Fig. 1. While the rate of climb (g_5, m/s) criterion had the highest criterion weight with 0.3424, the maximum speed (g_2, km/s) criterion was found to be the second important attribute with 0,3002.

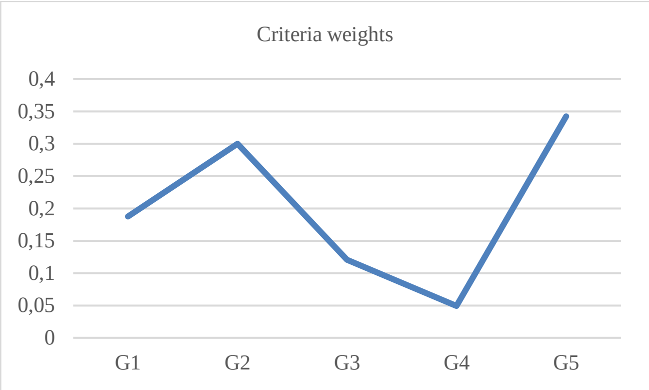

Fig. 1 Calculated objective criteria weights

The following computational evaluation results were obtained by applying the procedural steps of the composite programming technique. The computational model parameters λ and q are properly set to perform the sensitivity analysis. The ranking results of composite programming are given in Table 4 to Table 15.

The sensitivity analysis reflects the robustness of the composite programming model when the aircraft selection problem is handled with a multiple decision making analysis approach.The additive weighted model and the multiplicative weighted model are combined to enrich sensitivity analysis process.

Table 4. Additive weighted model solutions ($q = 1$)

$q = 1$	g_1	g_2	g_3	g_4	g_5
a_1	0,18742	0,17804	0,10454	0,04618	0,19370
a_2	0,13285	0,30022	0,10052	0,04926	0,34244
a_3	0,18742	0,28241	0,12067	0,04618	0,34244

Table 5. Additive weighted model solutions ($q = 2$)

$q = 2$	g_1	g_2	g_3	g_4	g_5
a_1	0,18742	0,10558	0,09057	0,04329	0,10957
a_2	0,09417	0,30022	0,08374	0,04926	0,34244
a_3	0,18742	0,26567	0,12067	0,04329	0,34244

Table 6. Additive weighted model solutions ($q = 3$)

$q = 3$	g_1	g_2	g_3	g_4	g_5
a_1	0,18742	0,03713	0,06798	0,03805	0,03506
a_2	0,04732	0,30022	0,05811	0,04926	0,34244
a_3	0,18742	0,23509	0,12067	0,03805	0,34244

Table 7. Additive weighted model solutions ($q = 4$)

$q = 4$	g_1	g_2	g_3	g_4	g_5
a_1	0,18742	0,03713	0,06798	0,03805	0,03506
a_2	0,04732	0,30022	0,05811	0,04926	0,34244
a_3	0,18742	0,23509	0,12067	0,03805	0,34244

Table 8. Additive weighted model solutions ($q = 5$)

$q = 5$	g_1	g_2	g_3	g_4	g_5
a_1	0,18742	0,02202	0,05889	0,03568	0,01983
a_2	0,03354	0,30022	0,04841	0,04926	0,34244
a_3	0,18742	0,22115	0,12067	0,03568	0,34244

Table 9. Additive weighted model solutions

Q_i^a	Q_1^a	Q_2^a	Q_3^a	Q_4^a	Q_5^a
$q > 0$	$q = 1$	$q = 2$	$q = 3$	$q = 4$	$q = 5$
a_1	0,70988	0,26822	0,14369	0,09141	0,06477
a_2	0,92529	0,43491	0,27614	0,19934	0,15477
a_3	0,97912	0,47974	0,31368	0,23092	0,18147

Table 10. Multiplicative weighted model solutions

Q_i^m	Q_1^m	Q_2^m	Q_3^m	Q_4^m	Q_5^m
$q > 0$	$q = 1$	$q = 2$	$q = 3$	$q = 4$	$q = 5$
a_1	0,68903	0,23738	0,10904	0,05635	0,03106
a_2	0,91710	0,42054	0,25712	0,17685	0,12976
a_3	0,97870	0,47893	0,31248	0,22937	0,17959

Table 11. Composite programming solutions ($q = 1$)

λ	0	0,1	0,3	0,5	0,7	0,9	1
a_1	0,68903	0,69112	0,69529	0,69946	0,70362	0,70779	0,70988
a_2	0,91710	0,91792	0,91956	0,92120	0,92283	0,92447	0,92529
a_3	0,97870	0,97874	0,97882	0,97891	0,97899	0,97908	0,97912

Table 12. Composite programming solutions ($q = 2$)

λ	0	0,1	0,3	0,5	0,7	0,9	1
a_1	0,23738	0,24047	0,24663	0,25280	0,25897	0,26513	0,26822
a_2	0,42054	0,42198	0,42485	0,42773	0,43060	0,43348	0,43491
a_3	0,47893	0,47901	0,47917	0,47933	0,47950	0,47966	0,47974

Table 13. Composite programming solutions ($q = 3$)

λ	0	0,1	0,3	0,5	0,7	0,9	1
a_1	0,10904	0,11251	0,11944	0,12636	0,13329	0,14022	0,14369
a_2	0,25712	0,25902	0,26283	0,26663	0,27044	0,27424	0,27614
a_3	0,31248	0,31260	0,31284	0,31308	0,31332	0,31356	0,31368

Table 14. Composite programming solutions ($q = 4$)

λ	0	0,1	0,3	0,5	0,7	0,9	1
a_1	0,05635	0,05986	0,06687	0,07388	0,08089	0,08790	0,09141
a_2	0,17685	0,17910	0,18360	0,18810	0,19259	0,19709	0,19934
a_3	0,22937	0,22952	0,22983	0,23014	0,23045	0,23076	0,23092

Table 15. Composite programming solutions ($q = 5$)

λ	0	0,1	0,3	0,5	0,7	0,9	1
a_1	0,03106	0,03443	0,04117	0,04791	0,05466	0,06140	0,06477
a_2	0,12976	0,13226	0,13726	0,14226	0,14727	0,15227	0,15477
a_3	0,17959	0,17978	0,18015	0,18053	0,18091	0,18128	0,18147

As a result of the computational decision making analysis, the ranking order of the advanced jet trainer and light attack aircraft candidates was determined as follows:

$$\text{Preference ranking: } a_3 \succ a_2 \succ a_1$$

Hürjet, advanced jet trainer and light attack aircraft alternative (a_3) was chosen as the most suitable aircraft candidate for the Air Force. Hürjet outperformed the other two candidate aircraft in all utility function scores. Therefore, Hürjet, advanced jet trainer and light attack aircraft alternative (a_3), was chosen as the most suitable aircraft candidate. Also, the sensitivity analysis was performed using the coefficients λ and q. Therefore, in the part of the sensitivity analysis, a change in the coefficient λ and q was made, which is shown in Tables 4 to Table 14. The Spearman correlation coefficient of the ranks obtained was calculated which confirms the applicability of all the proposed approaches.

In this work, advanced jet trainer and light attack aircraft selection problem from the real-time decision environment are solved using the composite programming method, which is a combination of two MCDMA methods, namely additive weighted model, and multiplicative weighted model. It has already been proven that the accuracy of an aggregated method would always be better than single methods. For the advanced jet trainer and light attack aircraft selection problem under consideration, it has been observed that the composite programming method provides the accurate rankings of candidate alternatives as those obtained using the compromise programming model.

The effect of the λ and q parameters on the ranking performance of the proposed method was also examined and it was revealed that better performance was achieved at higher λ and q values. When λ is set to 0, the composite programming method behaves like an additive weighted model, and when λ is 1, it is converted to a multiplicative weighted model.

The main advantage of this method is defined as its strong resistance to reversal of the order of the considered alternatives. Because this method contains simple and robust mathematics and is quite comprehensive in nature, it can be successfully applied to any MCDMA decision making situation.

IV. Conclusion

The approach developed represents an MCDMA method of composite programming technique, in which the standard deviation method is used to calculate the objective weight values of the criteria, and the proposed model is applied for the evaluation and ranking of the advanced jet trainer and light attack aircraft. The model is validated by the aircraft selection process based on five decision criteria.

The results obtained using the proposed approach show that the third alternative Hürjet (a_3), is the best solution in both parts of the sensitivity analysis, which involves changing the value of the coefficients λ and q in the decision making process. Analysis of the results obtained by calculating the Spearman correlation coefficient found that the composite programming approach was in full correlation with the ranks obtained. Through the research, two contributions can be distinguished, one of which is the development of a new MCDMA approach to composite programming model that allows decisions to be unified in an objective way.

The development of a new approach contributes to the development of the advanced jet trainer and light attack aircraft selection problem that takes into account the theoretical and practical application of MCDMA methods.

The developed approach allows the evaluation of alternatives in the decision making process. With the application of the developed approach, it is possible to solve the MCDMA problem in a very simple way, and to make an aircraft evaluation and selection that has a significant impact on efficiency. The developed approach to the aircraft selection problem can be used in decision making process in other areas besides the problem under consideration. Its flexibility is reflected in the fact that validation can be performed with the integration of any of the multiple criteria decision making methods to determine the weight values of the criteria.

A case study on the multiple criteria evaluation of three alternative advanced jet trainer and light attack aircraft selection solutions, considering the performance parameters, was carried out by applying the composite programming method. When applying the joint composite programming method, it is considered that the most preferred alternative depends on the values of λ and q. Alternative (a_3) ("Hürjet") is ranked as best, alternative (a_2) ("FA-50") remains in second place, and alternative (a_1) ("M-346") remains in third place when parameters λ and q change.

It has been proven that higher ranking accuracy is achieved when the weighted aggregate function is applied compared to the accuracy of the individual additive weighted model or the multiplicative weighted model, ie., a certain robustness condition is met. Optimal values of λ_i and q_i are calculated, assuming that the ranking accuracy is increased and applying the proposed methodology for optimization of the weighted aggregated function.

Finally, based on the results of the research, the conclusion that the developed composite programming method seems robust can be confirmed. The method can also be validated for real-life applications. Future research is related to the use of fuzzy, intuitionistic, and neutrosophic sets in integration with other methods.

References

[1] Ardil, C. (2021). Comparison of Composite Programming and Compromise Programming for Aircraft Selection Problem Using Multiple Criteria Decision Making Analysis Method.International Journal of Aerospace and Mechanical Engineering, 15(11), 479 - 485.

[2] Ardil, C. (2020). A Comparative Analysis of Multiple Criteria Decision Making Analysis Methods for Strategic, Tactical, and Operational

Decisions in Military Fighter Aircraft Selection. International Journal of Aerospace and Mechanical Engineering, 14(7), 275 - 288.
[3] Ardil, C. (2020). Aircraft Selection Process Using Preference Analysis for Reference Ideal Solution (PARIS). International Journal of Aerospace and Mechanical Engineering, 14(3), 80 - 93.
[4] Ardil, C. (2020). Regional Aircraft Selection Using Preference Analysis for Reference Ideal Solution (PARIS). International Journal of Transport and Vehicle Engineering, 14(9), 378 - 388.
[5] Ardil, C. (2020). Trainer Aircraft Selection Using Preference Analysis for Reference Ideal Solution (PARIS). International Journal of Aerospace and Mechanical Engineering, 14(5), 195 - 209.
[6] Saaty, T. L. (1990). How to make a decision: The Analytic Hierarchy Process. European Journal of Operational Research, 48(1), 9-26. doi: 10.1016/0377-2217(90)90057-I
[7] Saaty, T. L. (2008). Decision making with the analytic hierarchy process. International Journal of Services Sciences, 1(1), 83-98. doi: 10.1504/IJSSCI.2008.017590
[8] Saaty, T.L. (1980). Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. McGraw-Hill, New York.
[9] Opricovic, S. (1998). Multicriteria Optimization of Civil Engineering Systems. PhD Thesis, Faculty of Civil Engineering, Belgrade (in Serbian).
[10] Opricovic, S. (2007). A fuzzy compromise solution for multicriteria problems. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 15(3), 363–380.
[11] Opricovic, S., Tzeng, G.-H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. European Journal of Operational Research, 156(2), 445–455.
[12] Brans JP., Mareschal B. (2005). Promethee Methods. In: Multiple Criteria Decision Analysis: State of the Art Surveys. International Series in Operations Research & Management Science, vol 78, pp 163-186. Springer, New York, NY. https://doi.org/10.1007/0-387-23081-5_5.
[13] Brans, J., Ph. Vincke. (1985). A Preference Ranking Organisation Method: (The PROMETHEE Method for Multiple Criteria Decision-Making). Management Science, 31(6), 647-656.
[14] Brans, J.P., Macharis, C., Kunsch, P.L., Chevalier, A., Schwaninger, M., (1998). Combining multicriteria decision aid and system dynamics for the control of socio-economic processes. An iterative real-time procedure. European Journal of Operational Research 109, 428-441.
[15] Brans, J.P., Vincke, Ph., Mareschal, B., (1986). How to select and how to rank projects: the PROMETHEE method. European Journal of Operational Research, 24, 228-238.
[16] Hwang, C.L.; Yoon, K. (1981). Multiple Attribute Decision Making: Methods and Applications. New York: Springer-Verlag.
[17] Chu, T.C. (2002. Facility location selection using fuzzy TOPSIS under group decisions", International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, Vol. 10 No. 6, pp. 687-701.
[18] Choudhary, D. and Shankar, R. (2012. A STEEP-fuzzy AHP-TOPSIS framework for evaluation and selection of thermal power plant location: a case study from India", Energy, Vol. 42 No. 1, pp. 510-521.
[19] Zavadskas, E.K., Mardani, A., Turskis, Z., Jusoh, A., Nor, K.M. (2016) Development of TOPSIS method to solve complicated decision-making problems: An overview on developments from 2000 to 2015. International Journal of Information Technology & Decision Making, 15, 645-682.
[20] Roy, B. (1991). The outranking approach and the foundation of ELECTRE methods. Theory and Decision, 31(1), 49–73.
[21] Fei, L., Xia, J., Feng, Y., Liu, L. (2019) An ELECTRE-Based Multiple Criteria Decision Making Method for Supplier Selection Using Dempster-Shafer Theory. IEEE Access, 7, 84701-84716.
[22] Zadeh L.A., (1965). Fuzzy Sets. Information and Control, 8, 338-353.
[23] Bellman, R.E., Zadeh, L.A. (1970). Decision-making in a fuzzy environment. Management Science, 17(4), 141–164.
[24] Modarres, M., Sadi-Nezhad, S. (2005). Fuzzy simple additive weighting method by preference ratio, Intelligent Automation and Soft Computing, 235-244.
[25] Kaur, P., Kumar, S. (2013). An Intuitionistic Fuzzy Simple Additive Weighting Method for selection of vendor. ISOR Journal Business and Management, 78-81.
[26] Sagar, M.K., Jayaswal, P., Kushwah, K. (2013). Exploring Fuzzy SAW Method for Maintenance strategy selection problem of Material Handling Equipment, (2013), ISSN 22 77 – 4106.
[27] Wang,Y.J. (2015). A fuzzy multi-criteria decision making model based on additive weighting method and preference relation, Applied Soft Computing, 30,412-420.
[28] Roszkowska, E., Kacprzak, D. (2016). The fuzzy saw and fuzzy TOPSIS procedures based on ordered fuzzy numbers. Inf. Sci., 369, 564-584.
[29] Atanassov K. (1986). Intuitionistic Fuzzy Sets, Fuzzy Sets and Systems, Vol. 20(1), 87-96.
[30] Smarandache, F. (2019). Neutrosophic Set is a Generalization of Intuitionistic Fuzzy Set, Inconsistent Intuitionistic Fuzzy Set (Picture Fuzzy Set, Ternary Fuzzy Set), Pythagorean Fuzzy Set, Spherical Fuzzy Set, and q-Rung Orthopair Fuzzy Set, while Neutrosophication is a Generalization of Regret Theory, Grey System Theory, and Three-Ways Decision (revisited) . Journal of New Theory, (29), 1-31.
[31] Ardil, C. (2019). Fighter Aircraft Selection Using Technique for Order Preference by Similarity to Ideal Solution with Multiple Criteria Decision Making Analysis. International Journal of Transport and Vehicle Engineering, 13(10), 649 - 657.
[32] Ardil, C. , Pashaev, A. , Sadiqov, R. , Abdullayev, P. (2019). Multiple Criteria Decision Making Analysis for Selecting and Evaluating Fighter Aircraft. International Journal of Transport and Vehicle Engineering, 13(11), 683 - 694.
[33] Ardil, C. (2019). Aircraft Selection Using Multiple Criteria Decision Making Analysis Method with Different Data Normalization Techniques. International Journal of Industrial and Systems Engineering, 13(12), 744 - 756.
[34] Ardil, C. (2019). Military Fighter Aircraft Selection Using Multiplicative Multiple Criteria Decision Making Analysis Method. International Journal of Mathematical and Computational Sciences, 13(9), 184 - 193.
[35] Ardil, C. (2021). Neutrosophic Multiple Criteria Decision Making Analysis Method for Selecting Stealth Fighter Aircraft. International Journal of Aerospace and Mechanical Engineering, 15(10), 459 - 463.
[36] Leonardo S.p.A. Accessed on December 06, 2021. https://www.leonardocompany.com/
[37] Korea Aerospace Industries, Ltd. Accessed on December 06, 2021. https://www.koreaaero.com/
[38] Turkish Aerospace Industries, Inc. Accessed on December 06, 2021. https://www.tusas.com/