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Comparison of Composite Programming and Compromise Programming for Aircraft Selection Problem Using Multiple Criteria Decision Making Analysis Method

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***Abstract*—**In this paper, the comparison of composite programming and compromise programming for the aircraft selection problem is discussed using the multiple criteria decision analysis method. The decision making process requires the prior definition and fulfillment of certain factors, especially when it comes to complex areas such as aircraft selection problems. The proposed technique gives more efficient results by extending the composite programming and compromise programming, which are widely used in modeling multiple criteria decisions. The proposed model is applied to a practical decision problem for evaluating and selecting aircraft problems.

A selection of aircraft was made based on the proposed approach developed in the field of multiple criteria decision making. The model presented is solved by using the following methods: composite programming, and compromise programming. The importance values of the weight coefficients of the criteria are calculated using the mean weight method. The evaluation and ranking of aircraft are carried out using the composite programming and compromise programming methods.

In order to determine the stability of the model and the ability to apply the developed composite programming and compromise programming approach, the paper analyzes its sensitivity, which involves changing the value of the coefficient λ and q in the first part. The second part of the sensitivity analysis relates to the application of different multiple criteria decision making methods, composite programming and compromise programming. In addition, in the third part of the sensitivity analysis, the Spearman correlation coefficient of the ranks obtained was calculated which confirms the applicability of all the proposed approaches.

***Keywords*—**composite programming, compromise programming, additive weighted model, multiplicative weighted model, multiple criteria decision making analysis, MCDMA, aircraft selection.

I. Introduction

Multiple criteria decision making analysis (MCDMA) is an important situation that expresses preference based on viable attributes, which are described as multiple criteria in a decision environment. MCDMA is a quantitative method for ranking decision alternatives and selecting the best one when the decision maker has multiple criteria. With MCDMA, 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.

Out of many MCDMA methods, only a few are mentioned such as preference analysis for reference ideal solution (PARIS) [1-4], analytical hierarchical process (AHP) [5-7], VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) [8-10], preference ranking organization method for enrichment evaluation (PROMETHEE) [11-14], technique for order of preference by similarity to ideal solution (TOPSIS) [15-18], ÉLimination et Choix Traduisant la REalité (ELECTRE) [19-20], and fuzzy decision making, and so on.

Fuzzy [21-22], intuitionistic [28], and neutrosophic [29] 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 types of factors influencing the classification, ranking, and selection problem. Mostly, the values for the qualitative criteria are not accurately defined for decision makers. Moreover, individual evaluations and importance weights of criteria are usually defined as "very low", "low", "medium", "high", "very high". So, it is quite hard to accurately quantify the rating of each alternative.

Selecting an appropriate aircraft model is important to increase the effectiveness of the operation schemes. A few studies deal with the aircraft selection problem. Aircraft selection problem is one of the most important strategic decisions due to its cost and flight effects. The aim of this study is to present a new composite programming approach additive weighted model, and multiplicative weighted model, which are applied in MCDMA problems with utility function for the selection of potential aircraft candidates.

The aircraft selection problem is conceptualized as a multiple criteria decision making analysis problem. The multiple criteria evaluation methodology captures the uncertainty which characterizes the decision context of decision makers. Therefore, this study fills an important gap particularly in aircraft selection problems, and more generally decision problems concerning aviation environment. The MCDMA method employed presents a refined and improved way of dealing with uncertainty in aircraft selection decision problems [1-4, 30-34].

In order to deal with the complex selection problems that arise in the decision environment, various multiple criteria decision making analysis (MCDMA) methods have already been proposed and augmented in different fields [35-36]. Every selection problem basically consists of four main

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components, namely (a) alternatives, (b) attributes/criteria, (c) relative importance (weight) of each attribute, and (d) performance measures of alternatives according to different attributes.

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, an effort is made to compare the applicability and solution accuracy of a new MCDMA approach, i.e., composite programming and compromise programming methods, when solving real-time selection problems encountered in the decision environment.

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

The steps of the proposed MCDMA method, the *q*th power of the degrees of utility functions, and the proposed composite programming and compromise programming procedure were used to develop the hybrid approach. Also, it should be emphasized that a hybrid computational analysis method is employed to facilitate decision making.

In the composite programming approach, the additive weighted method is integrated to 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. The ranking performance of the composite programming approach was compared with compromise programming to evaluate potential aircraft candidates.

This MCDMA work 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 and compromise programming approach. The second goal of this work is to enrich the evaluation methodology and selection of aircraft through a new approach to the treatment of uncertainty that is based on the composite programming and the compromise programming models.

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 and the compromise programming method. Section 3 presents a case study for aircraft selection problem, a comparison of the performance of different MCDMA techniques applied to this case study, and 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 problems 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:

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

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

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:

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

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

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

$$Q_i = \lambda Q_i^a + (1-\lambda) Q_i^m \quad (4)$$

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. Compromise Programming

The compromise programming is a compensatory multiple criteria decision making analysis (MCDMA) method. The basic idea in compromise programming is to identify an ideal solution or utopian solution, which is only a point of reference for the decision maker. Compromise programming assumes, quite realistically, that any decision maker seeks a solution as close as possible to the ideal point, possibly the only assumption made by compromise programming about human preferences. To achieve this closeness, a distance function is introduced into the analysis.

The important point to emphasize here is that the concept of distance is not used in its geometric sense, but as a proxy measure for human preferences. The idea of a distance metric or a family of distance functions is essential for the compromise programming technique to work.

Compromise programming is a multiple criteria decision making analysis (MCDMA) approach with many theoretical extensions and with applications in various fields [37-41]. Its basic idea is to determine a subset of efficient solutions that is nearest with respect to an ideal and infeasible point (called ideal point), for which all the criteria are optimized. The corresponding distance functions are introduced through a family of q-metrics. Compromise programming method steps are given as below:

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

$$r_{ij} = \begin{cases} \dfrac{x_{ij}}{\max_i x_{ij}} & if \quad j \in B \\ \dfrac{\max_i x_{ij}}{x_{ij}} & if \quad j \in C \end{cases} \quad (5)$$

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 the maximum group utility (ψ_i^u) and the maximum individual regret of the opponent (ψ_i^r) for each alternative using the following:

$$\psi_i^u = \left\{ \left(\sum_{i=1}^{I} \omega_j (r_{ij})^q \right)^{1/q} \right\} \quad (6)$$

$$\psi_i^r = \max \left\{ \sum_{i=1}^{I} \left(\omega_j (r_j^* - r_{ij})^q \right)^{1/q} \right\} \quad (7)$$

where r_j^* is the maximum point or utopia point.

Step 3. Compute the aggregated measure of the compromise programming for each alternative using the following expression:

$$\psi_i = \lambda \psi_i^u + (1-\lambda) \psi_i^r \quad (8)$$

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 of the maximum group utility (ψ_i^u) model, and $\lambda = 0$ leads to the maximum individual regret of the opponent (ψ_i^r) model.

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

The compromise programming is a helpful mathematical tool in multiple criteria decision making, particularly in a situation where the decision maker is not able to express his/her preference at the beginning of system design. The obtained solution is compromised by a maximum group utility (ψ_i^u) of the majority and a maximum individual regret (ψ_i^r) of the opponent.

C. Determination of Criteria Weights

The mean weight technique assigns equal weights of importance to each decision criterion.

$$\omega_j = 1/J \tag{9}$$

where J is the number decision criteria, ω_j is criterion weight, $\sum_{j=1}^{J}\omega_j = 1$, $j = 1,...,n,...,J$, and $\omega_j = 1/5 = 0,20$.

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, four commercial passenger aircraft {Airbus A320neo (a_1), Airbus A321neo (a_2), Boeing 737 MAX 8 (a_3), and Boeing 737 MAX 9 (a_4)} were selected for multiple criteria evaluation problem. The decision criteria are Maximum Takeoff Weight (g_1, kg x10^3), Seat Capacity (g_2, #), Fuel Consumption (g_3, kg/km), Fuel Per Seat (g_4, L/100 km), and Price of Aircraft (g_5, \$ x10^6). The normalized decision matrix is given in Table 2.

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

	g_1	g_2	g_3	g_4	g_5
a_1	79	180	2,79	2,25	110,6
a_2	93,5	210	3,3	2,19	129,5
a_3	82	178	3,04	2,28	121,6
a_4	88	193	3,3	2,28	128,9

Table 2. Normalized decision matrix

	g_1	g_2	g_3	g_4	g_5
a_1	0,845	0,857	1,000	0,973	1,000
a_2	1,000	1,000	0,845	1,000	0,849
a_3	0,877	0,848	0,918	0,961	0,905
a_4	0,941	0,919	0,845	0,961	0,853

A. Composite Programming Solutions

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 3 to Table 10.

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 3. Additive weighted model solutions ($q = 1$)

$q=1$	g_1	g_2	g_3	g_4	g_5
a_1	0,211	0,214	0,250	0,243	0,250
a_2	0,250	0,250	0,211	0,250	0,212
a_3	0,219	0,212	0,229	0,240	0,226
a_4	0,235	0,230	0,211	0,240	0,213

Table 4. Additive weighted model solutions ($q = 2$)

$q=2$	g_1	g_2	g_3	g_4	g_5
a_1	0,178	0,184	0,250	0,237	0,178
a_2	0,250	0,250	0,179	0,250	0,250
a_3	0,192	0,180	0,211	0,231	0,192
a_4	0,221	0,211	0,179	0,231	0,221

Table 5. Additive weighted model solutions ($q = 3$)

$q=3$	g_1	g_2	g_3	g_4	g_5
a_1	0,151	0,157	0,250	0,231	0,151
a_2	0,250	0,250	0,151	0,250	0,250
a_3	0,169	0,152	0,193	0,222	0,169
a_4	0,208	0,194	0,151	0,222	0,208

Table 6. Additive weighted model solutions

Q_i^a	Q_1^a	Q_2^a	Q_3^a
$q>0$	$q=1$	$q=2$	$q=3$
a_1	1,16885	0,54950	0,34625
a_2	1,17372	0,55454	0,35143
a_3	1,12688	0,50885	0,30691
a_4	1,12989	0,51201	0,31016

Table 7. Multiplicative weighted model solutions

Q_i^m	Q_1^m	Q_2^m	Q_3^m
$q>0$	$q=1$	$q=2$	$q=3$
a_1	0,16198	0,01101	0,00119
a_2	0,16273	0,01122	0,00140
a_3	0,15511	0,00926	0,00087
a_4	0,15555	0,00937	0,00093

Table 8. Composite programming solutions ($q = 1$)

λ	0	0,1	0,3	0,5	0,7	0,9	1
a_1	0,16198	0,26267	0,46404	0,66541	0,86679	1,06816	1,16885
a_2	0,16273	0,26383	0,46603	0,66823	0,87042	1,07262	1,17372
a_3	0,15511	0,25229	0,44664	0,64100	0,83535	1,02970	1,12688
a_4	0,15555	0,25298	0,44785	0,64272	0,83759	1,03246	1,12989

Table 9. Composite programming solutions ($q = 2$)

λ	0	0,1	0,3	0,5	0,7	0,9	1
a_1	0,01101	0,06486	0,17256	0,28025	0,38795	0,49565	0,54950
a_2	0,01122	0,06555	0,17422	0,28288	0,39154	0,50021	0,55454
a_3	0,00926	0,05922	0,15914	0,25906	0,35897	0,45889	0,50885
a_4	0,00937	0,05963	0,16016	0,26069	0,36122	0,46175	0,51201

Table 10. Composite programming solutions ($q = 3$)

λ	0	0,1	0,3	0,5	0,7	0,9	1
a_1	0,00119	0,03569	0,10471	0,17372	0,24273	0,31175	0,34625
a_2	0,00140	0,03640	0,10641	0,17642	0,24642	0,31643	0,35143
a_3	0,00087	0,03147	0,09268	0,15389	0,21510	0,27631	0,30691
a_4	0,00093	0,03185	0,09370	0,15555	0,21739	0,27924	0,31016

The ranking order of the aircraft candidates was determined as follows:

Preference ranking: $a_2 \succ a_1 \succ a_4 \succ a_3$

The Airbus A321neo aircraft alternative (a_2) was chosen as the most suitable aircraft candidate.

B. Compromise Programming Solutions

The following computational evaluation results were obtained by applying the procedural steps of the compromise programming technique. The computational model parameters λ and q are properly set to perform the sensitivity analysis. The ranking results of compromise programming are given in Table 11 to Table 18.

The sensitivity analysis reflects the robustness of the compromise programming model when the aircraft selection problem is handled with a multiple decision making analysis approach.The maximum group utility model and the maximum individual regret of the opponent model are combined to enrich sensitivity analysis process.

Table 11. Maximum group utility model solutions ($q = 1$)

$q=1$	g_1	g_2	g_3	g_4	g_5
a_1	0,211	0,214	0,250	0,243	0,250
a_2	0,250	0,250	0,211	0,250	0,212
a_3	0,219	0,212	0,229	0,240	0,226
a_4	0,235	0,230	0,211	0,240	0,213

Table 12. Maximum group utility model solutions ($q = 2$)

$q=2$	g_1	g_2	g_3	g_4	g_5
a_1	0,178	0,184	0,250	0,237	0,178
a_2	0,250	0,250	0,179	0,250	0,250
a_3	0,192	0,180	0,211	0,231	0,192
a_4	0,221	0,211	0,179	0,231	0,221

Table 13. Maximum group utility model solutions ($q = 3$)

$q=3$	g_1	g_2	g_3	g_4	g_5
a_1	0,151	0,157	0,250	0,231	0,151
a_2	0,250	0,250	0,151	0,250	0,250
a_3	0,169	0,152	0,193	0,222	0,169
a_4	0,208	0,194	0,151	0,222	0,208

Table 14. Maximum group utility model solutions model solutions

Q_i^u	Q_1^u	Q_2^u	Q_3^u
$q>0$	$q=1$	$q=2$	$q=3$
a_1	1,16885	0,54950	0,34625
a_2	1,17372	0,55454	0,35143
a_3	1,12688	0,50885	0,30691
a_4	1,12989	0,51201	0,31016

Table 15. Maximum individual regret of the opponent model solutions

Q_i^r	Q_1^r	Q_2^r	Q_3^r
$q>0$	$q=1$	$q=2$	$q=3$
a_1	0,08115	0,00484	0,00059
a_2	0,07628	0,00497	0,00062
a_3	0,12312	0,00614	0,00065
a_4	0,12011	0,00620	0,00070

Table 16. Compromise programming solutions ($q = 1$)

λ	0	0,1	0,3	0,5	0,7	0,9	1
a_1	0,08115	0,18992	0,40746	0,62500	0,84254	1,06008	1,16885
a_2	0,07628	0,18602	0,40551	0,62500	0,84449	1,06398	1,17372
a_3	0,12312	0,22350	0,42425	0,62500	0,82575	1,02650	1,12688
a_4	0,12011	0,22108	0,42304	0,62500	0,82696	1,02892	1,12989

Table 17. Compromise programming solutions ($q = 2$)

λ	0	0,1	0,3	0,5	0,7	0,9	1
a_1	0,00484	0,05931	0,16824	0,27717	0,38610	0,49503	0,54950
a_2	0,00497	0,05992	0,16984	0,27975	0,38967	0,49958	0,55454
a_3	0,00614	0,05641	0,15695	0,25749	0,35804	0,45858	0,50885
a_4	0,00620	0,05678	0,15794	0,25911	0,36027	0,46143	0,51201

Table 18. Compromise programming solutions ($q = 3$)

λ	0	0,1	0,3	0,5	0,7	0,9	1
a_1	0,00059	0,03516	0,10429	0,17342	0,24255	0,31169	0,34625
a_2	0,00062	0,03571	0,10587	0,17603	0,24619	0,31635	0,35143
a_3	0,00065	0,03128	0,09253	0,15378	0,21504	0,27629	0,30691
a_4	0,00070	0,03164	0,09354	0,15543	0,21732	0,27922	0,31016

The ranking order of the aircraft candidates was determined as follows:

Preference ranking: $a_2 \succ a_1 \succ a_4 \succ a_3$

The Airbus A321neo aircraft alternative (a_2) was chosen as the most suitable aircraft candidate. 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 3 to Table 18. The Spearman correlation coefficient of the ranks obtained was calculated which confirms the applicability of all the proposed approaches.

In this work, 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 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 a 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 a comparison of composite programming and compromise programming methods, in which the mean weight technique is used to calculate the weight values of the criteria and the proposed model is applied for the evaluation and ranking of the 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 second alternative Airbus A321neo (a_2), 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 of the compromise programming approach. Through the research, two contributions can be distinguished, one of which is the development of a new MCDMA approach to composite programming and compromise programming models that allow decisions to be unified in an objective way.

The development of a new approach contributes to the development of the 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. Future research is related to the use of fuzzy, intuitionistic, and neutrosophic sets in integration with other methods and an attempt to develop a new MCDMA method in this field.

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