MULTICRITERIA ANALYSIS OF PARACHUTES USED BY SPECIAL OPERATIONS FORCES

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Abstract: *Special operations forces are well-known for their expertise in rapid tactical interventions, and the use of parachutes plays a crucial role in their arsenal. These elite units rely heavily on parachutes to conduct swift and clandestine insertions into inaccessible or challenging terrain, allowing them to catch adversaries off guard and execute critical missions with precision and efficiency.*

To establish a ranking of parachutes utilized by special operations forces using multicriteria analysis, it is imperative to delineate evaluation criteria and assign appropriate weights based on their relative significance. Each parachute undergoes assessment according to these criteria, receiving scores commensurate with its performance. Subsequently, total scores are tabulated for each parachute, predicated on the weights allotted to each criterion. The resultant ranking affords a lucid perspective on the optimal options, aiding special forces in making well-informed and strategic decisions concerning the equipment utilized in their operations.

Keywords: *multicriteria analysis, parachute, special operations forces*

1. INTRODUCTION

Special forces represent the pinnacle of military capabilities, equipped with state-of-the-art skills and technologies to carry out missions in the most challenging and hazardous environments. The use of parachutes constitutes one of the most essential components of their arsenal, enabling them to execute operations rapidly and without detection. These elite units are trained to utilize parachutes in a variety of scenarios, including infiltrations into steep mountain terrain or deep jungle environments where ground access would be impossible or extremely perilous. The ability to land precisely and swiftly maneuver post-descent provides them with a significant strategic advantage, allowing them to surprise the enemy and accomplish objectives efficiently. Additionally, parachuting plays a crucial role in emergency evacuations or personnel recovery operations in conflict zones, providing special forces with the capability to act swiftly and decisively in critical situations. Thus, parachuting is not merely a technique but a vital element in the arsenal of special forces, significantly contributing to the success and effectiveness of their missions in the most extreme and unpredictable circumstances. [1]

The article outlines the complex and meticulous process of compiling a ranking of parachutes used by special forces through multicriteria analysis. The authors emphasize the importance of establishing evaluation criteria such as reliability, landing accuracy, versatility, weight, and costs. By employing a systematic and objective approach, each parachute undergoes assessment based on these criteria, receiving corresponding scores.

Following the assignment of weights and calculation of total scores, a ranking is formulated that reflects the best options according to the specific needs and requirements of the special forces. The article underscores the essential role of multicriteria analysis in making informed and strategic decisions, contributing to optimizing operational performance and resource utilization in special operations.

Therefore, within the multicriteria analysis, we will consider the following items: wing-type parachutes used for infiltration, both through the HAHO (High Altitude High Opening) and HALO (High Altitude Low Opening) methods, as well as round parachutes used for infiltration from low to very low altitudes.

2. THE CONCEPT OF THE STUDY OF A MULTICRITERIA ANALYSIS

Multicriteria analysis describes a structured approach used to determine overall preferences from multiple alternative options, which aim to achieve a set of specific objectives. Within such an analysis, the pursued objectives are specified, and the relevant indicators are identified. [2]

Therefore, the analysis proves useful for a wide variety of applications, ranging from the most mundane (such as purchasing a car) to simulating more complex public procurement processes, such as acquiring a multi-role aircraft or modernizing the fleet of attack helicopters of the Romanian Air Force.

The purpose of this method is to achieve a comparative evaluation of heterogeneous measures or alternative projects. Therefore, the actual measurement process and the indicators used in multicriteria analysis should not be monetarily based, but they still rely on quantitative analysis (through scoring, ranking, and weighting) of a range of qualitative categories and criteria. Given that this method provides techniques for making comparisons and hierarchies of different outcomes, utilizing a wide variety of indicators, it can be concluded that it is particularly applied in cases where addressing the problem through a single criterion is insufficient. The aim of this analytical tool is to structure and combine different evaluations that need to be taken into account in the decision-making process, in cases where decision-making involves multiple alternatives, and the treatment applied to each of these largely conditions the final decision.[3]

It is important to note that multicriteria analysis is used to highlight subjective opinions and the reasoning of stakeholders regarding each problem presented. It is often used to establish priority structures, synthesize expressed opinions, analyze conflicting situations, and formulate recommendations or provide operational advice.

In multicriteria analysis, the criterion represents the unit of measurement according to which options are compared and evaluated to determine the extent to which they contribute to achieving the proposed objective. It is crucial that each criterion measures a relevant aspect and does not depend on another criterion. [4]

In the example provided below, the acquisition of a helicopter for the modernization of the Romanian Air Force fleet is being considered. The selection of a helicopter model is the subject of a Multicriteria Analysis. The information in Table 1 presents the description of 5 criteria, providing: the symbol and name of the criteria, the indicator used for quantifying the criteria, the value ranges of the criteria, and the effect pursued for each criterion.

Table 1.The criteria and their respective value ranges

Criteria		Indicator	Value Ranges	Effect Maximum(+)/ Minimum(-)
C_1	Maximum Takeoff Weight	Kilograms	$[x_1...x_n]$	-
C_2	Performance	Engine Power(horsepower)	$[x_1...x_n]$	+
C_3	Rate of Climb	Feet/minute	$[x_1...x_n]$	-
C_4	Maximum Speed	Knots	$[x_1...x_n]$	+
C_5	Range	Kilometers	$[x_1...x_n]$	+

A standard tool of multicriteria analysis is the performance matrix (also known as the consequence table or decision matrix). Each row of this matrix describes an option, and each column shows the performance of the options based on each criterion. Performance evaluations are often numerical but can also be expressed through scoring, graphical representation, or color coding. The table below presents the general form of a performance matrix for options and criteria. The scores in the matrix cells are denoted as a_{ij} and represent the value associated with option i for criterion j.

Table 2.The performance matrix

Criterion / Options	C_1	C_2	$...C_j...$	C_n
A_1	***a11***	***a12***	**...**	***a_{1n}***
A_2	***a21***	***a11***	**...**	***a11***
$...A_i...$	**...**	**...**	***a_{ij}***	**...**
A_m	***am1***	***am2***	**...**	***amn***

In the basic form of multicriteria analysis, this performance matrix can represent the final product of the analysis. In the techniques of multicriteria analysis, the information from the basic matrix is transposed into coherent numerical values. Normally, numerical analysis of a performance matrix is applied in two different stages:

Firstly, scoring involves assigning a numeric score on the preference level scale for each option of the criteria, based on the anticipated consequences for each option. Options that are preferred receive a higher score on the preference scale, while less preferred options receive a lower score. In the proposed study, the scale used will range from 1 to 3, where 1 represents the least preferred option, while 3 is associated with the most preferred option. Ultimately, all options considered in the study will fall between 1 and 3.

The second step is weighting, which involves assigning numerical weights to define, for each criterion individually, the estimates of oscillations between the lower and upper limits of the chosen scale. At this stage, each decision criterion is assigned a "value" or "weight," and the decision criteria acquire a relative weight compared to each other - weighting the decision factors is necessary if we want to combine them in the end.

For the numerical example used so far, let's consider that a group of experts has analyzed the selection criteria for the proposed alternatives and consulted with the main stakeholders. Regarding the consideration of weights, the interval [1,5] is taken into account, where the value 1 represents the least important criterion, while the value 5 represents the most important criterion. They have decided that helicopter performance is the most important criterion, and its weight should be 4, while rate of climb and maximum takeoff weight are the least important criteria, with a weight of 1, whereas maximum speed and range have moderate relevance and a weight of 3.

These results are presented in Table 3.

Table 3.The estimated weights directly

Criterion	C_1	C_2	C_3	C_4	C_5
Weight	1	4	1	3	3

In the final stage of multicriteria analysis, mathematical calculations are used to suggest the preferred option, representing the variant that best meets the needs and standards for the acquisition of helicopters for the modernization of the Romanian Air Force fleet.

It is important to note that, in developing the mathematical calculations, column-wise multiplication is performed, element by element, followed by adding up the values. The resulting sum represents the value of the respective option, with the maximum value indicating the winning option.

$$R= \max (\Sigma pc*p) \tag{1}$$

where:
R=the preferred option
Σ= sum
pc= criterion weight
**= multiplication*
p= score

3. MULTICRITERIA ANALYSIS OF PARACHUTE TYPES

3.1. Multicriteria analysis of wing-type parachutes used by special operations forces

To begin with, we will establish the wing-type parachutes used by special operations forces:

Table 4. The wing-type parachutes

The wing-type parachutes	Country
JANUS 300 [5]	Spain
ARZ G9 [6]	France
AS-33 INTRUDER [7]	UK
MC-4 [8]	USA
ARBALET-2 [9]	Russia

Once we have established the wing-type parachutes used by special operations forces, we will initiate the process of multicriteria analysis. To begin with, we will determine the items we consider viable in establishing the final ranking. From my perspective, the most important characteristics to be considered, given the purpose of these parachutes, are: weight, maximum load capacity, aerodynamic efficiency, surface area, and finally, maximum opening altitude.

For this step, I will introduce the items in the table below, along with the indicators and numerical ranges corresponding to each criterion:

Table5. The criteria and value ranges

Criterion		Indicator	Value ranges
C1	Weight	Kilograms	19-29
C2	Maximum Load	Kilograms	159-205
C3	Aerodynamic Efficiency	-	2,5-4:1
C4	Surface Area	Square Meters	29-37
C5	Maximum Opening Altitude	Meters	4500-12000

Once the criteria, their indicators, and their respective value ranges are established, I will create the performance matrix. The rows will represent the criteria, while the columns will represent the wing-type parachute alternatives.

Table 6.The performance matrix

Criteria Alternatives	Weight	Maximum Load	Aerodynamic Efficiency	Surface Area	Maximum Opening Altitude
JANUS 300 [10]	25	160	3:1	29	8000
ARZ G9 [11]	24	160	2,8:1	35,7	10000
AS-33 INTRUDER [12]	29	205	4:1	37	12000
MC-4 [13]	25	180	3:1	35	10000
ARBALET-2 [14]	19	159	2,5:1	34	12000

The next step involves assigning a scoring range to each criterion considered in the performance matrix, for the purpose of normalizing the matrix and facilitating calculations. As mentioned in subsection 3.1.1., the scoring is in the range of values [1,3], where 1 represents the least preferred option, 2 represents the average option, while 3 is associated with the most preferred option.

Table7. The score of each wing-type parachute

Criteria Alternatives	Weight	Maximum Load	Aerodynamic Efficiency	Surface Area	Maximum Opening Altitude
JANUS 300	2	1	2	3	1
ARZ G9	2	1	1	2	2
AS-33 INTRUDER	1	3	3	1	3
MC-4	2	2	2	2	2
ARBALET-2	3	1	1	2	3

Once the scores are established, we need to assign a weight to each criterion mentioned up to this point in the multicriteria analysis. As stated in subsection 3.1.1, in the explanation of this analysis method, the weights are assigned between the values [1,5], where the values represent: 1 - least important, 2 - somewhat important, 3 - moderate, 4 - important, and finally, 5 - most important. Thus, we create the weight matrix as follows.

Table 8. Directly estimated weights

Weight	Maximum Load	Aerodynamic Efficiency	Surface Area	Maximum Opening Altitude
2	4	5	1	3

The final step of the wing-type parachute analysis involves solving the mathematical calculations using the formula presented and subsequently determining the final ranking. Following the mathematical calculations, the following values have been obtained:

Table 9. Scores of the wing-type parachutes

Alternatives	Score
JANUS 300	***24***
ARZ G9	***21***
AS-33 INTRUDER	***39***
MC-4	***30***
ARBALET-2	***26***

Once we have obtained the numerical values, we compile the final ranking as follows:

Table 10. Final Ranking

Position obtained	Final Ranking
1	AS-33 INTRUDER
2	MC-4
3	ARBALET-2
4	JANUS 300
5	ARZ G9

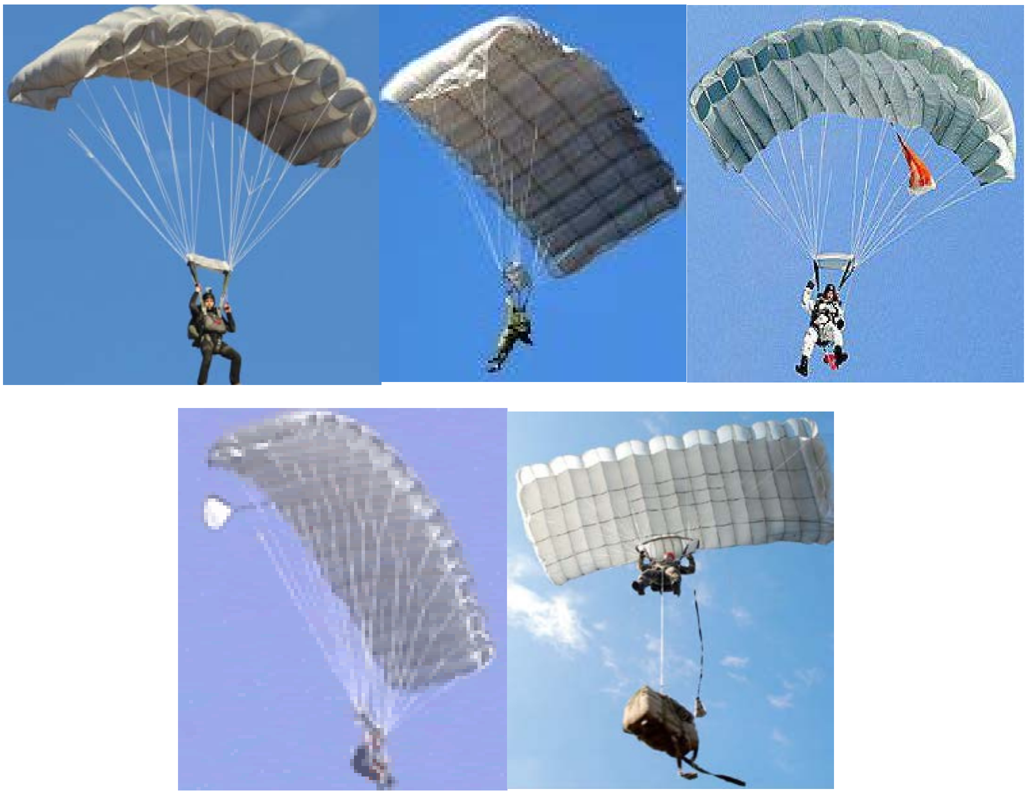

FIG 1. The wing-type parachutes (1-AS-33 INTRUDER [15], 2- MC-4 [16], 3 - ARBALET-2 [17], 4 - JANUS 300 [18], 5- ARZ G9 [19])

3.2. Multicriteria Analysis of Round-Type Parachutes Used by Special Operations Forces

To begin with, we will establish the round-type parachutes used by special operations forces:

Table 11. Round-Type Parachutes

Round-Type Parachute	Country
CIMSA TP-2Z [20]	Spain
TAP 696-26 [21]	France
GQ 8M-LLP [22]	UK
MC-6 [23]	USA
D10 [24]	Russia

Once we have established the round-type parachutes used by special operations forces, we will initiate the process of multicriteria analysis. To begin with, we will determine the items we consider viable in establishing the final ranking. From our perspective, the most important characteristics to be considered, given the purpose of these parachutes, are: weight, maximum load capacity, vertical speed, surface area, and finally, minimum opening altitude.

For this step, I will introduce the items in the table below, along with the indicators and numerical ranges corresponding to each criterion:

Table 12. The criteria and value ranges

Criterion		Indicator	Value ranges
C1	Weight	Kilograms	13-17,5
C2	Maximum Load	Kilograms	140-181
C3	Vertical Speed	Meters per second	5-6
C4	Surface Area	Square Meters	71-100
C5	Minimum Opening Altitude	Meters	76-200

Once the criteria, their indicators, and their respective value ranges are established, I will create the performance matrix. The rows will represent the criteria, while the columns will represent the alternatives of round-type parachutes.

Table 13. The performance matrix

Criteria Alternatives	Weight	Maximum Load	Vertical Speed	Surface Area	Minimum Opening Altitude
CIMSA TP-2Z [25]	14	160	5,5	79	125
TAP 696-26 [26]	13,5	160	5,5	74	150
GQ 8M-LLP [27]	13,6	160	6	75	76
MC-6 [28]	13	181	5	71	152
D10	17,5	140	5	100	200

The next step involves assigning a scoring range to each criterion considered in the performance matrix, in order to normalize the matrix and facilitate calculations. As mentioned in subsection 3.1.1., the scoring is in the range of values [1,3], where 1 represents the least preferred option, 2 represents the average option, while 3 is associated with the most preferred option.

Table 14. The score of each round-type parachute

Criteria Alternatives	Weight	Maximum Load	Vertical Speed	Surface Area	Minimum Opening Altitude
CIMSA TP-2Z	2	2	2	2	2
TAP 696-26	2	2	2	2	2
GQ 8M-LLP	2	2	1	2	3
MC-6	3	3	3	3	2
D10	1	1	3	1	1

Once the scores are established, we need to assign a weight to each criterion mentioned up to this point in the multicriteria analysis. As stated in subsection 3.1.1., in the explanation of this analysis method, the weights are assigned between the values [1,5], where the values represent: 1 - least important, 2 - somewhat important, 3 - moderate, 4 - important, and finally, 5 - most important. Thus, we create the weight matrix as follows.

Table 15. Directly estimated weights

Weight	Maximum Load	Vertical Speed	Surface Area	Minimum Opening Altitude
2	4	5	1	3

The final step of the round-type parachute analysis involves solving the mathematical calculations using the formula presented and subsequently determining the final ranking. Following the mathematical calculations, the following values have been obtained:

Table 16. Scores of the round-type parachutes

Alternatives	Score
CIMSA TP-2Z	30
TAP 696-26	30
GQ 8M-LLP	26
MC-6	42
D10	25

Once we have obtained the numerical values, we compile the final ranking as follows:

Table 17. Final Ranking

Position obtained	Final Ranking
1	MC-6
2	CIMSA TP-2Z
3	TAP 696-26
4	GQ 8M-LLP
5	D10

FIG. 2. The round-type parachutes (1-MC-6, 2-GQ 8M-LLP, 3-D10, 4-TAP 696-26, 5- CIMSA TP-2Z)

CONCLUSIONS

This multicriteria analysis provides a detailed perspective on various aspects of wing-type parachutes used by special forces, highlighting the importance of each criterion and how they influence the operationality and effectiveness of these vital equipment in different usage scenarios. Proper weighting of the criteria is crucial for obtaining a balanced and relevant assessment of the available options. For instance, weight and load capacity are essential for the mobility and flexibility of special operations forces in challenging terrains or during long-duration missions, while aerodynamic finesse and vertical speed can directly impact the precision and control of landing, being vital in high-risk situations or urban areas. Surface area and minimum opening altitude also play a crucial role in the range and adaptability of parachutes in different terrain and operational conditions. Therefore, it is evident that a holistic and balanced approach in evaluating these criteria is essential for the selection and optimal use of parachutes by special forces.Multicriteria analysis provides significant benefits in the decision-making process, offering a comprehensive and objective perspective on the available options.

These conclusions help substantiate strategic decisions regarding the acquisition, modernization, and utilization of parachutes in special operations, contributing to improving operational capability and increasing the efficiency of special forces in their mission contexts.

The article provides a detailed and well-structured presentation of the multicriteria analysis process for wing-type parachutes used by special forces. Starting from identifying relevant criteria and their value ranges to developing the performance matrix and assigning weights, the analysis is presented coherently and accessibly.

The importance of each criterion in the context of special operations is clarified, and the relevance of each step of the analysis process is argued. The article serves as a valuable starting point in understanding multicriteria analysis of both wing-type and round parachutes, yet there is room for improvement in terms of methodological clarity and detailed discussion of limitations and subjective aspects of the analysis process.

Looking ahead, it is essential to continue developing and refining our multicriteria analysis methods, especially regarding the evaluation and prioritization of criteria based on the specific needs and requirements of special forces. We plan to expand our research to include a broader range of parachutes, thus obtaining a more comprehensive understanding of available options and their potential impact on operational performance. Ultimately, we aim for the results of this research to contribute to enhancing the operational capabilities of special forces and providing support for informed and strategic decision-making regarding the equipment and technologies used in their critical operations.

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