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Multicriterial Analysis and Comparison of Air-to-Air Fighter Jets

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Abstract

Fighter aircraft are the dominant tools for gaining the desired level of air control. As the crisis over Ukraine since 2022 showed, air superiority in congested airspace plays a crucial role. The aim of this article is to present the methodological approach to compare different aircraft dedicated to air-to-air roles. For this purpose, the Multi-Criteria Decision-Making Method, based on the analytical hierarchy process, was used to identify the most suitable military fighter aircraft for air-to-air operations. To demonstrate the method, four operational representatives of the North Atlantic Treaty Organization countries were selected to compare specific aircraft types.

KEY WORDS: *multicriterial analysis, analytical hierarchy process, fighter aircraft, decision-making*

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1. Introduction

Fighter aircraft have historically played a crucial role in establishing the desired degree of control in the air. From an operational management perspective, achieving this position is necessary for success on the contemporary battlefield. The unfolding conflict in Ukraine serves as the evidence supporting this principle. Initial offensives conducted by the Russian Federation targeted at various strategic locations, including air bases, air defense sites, and airspace surveillance systems. Despite the inability to completely neutralize the Ukrainian air forces on the ground, ongoing confrontations between aircraft of the two opposing factions persist. [1]

The delivery of air power can be defined in terms of roles, missions, and sorties. This study will be further elaborated and focused only on Counter-Air Operations conducted to obtain and maintain the required degree of Control of the Air. The desired level of Control of the Air will allow the actual operation to be conducted under the required degree of freedom for ground units and other components in the required time and space. Achieving this level is ongoing, but further action is required to maintain this state [2]. The most important factor affecting the probability of fulfilling the task is the human factor, followed by the technological level of development and the aircraft capabilities [3]. All these factors should be included in the phase of developing plans and stating the standards, thus it is important to the strengths and weaknesses evaluation [4]. When evaluating any object, the first phase is to establish the requirements. In the case of modern fighter aircraft, the trend is that one aircraft can play different roles, such as a multi-role aircraft or a swing-role [5].

The aim of this study is to introduce a systematic approach to the selection and comparison of suitable tactical aircraft for Counter-Air operations. To achieve this objective, it is essential first to identify the fundamental capabilities and characteristics of the aircraft that are critical to the performance of these missions. Evaluation criteria will then be derived from these parameters. The criteria will be selected based on the historical development of tactical aircraft, their operational deployment, potential tactics, principles of air warfare, technical advances, and the capabilities of current platforms. A multi-criteria method will be developed to incorporate the significant number of sub-criteria that determine an aircraft's readiness level. The effectiveness of this method will then be demonstrated through a comparative analysis of a few selected aircraft.

The purpose of this study is not to evaluate aircraft for specific operations in a specific location or to select the appropriate aircraft for a specific military or government agency. Its primary focus is to evaluate the disposition of Counter

Air Operations only, without regard to aircraft characteristics that are not analytically critical to this effort. An example would be acquisition cost or cost per flight hour. Calculating the cost per flight hour or mission accomplishment is highly complex and can vary from nation to nation. Therefore, this study does not address the price in general.

2. Method of Investigation

The operational deployment of fighter jets involves a wide range of factors that significantly impact on the feasibility of deployment under specific conditions and mission requirements. These factors, such as information support, maintenance complexity, operational economics, logistics support, and navigation performance, must be considered in practice. However, this study focuses on assessing the effectiveness of air dispositions in achieving success in air-to-air operations, specifically in conducting air combat. Therefore, the study will not explore the factors mentioned above or consider scenarios where adversaries have equal capabilities in certain variables to isolate the analysis of aircraft dispositions.

The study employed the Multi-Criteria Decision-Making Method (MCDM) [6], which is based on the analytical hierarchy process (AHP) [7], to identify the most appropriate military fighter aircraft for air-to-air operations.

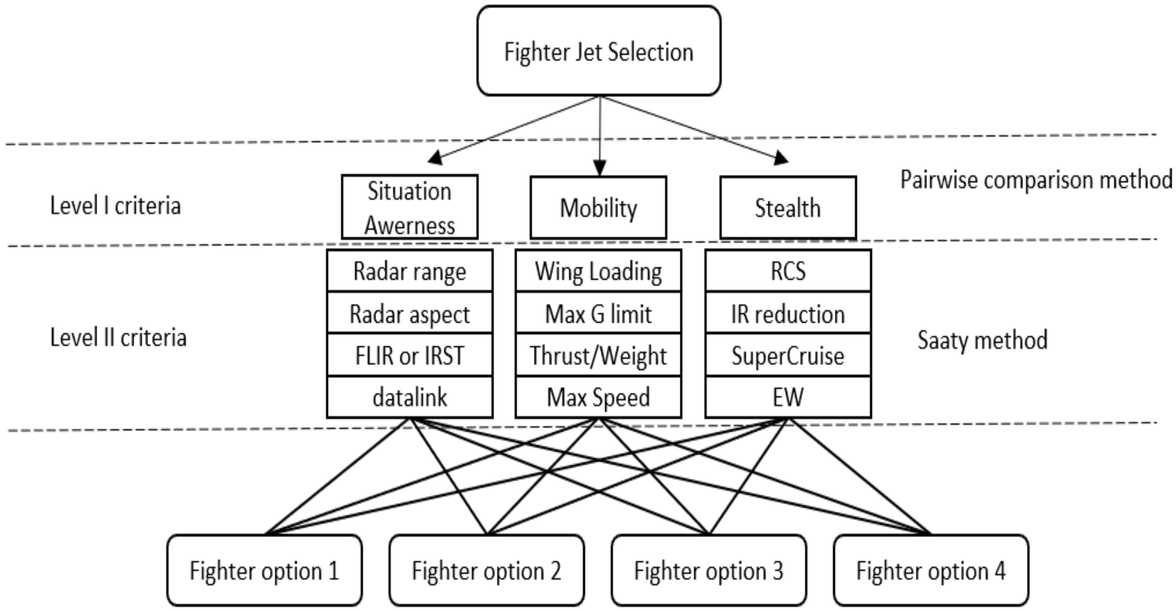

Fig. 1. Analytic hierarchy structure

The analytical hierarchy method was used to establish three primary criteria, and their weights were determined by a group of experts using Fuller's pairwise comparison method. At the second level, experts identified four criteria for each category from the primary criteria. Based on the evaluation by the expert team, the weights of these criteria were determined using the Saaty method [8]. The structure of the AHP is illustrated in Fig. 1.

2.1. Level I Criteria

The identified Level I Criteria defining modern Air-to-Air Fighter Jets, including the 5th GEN fighters, were chosen upon Senior Matter Experts (SME). The pairwise comparison method using Fuller's triangle was used to determine the weights of these criteria. Air Force SME's task was to choose which pair of criteria was more critical. The SME compared the pairs of criteria sequentially, with the number of pairs defined by formula (1). For the example of three Level I criteria ($k = 3$), the number of pairs is $N = 3$.

$$N = \binom{k}{2} = \frac{k(k-1)}{2} \tag{1}$$

From Fuller's pairwise comparison method and the SME's evaluation, the weights are assigned by scoring, where the preferred criteria are awarded 1 point. In the case of a situation where the SME prefers both criteria equally, both criteria in a pair receive 0.5 points. The final weight v_i of the i-th criterion is defined by formula (2), where n_i indicates how many preference points the criterion received. The results of SME are presented in Table 1.

$$v_i = \frac{n_i}{N}; \quad i = 1, \dots, k \tag{2}$$

Table 1.

The results of SME evaluation (data are rounded)

Level I criteria	
Situation Awareness (SA)	$v_{SA} = 0.50$
Stealth	$v_{Stealth} = 0.34$
Mobility (MOB)	$v_{MOB} = 0.16$
Sum	**1.00**

2.2. Level II Criteria

Level II Criteria for each category were chosen after analysing the avionics capability, aerodynamic characteristics, performance, and other aircraft qualities. The armament characteristics were intentionally omitted due to limited access to valid data and variations in the types of munitions used for each aircraft worldwide. In this case, Saaty's matrix with a nine-point scale was used for pairwise comparison of these criteria. The weights v_{jA}, v_{jB} and v_{jC} of the individual criteria were then calculated as the ratio of the geometric mean in the given row and the sum of the geometric means for all criteria in the Saaty matrix (see Table 2).

Table 2.

Situation Awareness (SA)

	Radar range	Radar aspect in azimuth and vertical	FLIR or IRST	NATO compatible datalink	Geometric Mean	v_{jA}
Radar range	1.000	7.000	5.000	0.200	1.627	0.248
Radar aspect in azimuth and vertical	0.143	1.000	0.250	0.143	0.267	0.041
FLIR or IRST	0.200	4.000	1.000	0.125	0.562	0.086
NATO compatible datalink	5.000	7.000	8.000	1.000	4.091	0.625
					Σ=6.547	**1.00**

Stealth

	Radar Cross Section	IR reduction	Super Cruise	Electronic Warfare Capability	Geometric Mean	v_{jB}
Radar Cross Section	1.000	3.000	2.000	0.200	1.047	0.171
IR reduction	0.333	1.000	0.167	0.143	0.298	0.049
SuperCruise	0.500	6.000	1.000	0.143	0.809	0.132
Electronic Warfare Capability	5.000	7.000	7.000	1.000	3.956	0.647
					Σ=6.111	**1.00**

Mobility (MOB)

	Wing Load	Max G limit	Thrust to Weight Ratio	Maximal Speed	Geometric Mean	v_{jC}
Wing Load	1.000	0.333	0.250	0.125	0.319	0.056
Max G limit	3.000	1.000	0.333	0.200	0.669	0.117
Thrust to Weight Ratio	4.000	3.000	1.000	0.333	1.414	0.248
Maximal Speed	8.000	5.000	3.000	1.000	3.310	0.579
					Σ=5.712	**1.00**

3. Investigation Results

Four representative aircraft from the North Atlantic Treaty Organization countries were selected to compare specific aircraft types [9], [10]. This selection was made to demonstrate the functionality of the method. This selection can be further supplemented or modified for possible specific use at the national or international level.

The data on specific aircraft were taken from publicly available sources, mainly the English version of Wikipedia. The authors are fully aware of the imperfections of this data. However, again, the method can be supplemented with accurate and often classified data for any specific use. The purpose of the paper is to establish a methodological approach to the Multicriterial Analysis [11] for comparing different types of aircraft where a comparison was made between four representatives currently in service within the NATO.

The selected types of aircraft deployed in the North Atlantic Alliance include:

1. JAS-39 C Gripen.
2. Dassault Rafale C.
3. Eurofighter Typhoon.
4. F-35 Lightning II.

For the analytical approach and the final evaluation, it was necessary to transverse the data for each Level II criteria to value them in a points scale. The scoring principle is described in Table 3.

Table 3.

Situation Awareness (SA)

	criterion	*scale*	*JAS-39C*	*Rafale*	*Eurofighter*	*F-35*
f_{1A}	Radar range	Highest value = 100 points Zero value = 0 points	93	100	80	100
f_{2A}	Radar aspect in azimuth and vertical	360° + 360° = 100 points 0° = 0 points	33	36	55	70
f_{3A}	FLIR or IRST	Both = 100 points Only one = 50 points None = 0 points	100	100	100	100
f_{4A}	NATO compatible datalink	Yes = 100 points No = 0 points	100	100	100	100

Stealth **score**

	criterion	*scale*	*JAS-39C*	*Rafale*	*Eurofighter*	*F-35*
f_{1B}	Radar Cross Section	Lowest value = 100 points Highest value = 0 points	50	0	0	100
f_{2B}	IR reduction	Yes = 100 points No = 0 points	100	100	100	100
f_{3B}	SuperCruise	Yes = 100 points No = 0 points	0	100	100	100
f_{4B}	Electronic Warfare Capability	Yes = 100 points No = 0 points	100	100	100	100

Mobility (MOB) **score**

	criterion	*scale*	*JAS-39C*	*Rafale*	*Eurofighter*	*F-35*
f_{1C}	Wing Load	Lowest value = 100 points Highest value = 0 points	27	31	30	20
f_{2C}	Max G limit	Highest value = 100 points Zero value = 0 points	100	100	100	100
f_{3C}	Thrust to Weight Ratio	Highest value = 100 points Zero value = 0 points	73	94	100	83
f_{4C}	Maximal Speed	Highest value = 100 points Zero value = 0 points	80	90	100	80

After examining the characteristic data, the final result was calculated for each criterion in the category using the formula (3), where the weights v_{SA}, v_{Stealth} and v_{MOB} are the weights calculated in Fuller's pairwise comparison method in Table 1.

$$\mathrm{SCORE} = v_{\mathrm{SA}} \cdot \mathrm{Sum(SA)} + v_{\mathrm{Stealth}} \cdot \mathrm{Sum(Stealth)} + v_{\mathrm{MOB}} \cdot \mathrm{Sum(MOB)} \tag{3}$$

The sum for each Level II category is calculated as specified in formula (4), where weights v_{jA}, v_{jB} and v_{jC} were calculated using the Saaty matrix (see Tab. 2) and f_{jA}, f_{jB} and f_{jC} were determined from Tab. 3.

$$\mathrm{Sum(SA)} = \sum_{j=1}^{4} v_{jA} \cdot f_{jA}, \qquad \mathrm{Sum(Stealth)} = \sum_{j=1}^{4} v_{jB} \cdot f_{jB}\,, \qquad \mathrm{Sum(MOB)} = \sum_{j=1}^{4} v_{jC} \cdot f_{jC}. \tag{4}$$

4. Conclusions

Thanks to the methodical comparison of aircraft for air-to-air operations, the final ranking of the aircraft was determined. In the category of stealth and situational awareness, the F-35 stood out the most, thanks to its 5th generation aircraft concept. Conversely, the remaining aircraft were tied in these categories. On the other hand, the F-35 fell short in mobility, where the aircraft lost points due to its higher surface load and lower top speed. However, the F-35 outperformed the other aircraft in the overall rating. This result underlines the importance of the 5th generation aircraft, where the emphasis is on information superiority on the battlefield, which is achieved through powerful radars and the Stealth concept in general. The Rafale and Eurofighter had similar score gains. The Gripen fell slightly behind due to its outdated airborne radar and single-engine concept. The resulting scores are shown in Table 4. In conclusion, the concept of 5th generation aircraft is an essential element of the modern battlefield concept, and the philosophy of the relevance of information superiority for air-to-air engagements has been demonstrated by comparison using multicriterial analysis.

Table 4.

MCA Results

aircraft type	SCORE
F-35 Lightning II	**95.9**
Dassault Rafale C	**91.0**
Eurofighter Typhoon	**90.1**
JAS-39 C Gripen	**86.7**

Limitations

A limitation of the study is the source of valid data, where certain specific data are very often classified. The authors mainly relied on publicly available sources. For further specific use at the level of a particular army, the data can be further specified as categories can be expanded to include additional criteria for comparison.

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